1.0 INTRODUCTION

1.1 History of Manual

In June 1991, the Ministry of the Environment published a report entitled *Stormwater Quality Best Management Practices*. The report documented experience with structural and non-structural Stormwater Management Practices (SWMPs) and concluded that they should be implemented in conjunction with new urban development and redevelopment.

Guidance, and a procedure for selecting appropriate SWMP types, was provided. The report stated, however, that "integrated watershed planning is the preferred means of defining uses of the receiver and hence the basis for SWMP selection." Recognition of the importance of watershed and subwatershed-based planning has continued to grow since the release of the 1991 study.

The Ministry of the Environment initiated the development of a *Stormwater Management Practices Planning and Design Manual* which was published in June 1994. Stormwater management has evolved considerably in Ontario since 1994; therefore, the Ontario Ministry of the Environment together with the Government of Canada's Great Lakes Sustainability Fund, Credit Valley Conservation, and other agencies undertook a project to update the manual. Furthermore, the 1994 manual focused more on water quality and there was an interest by various parties to produce a more integrated approach that incorporated water quantity and erosion considerations. This manual provides further development and update of key components.

Regarding the intended use of this document, it is worth emphasizing points made in the preface.

The "state-of-the-art" of stormwater management has been rapidly evolving and this manual is one step in this evolutionary process. The manual provides technical and procedural guidance for the planning, design, and review of stormwater management practices. It is important that the manual be viewed as a tool for understanding the performance requirements of stormwater management projects and not as a rulebook for all stormwater management solutions.

The manual provides practical guidance which has been found effective in specific circumstances. However, users must exercise judgement and flexibly adapt the guidance provided. Stormwater management solutions need to consider specific site conditions and this must be recognized when applying the guidance provided in the manual.

It is not the intent of the Ministry to limit innovation with the manual. Significant effort has been made to write the manual in a manner that does not inadvertently restrict creative solutions. The Ministry encourages the development of innovative designs and technologies. Where the designer can show that alternate approaches can produce the desired results or even better, such designs should be considered. However, the designer is responsible for the designs which are made with respect to stormwater management for any given site. This manual should be used in conjunction with other established manuals and practices. It updates the Stormwater Management Practices Planning and Design Manual (June 1994).

This manual will also be used as a baseline reference document in the review of stormwater management applications for approval under section 53 of the <u>Ontario Water</u> <u>Resources Act</u> as administered by the Ministry of the Environment.

Changes incorporated in the 2003 Manual were based on feedback received from a variety of sources including: a User's Survey given to individuals who obtained the 1994 Manual or attended a seminar in 1994; a questionnaire, circulated in 1997 to provincial agencies, conservation authorities, municipalities and other storm water management professionals; and, two workshops. A Steering Committee, comprised of stakeholders from a variety of agencies, reviewed material and provided input and direction throughout the development of the manual.

The key components (topics) which have been added, expanded, or updated in this manual include:

- providing an overview of the impacts of urbanization on the hydrologic cycle and stream ecosystems;
- addressing the evolution of the watershed planning process and implications for the design process;
- incorporating water quantity, erosion control, water quality protection, and water balance principles into the selection and design of Stormwater Management Practices (SWMPs);
- documenting the performance of SWMPs that have been monitored;
- incorporating design considerations for cold climate conditions for SWMPs;
- providing information on SWMPs such as sand filters, bioretention filters, wet swales and hybrid wet ponds/wetlands;
- writing a chapter on infill projects;
- updating the operation and maintenance chapter;
- providing design examples for SWMPs;
- updating material relating to planting strategies and the function of plant material in the design of SWMPs;
- providing an appendix on assessment methodology for retrofitting SWMPs together with an example; and
- providing an appendix which deals with integrated planning for stormwater management.

Further consultation with stakeholders took place through the posting of a revised draft on the Environmental Bill of Rights registry in 1999-2000. The final manual reflects the changes made as a result of the comments received.

There will be a transition period in which the guidance in the new manual will begin to be applied. Reasonable efforts should be taken to minimize any disruption to on-going projects during the transition period.

1.2 Manual Outline

Provided below is a brief overview of each chapter, as well as the key components that have been added to this version.

Chapter 1 – Introduction

Provides an introduction to the Manual, outlining its history and topics which have been introduced, further developed, or updated, as well as a brief overview of the contents within each chapter. Also provided is an introduction to the potential impacts of urbanization on hydrological aspects of the natural environment.

Chapter 2 – Environmental Planning

Describes the environmental planning process and its relationship with the municipal land use planning and approval process. It describes the types of environmental planning studies that may be undertaken, the deliverables provided by each study, and methods for integrating planning for stormwater management. It also notes that if there are insufficient environmental studies completed to define environmental conditions to set environmental goals/objectives and targets, and to provide a basis for selection and design of SWMPs, additional work (Chapter 3) will be required prior to the initiation of the design process (Chapter 4).

Chapter 3 – Environmental Design Criteria

Presents general environmental design criteria to be used in lieu of criteria that would normally be available from the environmental planning process. Information outlining the required areas of consideration is provided, as is guidance which should be used in order to identify potential problems and provide a reasonable level of impact mitigation. Criteria are presented for water balance, water quality, erosion control/geomorphology, and water quantity.

Chapter 4 – Stormwater Management Plan and SWMP Design

Provides design guidance on SWMPs. The guidance has been updated to reflect recent experience and supplemented where new techniques are available. Quantity control SWMPs have been added. The SWMPs have been grouped as lot level and conveyance controls and end-of-pipe controls. New SWMPs introduced include storage controls, wet swales, hybrid wet pond/wetlands, perimeter sand filters, and bioretention filters.

Chapter 5 – Infill Development

Discusses the challenge of applying stormwater management practices for small, infill sites within developed areas. Approaches and techniques are discussed, including use of off-site systems as an alternative.

Chapter 6 – Operation, Maintenance, and Monitoring

Topics include the need for maintenance, the tasks to be completed, as well as the frequency with which the activities should be undertaken. This advice remains essentially as provided in the 1994 manual although information on vegetation (natural succession) and hard-bottom forebays has been updated.

Chapter 7 – Capital and Operational Costs

Remains largely unchanged from the advice provided in the 1994 Manual. Costs have been updated.

Chapter 8 – References

1.3 Hydrological Effects of Urban Development and their Impacts on Ecosystems

Hydrologic Cycle

The hydrologic cycle describes the continuous circulation of water between the oceans, atmosphere, and land. Water is supplied to the atmosphere by evapotranspiration, which includes evaporation from all water, snow, vegetation, and other surfaces, plus transpiration from plants. It is returned to the land through precipitation. Within the hydrologic cycle, water may be stored by vegetation, snowpacks, land surfaces, water bodies, saturated subsurface zones, and unsaturated subsurface zones/soils. Water may be transported between these storages via overland runoff, streamflow, infiltration, groundwater recharge, and groundwater flow, among other processes (Figure 1.1).

Humans interact with the hydrologic cycle by extracting water for agricultural, domestic, and industrial uses, and returning it as wastewater discharges. Urban development may also interfere with the natural transfers of water between storage components of the hydrologic cycle.

For any system with defined boundaries (e.g., a watershed), a water balance may be used to describe the hydrological cycle. More specifically, the water balance provides for an accounting of water transfers across the system's boundaries over some time period. Any difference between inflows to the system and outflows from the system during this time period must be balanced by a change of storage within the system.

Changes to the Hydrologic Cycle/Water Balance

A major consequence of the increase in impervious area which accompanies urbanization is an increase in direct runoff and a corresponding decrease in infiltration. Table 1.1 (WEF, 1998) illustrates the changes in hydrological components that result from developing a forested area. Urbanization also results in decreased evapotranspiration. The net effect of conventional development practices on an urban stream is a dramatic change in the hydrologic regime of the stream.

Effects include:

- an increase in the magnitude and frequency of runoff events of all sizes;
- delivery of more of the stream's annual flow as surface storm runoff rather than base flow or interflow; and
- increases in velocity of flow during storms.

The decrease in infiltration that occurs with urbanization reduces soil moisture replenishment and groundwater recharge. In Ontario, a significant proportion of domestic and agricultural water supplies are from a groundwater source. Groundwater is also the source of stream baseflow which is important for sustaining aquatic life.

Figure 1.1: Hydrological Cycle



Source : After, M. L. Davis, D. A. Cornwell. Introduction to Environmental Engineering, 1991.

Definitions: Overland runoff – water that travels over the ground surface to a channel Streamflow – movement of water via channels Groundwater flow – movement of water through the subsurface Infiltration – penetration of water through the ground surface Groundwater recharge – water that reaches saturated zone The preservation of the natural hydrologic cycle, to the greatest extent possible, will not only maintain groundwater recharge so as to reduce baseflow impacts, but it will reduce the potential for flooding and erosion, and hence, the size and cost of stormwater infrastructure. Therefore, it is one of the primary goals of stormwater management.

Changes in Stream Response to Storm Events

Urban floods differ from those in natural basins in the shape of flood hydrographs (Figure 1.2), peak magnitudes relative to the contributing area, and times of occurrence during the year. The imperviousness of urban areas along with the greater hydraulic efficiency of urban conveyance elements cause increased peak streamflows but also more rapid stream response. Summer floods resulting from high intensity thunderstorms are more common in urban areas. Infiltration and evapotranspiration are much reduced at this time of the year under developed conditions.

The goal of stormwater management is to minimize the risks of loss of life and property damage due to urban floods.

	Forested Areas		Urban Areas with 40% Impervious Cover	
Item	Depth (mm)	% of Total Depth	Depth (mm)	% of Total Depth
May to November Rainfall	515	100.0	515	100
Interception Storage and Depression Storage on Impervious Areas	342	66.5	235	45
Infiltration	155	30.0	100	20
Runoff	18	3.5	180	35

Table 1.1: Distribution of May to November Rainfall for Forested and Urbanized Areas

Note: Sandy soils assumed.

Source: Modified by Chris Doherty of Environmental Water Resources Group

Figure 1.2: Flood Hydrographs for Urbanized and Natural Drainage Basins (Watt et al, 1989)



Changes in Stream Morphology

Stream channels in urban areas respond and adjust to the altered hydrologic regime that accompanies urbanization (WEF, 1998). The severity and extent of stream adjustment is a function of the degree of watershed imperviousness as well as the stream type. Examples of stream adjustments include:

- increased stream cross-sectional area to accommodate higher flows;
- significant downcutting of the stream channel;
- increased sediment loads in the stream because of increased instream erosion as well as watershed inputs;
- modification of the streambed (typically the grain size of channel sediments shifts from coarse-grained particles to a mixture of fine- and coarse-grained particles); and
- changes in characteristics such as location and meander pattern in response to stream crossings by roads and pipelines.

There may also be direct modifications of streams, such as straightening and/or lining, by humans to "improve" drainage and reduce flooding risks.

A critical issue is the level of development at which stream morphology begins to change significantly. Research models developed in the Pacific Northwest (U.S.) suggest that a threshold for urban stream stability exists at approximately 10% imperviousness of a watershed (Figure 1.3) (Booth and Reinelt, 1993). Watershed development beyond this threshold consistently results in unstable and eroding channels. The severity and extent of stream adjustment is a function of the magnitude of the change in the sediment-flow regime and the resistance of the channel materials to erosion. The goal of stormwater management is to protect the aquatic ecosystem, as well as the stream's aesthetic and recreational values, by maintaining a stable fluvial system.



Figure 1.3: Channel Stability as Function of Imperviousness (Booth and Reinelt, 1993)

Changes to Water Quality

Deterioration of urban stream water quality is associated with two phases of urbanization. During the initial phase of development, an urban stream can receive a significant pulse of sediment

eroded from upland construction sites, even if erosion and sediment controls are used. In the second phase of urbanization, the washing off of accumulated deposits from impervious areas during storms becomes the dominant source of contaminants. This manual focuses on mitigation of the effects of the second phase of urbanization. Guideline B-6: Guidelines for Evaluating Construction Activities Impacting on Water Resources (MOE, 1995) provides guidance for mitigation of the effects of construction activities.

Urban stormwater runoff may contain elevated levels of suspended solids, nutrients, bacteria, heavy metals, oil and grease, and pesticides, as well as sodium and chloride from roadsalt. Table 1.2 shows the concentrations of selected constituents of stormwater runoff compared to the Provincial Water Quality Objectives (Aquafor, 1993). Urban runoff may also cause increased water temperatures.

Parameter	Units	PWQO	Observed Concentrations
Fecal coliforms	CNT/dL	_	10,000 - 16E6
SS	mg/L	—	87 - 188
TP	mg/L	0.03	0.3 - 0.7
TKN	mg/L	_	1.9 - 3
Phenolics	mg/L	0.001	0.014 - 0.019
Al	mg/L	—	1.2 - 2.5
Fe	mg/L		2.7 - 7.2
Pb	mg/L	0.025	0.038 - 0.055
Ag	mg/L	0.0001	0.002 - 0.005
Cu	mg/L	0.005	0.045 - 0.46
Ni	mg/L	0.025	0.009 - 0.016
Zn	mg/L	0.030	0.14 - 0.26
Cd	mg/L	0.0002	0.001 - 0.024

 Table 1.2: Comparison of Urban Stormwater Runoff Concentrations with Provincial Water Quality Objectives

The change in the sediment load of a stream is one of the key factors affecting channel erosion but elevated levels of suspended solids, including both organic and inorganic matter, may have a number of other effects on a receiving water. Increased turbidity interferes with photosynthetic activity by reducing light penetration. Solids in suspension may clog gills and interfere with fish feeding, and the deposition of sediment may cover spawning areas and smother benthic communities. Organic matter exerts an oxygen demand and may severely depress the levels of dissolved oxygen in the receiving water. In addition, several other stormwater contaminants are commonly associated with solids.

The priority of stormwater management with respect to water quality has been control of suspended solids. However, many of the SWMPs can successfully remove other stormwater contaminants as well. Measures that prevent or minimize releases of contaminants that may be carried to streams by stormwater are, of course, preferable to treatment options.

Groundwater quality may also be affected in urban areas, and care must be taken that the stormwater management controls chosen do not contribute to groundwater degradation.

Changes in Aquatic Habitat and Ecology

The ecology of urban streams and other aquatic habitat is shaped and molded by extreme shifts in hydrology, geomorphology and water quality that accompany the development process. Stresses on the aquatic communities of urban streams and other water resources are often manifested as:

- a shift from external (leaf matter) to internal (algal organic matter) stream production;
- a decline in aquatic habitat quality;
- a reduction in diversity in the fish, plant, animal and aquatic insect communities in the stream;
- a loss of sensitive coldwater species;
- a destruction of freshwater wetlands, riparian buffers and springs; and
- a decline in wetland plant and animal community diversity.

1.4 Environmental and Municipal Land Use Planning

There is a recognition that a more holistic approach is required to mitigate the impacts of urbanization. This has led to the ecosystem approach for development where environmental

planning such as watershed and subwatershed planning is done to provide important information to key decision points in the municipal land use planning process. Chapter 2 describes the typical deliverables from each type of environmental plan such as the watershed plan, subwatershed plan, environmental management plan and the stormwater management plan. The plans should provide direction to proponents of development regarding the impacts of the levels and types of development and the management actions required.

The intent of watershed and subwatershed plans is to prepare goal-oriented strategic plans which will allow urban development to occur while protecting the natural ecosystem functions. Watershed-wide policies or management programs are proposed which are mainly oriented towards conservation and preservation such as agricultural restrictions, buffer strips, salt management, topsoil preservation, wildlife linkages, wetland preservation, natural areas preservation, and forest preservation. Watershed and subwatershed plans look at the cumulative effect of development and do not go down to the level of detail needed for design.

The subwatershed plan evaluates the integrated effect of land use scenarios (development, terrestrial linkages preservation, stream buffer preservation, environmentally sensitive/significant area preservation), and urban SWMPs on objectives related to water balance, stream erosion, water quality, temperature, baseflow, flooding, fisheries habitat and aquatic life. For example, a subwatershed plan may set tributary-based targets for peak flows, baseflow and water quality and specify the aggregate levels of stormwater control. Decisions made at the subwatershed plan have direct bearing on the type of development and acceptable SWMP types and performance level at the stormwater management plan level. The results will govern SWMP selection and design for urban development.

An environmental management plan summarizes the findings of the previous plans and is done on a tributary subcatchment boundary or Secondary Plan boundary or a portion thereof. The smaller scale analysis done for an EMP allows for more refined and specific deliverables than a subwatershed plan. EMPs should be of sufficient detail such that all remaining environmental and/or SWM work may be completed as conditions of the Draft or Site Plan stage. Preliminary SWM designs are done at this stage.

The more detailed SWM plan is prepared at the urban subdivision level to meet the conditions and targets set at the Draft or Site Plan stage. The SWM plan is carried out under private proponency and submitted to the review agencies for comment and approval. The SWM planning is integrated with environmental site planning which includes subdivision planning, site planning and engineering, landscape design, architectural and building design, and local street design. It includes the detailed design of SWMPs.

Subdivision/site planning extends the ecosystem approach from watershed planning to the actual layout of the development. Site planning techniques refer to the layout of development and

development standards imposed by the local municipalities. It is a fundamental determinant of the overall change in the hydrologic cycle for a given development. The way a development is planned, and the specific design criteria adopted by the planner or engineer, can have a great impact on the level of success achieved by the stormwater management measures which are implemented.

1.5 Urban Stormwater Management Practices

Table 1.3 introduces the types of stormwater management controls which will be discussed in this manual, and their suitability for mitigating the impacts of urban development. Lot level and conveyance controls include those that are applied at the individual lot level, those which form part of the conveyance system, and controls which may serve multiple lots but are only suitable for small drainage areas (< 2 hectares). End-of-pipe controls receive water from a conveyance system and discharge to a receiving water. They are typically the facilities used to service numerous lots or whole subdivisions.

The term "treatment train" is used to describe the combination of controls usually required in an overall stormwater management strategy to ensure that:

- groundwater and baseflow characteristics are preserved;
- water quality will be protected;
- the watercourse will not undergo undesirable geomorphic change;
- there will not be any increase in flood damage potential; and ultimately
- that an appropriate diversity of aquatic life and opportunities for human uses will be maintained.

Lot level and conveyance controls are required to maintain the natural hydrologic cycle to the greatest extent possible. End-of-pipe facilities are usually required for flood and erosion control and water quality improvement, although lot level and conveyance controls can reduce the size of the end of pipe facilities required.

An overall stormwater management strategy may incorporate broader solutions to stormwater management than the practices described in this manual. These broader solutions may be elements of community design (e.g., reduced pavement width, compact building forms) or preventative measures that can be taken by individuals, businesses, or government agencies (e.g., use of safer alternative products and methods, street cleaning, spill prevention and control).

SWMP	Water Balance	Water Quality	Erosion	Water Quantity				
Lot Level and Conveyance Controls								
Rooftop storage	F	F	F	М				
Parking lot storage	F	F	F	М				
Superpipe storage	F	F	F	М				
Reduced lot grading	М	•	•	F				
Roof leader to ponding area	М	•	•	F				
Roof leader to soakaway pit	М	•	•	F				
Infiltration trench	М	М	•	F				
Grassed swales	М	•	•	•				
Pervious pipes	М	М	•	F				
Pervious catchbasins	М	•	•	F				
Vegetated filter strips	М	•	•	F				
Natural buffer strips	•	•	•	F				
Rooftop gardens	F	•	•	F				
End-of-Pipe Controls								
Wet pond	F	М	М	М				
Artificial Wetland	F	М	М	М				
Dry pond	F	•	М	М				
Infiltration basin	•	М	•	F				
Filters*	F	М	F	F				
Oil/grit separators*	F	•	F	F				

Table 1.3: Stormwater Management Practices

M High Suitability

• Medium Suitability

F Low Suitability

*Water Quality suitability is highly dependent on sizing and by-pass design.

Source: Aquafor Beech Ltd., Wet Weather Discharges to the Metropolitan Toronto Waterfront, prepared for the Metropolitan Toronto & Region Remedial Action Plan, 1993