Water Budget Discussion Paper

Prepared for
Toronto and Region Conservation

Submitted by
Gartner Lee Limited

October, 2006

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1. INTRODUCTION

Objective

Recent studies and analyses of available data indicate an imperative need to achieve volume control of storm runoff in order to avoid adverse impacts on aquatic habitat, streambank` erosion, and overall water quality in our creeks and rivers *(Aquafor, 2005; Stanfield and Kilgour, 2004; Schueler and Holland, 2000)*. Continuing the practices of recent years, which addressed a wide range of issues, but generally neglected any significant attempts to preserve the natural water balance through volume control measures, is no longer acceptable.

In response to this developing need, and in order to deal with the issue in an inclusive and comprehensive manner, Toronto and Region Conservation (TRCA) has prepared this *Water Budget Discussion Paper* to facilitate the following:

- document and confirm the rationale for striving to maintain the natural water budget;
- summarize the evolution of stormwater management, and how the time has arrived for the inclusion of water balance considerations;
- review the current direction being adopted in local municipalities, and examine how other jurisdictions have/are dealing with it; and,
- provide information that can form the basis for discussions with area municipalities.

This document focuses on the need for the inclusion of water balance considerations within the context of stormwater management practices for new development. This initiative on the part of TRCA to incorporate the water balance within the development process forms part of a broader set of policy directives that collectively contribute to overall water balance management; these include: surface and groundwater takings, and servicing infrastructure design.

To support this *Water Budget Discussion Paper,* TRCA is undertaking an additional literature review to identify the current understanding of the interrelations between water balance, erosion, and stormwater management practices. The goal is to prepare a report that synthesizes the overall state of knowledge with respect to the need for, and practice of, improved stormwater management to minimize impacts to receiving watercourses.

For the purposes of this document, the term *new development* is intended to encompass the various forms of urbanization that can occur, including greenfield development, redevelopment of existing lands, and infill/retrofit situations.

Watershed Areas

TRCA's jurisdiction includes an area of 3,487 km^2, of which 2,506 km^2 are on land and the remaining 961 km^2 being water-based. This area is comprised of nine watersheds that encompass the following:

- Etobicoke Creek
- Mimico Creek
- Humber River
- Don River
- Highland Creek
- Rouge River
- Petticoat Creek
- Duffins Creek
- Carruthers Creek

TRCA's jurisdiction also extends into Lake Ontario to a point defined by the Territorial Divisions Act, R.S.O.S.O. 1980. The watershed limits, together with the key municipal boundaries, are shown on ***Figure 1***.

The jurisdictional area of TRCA extends within the boundaries of six participating or member municipalities:

- City of Toronto
- Town of Mono
- Twp. Adjala-Tosorontio
- Regional Municipality of Durham
- Regional Municipality of Peel
- Regional Municipality of York

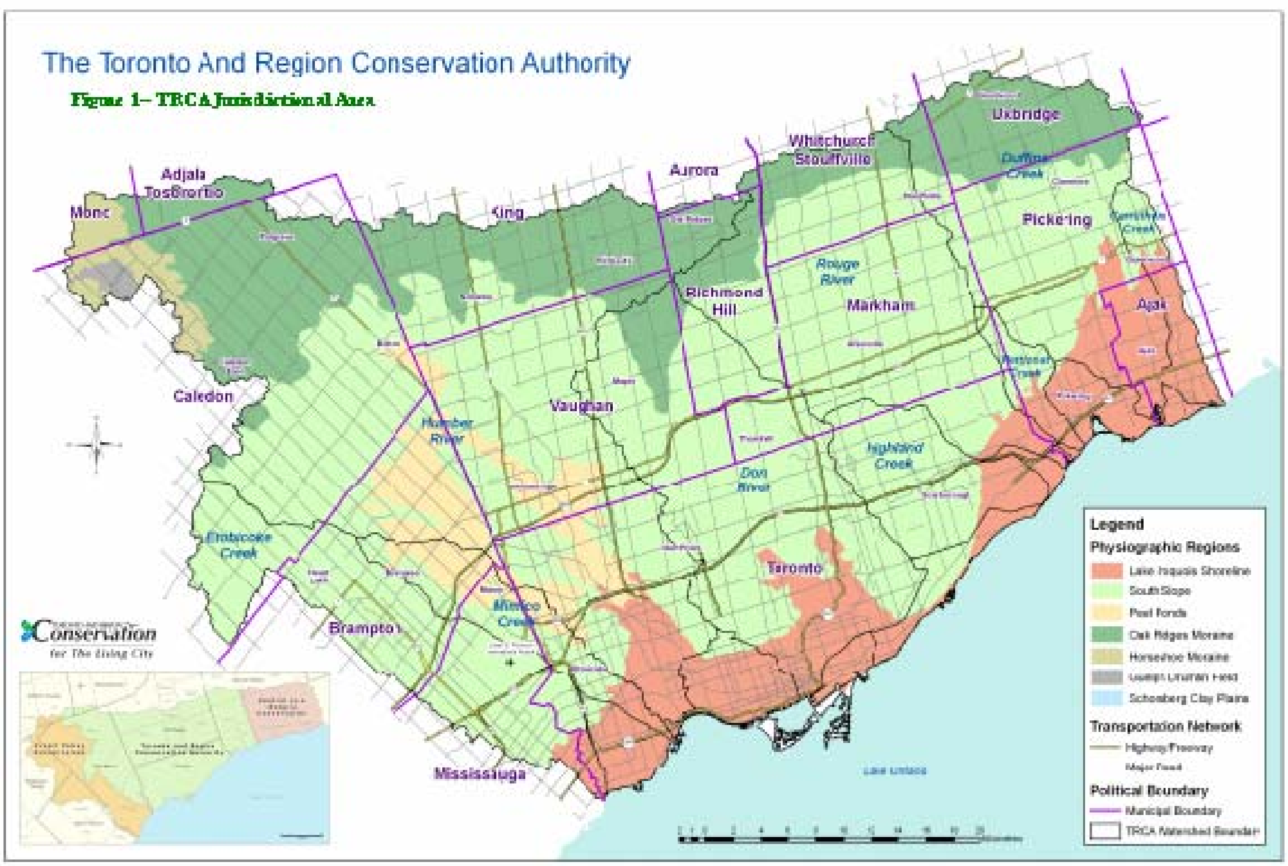


Figure 1 – TRCA Jurisdictional Area

The TRCA's jurisdictional area wholly encompasses the City of Toronto and significant parts of the three Regional municipalities, including all or part of the following local municipalities:

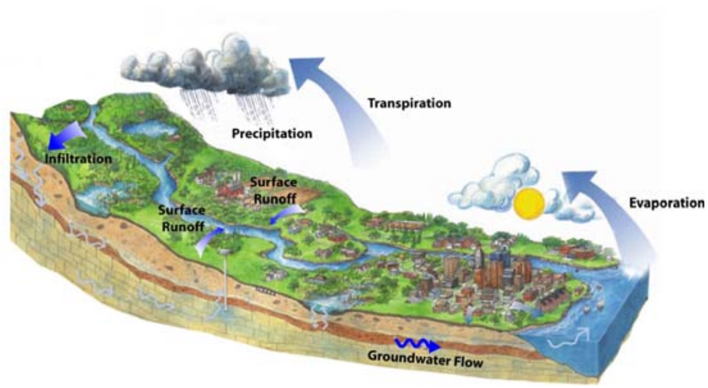
- City of Brampton
- City of Mississauga
- Town of Caledon
- City of Vaughan
- Township of King
- Town of Richmond Hill
- Town of Markham
- Township of Uxbridge
- City of Pickering
- City of Ajax
- Town of Whitchurch-Stouffville

The TRCA works cooperatively with the Regional and municipal governments to help plan and implement future growth and services in a manner that is founded on sound scientific principles aimed at the long term sustainability of the ecosystem, which are fundamental to the health and well being of area residents.

2. PRINCIPLES OF THE HYDROLOGIC CYCLE

As our cities and communities grow, visible changes are affected on our environment in the form of housing developments, roadway systems and municipal servicing infrastructure.

Accompanying these very visible changes are the impacts to water resource systems and the dependent ecosystems.



Adapted from Conservation Ontario

To understand the impacts, it is beneficial to gain an insight into the hydrologic cycle. Also referred to as the water budget[1], it represents the endless recirculatory transport process that constantly moves water between the earth's storage reservoirs – the land, the oceans and the atmosphere. Water is unique among the substances found in the earth's environment due to it's occurrence in all three states of matter: liquid, solid, and gaseous.

The largest of the reservoirs are the oceans, which contain approximately 97.47% of the world's supply. Of the remaining quantity, 1.76% is frozen in the icecaps, and 0.76% is in storage as deep groundwater. The remaining 0.01% constitutes the earth's fresh water resource that supports a diverse range of plants and animals, and which is available for human use *(Cumming Cockburn, 2000)*.

Water moves constantly between the reservoirs through the following major processes of the hydrologic cycle.

i) Precipitation

This includes all the moisture that reaches the earth's surface in the form of rain, snow, sleet and hail. Through the process of condensation, atmospheric moisture is converted to precipitation and replenishes the surface and subsurface supplies and storages. Additional supply is provided by snow, precipitation formed by the sublimation of water vapour into solid crystals at temperatures below freezing.

Within the TRCA watersheds, the average annual precipitation is in the order of 825 to 845 mm, with over 80% delivered as rainfall *(Gerber, 2004)*. More detailed information on the components of the hydrologic cycle within the TRCA watersheds is presented in *Section 5*.

1. The terms *hydrologic cycle, water balance* and *water budget* are used interchangeably in this document.

A minor portion of all precipitation is intercepted by the vegetation and structures and does not reach the ground, and is eventually returned to the atmosphere through the evaporation process.

ii) Groundwater Infiltration

The precipitation reaching the earth's surface is dispersed in three primary pathways. Groundwater infiltration represents one of these pathways, and describes the movement of rainfall that enters the surficial soils and travels downward through cracks and pores in the soil and rocks to replenish groundwater aquifers, which can be a source of drinking water (wells). Subsurface water can also move upwards through capillary action, or travel horizontally below the earth's surface until it re-enters a surface water body as baseflow. The contribution of baseflow is important for sustaining the ecological functions in the receivers, particularly during the low flow periods that are normally experienced in the summer months. Water in the shallow soil is also available and used by plants in life functions and transpiration.

Infiltration has been referred to as the single most important process in the hydrologic environment because it interacts with precipitation to divide surface and subsurface flow.

The portion of rainfall that infiltrates into the subsurface is directly dependent on a number of factors, including: the amount and intensity of the rainfall, soil type, the prior moisture condition of the soil, vegetative cover, land use, and topography.

The amount of infiltration that occurs varies significantly within the TRCA watersheds, depending on the arrangement of the above factors within the individual watersheds. Past and on-going studies undertaken by TRCA aimed at establishing the water budgets for the individual watersheds indicate that as a preliminary estimate, 10 to 40% of the total precipitation will find its way into the subsurface environment *(Gerber, 2004, 2003)*. This value depends to a significant extent on the level of urbanization within the watershed, together with the soil texture and structure.

iii) Evapotranspiration

This process describes the process by which water is converted from a liquid state to a gaseous state as it is returned from the earth's surface to the atmosphere as water vapour. Evapotranspiration is composed of two components: evaporation, which is the primary pathway for the movement of water into the atmosphere, and transpiration, which is the process by which moisture is carried through plants and released to the atmosphere as vapour from pores on the underside of the leaves.

Studies have shown that evaporation from waterbodies (oceans, lakes, rivers, etc) provide nearly 90% of the moisture in the atmosphere through evaporation, with the remaining 10% being contributed by transpiration. It is estimated that approximately 1-2% of the water taken up by plants is used for photosynthesis and life cycle functions, with the remainder being transpired as water vapour (*U.S. Geological Survey, 2005*).

Another mechanism that produces the surface to air transfer of moisture is sublimation, which is the process by which solid ice or snow is converted directly to water vapour. This process is prevalent in areas at high and/or northern altitudes, during periods of strong winds, intense sunlight and low air pressures.

Preliminary values for evapotranspiration within the TRCA watersheds have yielded a fairly wide range of 40-60% of the total precipitation (*Gerber, 2004; Clarifica, 2002*).

iv) Surface Runoff

Also referred to as excess water, this component of the hydrologic cycle refers to the precipitation or snowmelt which exceeds the moisture holding capacity of the soils, and the depressional storage of the landscape, and flows on the earth's surface to a receiving waterbody. Surface runoff occurs as uniform sheet flow, or as accumulated flow in swales, ditches, streams, creeks, and rivers. Surface runoff is also generated by the melting of snowpacks. As air temperatures rise above freezing, melting snow waters are initially absorbed into the snowpack until the liquid fills the holding capacity, and then are released to the surface as surface runoff and/or into underlying soil as infiltration. The infiltration of snowmelt is dependent on the presence of frost in the underlying overburden, particularly for fine-grained soils, which are easily affected by frost. Surface runoff is affected by meteorological factors and the physical geography and topography of the landscape.

In urbanized watersheds, the extent of impervious cover produces the most direct influence on the percentage of precipitation that becomes surface runoff.

The mean annual runoff within the Lake Ontario/Erie watersheds of southwestern Ontario is in the order of 300 mm, which represents approximately 36.5% of the mean annual precipitation (820 mm) that has been recorded in the area (*Ontario Ministry of Natural resources, 1984*).

Within the TRCA watersheds, this component varies considerably, depending on the degree of urbanization and the geologic/soil characteristics within the individual watersheds. Preliminary estimates indicate that surface runoff comprises 20-40% of total precipitation on an average annual basis (*Gerber, 2004; Clarifica, 2002*).

3. EFFECTS OF URBAN DEVELOPMENT

General

Decades of available studies clearly demonstrate the adverse impacts of urbanization on all facets of the natural environment (*Schueler, 2000*). The impacts are felt not only on the physical aspects but also on the chemical and biological conditions of our water resources.

The water balance describes the hydrologic cycle within a watershed and provides a measure of the natural balance within the system between the precipitation, runoff, infiltration, evaporation and transpiration components.

When land is developed, the natural water cycle is profoundly and permanently altered. The impacts begin with the initial clearing of lands to prepare the site, which removes the natural vegetation that intercepts, slows down, and returns water to the atmosphere through evaporation and transpiration. The accompanying grading works flatten hummocky and hilly terrain, and eliminate natural depressions that slow flow velocities and provide temporary storage for rainfall to infiltrate or evaporate. The scrapping of topsoil and surficial layers of humus, and the compaction of the remaining subsoils eliminates and/or considerably reduces the groundwater recharge pathway, and also reduces the capacity of the soils to store moisture and return water to the atmosphere through evapotranspiration. Rainfall that previously would seep into the ground and replenish groundwater supplies is now quickly converted to energy-laden surface runoff. The addition of impervious surfaces associated with communities, including the buildings, roadways, and parking lots, further reduce the infiltration characteristic of the lands and contribute to increased surface runoff.

The magnitude of changes to the water budget and the natural equilibrium of the watershed is a function of the alterations made to the landscape and the level of impervious cover associated with the urban built form.

The changes not only increase the total volume of surface runoff, but also accelerate the rate at which runoff travels across the land, and elevate the flow velocities and peak flows that are attained within receiving rivers and streams. This escalating effect is further aggravated by the efficient servicing systems, comprised of the gutters, storm sewers, and lined channels, that are incorporated into the developments to provide for the quick delivery of storm runoff to receiving streams.

As noted previously, development and impervious surfaces also significantly reduce the amount of rainfall that can infiltrate into the subsurface environment and recharge aquifers and contribute to stream flows during dry weather periods.

In addition to affecting the distribution of the water quantities in the different components of the water budget, development and urbanization adversely impacts the quality of the rainfall that comes into contact with the ground surface and associated features. As storm runoff travels across the rooftops and lawns, commercial and industrial sites, and parking lots, a variety of contaminants and pollutants are taken up and accumulated, which are ultimately conveyed to the receiving streams. Soluble contaminants may also infiltrate into the ground and reach the underlying aquifer systems. The loss of the original vegetation and topsoil eliminates an invaluable filtering mechanism for storm runoff.

Water Budget Component	Current Land Use	Urban Land Use	Change (%)
Av. Annual Precipitation (mm)	840	840	
Infiltration (%)	27.0	19.6	-27
Surface Runoff (%)	14.3	35.7	250
Evapo-Transpiration (%)	58.7	44.7	-24

The wholesale effects on the distribution of water in the watershed are reflected in the alterations to the water budget of the basin.

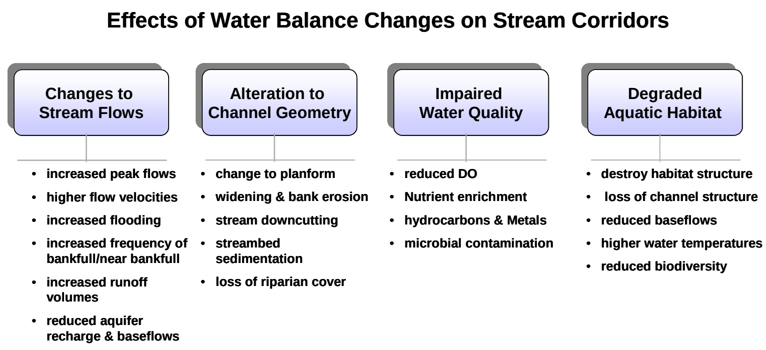
Watershed studies undertaken by TRCA within their watersheds indicate that unchecked urban development can produce significant shifts in the quantity of water within the components of the water budget. A typical analysis revealed that the proposed conversion of lands from an agricultural and undisturbed condition to a high-density commercial use could produce profound changes to the water budget. As can be noted from the above table, surface runoff is increased by 250% at the expenses of major reductions in both infiltration and evapotranspiration.

The single common physical unit of all forms of urban development that is a useful predictor of potential effects is – impervious area, defined as the sum of roads, parking lots, sidewalks, rooftops, and other impermeable surfaces of an urban landscape. Imperviousness represents the imprint of the land development on the natural environment, and has emerged as a unifying theme for assessing the impacts of development on the hydrology, habitat structure, water quality and biodiversity of watersheds.

The impacts of urban development have both direct and indirect systemic consequences on the watershed, including downstream waters. Recent research models in the United States suggest a threshold value of 10% as the level at which the aquatic systems begin to exhibit symptoms of degradation, including unstable and eroding channels, the loss of instream structure, and the decline in biodiversity (*Schueler, 2000*).

Effects of Changes to the Water Budget

The manifestation of the changes to the water budget due to urban development and the attendant impervious area can be placed into the following four interrelated categories: *changes to stream flows; alterations to the channel geometry; degradation of aquatic habitat;* and *impairment of water quality.*



i) ***Changes to Stream Flows*** – The alteration to the hydrology of the watershed and disruption to the natural water budget associated with urban development produce adverse effects that include:

- increased peak flows – the loss of groundwater infiltration, and the reduction in evapotranspiration, combined with the more efficient drainage system result in considerable higher peak discharges to the receiving streams; peak flows from urbanized watersheds can range from 2 to 5 times the rates generated from undisturbed watersheds;
- higher runoff velocities – the higher imperviousness and compacted soils, together with the improved drainage system comprised of storm drains, sewers and ditches increase the speed at which storm runoff is collected and conveyed from the watershed;
- increased flooding – the higher and more frequent runoff volumes and peak flows also increase the frequency, duration and severity of out-of-bank flooding, which increase the risk to human safety and flooding of private property;
- increased frequency of bankfull/near bankfull events – higher runoff volumes and peak flows increase the frequency and duration of smaller bankfull and near bankfull events which are the most significant in terms of channel and bank erosion;
- increased runoff volumes – the impervious surfaces reduce infiltration and dramatically increase the volume of runoff generated in a urbanized watershed; and,
- lower baseflows – the reduced infiltration of stormwater runoff causes streams to experience less baseflow during dry weather periods and reduces the amount of rainfall available to recharge groundwater and sustain aquifers.

Typically, streams in urban watersheds are characterized by a very fast or *flashy* response to rainfall events due to the increased volume of stormwater, higher peak flows and the quicker hydrologic response of the collection and conveyance systems.

ii) ***Changes to Stream Geometry* –** The changes in the water budget, and the attendant shifts in the rates and amount of surface runoff that accompany the urbanization of a watershed have a direct bearing on the morphology, or physical shape and character of the local receiving streams. The effects include:

- stream widening and bank erosion – in order to convey the higher stormwater volumes and peak flows, the stream channels widen to achieve sufficient capacity; the more frequent, small to moderate runoff events undercut and erode the lower parts of the stream channel, causing steeper banks to slump and fail during more severe storms;
- stream bed changes due to sedimentation – the channel erosion and other upstream sources provide sediments that are deposited in the stream as sandbars and other features, covering the substrate with shifting deposits of mud, silt and sand;
- stream downcutting – another adjustment that is often initiated by the stream to increase flow capacity is the downcutting of the channel bed; however, this creates instability in the stream profile, which triggers increases in velocities that causes further erosion to occur in both the upstream and downstream directions; and,
- loss of riparian tree canopy cover – the continual undercutting and failure of the stream banks exposes the roots of trees and other woody vegetation that serve to protect and stabilize the banks; the trees are then vulnerable to being uprooted during major storm events, which further weaken the structural integrity of the channel bank.

iii) ***Impacts to Aquatic Habitat*** – Accompanying the alterations to the hydrology and morphology that occurs as the watershed is transformed from a natural to an urban condition is the diminishment of the habitat quality. The impacts on the habitat consist of the following:

- increased water temperature – the combination of warmer runoff from the impervious area and stormwater management ponds, the loss of riparian cover and shallower in-stream flow depths can produce severely elevated temperatures in the receiving streams, which can contribute to reductions in the level of dissolved oxygen, and thereby negatively affect the stream ecology;
- reduced low flow conditions (baseflows) – the loss of infiltration of rainfall into the soil adversely affects the groundwater resources, ultimately leading to a decline in baseflow during low flow conditions, which in turn can adversely affect in-stream habitat during the periods when they are most vulnerable to declining flow rates;

- degradation of habitat structure – the negative effects on the quality of the aquatic environment takes several forms: the higher and faster flowing waters in the stream scours existing banks and can wash away entire biological communities; the loss of riparian vegetation reduces habitat for many fish species; and the deposition of sediments can smother benthic (i.e., bottom-dwelling) organisms, resulting in a reduction in food and spawning habitat for sensitive fish species;
- loss of channel structure – a common feature of natural channels is an alternating sequence of pools and riffles that provide valuable habitat for fish and aquatic insects; due to the combined effects of increased flows and sediment loads from erosive action, the pools and riffles typically disappear and are replaced with more uniform and often shallower streambeds that provide less diverse and poorer quality fish habitat; and,
- reduction in biodiversity – collectively, the above effects will degrade the quality of the aquatic habitat, leading to a decline in the number, variety and diversity of the organisms (wetland plants, fish, microinvertebrates, etc) in the stream; sensitive fish species and organisms are replaced by those better suited to poorer water quality, flow and chemistry.

iv) ***Impaired Water Quality –*** Contamination of surface runoff comes from many diffuse or scattered sources within the built environment (*USEPA, 2000*). As stormwater runoff flows across the urban landscape, it captures and carries away an assortment of both natural and man-made pollutants, and conveys them to the local streams, rivers, lakes, wetlands and underground aquifers. Stormwater runoff is recognized as the leading source of pollution in the local watersheds (*Toronto and Region Conservation, 1994b*). A summary of the most frequently occurring pollution impacts and their sources in the urban setting is provided below.

- reduction in dissolved oxygen – dissolved oxygen is essential for sustaining fish and other aquatic species that live in streams and other waterbodies. The decomposition of organic material (leaves, grass clippings, pet waste, etc.) that is washed off by storm runoff and delivered to the receiving waters consumes the available dissolved oxygen, making it unavailable for living organisms; if the dissolved oxygen deficit becomes severe enough, fish kill and the die–off of other stream life can occur;
- nutrient enrichment – urban stormwater runoff contains excessive concentrations of nutrients, including phosphorus and nitrogen, derived from fertilizers applied to agricultural fields, golf courses, and suburban lawns; deposition of nitrogen from the atmosphere; erosion of soil containing nutrients; and sewage treatment plant discharges;
- hydrocarbons and metals – given the vast paved areas and the heavy reliance on automobiles, oils, greases and gasoline are a commonly found constituent of stormwater runoff; these contaminants have been shown to be carcinogenic and mutagenic in certain species of fish and can also negatively affect water supplies and recreational uses of water.

In addition to the oils and hydrocarbons, stormwater is known to frequently contain a number of other toxins and compounds including heavy metals (lead, zinc, copper, and cadmium) and organic compounds (pesticides, herbicides, and phenols), which are toxic to aquatic organisms and can be harmful to drinking water sources and human health.

- microbial contamination – the level of bacterial, viral and other microbial contamination in urban stormwater frequently exceeds the public health standards for recreational activities such as swimming and wading; beach closures are a common occurrence along Lake Ontario beaches during the summer low flow months, with the primary source of these harmful agents being: malfunctioning or overloaded sewage systems, combined sewer overflows, leaking septic tanks, pet waste, and urban wildlife, i.e., geese, gulls, squirrels, raccoons etc (*City of Toronto, 2003b*).

4. THE NEED FOR CHANGE

Introduction

The health and vitality of our local creeks and rivers is an essential ingredient to the overall health and well-being of the residents of the watersheds. Together with Lake Ontario, which they feed, these water features help sustain the natural systems, support an array of recreational opportunities, e.g. swimming, boating, hiking, cycling, and contribute to the aesthetic backdrop of the urban landscape. Ensuring their continued sustainability to achieve social, economic, cultural and environmental benefits is a goal shared by all stakeholders.

Since the arrival of early settlers to the area, the rivers, creeks and natural systems have endured large-scale changes that were deemed necessary to accommodate the evolving human needs for housing, agriculture, industry, institutions and servicing. Accompanying the direct effects (i.e., the topographic alteration, the loss of forest cover, the infilling of wetlands and marshes, the removal of riparian vegetation, and the increase in impervious surfaces), the manner in which land drainage has been handled has led to serious and long lasting degradation and loss of natural functions within the watersheds.

Flood Control

In the aftermath of Hurricane Hazel in 1954, and throughout the following decade, storm drainage consideration concentrated on ensuring public safety and the provision of flood protection for vulnerable properties. Flood control plans were developed throughout the Province that resulted in the construction of dams and reservoirs, concrete channels, and other control and management structures. Within this context, in 1959, TRCA finalized their *Plan for Flood Control and Water Conservation*, which identified a need for 15 large control dams, as well as four major flood control channels, and initiated an erosion control program. In addition, over 2900 hectares of land were identified for acquisition to acquire floodplain areas, and to provide lands necessary for the construction of flood protection works.

In urban areas, the management of runoff during wet weather conditions focused on the conveyance of runoff to local creeks and rivers as quickly and efficiently as possible. Accordingly, urban design standards required lot grading to maximize the removal of runoff from individual lots to the roadways, ditches and storm sewers, which in turn connected to the receiving waterbodies.

In the late 1970s, evidence began to emerge pointing to the detrimental effects of uncontrolled stormwater runoff on flooding conditions and streambank erosion in downstream areas. To address this concern, TRCA in concert with local municipalities, developed a stormwater management program aimed at the control of peak flows increases by requiring new development to maintain post development flows at pre- development levels. Typically, runoff control was achieved through the implementation of stormwater ponds designed to temporarily detain excess runoff volume and release it at acceptable rates over a longer period of time.

Master Drainage Plans

In the 1980's, the Master Drainage Plan approach materialized as the preferred method for addressing urban development, and minimizing the potential impacts on the watercourses and adjacent properties. Floodplain management, peak flow control, erosion prevention and the major/minor system considerations remained the central areas of interest.

While the flood control peak shaving methodology proved effective, the approach for erosion prevention proved significantly less useful. These control measures, especially the use of on-line facilities, were causing changes to the natural sediment regime and increased erosion in downstream channel reaches.

Taken together with the direct physical impact of construction in streams and river corridors, it was becoming evident that the stormwater management practices of the day were not achieving the intended objectives. The direct impacts being the combined effects of inadequate sediment and erosion measures, encroachment into the stream corridors during the construction phase, and the build up of development to the corridor edge, without the provision of a proper buffer.

EVOLUTION OF WATER MANAGEMENT	
2006…..	Water Budget
	Climate Change
2000…..	Source Water Protection
	Adaptive Management
	Sediment Transport
	Natural Channel
	Geomorphology
	Terrestrial Habitat
	Ground Water
	Woodlots
	Monitoring
	Enhancement Opportunities
	Infiltration
	Water Temperature
1990…..	Baseflow Maintenance
	Fisheries/Aquatic Habitat
	Water Quality
	Wetlands/ESAs/ANSIs
	Erosion/Sediment Control
	Runoff Quantity Control
	Erosion/Flood Control Works
	Major/Minor System Design
	Culvert Improvements
1980…..	Floodplain Management

The decline in the health of local and regional aquatic systems continued through the 1980's, as a direct result of intensifying urbanization throughout the Greater Toronto Area (GTA). The eventual realization in the late 1980's that urban stormwater runoff was contributing to a decline in river system health and possibly to the quality of drinking water (despite the measures being taken) led to a significant shift in stormwater management objectives. While flood control remained one of the primary goals, stormwater management strategies were broadened and revised to incorporate provisions for the control of water quality, protection of fish habitat and in-stream erosion. More recently, maintaining groundwater recharge and the management of risk associated with groundwater contamination has become a central issue for the general public and all levels of government.

Ecosystem Approach

Through the continual process of assessing results, and a broadening of the issues to be considered, it became apparent that an ecosystem-based approach was the logical manner for dealing with the diverse range of issues that needed to be considered. As a result, subwatershed planning supplanted the Master Drainage Plan as the process for the management and integration of water resources and land use planning. Based on natural watershed boundaries, it acknowledges the inherent linkages within watersheds, and recognizes the continuous movement of water throughout the watershed, and its influences on the diverse natural processes. This allows a more comprehensive assessment and integration of the natural processes at work and the influences exerted by human social and economic needs. It represents an evolutionary growth from the more reactive Master Drainage Plan thinking, which dealt primarily with risk to the built environment, to a proactive, forward thinking way of managing the natural and built environment as interdependent and integrated components.

Provincial direction and guidance on the principles and application of ecosystem planning are outlined in the following three documents that were jointly published by the Ministry of the Environment and Energy (MOEE) and the Ministry of Natural Resources (MNR) in 1993: *Subwatershed Planning*, *Water Management on a Watershed Basis: Implementing an Ecosystem Approach,* and *Integrating Water Management Objectives into Municipal planning Documents.*

Collectively, these documents discuss the elements essential to successful watershed planning; outline why, when, and how to prepare subwatershed plans; and provide assistance to municipalities in developing official plan policies that incorporate the goals and objectives of water and related resource planning, protection and management.

While the importance of, and the need to maintain the natural water balance, through the infiltration of stormwater following urbanization has been a long stated objective of the ecosystem-based approach, serious efforts at following through at the development design phase has lagged considerably for several reasons:

- the lack of science-based data and an understanding of the issue at the local level;
- a perception that the implementation of infiltration measures is not practical and/or prohibitively costly; and,
- the lack of a formal policy that provides clear direction on the goals, objectives and guidelines for addressing the preservation of the natural water balance as a fundamental component of development plans.

5. TIME FOR ACTION

Introduction

The fundamental challenge for stormwater management is how to balance the three crucial components for achieving sustainable communities: the societal needs for services; the environmental needs for ensuring the long-term health and vitality of the rivers, stream and associated corridors; and the economic need to achieve solutions that are cost-effective, both in the short and long-term.

Over the last decade, data from field monitoring, together with increased scientific study of watershed interrelationships is confirming the importance that the water budget plays in maintaining the balance in watersheds. The control of peak flows and the attention to water quality, which form an integral part of the current practice of stormwater management, are achieving significant benefits for the protection of property and public safety, and in minimizing the contaminant levels reaching the rivers and streams.

However, the imbalance that remains in the water budget through the increase in the volume of storm runoff is creating potentially long-term problems within the watercourses as they adjust to accommodate the changes in the hydrologic regime. If left unabated, the shifting channel morphology will leave the watercourses, and the associated aquatic ecosystem vulnerable to adverse impacts, and expose existing infrastructure located in the valleylands to increased repair and maintenance requirements. Similarly, the accompanying reduction in the volume of water that is infiltrated can lead to long-term reductions in groundwater levels, which can affect local water supplies (wells), and also decrease the quantity of baseflow available to help sustain the local streams, particularly during the summer period.

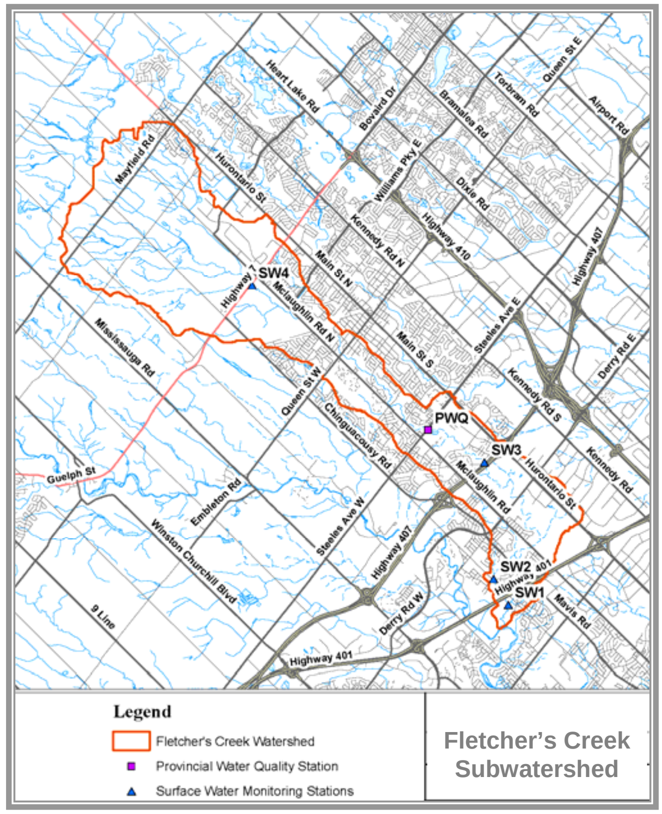
Locally, study results are becoming available for two subwatershed areas within the GTA - *Fletcher's Creek and Burndenet Creek* -that are demonstrating the limitations of conventional stormwater management practices, i.e., quantity control, quality management, and erosion control.

Fletcher's Creek

Fletcher's Creek is a major tributary of the Credit River system (Refer to figure on next page). Situated in the lower third of the Credit River watershed, it has a drainage area of 45 km^2 that extends within the boundaries of the Town of Caledon, the City of Brampton and the City of Mississauga. While the headwater areas of Fletcher's Creek remain in agricultural use, residential development occupies and/or is expanding throughout the remaining lands. Between 1999 and 2003, it is estimated that the impervious cover within the subwatershed increased from approximately 17.2 % to 23.2% of the basin area

Stormwater management measures have been required as part of the servicing infrastructure for development within the Fletcher's Creek subwatershed. The scope and extent of these measures have evolved over time, starting with quantity control management in the older subdivisions (i.e., the southern part of the subwatershed), and progressing to current standards that require best management practices to address quantity, quality and erosion control considerations.

In 1998, a monitoring program was initiated by the Credit Valley Conservation and the Cities of Mississauga and Brampton to observe and record data on stream hydrology, aquatic biology, habitat quality and fluvial geomorphology at four monitoring stations that were established along Fletcher's Creek between Highway 401 and Highway 7. The goal of the program was to establish baseline conditions, measure temporal changes and assess the effectiveness of stormwater management measures on a subwatershed basis. Initially envisioned as a three-year study, the program was extended, and ultimately a database for a seven year period has been achieved.



The study report entitled *Fletcher's Creek Subwatershed Monitoring Strategy – Seven Year Data and Program Analysis* is in draft form, and is currently being finalized; however, the preliminary assessment of the results suggest that there has been measurable adjustments in the channel planform and cross-section. The watercourse is quite dynamic with a regular increase in cross-sectional area recorded at all four of the monitoring sites. These changes are occurring notwithstanding the use of conventional stormwater management practices that have formed part of the servicing infrastructure for the urban development.

Burndenet Creek

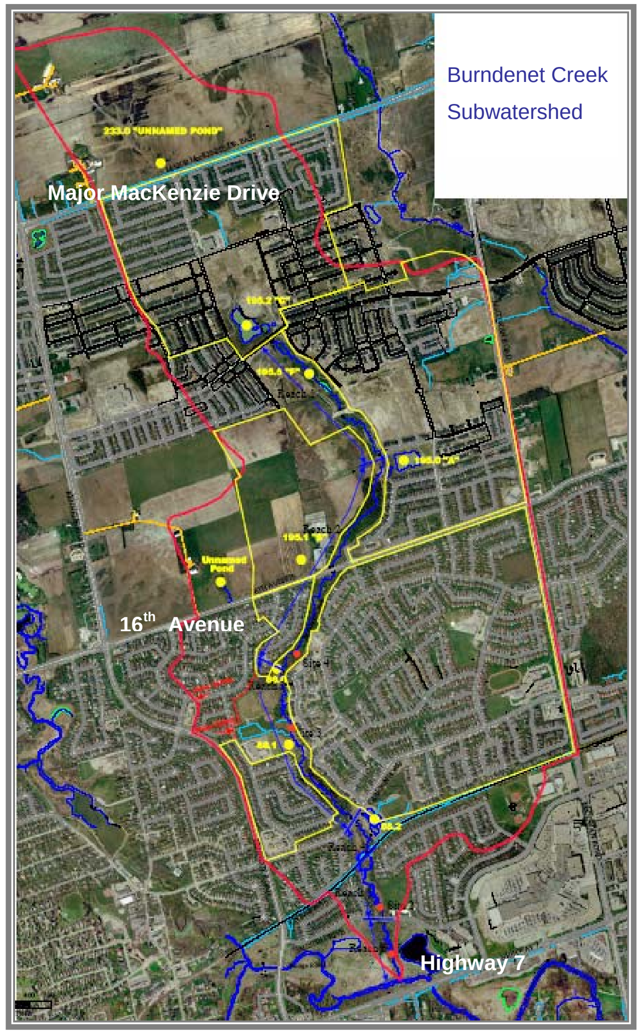
The final report dealing with Burndenet Creek was issued in September 2005, and is entitled *Burndenet Creek Erosion Optimization Study, Phase 1 Progress Report.* The following information was abstracted from the study report.

Burndenet Creek is a first/second order tributary of the Rouge River system, and is centrally located within the Town of Markham. The watershed is relatively small in size, with a drainage area of 5 km^2 and an overall length of approximately 4 km (Refer to figure on next page).

During the 1980's and 1990's, the lands south of 16th Avenue became fully urbanized. Currently, the lands north of 16th Avenue are approximately 60% urbanized and are experiencing pressures for further urban growth.

The study assessed a number of land use and stormwater management scenarios, ranging from the 1999 conditions, which were considered to be representative of the baseline conditions, to the designated land use for the upper watershed area, which represents the ultimate development scenario.

The report indicates that …..*applying traditional stormwater measures (i.e. ponds) will result in further aggravation of the stream as development occurs (it should be noted that the facilities may be required for other reasons: i.e., water quality control and/or flooding)*.



The preferred alternative for restoring the creek involves increasing evapotranspiration and infiltration on a watershed wide basis using a variety of source or conveyance control measures. The report also recommends … *that the target of infiltrating/evapotranspirating the first 10-12 mm of rainfall from impervious areas be applied for new subdivisions where possible (i.e., for lands which are not at the Draft Plan stage or further).*

Historical data also provides compelling evidence on the advantages of implementing integrated, strategic approaches to deal with urban development and environmental protection. This approach foresees potential impacts and incorporates appropriate mitigative measures as opposed to reacting to the consequences. Retrofitting measures to solve problems that have emerged are generally less effective, more costly, and more difficult to implement due to both land requirements and public acceptance.

The need to address the water budget balance and bring this concern into an expanded integrated approach to watershed and stormwater management planning is gaining widespread attention and support – actions that are being taken both locally and in other jurisdictions are discussed below.

Since the relatively short time from its inception, the practice of stormwater management has undergone significant changes as the response to the most pressing problems of the day did not provide a comprehensive solution, or created new or unanticipated problems. Just as the concern with the water budget has recently emerged as a significant issue, it is anticipated that as further monitoring data is accumulated and the scientific knowledge base is expanded in subsequent years, the scope of issues to address as part of the stormwater management and watershed planning will also broaden.

Province of British Columbia

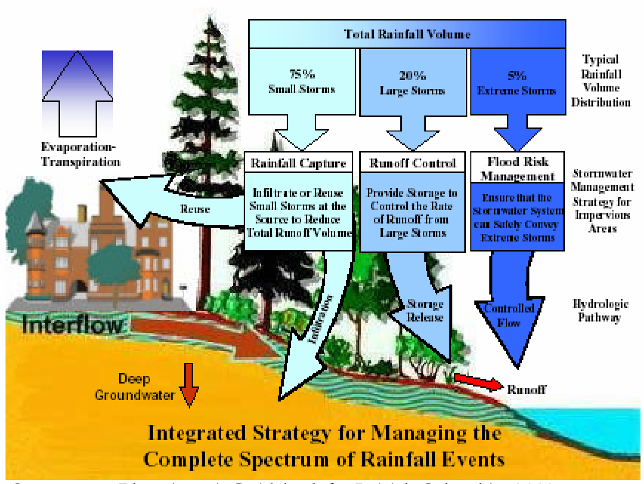
In the Province of British Columbia, all municipalities are required to prepare a Liquid Waste Management Plan (LWMP), which is aimed at eliminating the pollutant loadings from municipal wastewater, combined sewers and storm drainage systems *(British Columbia Environmental Management Branch, 1992*).

Accordingly, a stormwater management component is an integral component of the overall LWMP. The overarching goals are the protection of quality of life, property and aquatic ecosystems.

In addition, local municipalities have the statutory responsibility for drainage and stormwater management, and accordingly can be held liable for any downstream impacts associated with changes in upstream drainage patterns – in terms of peak flow, volume and quality.

Given the interrelation between land use and planning, a Provincial requirement also includes the provision of the goals and objectives for stormwater management to form part of the municipal planning documents – *Official Community Plans.*

Stormwater management planning in the Province is achieved through the preparation of *Integrated Stormwater Management Plans (ISMP)* that lay out the methods that will be implemented to proactively use planning and management measures to protect property and aquatic habitat, while also allowing urban growth to proceed.



Stormwater Planning, A Guidebook for British Columbia, 2002.

The development of the ISMP is founded on five guiding principles, of which the need to design for the complete range of rainfall events forms the foundation of the integrated stormwater solution. The aim is to develop a stormwater management strategy that mimics a naturally vegetated watershed, which means that the rainfall produced by frequent events must be infiltrated into the ground or re-used within the watershed.

As illustrated in the figure (previous page), the concept calls for the management of the complete spectrum of rainfall events by incorporating the following design practices:

- rainfall capture for small storms (runoff volume reduction and water quality control) – capture the small frequently occurring rainfall events at the source (building lots and streets) for infiltration and/or re-use;
- runoff control for moderate to large storms (runoff rate reduction) – store the runoff from these storms (e. g., a mean annual rainfall), and release it at a rate that approximates the natural forest condition; and,
- flood risk management for infrequent extreme storms (peak flow conveyance) – ensure that the drainage system can safely convey extreme storms (e.g. a 100-year rainfall).

The benefits and need for addressing the water budget considerations has attracted widespread attention by the municipal and provincial governments in British Columbia, and also at the federal level.

Following several initiatives to research and advocate the values of the water balance approach, an Inter-Provincial Partnership has been developed that includes over 20 local, regional, provincial and federal agencies with a mission to enable local governments and landowners to make informed land development decisions, while also meeting performance targets for rainfall volume capture and runoff control.

A key undertaking has been the development of the *Water Balance Model (Stephens, 2006)*, which is a non-proprietary web application for rainwater runoff modelling. The *Water Balance Model* (WBM) is intended to serve as a planning tool, which allows the use of basic principles of hydrology to identify the impacts of land use changes on the hydrologic cycle. Founded on established soil science principles, the WBM enables an understanding of the mechanisms by which rainwater is intercepted by trees and landscaping, and absorbed by the soils cover.

The goal is to have the use of the WBM become standard practice for land development decisions throughout British Columbia, and expand its accessibility through inter-provincial partnerships, which will also help improve its cost-effectiveness.

American Experience

The concept of a sustainable stormwater management strategy, premised on maintaining or restoring the natural hydrologic cycle, has been gaining rapid acceptance in the United States. Now commonly referred to as the *Low Impact Development* (LID) approach, it has emerged as the preferred method for addressing regulatory compliance, resource management goals and the increasing costs of infrastructure.

The LID approach originated during the 1990's in the State of Maryland, and focuses on the control of water – both rainfall and runoff at the source (*U.S. Department of Housing and Urban Development, 2003*). It involves a decentralized system that distributes stormwater through the subject watershed or study area in order to replenish groundwater supplies, rather than directing it to the storm sewer system and/or end of pipe facilities. This approach involves the application of smaller-scale systems that are dispersed throughout development areas with the purpose of managing water in a more evenly distributed manner, which allows for the elimination and/or downsizing of downstream infrastructure and stormwater management ponds. The goal is not merely to address the impacts of land use changes, but to take steps during the development design to minimize changes to the hydrologic cycle (runoff and infiltration after a storm).

Some of the more prevalent design considerations to achieve at source controls include: reducing the impervious areas, disconnection of impervious areas from the storm sewer system, the use of cisterns for rooftop drainage, the use of grassed swales, landscape infiltration, green roofs, stormwater retrofits, etc.

The overall goal is to employ a combination of non-structural (vegetated, natural systems) and structural measures to preserve the natural water budget, and thereby minimize the effects of land use changes on the natural ecosystems. Of particular concern is the recharge of water into the subsurface environment, controlling the peak flows reaching the streams, and protecting the water quality in the receiving waterbodies.

City of Portland

One example where this approach has been developed and incorporated directly into the City requirements is the City of Portland, Oregon. In 2002, the municipality developed a *Sustainable Stormwater Management Program* to fulfill Federal regulatory requirements, and to protect local streams that are considered vital for a number of reasons including: ecosystem protection, human health, recreation, and water supply. The goal of the program places the emphasis on reducing the generation of stormwater runoff at source to help preserve or mimic the natural hydrologic cycle, minimize sewer system problems and achieve water quality protection.

To assist property owners and designers, the City prepared a *Stormwater Management Manual* that provides the management principles and techniques to help achieve the water balance objectives (*City of Portland 2004*). The range of identified options include: green roofs on new buildings, the disconnection of downspouts, the installation of rain barrels and cisterns on private property, biofilters to treat and infiltrate stormwater, the installation of pervious pavement and the use of infiltration measures along road right-of-ways to help create *water friendly* streets. Explicit direction is provided to project proponents, including both new developments and redevelopment proposals on the need to incorporate infiltration methods to the extent possible.

State of Maryland

The State of Maryland has developed very progressive and comprehensive approaches and requirements for the management of stormwater. Detailed guidelines, design manuals, best management practices and design criteria have been formulated with the overall goal of removing pollutants, maintaining groundwater recharge, reducing channel erosion, preventing overbank flooding and conveying extreme floods (*Maryland, 2000 and 2001*).

Minimum control requirements have been established for the counties and municipalities within the State to deal with five separate aspects of stormwater management as follows:

- water quality volume - the storage needed to capture and treat the runoff from 90% of the average annual rainfall, which is directly related to the amount of impervious cover;
- recharge volume requirements – the recharge volume that must be provided, taking into account the average annual rainfall and the infiltration characteristics of the soils; the intent of this criteria is to maintain existing groundwater recharge rates, preserve existing water table elevations and maintain the hydrology of streams and wetlands;
- channel protection storage volume – this involves the 24 hour extended detention of a specified storm event, aimed at protecting the downstream stream reaches from exposure to erosive velocities;
- overbank flood protection volume – the primary purpose of this storage component is to prevent an increase in the frequency and magnitude of out-of -bank flooding that may arise due to land use changes; and,
- extreme flood volume – the objective is to maintain post development flows at pre-development levels such that flood damages from large flood events to both property and infrastructure are prevented, and no expansion of the existing floodplain area occurs.

This current approach to stormwater management represents an inherent philosophical change from the traditional approaches, by attempting to mimic existing hydrology as opposed to managing the impacts generated by land use changes.

Provincial Initiatives on Water Balance

The need to consider the water budget when addressing watershed management and land use change issues has been advocated by watershed managers and practitioners for some time. The importance of this approach has been recognized at the Provincial level in Ontario and continuous efforts have been made to advance the understanding and inclusion of the water budget in the land use decision-making process.

Following the initial efforts in the early 1990's, the *Watershed Management Initiative* project was undertaken with involvement from the Ministries of Environment and Energy (MOEE); Natural Resources (MNR); Municipal Affairs and Housing (MMAH); Agriculture, Food and Rural Affairs (MAFRA); the Association of Municipalities of Ontario (AMO); and the Association of Conservation Authorities of Ontario (ACAO). The Final Report was issued in 1997 and contains further endorsement of the balanced water budget approach and an identified need for improving the technical capabilities for assessing and predicting surface water-groundwater interactions.

In 2000, the *Watershed Management Committee* (MNR, MMAH, MAFRA, ACAO) prepared the document entitled *Water Budget Analysis on a Watershed Basis* to serve as a reference manual to assist practitioners in the application of water budget analysis techniques at both a watershed and subwatershed level.

In 2003, the Ministry of the Environment (MOE) published the updated version of the *Stormwater Management Planning and Design Manual* (initially released in 1994). The document provides guidance on assessment techniques using the water balance analyses to identity both the potential impacts of urban development and the appropriate best management practices that can be implemented for mitigative purposes.

More recent work on water budgets considerations has been carried out in support of the Provincial initiatives regarding the *Oak Ridges Moraine Conservation Plan (ORMCP)* and *Source Water Protection (SWP)*.

The ORMCP requires every upper and single tier municipality to prepare a water budget for each watershed within their area of jurisdiction. Given the importance of the ORM as a recharge zone that supports wetlands, lakes and streams, gaining an understanding of the groundwater and surface systems is important for meeting the ORMCP objectives that include the protection of the ecological and hydrological integrity of the area.

Since 2002, a coalition of municipalities and conservation authorities, led by the Conservation Authorities Moraine Coalition have been conducting investigations and studies aimed at establishing a quantitative understanding of the water budget for the ORM. The participating agencies are: the Regional municipalities of York, Peel, and Durham, the City of Toronto and the nine Conservation Authorities that have watersheds within the moraine. Other contributing agencies include the MOE, the Ontario Geological Survey and the Geological Survey of Canada. The Final Report for the study was issued in February 2006 (*CAMC/YPDT, 2006*).

In December 2005, the Province introduced the *Clean Water Act, 2005*, with the stated goal of protecting current and future sources of drinking water. This piece of legislation responds to the recommendations of the Walkerton Inquiry for achieving source water protection. The Act requires the preparation of source water protection plans for each watershed. Once approved by the Minister, all provincial and municipal planning decisions – including official plans and zoning by-laws, must conform with the requirements of the source water protection plan. Under the Act, the Conservation Authorities are generally designated as the drinking water protection authorities. A cornerstone of source water protection is the preparation of a watershed-based water budget to quantify and describe the amounts and movement of water through the various reservoirs in the watershed (lakes, streams, aquifers). The information provided by the water budget analyses is intended to support the completion of a water quantity risk assessment and the formulation of the overall source water protection plan.

City of Toronto Initiatives

In 2003, the City of Toronto completed the *Wet Weather Flow Management Master Plan (WWFMMP)*, which is aimed at achieving the long-term protection of the ecosystems within the area stream and river corridors, and the shoreline along Lake Ontario. Plan implementation will be carried out over a 25-year period, at a total estimated cost of $1.05 billon, or $42 million annually (*City of Toronto, 2003b*).

The findings, recommendations and targets arising from the Plan were formalized in a policy document entitled *Wet Weather Flow Management Policy*, which sets out the objectives and describes the actions that the City will undertake, and what is expected of others in order to ensure the implementation of the WWFMMP (*City of Toronto 2003a*).

A cornerstone of the City's *Wet Weather Flow Management Master Plan* is the concept that rainwater and snowmelt are viewed as valuable resources that should be prudently managed through the use of best management practices, and the recognition of the importance of the natural water cycle.

A stated object of the policy document is to preserve and re-establish the natural hydrologic cycle by maximizing permeability and minimizing runoff at-source. General policy statements are included that focus on protecting and re-establishing the water budget and working cooperatively with upstream municipalities, area property owners, and approval agencies.

Toronto & Region Conservation Initiatives

Due to the rapid growth that has been experienced in the GTA, the TRCA's jurisdictional area has undergone significant changes, and many watersheds are highly urbanized. The area also contains very sensitive features such as the Oak Ridges Moraine, and as such, surface water and groundwater play a fundamental role in sustaining the ecosystems; both systems are also used as drinking water sources.

The lack of attention and due care given to maintaining the water balance in both public projects and private development undertakings has been a long-standing concern of TRCA. Preserving and/or improving infiltration volumes and protecting groundwater resources has been a constant objective of the watershed plans that have been prepared for the creek and river systems within their jurisdiction. While recognized at the watershed plan level, the follow-up at the implementation level has been less than successful. In part this has been attributed to a lack of information on the water balance characteristics of the individual watersheds, and an absence of specific direction on the targets to be achieved.

Through cooperative efforts with the City of Toronto, and area municipalities on the *Wet Weather Flow Management Master Plan*, and the *Source Water Protection* initiatives, TRCA has made significant strides in establishing the existing water budget for each of the nine watersheds within their jurisdictional area. The methods being utilized to conduct the technical analyses include:

- HSP-F Models (Hydrological Simulation Program – Fortran);
- PRMS (Precipitation Runoff Modeling System);
- WABAS (Water Balance Analysis System); and,
- MODFLOW, a three-dimensional numerical groundwater flow model.

The results of the above efforts, combined with the watershed planning studies, have facilitated a detailed characterization of the individual watersheds and an integrated conceptual understanding of the water budgets.

The WABAS, HSPF and PRMS models are currently being used for the hydrologic analysis of TRCA watersheds for a number of purposes, including: determining flows, establishing the water budget and assessing water quality. A MODFLOW groundwater flow model has been developed for the GTA through a cooperative effort between the Regional Municipalities, the City of Toronto and TRCA. It has been the subject of extensive calibration efforts based on comprehensive data collection work. As such, it represents the most up-to-date model and understanding of the groundwater system in the GTA.

TRCA is currently working towards a consistent numerical modelling approach using the PRMS model to help achieve a fuller understanding of the linkages between the water budget components, and to establish accurate values for the water balance within each watershed. This model will be used by TRCA to establish an accurate depiction of the water balance, and the information will be used to assist in the management of the watersheds, provide input on land use planning matters, and support the protection of drinking water sources.

The output of the modelling will be used to prepare appropriate maps and tables indicating the values for each component throughout the TRCA watersheds. This information will then represent the existing water balance conditions in the watersheds, setting out the minimum conditions that should be protected, and not subjected to diminution due to land use changes. Subsequent updating of watershed plans can incorporate this information in the characterization of the ecosystems, improve the understanding of interdependencies, and assist in the decision-making process in regard to the setting of targets and determining management strategies.

6. DRAFT POLICY STATEMENT

In order to achieve the integration of water balance considerations into the planning and implementation of new undertakings, it would prudent to enshrine this goal in policy. Accordingly, the following Policy Statement has been prepared as the starting point for discussions towards that end.

Goal

To further the protection and restoration of the area streams, rivers, aquifers and lake waters for current and future users by avoiding and/or minimizing any impacts to water used for domestic, cultural, recreational, agricultural & industrial needs.

Principles

- Recognize rainwater and snowmelt as a valuable resource. Manage rainwater where it falls, on lots and streets, before it enters the streams and sewers.
- Protect and maintain the existing water balance to achieve improved watershed health, to help alleviate the liability and financial burden for operations and maintenance purposes, and to reduce development costs related to engineering structures.
- Incorporate the water balance assessment in the planning of stormwater management needs and the planning of watershed management strategies.
- Undertake stormwater management planning on an integrated basis throughout the entire watershed using an ecosystem approach.
- Initiate conservation of the water budget at the source, as rainfall reaches the ground (on the individual lots), to promote the retention of natural infiltration and runoff rates through the use of at-source management practices.
- Implement a hierarchy of stormwater management practices starting with ***at-source,*** followed by ***conveyance***, and finally ***end-of-pipe*** solutions.
- Encourage the implementation of measures that involve rainwater harvesting and re-use.
- Strategies and methods to protect the natural water budget should form part of all new development proposals.
- Accommodate the requirements of source water protection in the planning and implementation of stormwater and watershed management plans.

Objectives

- Preserve and re-establish the natural hydrologic cycle to protect and restore groundwater and surface water resources by minimizing impervious areas and advocating the need for at-source and distributed stormwater management measures.
- Maintain the hydrologic regime in streams and rivers such that it resembles existing

conditions, thereby avoiding increases in peak flows, velocities, and volumes, and reduction in dry weather baseflows.

- Strive for a natural channel morphology to avoid erosion problems, risk to adjacent properties and infrastructure, and degradation of the water quality.
- Maintain or improve baseflow conditions in existing stream and river corridors to help support the local fishery and contribute to the overall aesthetics and recreational value of the corridor.
- Ensure that the natural recharge capacity of an area and the quality of groundwater is maintained and remains unaffected by urban development.
- Participate with area municipalities to formulate a unified Policy Statement on water balance protection for ultimate integration into local planning documents and criteria manuals to ensure sustainable communities are achieved.

Policy Statements

TRCA will:

- Undertake the additional investigations and analyses required to characterize the ecosystem linkages within the nine watersheds and refine/complete the existing water balance for each.
- Cooperatively with municipal partners and other interested stakeholders, establish the numerical targets for the water balance components that are to be achieved across the entire TRCA jurisdictional area.
- Together with the area municipalities and other stakeholders, develop an Implementation Guideline document to provide direction to development proponents on the approach, methodology and targets that are to be satisfied in regard to the water balance.
- Promote the development of a computational tool for application in the assessment of the water balance and alternative mitigative measures, and lead the preparation of a TRCA model that will be made available to engineering practitioners, geoscientists, and land development interests.
- Participate in and promote further applied research to ensure continued improvement and advancement in the techniques and knowledge base associated with water balance assessment.
- Strive to re-establish and/or improve the hydrologic water balance throughout the area watersheds through collaborative efforts with municipal partners, watershed stakeholder groups, local residents and landowners.
- Use public information and communication tools to promote public awareness and understanding of the water balance, and its importance in achieving sustainable communities.

Ideal Targets for New Development

In the absence of a watershed plan, and/or specific criteria regarding water balance or infiltration targets, all development plans shall incorporate appropriate measures into the stormwater management system to achieve the following:

- The site water balance following new development should resemble pre-development conditions.
- There should no increase in the annual runoff volume from new development.
- The pre-development rate of infiltration should be maintained through a combination of on-site measures.
- To help achieve the above, for the frequent to moderate rainfall events, storm runoff collected by roofleader downspouts should be maintained on-site and dealt with through a combination of infiltration, evapotranspiration, and rain re-use/harvesting methods.

7. WATER BUDGET CONSIDERATIONS – IMPLEMENTATION GUIDELINES

An *Implementation Guideline* document is required in order to clearly outline the information, technical analyses, and content of the supporting documentation regarding the water balance protection that should accompany all project submissions. The following provides a recommended table of contents and outline that can be used in the preparation of the document.

Section 1 – Preamble

1.1 Scope and Objectives of Guideline Document
1.2 Summary of Process
1.3 Background Data Sources
1.4 Limitations
1.5 Watershed Characterization – physiographic units, recharge and discharge process, etc.
1.6 Conceptual Water Budget, including figures indicating TRCA jurisdictional area, recharge/discharge/ evapotranspiration values, physiography, and cross section.

Section 2- Existing Conditions

2.1 Background Information for Watershed Based Analysis
2.2 Models Applied for the Development of the Water Budget
2.3 Components for the Water Budget
2.4 Derivation of and Application of Unit Response Functions (URFs)
2.5 Use and Limitations

Section 3 – Criteria & Targets

3.1 General TRCA Criteria Regarding Water Budget, & Need to Maintain Current Characteristics
3.2 Watershed Specific Targets
3.3 Discussion of Applicable BMPs for TRCA watersheds: e.g., lot level, conveyance system, end-of pipe, storage, infiltration, green roofs, rainwater harvesting, clean water collector, pervious pipe system, constructed wetlands, wet ponds etc.
3.4 Exceptions and Limitations

Section 4 - Submission Requirements

4.1 Introduction

- general discussion on land development process and the components required as part of submission (e.g., fieldwork, hydrologic & hydrogeologic investigations, analyses, mitigation measures etc).

4.2 Required Studies for Secondary Plan Approval;

- scope, type and context of studies – OPs and OPAs, urban expansion, secondary plans;
- hydrogeologic setting and characterization;
- identification and quantification of recharge and discharge conditions;

- background data review – wells, borehole logs, land use etc.;
- baseflow assessment;
- synthesis of information to present overall characterization of existing conditions;
- proposed land uses, predicted impacts based on mapping and URFs;
- proposed strategy to address impacts – e.g., conceptual screening analysis and locations;
- potential issues at next stages and required studies; and,
- monitoring requirements.

4.4 - Studies Required for Draft Plan Approval

- scope, type and context of studies – e.g., Master Environmental Servicing Plan, Functional Servicing Study, multiple land owner;
- field work requirements – e.g., boreholes, piezometers, seepage meters, baseflow measurements, permeameter, falling head tests;
- confirmation of existing recharge, and flow gradients;
- refinements of existing land use and soil characteristics;
- confirmation of accuracy of existing groundwater recharge mapping; and,
- if additional analyses are required to establish groundwater recharge, tasks to be undertaken to include: proposed condition analysis using URFs, screening of mitigation measures, preliminary sizing and location of management measures, - annual volumes and event based - and identification of future monitoring requirements.

4.5 - Prior To Site Clearance (To Support Detailed Design)

- scope, type and context of studies – e.g., site plan application etc.;
- additional field work as specified in previous studies;
- detailed sizing of mitigation measures – annual volumes/event based values etc;
- design drawings;
- operation and maintenance requirements; and,
- post construction monitoring requirements and contingencies, where applicable.

4.6 – Budget Analyses For Wetland Features

- discussion on criteria and targets;
- monitoring requirements;
- analysis of baseline conditions and proposed impact assessment;
- protection and mitigation strategy;
- siting and design of development features;
- implementation, including any phasing requirements; and,
- post-construction monitoring.

8. MOVING FORWARD

The introduction of progressive policies and practices can often encounter resistance by some stakeholders, generally due to the lack of experience and understanding of the objectives, and available methods that can be applied for implementation. Accordingly, to move forward on the water balance policy and the associated requirements, and to help achieve wide-spread acceptance, the following actions should be taken:

i) The scientific literature review that TRCA is undertaking to support this document should be completed in a timely manner to help advance the water budget initiative.

ii) This document, together with the findings of the literature review, should be circulated to area municipalities for review and input. Follow-up meetings would be helpful to reach a consensus on the concept, and a final Policy Statement should be prepared.

iii) Circulation of the final document to the area development interests and the consulting industry would help to make involved stakeholders and practitioners aware of the impending requirements and would facilitate further opportunity for comment and collaboration.

iv) The finalized Policy Statement document should be presented to TRCA's Full Authority Board, as well as the local Municipal Councils for endorsement.

v) Work should be imitated on the preparation of the *Implementation Guidelines* document in order to provide clear and definitive direction on the objectives, the approach to be applied, the targets to be met, the type of mitigation measures to be considered, and the information to be submitted in support of development plans.

vi) The work on the water budget being undertaken by TRCA is fundamental for establishing a sound and defensible policy and approach. The results will establish reliable values for the components of the water budget under existing conditions, using sophisticated numerical modelling. The modelling will also be a key factor in the development of water balance targets for new development. Accordingly, efforts on this aspect should not be delayed.

The concept of developing a modelling tool – linking WABAS/HSPF and MODFLOW – for the assessment of the water balance, which would be made available to engineering and geoscience practitioners, is a very progressive and forward-thinking approach. The tool would make a detailed modelling approach readily available, at relatively low cost, and would ensure consistency in the approach and the results.

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