

2.0 INTEGRATING STORMWATER MANAGEMENT INTO THE PLANNING PROCESS

2.1 Introduction

As the science of stormwater management has evolved, a variety of documents has been produced to assist and provide direction to practitioners in Ontario. These include documents such as the trilogy of watershed planning documents produced in 1993 (OMOEE & OMNR, 1993a; 1993b; 1993c), provincial stormwater management planning and design guidelines (OMOEE & OMNR, 1991, OMOEE, 1994; OMOE, 2003), and municipal stormwater management guidelines (City of Toronto, 2006). With the initiation of integrated watershed monitoring programs by CVC and TRCA early in this decade, information is becoming available to evaluate and track watershed health at scales that are informative to watershed managers, land use planners and stormwater management system designers. Information being generated by watershed monitoring programs and from recent regional scale studies of hydrogeology (e.g., York Peel Durham Toronto Groundwater Management Project), terrestrial natural heritage (e.g., CVC, 2004; TRCA, 2007e), and aquatic natural heritage (e.g., CVC, 2002; OMNR & TRCA, 2005; TRCA, 2009b), has greatly improved our understanding of watershed system features, functions and linkages and the effectiveness of conventional management approaches to maintain watershed health. The latest generation of watershed planning studies has integrated this information into recommendations to improve conventional management approaches, which include integrating low impact development practices into stormwater management planning and design (Aquafor Beech Ltd., 2006; CVC, 2007b; TRCA, 2007c; TRCA, 2008a; TRCA, 2009a). Drawing on direction from stormwater management guidelines and recent watershed planning studies, guidance regarding study requirements at various stages in the development planning and review process has also been produced (e.g., CVC, 2007a; TRCA, 2007b). Collectively, this body of knowledge provides:

- a rationale for considering watersheds as the natural and logical boundary for environmental and land use planning;
- direction with respect to the types of environmental studies that are required for development to take place and the range of expertise needed to be involved;

- evidence that current urban design and stormwater management approaches are not sustainable over the long term if watershed goals are to be realized, and, therefore, that a change in planning and design practices is required;
- a need to enhance stormwater management in existing urban areas;
- direction with respect to the diverse range of disciplines needed to effectively and successfully undertake an integrated planning and design approach; and
- recognition that new technologies such as the treatment train approach, low impact development (LID) principles and green building certification systems (e.g., Leadership in Energy and Environmental Design - LEED, Green Globes) represent the next step in the evolution of stormwater management practice.

The primary objective of this chapter is to outline an approach to the planning and design of stormwater management systems and facilities that is focused on ensuring that infrastructure is fully integrated within both the urban fabric of the community and the functional landscape.

The chapter provides an overview of a landscape-based approach to stormwater management planning. This approach is founded on the principle that development form, servicing and stormwater management strategies should be defined by the biophysical, hydrological and ecological attributes of the environment and landscape in addition to other planning objectives (e.g., land use, densities, transportation, and urban design).

This chapter also provides a brief overview of key steps in the recommended process for designing best management practices (BMPs) for stormwater management. More detailed discussion is provided in CVC's *Credit River Water Management Guidelines* (2007a) and TRCA's *Planning and Development Procedural Manual* (2007b).

Lastly, it provides examples of opportunities for integrating landscape-based stormwater management at various planning scales (i.e., the community, neighbourhood and site scales) and stages in the process.

2.2 Environmental, Land Use and Stormwater Management Planning

Documents such as CVC's *Credit River Water Management Guidelines* (2007a) and TRCA's *Planning and Development Procedural Manual* (2007b) describe the types of environmental studies at the watershed, subwatershed and site scales that should be undertaken and submitted in support of development proposals. Each municipality tends to be unique with respect to how it carries out its municipal land use and environmental planning processes. It is therefore not possible to define a process that is applicable to all municipalities for all types of studies.

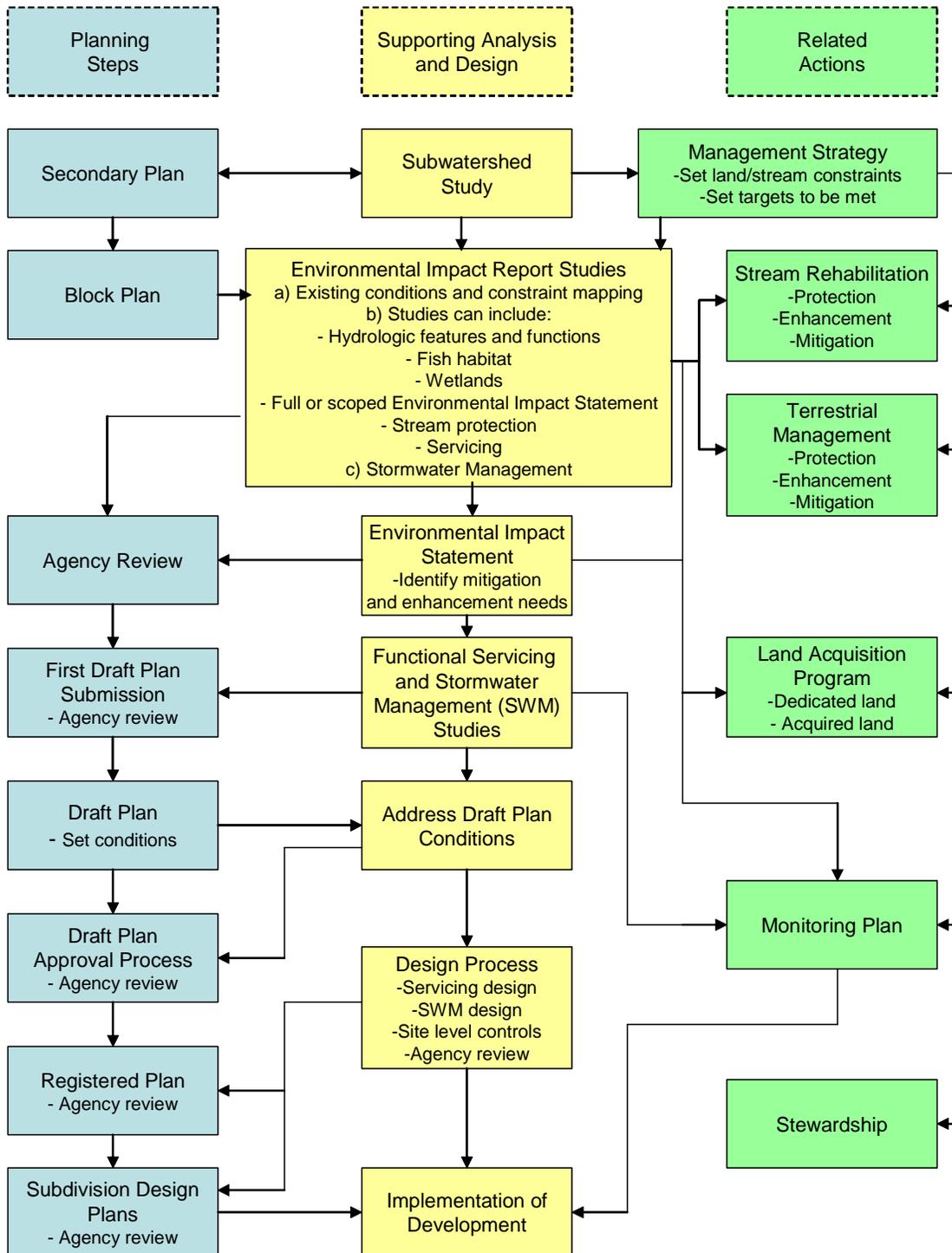
Figure 1.5.1, adapted from the 2003 OMOE Stormwater Management Planning and Design Manual illustrates the general inter-relationship between municipal land use planning and environmental (watershed) planning studies. Figure 1.5.1 includes the agencies that are typically involved in the review of documents at each phase in the land use planning and development proposal review processes. Figure 2.2.1 illustrates the relationship between the major land use planning stages, requirements for supporting analysis and design, and related actions such as stream rehabilitation, management of terrestrial habitats, land acquisition and monitoring.

This section of the *LID SWM Guide* illustrates how landscape-based stormwater management planning can take place at various scales and land use planning stages. This is summarized in Table 2.2.1.

Table 2.2.1 Summary of stormwater management planning at key scales and land use planning stages

Scale	Planning Stage	Description
Watershed plans	Master Plans Growth Plan Official Plan	Major themes and objectives for the municipality's future growth are established, and challenges and opportunities for growth are identified, such as municipal policy direction for innovative SWM approaches and other climate change initiatives.
Community/ Subwatershed	Secondary Plan	Major elements of the natural heritage system are identified including terrestrial, aquatic and water resources (hydrology, hydrogeology, fluvial geomorphology, etc.). Stormwater management objectives for surface and groundwater resources. Future drainage boundaries, locations of stormwater management facilities and watercourse realignments are established.
	Block Plan	The location of lots, roads, parks and open space blocks, natural heritage features and buffers, and stormwater management facilities are defined. A full range of opportunities to achieve stormwater management objectives are identified, establishing a template for the more detailed resolution of the design of stormwater management facilities at subsequent stages in the planning and design process.
Neighbourhood	Draft Plan of Subdivision/ Functional Servicing Plan	Conceptual design is carried out for stormwater management facilities. Consideration must be given to how stormwater management objectives can be achieved and how these objectives influence the location and configuration of each of the components listed above
	Registered Plan	Detailed design is carried out for stormwater management facilities.
Site	Site Plan	Site-specific opportunities are identified to integrate stormwater management facilities into all of the components of a development including landscaped areas, parking lots, roof tops and subsurface infrastructure. Solutions must be considered in the context of the overall stormwater management strategy for the block or secondary plan area to ensure that functional requirements are achieved
Site	CA Permits and other approvals	Detailed design of SWM for the site

Figure 2.2.1 Example of relationship between major land use planning stages, supporting environmental analysis and design, and related actions¹



¹ This figure provides a general description of various land use planning stages which may not always take place in this order and may not be limited to only these steps and studies. Requirements noted are not an exhaustive list. Guidance regarding required supporting analysis and design should be obtained from the relevant approval authorities which will be specific to the context of the proposed development.

2.3 Overview of Landscape-based Stormwater Management Planning

This section of the *LID SWM Guide* is focused on promoting an approach to the planning and design of stormwater management systems and facilities that ensures that infrastructure is fully integrated into the urban fabric of the community while protecting natural heritage features and functions. This landscape-based approach to stormwater management planning is founded on the principle that development form, servicing and stormwater management strategies should be defined by the biophysical, hydrological and ecological attributes of the landscape.

Landscape-based stormwater management planning is founded on an understanding of the interrelated functions of the natural and hydrological features that comprise the landscape. This approach has regard for the environmental context of a specific site or sub-catchment within the matrix of the larger landscape, subwatershed and watershed, including features, functions and systems that are situated beyond the limits of the site. The landscape-based approach to stormwater management planning also recognizes the importance of temporal, seasonal and microclimatic factors on ecological function. The ultimate goal of a landscape-based approach to stormwater management planning is to maintain the ecological integrity of healthy sites, subwatersheds and watersheds, or enhance it where predevelopment conditions are degraded. The application of this approach to stormwater management planning requires a comprehensive understanding of natural and hydrologic features and functions, including the following:

- biophysical, hydrological, hydrogeological and natural heritage features;
- the interrelated functions of these features;
- modifying factors (such as climate); and
- temporal factors (such as seasonal changes, life cycles and successional processes).

The landscape-based approach to stormwater management planning and design is also founded on recognition of the value of land, both as a commodity and as the fundamental basis of a sustainable ecosystem. The approach is focused on utilizing land efficiently and where possible overlaying more than one function on any given piece of land. This requires a commitment to innovation in the design process, which

facilitates exploring opportunities to integrate stormwater management infrastructure within the streets, lots, parks and other components of a proposed development.

To be successful, the landscape-based approach to stormwater management planning must be implemented at successive stages and scales within the overall planning process, beginning at the watershed scale and proceeding through the community or subwatershed, neighbourhood and site scales and associated planning stages. At each stage in the process, a multi-disciplinary team should identify opportunities to integrate facilities into the landscape. These can be built upon and resolved in further detail at subsequent stages in the planning process. Flexibility in the stormwater management planning and design process is important to allow for innovative thinking and problem solving. The product of this process will be a comprehensive and effective stormwater management strategy that is comprised of a suite of practices that are fully integrated into the landscape of a proposed development.

2.4 Landscape-based SWM Planning and Design Principles

The landscape-based stormwater management planning approach is founded on the following principles:

- Stormwater is a resource.
- Stormwater management facilities and practices (*i.e.*, lot level, conveyance and end-of-pipe practices) should be fully integrated within their physical, social and ecological contexts.
- The planning of stormwater management facilities should be an integral component of the overall land use and environmental planning process. It should begin at the watershed scale to ensure that opportunities to achieve a full range of community and environmental objectives and targets are realized, along with the primary stormwater management objective and targets.
- The design process should be focused on maximizing the benefits that can be achieved as a product of the implementation of stormwater management facilities, including the protection and enhancement of existing natural heritage resources

and the provision of recreational and interpretive opportunities.

- Since developable land is a valuable and limited resource, integration of stormwater management facilities with other land uses is desirable (e.g., within road right-of-ways, below parking areas, sports fields or landscaped areas).
- Stormwater management facilities should be situated and configured to ensure that they are integral components of the community and regional open space system, as well as to contribute to the quality of urban design of the community.
- Stormwater management planning should consider the maintenance requirements of facilities and aim to minimize them.
- A range of innovative techniques should be used to enhance facility performance, minimize maintenance requirements, ensure longevity and address public safety issues in addition to other functional and pragmatic considerations.
- Integration of stormwater management facilities into the landscape should take place at a range of scales. However, proposed solutions should be supported by strategies to ensure that long-term functional requirements are achieved when facilities are proposed on private lands.
- Whenever possible, public education and interpretation of the important function of stormwater management facilities should be an integral component of the management strategy for the community.

These principles provide the foundation for exploring innovative design solutions that integrate stormwater management facilities into the landscape. The landscape-based approach to stormwater management planning recognizes that some facilities take up significant space in the community and therefore are key components of the visual landscape and open space system.

2.5 Integrated Design Process

The landscape in the CVC and TRCA watersheds is comprised of a diverse assemblage of natural and cultural heritage elements integrated within a complex, functional system. The influence of hydrology on the function of the individual components of the system and the system as a whole is profound. The viability of vegetation communities, aquatic and terrestrial habitats and other key natural and cultural features within the landscape is directly influenced by hydrology. Modifications to the hydrologic regime result in alterations to stormwater runoff patterns and water quality. These changes can compromise the long-term sustainability of aquatic and terrestrial natural heritage features and functions within the landscape. The complexity of the system dictates that any planning process that changes the landscape to create a new community, development or site-specific initiative, and the stormwater management system related to the development, must have regard for all of the interrelated features and functions that sustain the landscape.

The most effective way to achieve sustainable solutions is to use a design process that dissects the landscape into its component parts, and then assesses and understands the function of each part and its influence on the others and the whole. Although the primary goal of the stormwater management design process is the appropriate treatment of runoff to control the quantity and ensure the quality of stormwater discharge, an understanding of the influences of runoff on all of the various features and interrelated functions within the landscape is fundamental to the success of the design process. The integrated design process is an effective means to ensure that complementary environmental, social and practical objectives are achieved in the development and design of stormwater management strategies.

To be fully effective, the integrated design process requires the involvement of a range of disciplines including professionals from the fields of:

- engineering;
- landscape architecture;
- terrestrial and aquatic sciences;
- geosciences (hydrogeology, fluvial geomorphology); and
- planning.

Additional expertise may be required, depending on the characteristics of the study area, to ensure the planning and design decisions are made on the basis of a comprehensive understanding of the features, functions and regional influences of the landscape and the implications of the proposed development. The process also requires that a comprehensive understanding of watershed management and natural heritage system objectives and targets relevant to the site be gained early on in the planning and design phase of the project. It is also important that the design process has regard for the long-term implications of development on the environment as well as recognition of the anthropogenic influences that have contributed to the present state of the landscape, with the objective of identifying opportunities for restoration and enhancement. The involvement of a multi-disciplinary team is essential during the design process, to ensure that objectives identified at the conceptual planning stage are achieved in the detailed design. Although the specific contribution of each discipline may vary during the design process, it is important that all disciplines be involved in the review of design solutions at key milestones to ensure that the full range of objectives remains attainable as the process moves forward.

The integrated design process is comprised of four progressive steps which are described below:

1. Establish objectives
2. Identify targets
3. Define techniques
4. Design development

Step 1: Establish Objectives

It is necessary to establish a full range of environmental, social and functional objectives to guide the planning and design process of a new development, regardless of scale. Objectives should be established based on a detailed understanding of the environment characteristics of the site and its larger contexts. Watershed and subwatershed studies provide contextual information, objectives and targets for watershed management that inform land use planning and stormwater management planning and design at both the neighbourhood and site scales. Municipal and conservation authority stormwater management guidelines and criteria documents provide specific objectives and targets for stormwater management design. While objectives for stormwater management are a subset of the complete suite of design objectives to address a full range of

development considerations, it is important that they be considered as a first step in the design process.

Step 2: Identify Targets

In addition to specific stormwater management targets, a full range of targets should be established related to other design objectives. These may include targets relating to development density, land use mix, transportation systems and natural heritage systems that address ecological, social, functional, economic and practical considerations. Targets related to operations and maintenance should also be established for each component of a development to ensure that solutions proposed will remain practical, affordable and operational over the long-term.

Step 3: Define Techniques

Once site and project-specific objectives and targets are established, the range of stormwater management techniques required to achieve these targets is generated. This will include techniques that go beyond those that relate specifically to servicing or stormwater management. For example, techniques such as tree preservation and enhancement of natural cover may relate more to natural heritage objectives, but can also be effective stormwater management practices. Similarly there are techniques that can be implemented related to road network configuration and design, grading, built form and land use patterns that can contribute to the efficiency and effectiveness of a stormwater management strategy for a development. For this reason it is essential that a multi-disciplinary team be involved in the process of defining techniques to ensure that all opportunities are identified and considered as well as to catalyze the development of innovative, integrated solutions.

Step 4: Development Design

In this step stormwater management techniques are integrated and refined to generate site-specific design solutions and implementation strategies. Development design should be executed as a collaborative process involving the multi-disciplinary team. A workshop or charrette can be effective forums for refining design solutions efficiently while ensuring that the interests of all disciplines are addressed. As the development design phase proceeds, the solutions proposed should be evaluated with respect to the objectives and targets established in the initial stages of the design process.

The underlying goal of the integrated design process is to ensure that the fullest range of opportunities to achieve stormwater management objectives are identified and capitalized on, as well as to ensure that designs are resolved to achieve maximum benefits that consider all development related factors, even at the finest level of detail.

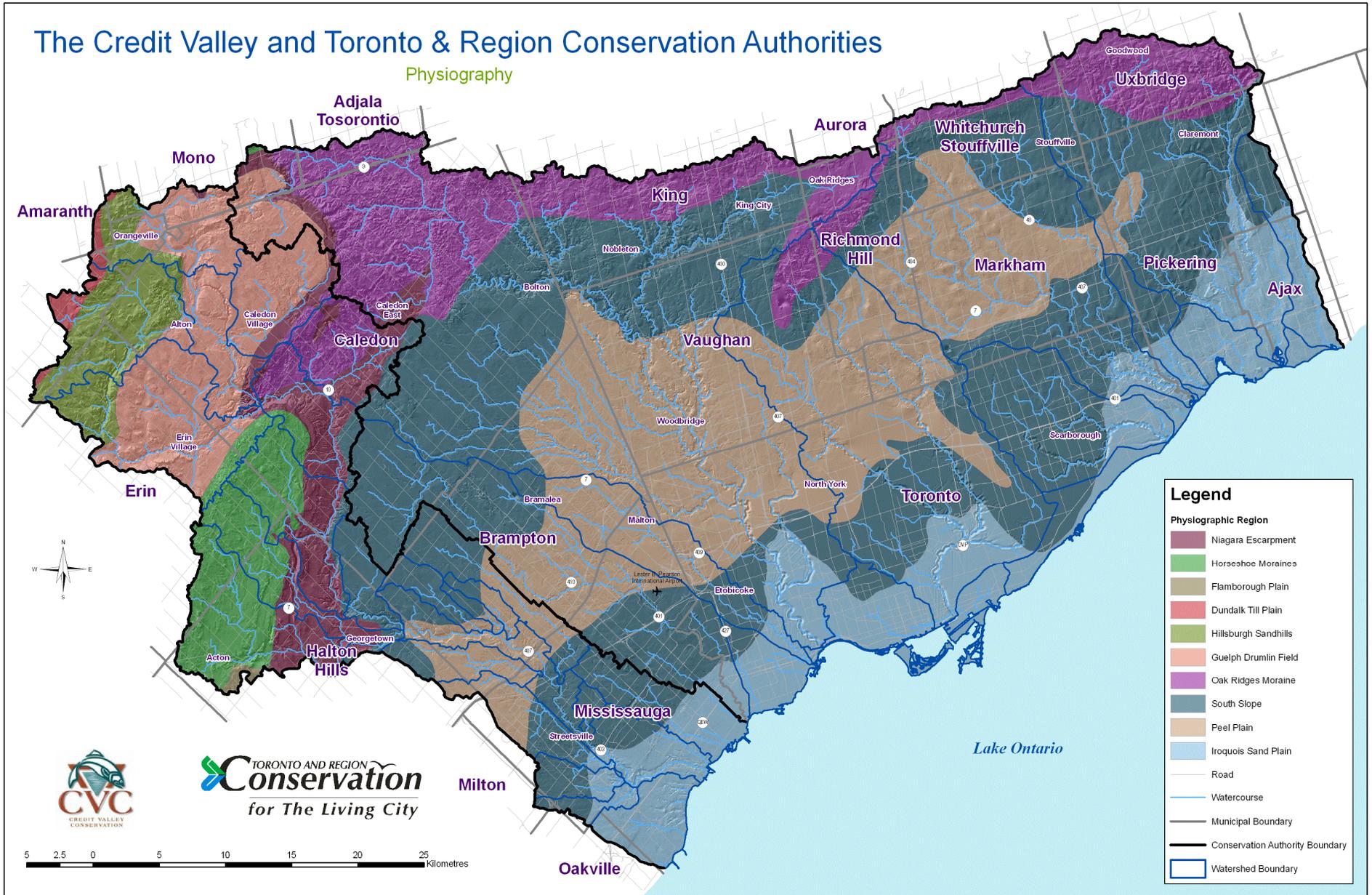
2.6 Opportunities Afforded by Landscape and Context

An understanding of the landscape and regional context of a development site provides inspiration and direction for the design of stormwater management systems that are functionally effective, efficient and complementary to the environment and the community of which they are a part. At the broad scale, planners can identify the basic strategies to address stormwater management objectives. For example, as illustrated in Figure 2.6.1, the underlying pervious soil stratigraphy associated with physiographic regions like the Lake Iroquois Sand Plain and the Oak Ridges Moraine, signals the potential to develop a stormwater strategy based primarily on infiltration practices. In contrast, sites located on the more impervious clay-based soils of the South Slope and Peel Plain may require the designer to explore strategies that employ a combination of attenuation, filtration, harvesting, evapotranspiration and infiltration practices to achieve stormwater management objectives. Stormwater management opportunities afforded by the physiographic, biophysical and ecological characteristics of the landscape can be identified and capitalized upon when sites are examined with consideration of regional landscape and watershed scale contexts.

The watershed planning approach ensures that important natural features and ecological functions and other factors that contribute to the sustainability of the regional ecosystem are identified. Watershed and subwatershed plans provide the foundation for developing a stormwater management strategy that capitalizes on the opportunities afforded by context, while respecting and responding to the elements that are fundamental to ensuring the long-term sustainability of the regional landscape.

The following section describes components of the regional landscape and the cues that they provide for designing more sustainable stormwater management strategies. Information and management recommendations regarding these components are typically provided in watershed and subwatershed plans which help to inform planning at more detailed scales of study.

Figure 2.6.1 Physiographic regions in the CVC and TRCA jurisdictions



2.6.1 Physiography and Landform

The physiography of a proposed development site is a key determinant in the process of formulating stormwater management strategies (Figure 2.6.1). In simplistic terms, physiographic characteristics such as topography and the characteristics of the soils and geology underlying the site dictate the potential to implement stormwater management strategies that employ infiltration as the primary solution. Similarly, other hydrogeologic characteristics such as depth to water table or depth to bedrock profoundly influence the feasibility of using various types of stormwater management facilities (also see section 2.6.5).

Landform also has a strong influence on the potential to implement various types of stormwater management techniques. Landform provides insight on how to design facilities such as ponds and wetlands so that they are well integrated into the landscape. Landform also dictates flow patterns, runoff velocities and discharge rates. As a general principle, development plans and stormwater management strategies should respect existing landform characteristics including maintaining predevelopment drainage divides and catchment area discharge points as closely as possible.

2.6.2 Ecological Context

The development of stormwater management practices (SWMPs), which include lot level, conveyance and end-of-pipe facilities, but in particular, detention ponds and wetlands, typically requires significant alteration of the landscape, not only in terms of physical change, but also with respect to ecosystem function. Beyond simply managing the quality and controlling the rate of discharge of runoff, ponds and wetlands can affect the function of the landscape of which they are a part. Consequently, stormwater management strategies need to be developed in consideration of their context not only with respect to the physical landscape, but also related to the function of the subwatershed ecosystem. The degree to which positive influences can be realized is determined by factors relating to the selection, siting and design of facilities.

Stormwater management practices represent opportunities in the urban environment to protect, enhance or complement existing wildlife habitat features and functions. These opportunities are typically associated with linear corridors that ultimately connect with the natural drainage system of the local landscape unit. Connecting SWMPs to neighbouring natural areas can enrich wildlife habitat in the adjacent natural areas due

to increased patch size or the provision of enhanced buffers. However, it is important to note that SWMPs are functional components of the servicing infrastructure of a development and as such, require periodic maintenance and management to ensure their optimal function. Furthermore, SWMPs are designed to remove contaminants from stormwater and as such, should not be considered natural habitat features.

While complementing wildlife habitat functions may be desirable in many circumstances, there are also situations in which wildlife use of these facilities should be deterred. This can include:

- where excessive numbers of animals are attracted and populations approach nuisance levels;
- where flocking birds need to be controlled in the low altitude vicinity of airport flight paths; and,
- where facilities are associated with or integrated into certain kinds of public park or open space areas.

2.6.3 Natural Heritage and Open Space Systems

The configuration of the natural heritage and open space systems presents opportunities to integrate stormwater management facilities into the landscape to improve connectivity, enhance the integrity of core habitat areas, and provide a spectrum of environmental benefits that extend well beyond the limits of the stormwater management facility. An understanding of the key attributes and deficiencies of the existing natural heritage system (both terrestrial and aquatic systems) is essential as a basis for the development of stormwater management strategies, to ensure that important features and functions are not compromised while identifying opportunities for enhancement.

The configuration of the open space system within a development presents opportunities to complement its size, function and connectivity through strategically locating SWMPs. SWMPs can be designed to complement the open space system by increasing its breadth, providing gateway points and view corridors and accommodating uses that further enhance the function of parks and open spaces within the community. It also presents opportunities to integrate SWMPs within parks and open spaces that could enhance the performance of the overall stormwater management system while

conserving developable land. Parks, sports fields, pedestrian plazas, walkways and other open spaces that form the public realm of a community can be strategically situated to accommodate SWMPs without compromising their utility or function. Integrating SWMPs into public spaces reduces the developable portion of a site that is used for stormwater management purposes.

2.6.4 Soils

The characteristics of soils within a site are key factors in designing stormwater management systems. A soil profile comprised predominantly of high permeability soils affords the opportunity to apply stormwater management strategies that employ infiltration as the primary treatment process. In contrast, in areas where soil permeability is low, the opportunities to use infiltration-based SWMPs may be limited, requiring the exploration of strategies that employ filtration, harvesting, evapotranspiration and detention as the primary treatment processes. The suitability of the surface soil to support healthy, dense vegetation cover is also an important consideration in the design of specific SWMPs that rely on vegetation as a functional element (e.g., bioretention, swales, vegetated filter strips).

2.6.5 Hydrogeology

Developing stormwater management plans requires an understanding of the depth to water table, depth to bedrock, native soil infiltration rates, estimated annual groundwater recharge rates, locations of significant groundwater recharge and discharge, groundwater flow patterns and the characteristics of the aquifers and aquitards that underlay the area. Shallow groundwater or bedrock conditions may present challenges with respect to the location, design and function of ponds and infiltration facilities. Of paramount concern is the potential for contamination of groundwater resources through the introduction of pollutants from stormwater into the groundwater system. In many areas within the jurisdictions of TRCA and CVC, residents still rely on groundwater for their potable water supply and so the protection of groundwater quality in these areas is of critical importance. Another important consideration is the potential to deplete groundwater resources (*i.e.*, lowering of groundwater levels in aquifers) as a consequence of unmitigated impacts on recharge from impervious cover.

2.7 Benefits of the Treatment Train Approach

Effective stormwater management strategies employ a treatment train approach that combines a suite of lot level, conveyance and end-of-pipe controls to treat runoff efficiently and effectively. At the present time, reliance on larger end-of-pipe detention pond facilities as the primary component of a stormwater management strategy is the norm. This compromises opportunities to implement low impact development practices that enhance the performance of stormwater management systems and provide ecological sustainability benefits. Treatment train stormwater management strategies that integrate a full range of facility types have the potential to achieve a broader range of benefits including:

- maintaining and enhancing shallow groundwater levels and interflow patterns;
- maintaining predevelopment drainage divides and catchment discharge points;
- moderating run off velocities and discharge rates;
- improving water quality;
- enhancing evapotranspiration;
- maintaining soil moisture regimes to support the viability of vegetation communities; and
- maintaining surface and groundwater supplies to support existing wetland, riparian and aquatic habitats.

Chapter 4 of this guide describes low impact development stormwater practices that can be applied as part of a treatment train approach to achieve this broader range of benefits.

2.8 Importance of the Runoff Source Area

With respect to water quality, all urban stormwater runoff is not equal. The types and levels of contaminants in runoff vary depending on the characteristics of the source area. For example, source areas like roads or parking lots are subject to vehicular traffic and application of sand and de-icing salt during winter, making them significant sources of such contaminants as sediment, de-icing salt constituents (*e.g.*, sodium and chloride), petroleum hydrocarbons and heavy metals. In contrast, roofs are only subject to atmospheric deposition of contaminants and are not subject to vehicular traffic, nor the

spreading of sand and de-icing salt. Roof runoff typically contains much lower levels of petroleum hydrocarbons and heavy metals than road runoff, particularly in residential areas, and is generally suitable for infiltration. Contaminant levels in runoff from low and medium traffic roads and parking lots, pedestrian plazas and walkways are typically lower than from highways or high traffic parking lots and can represent opportunities to minimize runoff through the application of permeable pavement or other infiltration practices. Certain types of source areas, referred to here as “pollution hot spots”, have a high potential to generate contaminated runoff due to the human activities and contaminant sources typically present, such as vehicle fuelling, service or demolition areas, outdoor storage and handling areas for hazardous materials and some types of manufacturing or heavy industry. Such differences in runoff contamination potential have implications on the types of treatment practices that are suitable and on opportunities for rainwater harvesting and the use of permeable pavements.

It is important that stormwater management plans be developed with consideration of the different types of runoff source areas that will be present, and recognition of source areas with low to moderate contamination potential that represent opportunities for rainwater harvesting, permeable pavement and other stormwater infiltration practices. Furthermore, it is vital to ensure that relatively clean runoff is not mixed with lesser quality runoff from surfaces that are subject to higher levels of contamination, rendering it less suitable for infiltration or harvesting. Table 2.8.1 provides descriptions of some general types of source areas, contaminant types and levels typically present in runoff and suggestions for suitable treatment practices and principles for their application.

Table 2.8.1 Types of stormwater source areas, typical runoff characteristics and opportunities for treatment and use

Stormwater Source Area	Runoff Characteristics	Opportunities	Principles
Foundation drains, slab underdrains, road or parking lot underdrains	Relatively clean, cool water.	Suitable for infiltration or direct discharge to receiving watercourses.	Should not be directed to stormwater management facility that receives road or parking lot runoff.
Roof drains, roof terrace area drains, overflow from green roofs	Moderately clean water, contaminants may include asphalt granules, low levels of hydrocarbons and metals from decomposition of roofing materials, animal droppings, natural organic matter and fall out from airborne pollutants, potentially warm water.	<ul style="list-style-type: none"> - Infiltration; - Filtration; - Harvesting with rain barrels or cisterns and use for non-potable purposes (e.g., irrigation, toilet flushing) after pretreatment; - Attenuation and treatment in wet pond or wetland detention facility. 	Runoff should be treated with a sedimentation and/or filtration practice prior to infiltration. Where possible, runoff should not be directed to end-of-pipe facilities to capitalize on potential for infiltration or harvesting. Flow moderation (quantity control) prior to discharge to receiving watercourse is required.
Low and medium traffic roads and parking lots, driveways, pedestrian plazas, walkways	Moderately clean water, contaminants may include low levels of sediment, de-icing salt constituents, hydrocarbons, metals and natural organic matter. Typically warm water.	<ul style="list-style-type: none"> - Infiltration after pretreatment; - Filtration after pre-treatment; - Harvesting with cisterns or permeable pavement reservoirs and use for outdoor non-potable purposes (e.g., vehicle washing, irrigation) after pretreatment; - Attenuation and treatment in wet pond or wetland detention facility. 	Runoff should be treated with a sedimentation and/or filtration practice prior to infiltration. Flow moderation (quantity control) prior to discharge to receiving watercourse is required. Water quality should be tested prior to use for non-potable purposes.
High traffic roads and parking lots	Potential for high levels of contamination with sediment, de-icing salt constituents hydrocarbons and metals. Typically warm water.	<ul style="list-style-type: none"> - Filtration after sedimentation pre-treatment; - Attenuation and treatment in wet pond or wetland detention facility; - Infiltration after pretreatment only where groundwater uses are limited. 	Runoff should be treated with a sedimentation and/or filtration pretreatment practice prior to infiltration.
Pollution hot spots* such as vehicle fueling, servicing or demolition areas, outdoor storage and handling areas for hazardous materials, some heavy industry sites	Potential for high levels of contamination with sediment, de-icing salt constituents, hydrocarbons, metals, and other toxicants.	<ul style="list-style-type: none"> - Attenuation and treatment in wet pond, wetland or hybrid detention facility; - Potential requirement for sedimentation pretreatment; - Infiltration and harvesting practices not recommended. 	Runoff from these sources should not be infiltrated or used for irrigation. Spill containment or mitigation devices recommended contingent on size of storage facilities.

* *Pollution hot spots* are areas where certain land uses or activities have the potential to generate highly contaminated runoff (e.g., vehicle fuelling, service or demolition areas, outdoor storage and handling areas for hazardous materials and some heavy industry sites).

2.9 Landscape-Based Stormwater Management Opportunities

Landscape-based stormwater management strategies can be applied at various scales ranging from the community scale (*e.g.*, Secondary Plan or Block Plan stages), neighbourhood scale (*e.g.*, Draft Plan of Subdivision or Registered Plan stages) to the site scale. The most effective strategies are developed at larger scales and subsequently refined at progressively more detailed scales in the planning and design process. Stormwater management opportunities identified at the larger scales provide the basis for an overall stormwater management strategy that functions as a system of integrated facilities applied at the subdivision or site scales. In addition, the recent focus on intensification within existing urban areas dictates the need to identify opportunities to retrofit stormwater management practices into existing developments and service infrastructure contexts. Creative problem solving will be required to achieve stormwater management objectives within these constrained sites.

Throughout the full range of scales, there is a need to consider landscape and the elements of urban development as a cohesive unit in order to identify the most effective set of solutions for a particular site. Components of urban development such as built form, roads and services present opportunities to achieve stormwater quality and quantity control objectives through innovative design. For built form, alternatives include the incorporation of green roofs, permeable pavement, and rainwater harvesting systems. With respect to roads, options include reduced on-street parking, innovative road network designs (*e.g.*, fused grid road network; CMHC, 2007), the installation of permeable pavement, the use of swales, vegetated filter strips and bioretention areas in boulevards or the integration of perforated pipe systems beneath the road bed. The application of these alternatives can help reduce reliance on end-of-pipe facilities by reducing the quantity of impervious cover in a development and treating stormwater closer to where it is generated. Opportunities that can be applied at scales ranging from large scale to site specific are discussed in the following sections.

2.9.1 Opportunities at the Community Scale

At the community scale (*e.g.*, Secondary and Block Plan stages), the exploration of stormwater management solutions should be focused on a thorough understanding of the physical and ecological characteristics of the landscape. The properties of the native soils, groundwater depth and flow patterns, topography and the assemblage of

natural heritage features within and adjacent to the limits of the site provide the fundamental basis for the exploration of landscape-based stormwater management strategies. Characteristics of the landscape can have a profound influence on stormwater management objectives and therefore the environmental inventory phase of the community design process needs to be sufficiently detailed. In addition to inventories of natural heritage features and functions that would typically be addressed within an Environmental Impact Report (EIR) or Master Environmental Servicing Plan (MESP), a landscape-based approach to stormwater management planning requires understanding the following additional parameters:

- small headwater drainage features and their contributing catchment areas; and
- groundwater recharge rates, flow patterns and discharge areas.

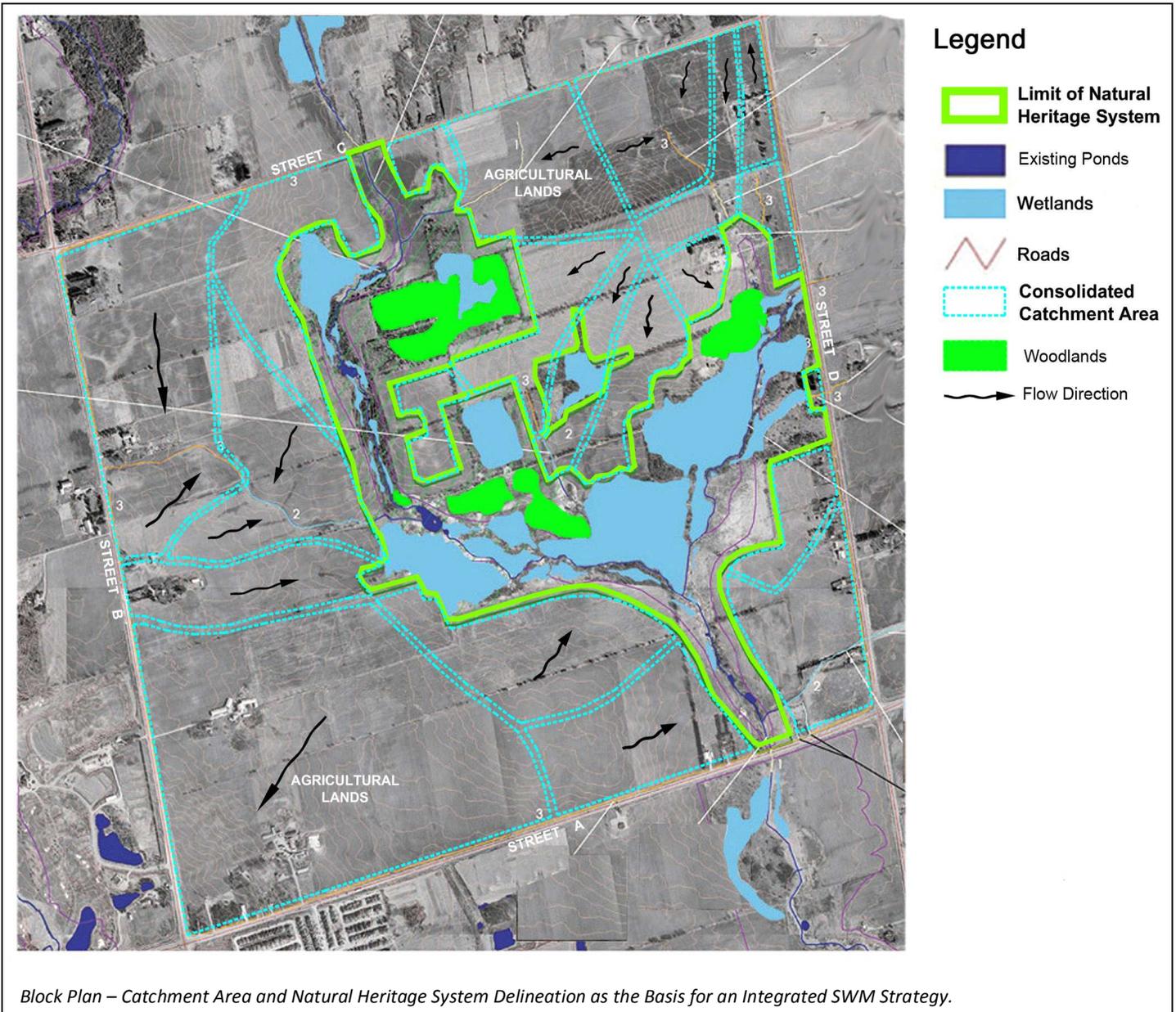
As an initial step in the planning process, opportunities to conserve natural heritage features (*i.e.*, green infrastructure) should be identified and features that contribute to the ecological integrity of the landscape should be incorporated into the overall development scheme (e.g., Figure 2.9.1). Natural features should be considered for preservation not only because of their ecological value and habitat function, but also in consideration of their contribution to evapotranspiring and infiltrating stormwater. Enhancement of the urban tree canopy and extent of forest cover in urban/urbanizing subwatersheds is an effective stormwater management strategy (TRCA, 2007c, TRCA, 2007d; TRCA 2008a). Preservation of existing natural heritage features can complement the function of SWMPs as part of a comprehensive stormwater management strategy.

New developments and communities are designed in consideration of a full range of environmental, transportation, social, practical and functional objectives to optimize their function, marketability and long term sustainability. It is important that stormwater management objectives be considered in the process of planning each of these components. For example, as mentioned in section 2.6.1, maintaining predevelopment drainage divides and catchment discharge points as closely as possible should be an objective that is considered. One means of achieving this is to align major roads to follow the divides between sub-catchment areas and local roads to follow overland flow directions. Open space components within a community plan should be situated, where possible, near the downstream limit of the sub-catchment area in order to optimize the potential to integrate stormwater management facilities within the open space system.

A suggested process for identifying landscape-based stormwater management opportunities at the community scale (e.g., Secondary Plan or Block Plan stage) is comprised of the following steps:

1. Use available information from regional, watershed and subwatershed scale studies to develop an understanding of the environmental contexts in which the site is located and the watershed management objectives and targets (e.g., stormwater management, natural heritage system and aquatic community objectives/targets) relevant to the site.
2. Undertake a comprehensive inventory of the biophysical, ecological and hydrological characteristics of the site.
3. Identify existing terrestrial and aquatic natural heritage features and functions that require protection as the basis for a natural heritage system.
4. Identify opportunities to enhance features, connectivity and functional integrity of the natural heritage system.
5. Identify soil and hydrogeologic conditions that are well-suited for stormwater infiltration practices.
6. Identify patterns of shallow groundwater flow and locations of discharge to receiving watercourses or wetlands within or adjacent to the limits of the site.
7. Identify strategic and desirable locations for stormwater management practices (SWMPs) and the nature and function of facilities (e.g., attenuation, infiltration, filtration, evapotranspiration, harvesting, etc.).
8. Identify a long list of opportunities to integrate desirable SWMPs into components of the community or built form.
9. Explore a full range of design options for the community that can achieve stormwater management objectives in conjunction with other community design objectives.
10. Develop the community design plan.
11. Resolve the design of the stormwater management strategy including defining the SWMPs to be incorporated into the design of specific components of the development and establish specific design and performance criteria for each practice.

Figure 2.9.1 Block plan – catchment area and natural heritage system delineation as the basis for an integrated stormwater management strategy



Block Plan – Catchment Area and Natural Heritage System Delineation as the Basis for an Integrated SWM Strategy.

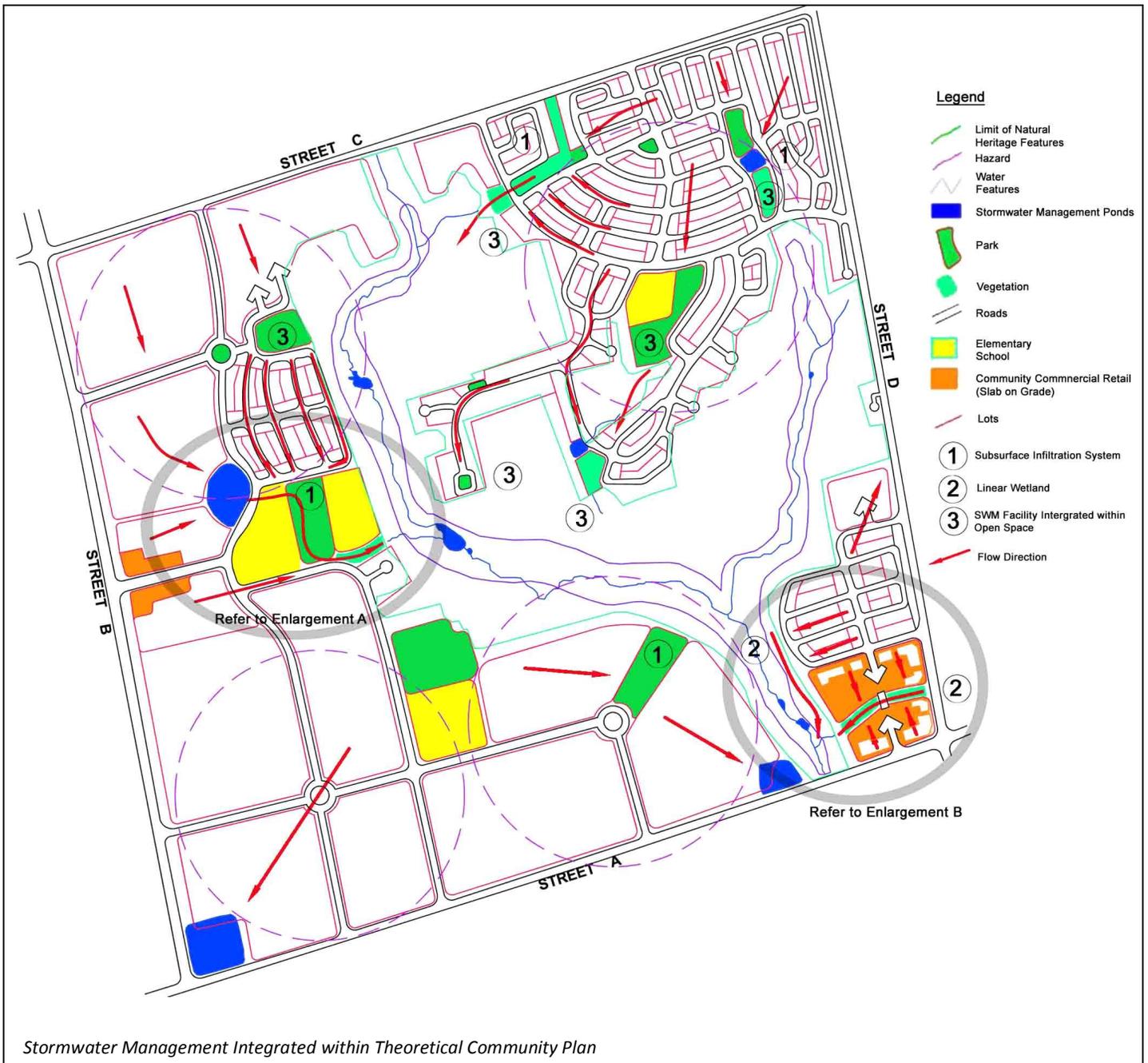
Source: Schollen and Company Inc. et al. 2006, Markham Small Streams Study

This process differs from traditional development planning and design processes in the following ways:

- detailed environmental inventory information regarding small drainage features and groundwater recharge, flow directions and discharge areas is required early in the process;
- where possible, configuration of the major road network and development blocks is defined by sub-catchment boundaries within the site;
- where possible, configuration of the local road network follows overland flow directions;
- open space corridors are located along important drainage features;
- where possible, parks are located at the downstream end of sub-catchments that contribute runoff to important drainage features to provide opportunities for integration of SWMPs;
- where underlying soils and geology are conducive, infiltration practices are a major component of the stormwater management system;
- surface conveyance systems (e.g., grassed swales) are considered, where feasible; and
- consideration is given to alternative built forms where topographic or hydrogeologic constraints exist.

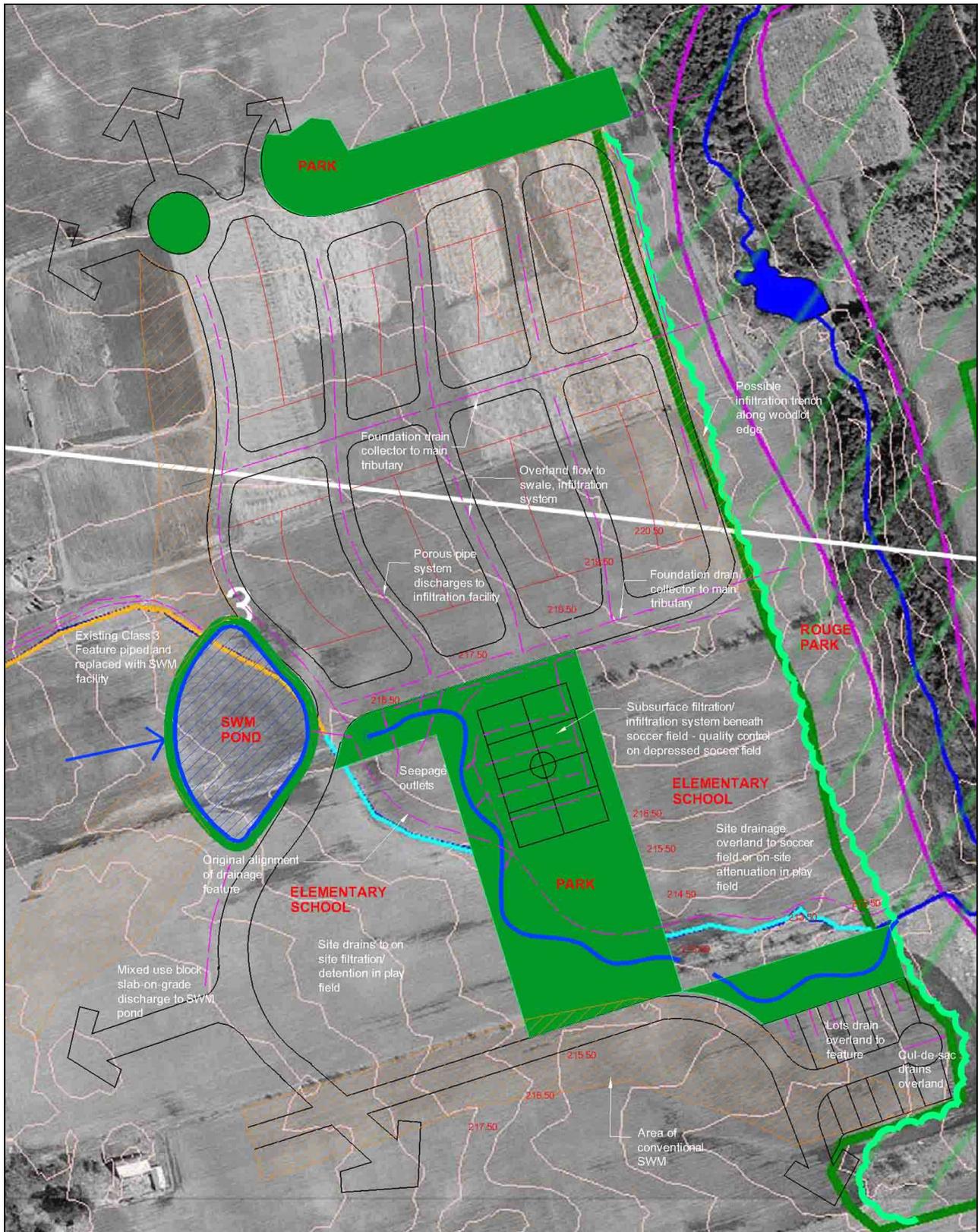
It is at the community scale that the full range of opportunities to achieve stormwater management objectives is identified. This establishes a template for more detailed resolution of the site specific design of SWMPs at subsequent stages in the planning and design process. To be fully effective, it is important at this early stage to explore the broadest range of SWMPs in order to ensure that opportunities are not missed prior to embarking on more detailed planning stages. Figures 2.9.2 to 2.9.4 illustrate the theoretical community design plan that would result from application of the landscape-based stormwater management planning process described above.

Figure 2.9.2 Stormwater management integrated within a theoretical community plan



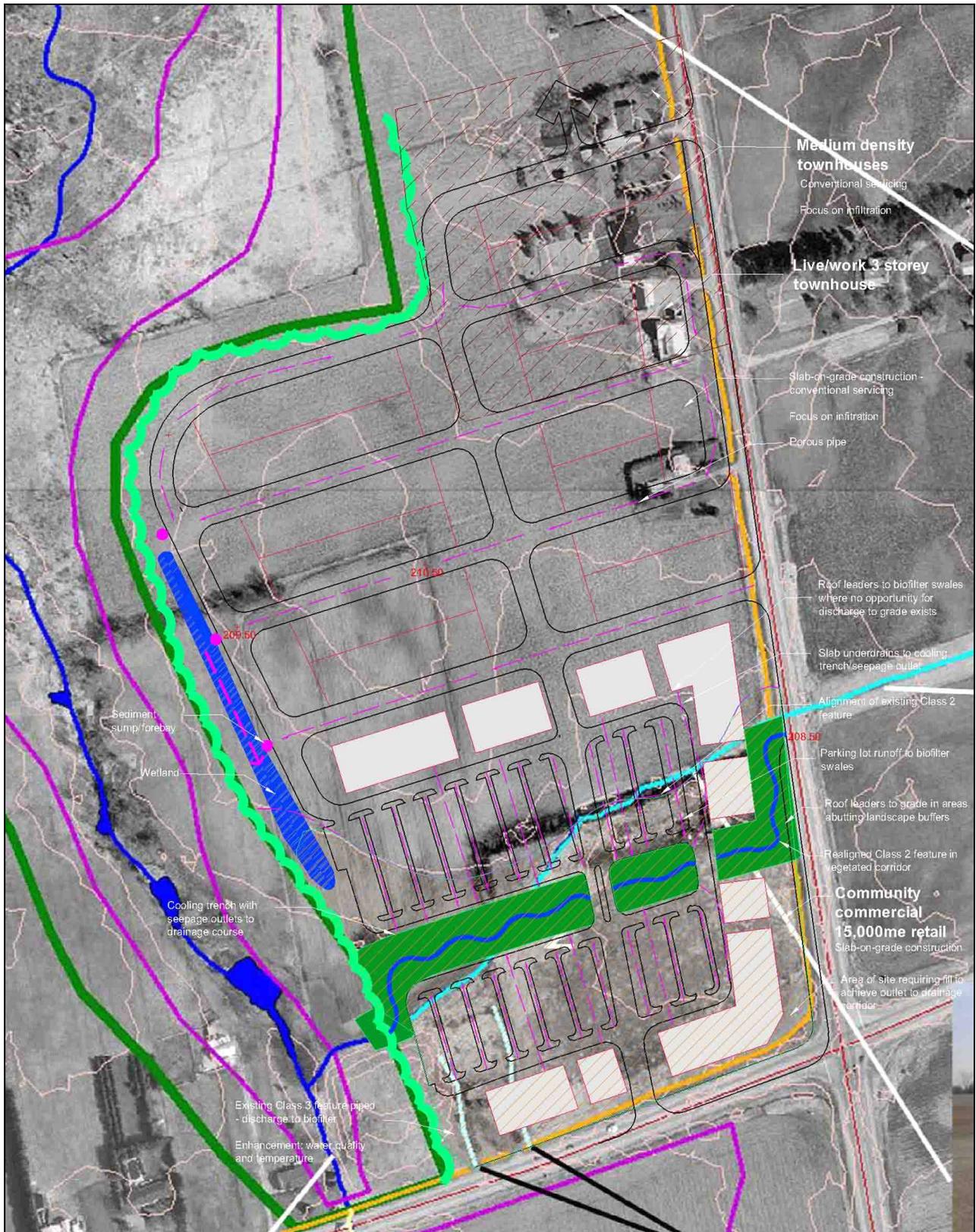
Source: Schollen and Company Inc. *et al.* 2006, Markham Small Streams Study

Figure 2.9.3 Demonstration plan – residential and institutional sub-catchment



Source: Schollen and Company Inc. *et al.* 2006, Markham Small Streams Study

Figure 2.9.4 Demonstration plan – commercial and mixed use sub-catchment



Source: Schollen and Company Inc. et al. 2006, Markham Small Streams Study

2.9.2 Opportunities at the Neighbourhood Scale

At the neighbourhood scale (e.g., Draft Plan of Subdivision stage), the location of lots, roads, parks and open space blocks, natural heritage features and buffers and SWMPs are defined. Consequently, it is important at this stage in the planning process to consider how stormwater management objectives can be achieved and how these objectives might influence the location and configuration of each of the components listed above. At the neighbourhood scale, there are opportunities to achieve stormwater management objectives:

- in road rights-of-way;
- in parks and open spaces; and
- at the lot level.

Road Right-of-Way Opportunities

The road network comprises a significant component of a Draft Plan of Subdivision with its configuration typically designed to address transportation, transit and servicing objectives alone. However, the road network also represents potential opportunities for low impact development (LID) practices that can help to minimize and treat runoff and achieve stormwater management objectives. Such opportunities include:

- incorporating SWMPs such as bioretention areas, soakways or permeable pavement into boulevards, parking lanes, cul-de-sac islands and roundabouts, and perforated pipe conveyance systems below the road bed;
- minimize impervious surfaces through innovative road network design (e.g., fused grid road network; CMHC, 2007) and by designing low traffic roads with only one lane of parking, sidewalks on only one side, and/or infiltration island cul-de-sacs or roundabouts.

Parks, Recreation and Open Space Opportunities

Parks, recreation areas (e.g., sports fields) and open spaces present the potential to integrate SWMPs as amenities within the landscape. However, it is important that the integration of SWMPs within the public amenity space does not compromise its utility or function.

Integrating SWMPs within parks and open spaces provides opportunities to:

- construct infiltration or filtration facilities beneath sports fields, picnic areas, parking lots, playgrounds, trails and walkways;
- incorporate bioretention, vegetated filter strips and swales into open spaces as components of the landscaping plan;
- integrate SWMPs as water feature amenities within a park; and
- incorporate infiltration facilities within buffers adjacent to natural heritage features where the function and ecological integrity of the feature would not be compromised.

Lot Level Controls

At the neighbourhood scale (e.g., Draft Plan of Subdivision stage), opportunities for a full range of lot level controls should also be considered. Lot level stormwater management facilities can be designed to be aesthetically attractive landscaping areas at the surface (e.g., rain gardens/bioretention areas, green roofs, vegetated filter strips), or subsurface practices located below parking areas, roads, walkways, plazas, parks or sports fields that are not visible and take up no footprint at the surface.

However, unlike conveyance and end-of-pipe controls that typically become property of the municipality and are operated and maintained as public infrastructure, operation and maintenance of lot level controls on private property are the responsibilities of the individual property owners, managers or management organizations. To ensure that their functions are maintained over the lifespan of the facility, legal agreements regarding their long term operation and maintenance will need to be established, and training provided on their function and inspection and maintenance requirements.

As integrated components of the overall stormwater management strategy developed at the Draft Plan of Subdivision stage, the feasibility and long term viability of lot level controls need to be confirmed at the outset in consultation with the municipality to ensure that the strategy proposed can be implemented and will remain effective. The successful application of lot level controls requires both the commitment of the municipality and the establishment of agreements between the developer, municipality and property owner. Strategies to achieve this include:

- placing easements over the areas within which the infrastructure is located in favour of the municipality to allow for periodic inspection and maintenance of the

facility should the owner or manager fail to do so;

- placing outlet control structures (e.g., an orifice control on a bioretention system outlet) on municipal property outside the limit of the private land holding to allow for inspection, operation and maintenance by municipal personnel;
- requiring the submission of performance monitoring reports for review by the municipality or conservation authority;
- requiring a legal agreement to ensure that the system remains fully operational and is properly maintained;
- requiring the owner to pay the present value LID maintenance cost for the service life of the development into a municipal maintenance fund; and
- implementing an annual storm sewer user fee as part of municipal property tax or water bills based on the quantity of impervious cover that drains directly to a storm sewer (i.e., does not first drain to a pervious area or LID practice) as an incentive for property owners to maintain existing LID practices and retrofit new practices on their properties where possible.

Implementation of a property owner/manager education program that is focused on ensuring operation and maintenance of lot level controls is also critical to realize consistent benefits over the long-term. A property owner/manager education program should be comprised of the following:

- *Pre-Sales Information Package*: This information package should be provided to prospective buyers and made available as a display in the sales office. The package should describe the lot level control to be implemented, its operation and the basic maintenance requirements. It is important that this information package also stipulate clearly that the lot level control is not to be altered.
- *Purchase Agreement Package*: This information package should form part of the agreement to purchase the property and should describe the system and any maintenance requirements as well, to encourage homeowners to maintain the installation. It is important that this document be focused on encouraging the

maintenance of lot level initiatives. This information package should also be attached to the purchase agreement of subsequent property owners in the event that the property is resold in the future.

- *Property Owner's Guide:* A user-friendly property owner's guide should be distributed to residents after they move in. The guide should be simple and informative and should provide a basic description of the lot level control, its function and any maintenance requirements.
- *Newsletter:* In some communities, periodic newsletters are circulated informing homeowners of the activities which are occurring in their community. Information regarding the function of lot level controls should be included in the newsletter on a periodic basis. This approach serves to remind homeowners about the need to ensure that the function of the installation should be maintained.

Implementation of lot level controls can effectively reduce reliance on end-of-pipe facilities and result in a stormwater management strategy that is more beneficial to the environment than conventional end-of-pipe based solutions. Other incentives for implementing lot level controls include reduced costs for the construction of end-of-pipe facilities and potential reductions in the amount of land needed for SWMPs. Legal agreements and training regarding long term operation and maintenance of lot level controls on private property will be required, in order to allow reductions in the required size of downstream end-of-pipe controls as compensation for implementing lot level controls upstream. In evaluating the viability of this approach on a particular site, stormwater management system designers will need to quantitatively estimate the performance of upstream SWMPs in order to rationalize a requested reduction in size of an end-of-pipe facility and must get approval from regulatory agencies.

The following sections describe different types of lot level stormwater management controls that should be considered at the neighbourhood scale (e.g., Draft Plan of Subdivision stage).

Depression Storage

Directing drainage from roof downspouts to shallow depressed areas in front, rear and side-yard areas is a simple technique to store and infiltrate runoff where possible. Depression storage areas can be located in low areas, planted as gardens or situated

beneath decks. Typically, depression storage areas are small and have limited capacity and limited duration of retention in order to address property owner concerns relating to insects, damage to structures and inconvenience of ponded water on their property. Although their individual effectiveness is limited by their size, cumulatively depression storage areas can provide significant benefits in a stormwater management system.

Depression storage and other stormwater infiltration practices are particularly effective in areas with high soil permeability. Stormwater directed to depression storage and other infiltration practices should be from relatively clean sources including roof leaders and walkways, rather than surfaces prone to the accumulation of sand, oil and grit, to ensure the long-term function of the facility. Infiltration practices should not be proposed in areas where the water table is shallow or where there is the potential for stormwater with high contaminant concentrations. Care must be taken on properties where potable water sources are groundwater based to ensure that infiltration practices will not impair the quality of groundwater in underlying aquifers for use as drinking water. Depression storage and infiltration practices should be designed with an overflow outlet to ensure that positive drainage away from the basement of the building is achieved in the event that the function of the installation is compromised, or its capacity is exceeded.

Bioretention Areas

Bioretention areas are shallow excavated surface depressions containing mulch and a prepared soil mix and planted with specially selected native vegetation that captures and treats runoff (see section 4.5 for detailed design guidance). During storms, runoff ponds in the depression and gradually filters through the mulch, prepared soil mix and root zone. The filtered runoff can either infiltrate into the native soil or be collected in a perforated underdrain and discharged to the storm sewer system. They remove pollutants from runoff through filtration in the soil and uptake by plant roots and can help to reduce runoff volume through evapotranspiration and full or partial infiltration. They can also provide wildlife habitat and enhance local aesthetics.

Bioretention areas can be integrated into a range of landscape areas including medians and cul-de-sac islands, parking lot medians and boulevards. A variety of planting and landscape treatments can be employed to integrate them into the character of the landscape. Biofilters are a design variation that feature an impermeable liner and underdrain due to site constraints and are typically applied as pretreatment to another stormwater control although they can be effective as stand alone filtration facilities.

Rain Gardens

A variation on depression storage and bioretention areas, the rain garden is a deliberately designed landscape, with specific plant species and soil media to receive and detain, infiltrate and filter runoff discharged from roof leaders (see section 4.5 for detailed design guidance). Rain gardens are effective in both new and retrofit situations and can be designed to complement the landscape of most properties. The rain garden is constructed on a base of granular material with plant material selected for its rooting characteristics and tolerance of varying soil moisture conditions. The drainage area of the roof plane contributing to the downspout determines the size of the garden.

As with depression storage, rain garden installations are effective in areas where soil permeability is high. In addition, provision must be made to facilitate positive drainage away from the rain garden in the event storm flows exceed capacity. Although rain gardens were initially conceived for implementation on private residential lots under retrofit situations, they are also applicable to larger commercial, industrial, institutional and condominium developments as components of a treatment train stormwater management strategy.

Soakaways

Soakaways, which can also be referred to as infiltration trenches, galleries or chambers, are constructed below grade and therefore take up little or no space at the surface (see section 4.4 for detailed design guidance). Such facilities can be installed below a broad range of land uses including residential yards, parking areas, walkways, pedestrian plazas, parks and sports fields. The following are examples of approaches that can be employed to integrate soakaways into the landscape:

- Linear soakaways or infiltration trenches can be designed for installation beneath granular surfaced trail systems. Runoff from the adjacent development can be directed to the infiltration trench, while the trail network enhances the connectivity of the open space network within the community.
- In new communities that have been designed based upon the principles of new urbanism, soakaways can be incorporated into the rear laneways. Runoff from the roof areas of adjacent garages and residences is directed to the soakaway. Soakaways can also be retrofitted below rear laneways (e.g., City of Chicago Green Alleys program).

- Soakaways can be constructed beneath decks, lawns and driveways of residential properties.

Permeable Pavement

Permeable pavement is a variation on traditional pavement design that utilizes pervious paving material underlain by a uniformly graded stone reservoir (see section 4.5 for detailed design guidance). The pavement surface may consist of permeable asphalt, permeable concrete, permeable interlocking concrete pavers, concrete grid pavers and plastic grid pavers. Openings in permeable interlocking concrete pavers, concrete grid pavers and plastic grid pavers are typically filled with pea gravel, sand or top soil and grass. Permeable pavements prevent the generation of runoff by allowing precipitation falling on the surface to infiltrate into the stone reservoir and, where suitable conditions exist, into the underlying soil. They are most appropriately applied in low to medium traffic areas (e.g., residential roads, low traffic parking lots, driveways, walkways, plazas, playgrounds, boat ramps etc.) that typically receive low levels of contaminants. In addition to the stormwater management benefits, permeable pavements can be more aesthetically attractive than conventional, impermeable pavements.

Vegetated Filter Strips

Gently sloping, densely vegetated areas that are designed to treat runoff as sheet flow from adjacent impervious surfaces (see section 4.6 for detailed design guidance). Filter strips function by slowing runoff velocities and filtering out sediment and other pollutants, and by providing some infiltration into underlying soils. Filter strips may be comprised of a variety of trees, shrubs, and native vegetation to add aesthetic value as well as water quality benefits. They are best suited to treating runoff from roads and highways, roof downspouts and low traffic parking lots. They are also ideal as pretreatment to another lot level or conveyance practice. Filter strips also provide a convenient area for snow storage and treatment.

Conveyance Controls

Opportunities to incorporate conveyance controls also need to be considered at the neighbourhood scale (e.g., Draft Plan of Subdivision stage). Conveyance controls include grassed swales and perforated pipe systems (*i.e.*, exfiltration systems), which treat and infiltrate runoff while it is being transported from individual lots to a treatment facility and ultimately, to the receiving watercourse or water body. Where suitable conditions exist, they can be used instead of conventional storm sewer pipes.

Conveyance controls are typically situated within road rights-of-way or on other public property and are operated and maintained as part of municipal infrastructure. However, their operation and maintenance requirements differ from conventional stormwater conveyance infrastructure. To ensure the facilities are properly maintained over their expected lifespan, municipal staff will need to be provided training on their function, inspection and maintenance requirements.

The following sections describe different types of conveyance controls that should be considered at the neighbourhood scale (e.g. Draft Plan of Subdivision stage).

Grass Swales

Grass swales are vegetated, open channels designed to convey, treat and attenuate runoff. Design variations include simple grass channels, enhanced grass swales (see section 4.8 for detailed design guidance), and dry swales or bioswales (see section 4.9 for detailed design guidance). Vegetation in the swale slows the water to allow sedimentation, filtration through the soil matrix and root zone, and infiltration into the underlying native soil, where suitable conditions exist. They are well suited for treating highway or residential road runoff because they are linear practices but may not be well suited to high density urban areas because they require a relatively large area of pervious surfaces. Swales can also be used as snow storage areas.

Perforated Pipe Systems

A stormwater conveyance system that features pipe that is perforated along its length and installed in a granular bedding which allows infiltration of water into the native soil through the pipe wall as it is conveyed (see section 4.10 for detailed design guidance). They can also be referred to as pervious pipes, percolation drainage systems or exfiltration systems. Design variations can also include catchbasins that are connected to granular stone reservoirs by pervious pipes or where the catchbasin sumps are perforated, allowing runoff to gradually infiltrate into the native soil. They are best suited to treat drainage from low to medium traffic areas with relatively flat or gentle slope.

2.9.3 Opportunities at the Site Scale

At the site scale (e.g., Site Plan stage), both the detailed configuration of built form and landscape are resolved, presenting a range of opportunities to design stormwater management controls as integral components of the development site. At this scale, there are opportunities to integrate stormwater management practices (SWMPs) into all of the components of a development including landscaped areas, parking areas, roof tops and subsurface infrastructure. Figures 2.9.5 and 2.9.6 illustrate examples of how SWMPs can be fully integrated into the design of the site. Facility designs must be considered in the context of the overall stormwater management strategy developed at the neighbourhood scale to ensure that watershed management objectives, targets and functional requirements are achieved. Legal agreements, incentives and/or property owner education materials may be needed to ensure long term operation and maintenance of stormwater management practices implemented at the lot level (see Section 2.9.2 - Lot Level Controls for further guidance).

Potential opportunities to integrate SWMPs at the site level stage in the planning process include:

- harvesting of rainwater from rooftops for non-potable uses (e.g., irrigation, toilet flushing) using rain barrels or cisterns;
- installation of green roofs;
- drainage of runoff from rooftops to pervious or depression storage areas;
- integration of soakaways (e.g., infiltration trenches or chambers) below landscaped areas, parking areas, parks, sports fields, etc.;
- incorporation of bioretention areas, rain gardens, biofilters or constructed wetlands into the landscape design for the site;
- use of permeable pavement in low and medium traffic areas;
- incorporation of bioretention areas, vegetated filter strips, and swales to intercept and treat parking lot and road runoff;
- incorporation of woodland restoration in upstream areas to reduce runoff rates;
- integration of detention ponds and wetlands as large aesthetic and recreational features within the landscape.

Figure 2.9.5 Institutional building – integrated stormwater management and landscaping plan



Source: Thunder Bay Regional Health Centre Model Study

Figure 2.9.6 Integrated stormwater management and landscaping plan for a school



Source: Bill Crothers Secondary School, Town of Markham.

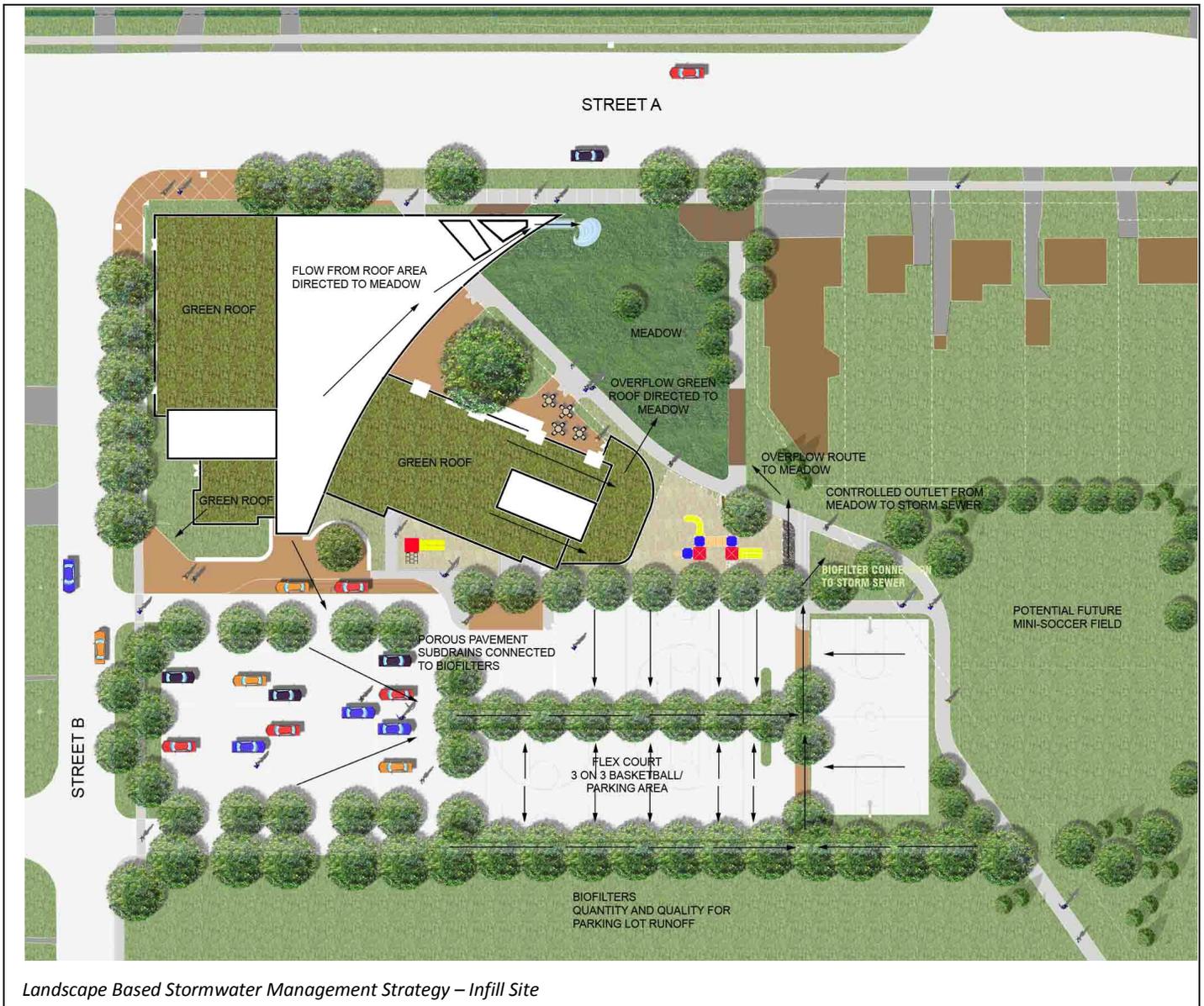
2.9.4 Infill and Redevelopment Opportunities

Infill and redevelopment present the most complex challenges with respect to integrating landscape-based solutions for stormwater management. This is because:

- sites are typically constrained with respect to the extent of potential open space available;
- there is typically limited flexibility to manipulate topography since grades around the perimeter of the site are fixed;
- service infrastructure around the site, including stormwater conveyance systems are typically fixed in terms of location, depth and capacity; and
- the presence of other service infrastructure beneath and around the site may limit potential excavation depths and opportunities for infiltration.

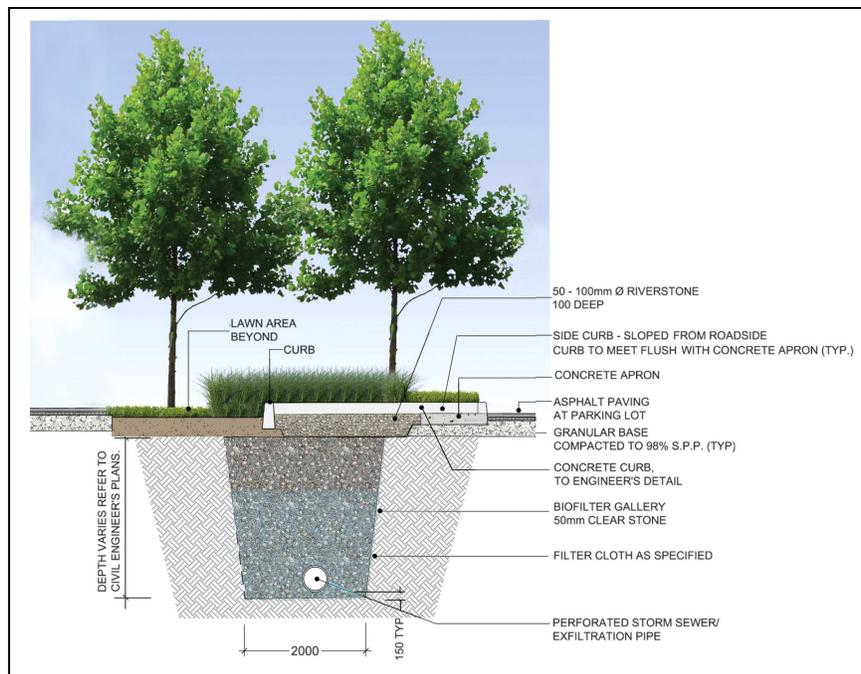
As a result, the exploration of stormwater management solutions for infill and redevelopment sites requires a high level of imagination, ingenuity and creativity. Figures 2.9.7 to 2.9.9 illustrate examples of SWMPs that can be incorporated into infill and redevelopment contexts.

Figure 2.9.7 Landscape-based stormwater management strategy – infill site



Landscape Based Stormwater Management Strategy – Infill Site

Figure 2.9.8 Examples of integrated SWM practices in infill and redevelopment sites



Source:, Schollen & Company Inc.

The opportunity for incorporating stormwater management facilities into infill and redevelopment sites needs to consider context and the limits of both landscape and built form. Stormwater management opportunities that should be explored for infill and retrofit developments include:

- roof top storage;
- green roofs;
- rainwater harvesting;
- bioretention areas;
- biofilters;

- grassed swales;
- permeable pavement;
- rain gardens;
- stormwater planters and fountains;
- depression storage;
- soakaways;
- constructed wetlands; and
- enhanced urban tree canopy.

Details regarding the application and design of these stormwater management techniques are discussed in Chapter 4.

Figure 2.9.9 More examples of SWM in infill and redevelopment sites



Durham College / UOIT – Linear SWM Wetland, Oshawa, Ontario – Schollen & Company Inc.



Biofilters – Edithvale Community Centre (Source: Schollen & Company Inc.)