Conservation Halton Guidelines for Stormwater Management Engineering Submissions

February 2024

Version 2.0

CONSERVATION HALTON GUIDELINES

Conservation Halton (CH) protects, manages, and enhances the area within its jurisdiction through the delivery of a range of programs and services, including mandatory programs and services related to managing the risks associated with natural hazards. In the planning and development process, CH exercises its roles and responsibilities in accordance with Section 21.1 of the *Conservation Authorities Act* and Ontario Regulation 686/21, including as:

- A regulatory agency under Section 28 of the *Conservation Authorities Act*;
- A body with delegated responsibility to represent the Provincial interest and ensure that development applications are consistent with the natural hazards policies of the Provincial Policy Statement (PPS), but not including those policies related to hazardous forest types for wildland fire;
- A public commenting body under the *Planning Act, Clean Water Act* and other Acts and Provincial Plans;
- A resource management agency operating on a local watershed basis; and
- A landowner in the watershed.

CH's Planning and Regulations staff (i.e., environmental planners, regulations officers, planning ecologists, water resource engineers, technologists, and hydrogeologists) work together on interdisciplinary teams to deliver timely and comprehensive reviews and advice to provincial agencies, municipalities and landowners across CH's jurisdiction.

Section 28 (1) of the *Conservation Authorities Act* allows conservation authorities to make regulations to protect life and property from natural hazards. CH's regulation is Ontario Regulation 162/06. Under Ontario Regulation 162/06, CH regulates:

- All development in or adjacent to river or stream valleys, wetlands and surrounding lands where development could interfere with the hydrologic function of the wetland, Lake Ontario shorelines, and hazardous lands such as karst and any prescribed allowances;
- Alterations to a river, creek, stream or watercourse; and
- Interference with wetlands.

Permission is required from CH for undertaking the above noted works within regulated areas. CH's Board-approved Policies and Guidelines for the Administration of Ontario Regulation 162/06 and Land Use Planning Policy Document outlines the policies and technical requirements which must be met before permission may be granted. As part of a CH permit application, an applicant must demonstrate that CH's Board-approved policies and technical standards can be met.

CH also provides technical advice and support to its municipal partners on planning and development applications where it relates to CH's mandatory programs and services, as well as a public commenting body and a resources management agency.

These Guidelines provide clear expectations regarding the criteria and approaches that are acceptable to CH and are used by staff to assess the technical merits of stormwater management plans. Applicants proposing works should follow these Guidelines when preparing plans to be submitted to CH. By doing so, more efficient and consistent reviews, fewer resubmissions, and faster approvals are anticipated.

These Guidelines are specific to CH and do not replace or supersede any other federal, provincial, or municipal requirement.

OBJECTIVE	The purpose of the **Stormwater Management Engineering Submission Guidelines is to:** • **Identify CH's** requirements for a SWM submission; and • **Outline CH's** key expectations for SWM design.
APPLICATION & USE	Applies to all stormwater management engineering submissions associated with *Planning Act* and *Ontario Regulation 162/06* applications. These Guidelines have been developed for: • **Qualified professionals** such as water resource engineers and other qualified persons tasked to guide the preparation of SWM plans • **CH staff** to assess the technical merits of SWM plans and to facilitate quicker, more consistent reviews
ADDITIONAL REFERENCE MATERIALS (to be read in conjunction with this document)	• Ontario Regulation 686/21: Mandatory Programs and Services, 2021 • Ontario Regulation 162/06 Halton Region Conservation Authority: Regulation of Development, Interference with Wetlands and Alterations to Shorelines and Watercourses, 2006 • Policies and Guidelines for the Administration of Ontario Regulation 162/06 and Land Use Planning Policy Document (November 26, 2020). • Municipal Stormwater Management/Engineering Guidelines/Standards • Conservation Halton Guidelines for Landscaping and Rehabilitation Plans, February 2024 • Conservation Halton Guidelines for Wetland Water Balance Assessments (forthcoming) • Stormwater Management Planning and Design Manual (MOE, 2003) • Low Impact Development Stormwater Management Planning and Design Wiki Guide (CVC and TRCA) • Erosion and Sediment Control Guidelines for Urban Construction (TRCA, 2019) • Approaches to Manage Regulatory Event Flow Increases Resulting from Urban Development (TRCA, 2016) • Halton-Hamilton Source Protection Plan • MECP Source Protection Information Atlas
VERSION	**Version 2.0** This version of the Stormwater Management Engineering Submission Guidelines was presented and approved by the CH Board of Directors on XXXX, 2024. The Guidelines may be updated from time to time. For more information, visit https://www.conservationhalton.ca/policies-and-guidelines.

TABLE OF CONTENTS

Tables

Figures

Abbreviations

The following table lists the various abbreviations used within this document:

TABLE 0-1: LIST OF ABBREVIATIONS

BMP	Best Management Practice	**CH**	Conservation Halton
CVC	Credit Valley Conservation	**EIR/FSS**	Environmental Impact Report/Functional Servicing Study
LID	Low Impact Development	**MECP**	Ministry of the Environment, Conservation and Parks
MESP	Master Environmental Servicing Plan	**MOE**	Ministry of the Environment
OP	Official Plan	**OPA**	Official Plan Amendment
O. Reg. 162/06	Ontario Regulation 162/06	**O.Reg. 686/21**	Ontario Regulation 686/21
SIS	Subwatershed Impact Study	**SP**	Secondary Plan
SWM	Stormwater Management	**SWMP**	Stormwater Management Pond
SWMPDM	Stormwater Management Planning and Design Manual	**SWP**	Source Water Protection
SWS	Subwatershed Study	**TRCA**	Toronto and Region Conservation Authority
WS	Watershed Study	**ZBA**	Zoning Bylaw Amendment

Section 1 Introduction

The purpose of the Guidelines for Stormwater Management (SWM) Engineering Submissions is to:

- Identify Conservation Halton's (CH) regulatory and technical requirements for a SWM submission; and
- Outline CH's key expectations for SWM design.

This document focuses primarily on CH's expectations related to water resources engineering aspects of SWM. Other disciplines may also be relevant such as hydrogeology, fluvial geomorphology, geotechnical engineering and ecology. Where this is the case, a reference to the appropriate guideline is included within the text.

1.1 Document Outline

This document has been divided into six sections and supporting appendices:

- **Section 1 – Introduction** – Outlines CH's role in hydrology and SWM review and how it relates to the planning and regulatory process.
- **Section 2 – Stormwater Management Objectives and Criteria** – Outlines CH's objectives and criteria for water quantity, stream erosion, and water balance.
- **Section 3 – Stormwater Management Practices** – Outlines requirements related to specific SWM infrastructure elements.
- **Section 4 – Hydrologic Modelling Requirements** – Outlines the technical recommendations for hydrologic modelling and associated hydraulic calculations.
- **Section 5 – Submission Requirement Checklists** – Outlines the components needed for various reports (e.g., Functional Servicing Report).
- **Section 6 – References** – Lists the various documents reviewed in preparation of this document.

These Guidelines are specific to CH and do not replace or supersede any other federal, provincial, or municipal requirement.

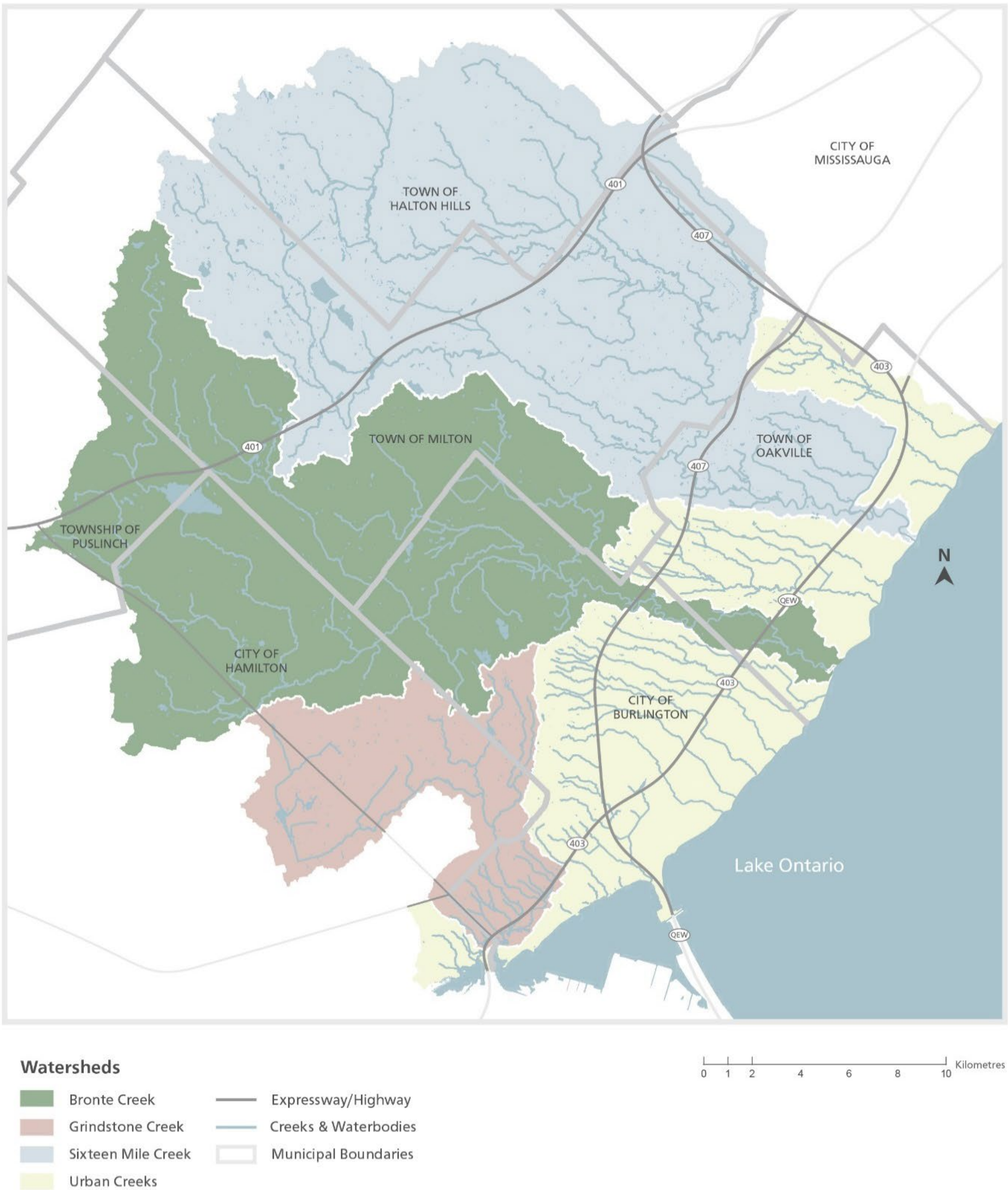
1.2 Conservation Halton's Role in Reviewing Hydrology and Stormwater Management

CH protects, manages, and enhances the area within its jurisdiction (see Figure 1-1) through a wide variety of mandatory programs and services. Under Ontario Regulation 686/21, CH must provide programs and services related to understanding and managing risks related to natural hazards, including preventing or mitigating those risks. Changes in stormwater runoff may impact natural hazards by changing when and how much stormwater reaches watercourses, valleys, shorelines, wetlands, or karst. For example, increases in runoff due to changes in land cover that are not mitigated through proper stormwater management can increase flood depths, velocities and limits within the receiving creek system, potentially increasing risks associated with natural hazards.

CH also administers Ontario Regulation 162/06 (O. Reg. 162/06), under which CH regulates:

- All development in or adjacent to river or stream valleys, wetlands and surrounding lands where development could interfere with the hydrologic function of the wetland, Lake Ontario shorelines, or hazardous lands such as karst and any associated allowances;
- Alterations to a river, creek, stream, or watercourse; and
- Interference with wetlands.

FIGURE 1-1: CONSERVATION HALTON WATERSHED



Source: Conservation Halton.

Permission is required from CH for undertaking any development within regulated areas. “Development” means,

- the construction, reconstruction, erection or placing of a building or structure of any kind,
- any change to a building or structure that would have the effect of altering the use or potential use of the building or structure, increasing the size of the building or structure or increasing the number of dwelling units in the building or structure,
- site grading, or
- the temporary or permanent placing, dumping or removal of any material, originating on the site or elsewhere.

Permission from CH is required for construction of storm water infrastructure or any associated work within an area regulated under the Regulation. These works may include outlet pipes/swales, emergency spillways, grading, or the entire facility.

CH’s Board-approved *Policies and Guidelines for the Administration of Ontario Regulation 162/06 and Land Use Planning Policy Document* (November 26, 2020) outlines the policies and technical requirements which must be met before permission may be granted. As part of a CH permit application, an applicant must demonstrate that CH’s Board-approved policies and technical requirements can be met to the satisfaction of CH.

CH also provides technical advice and support to its municipal partners on planning and development applications where it relates to CH’s mandatory programs and services, including those related to managing and understanding risks associated with natural hazards.

While CH does not review or provide advice on stormwater quality, it is an essential aspect of stormwater management. The municipality should be consulted for stormwater quality requirements.

CH’s review of proposed SWM works provides for a streamlined and integrated assessment of the merits of the proposal that is linked to CH’s roles and responsibilities.

1.3 Stormwater Management and Planning Processes

The level of SWM related detail required in each study depends on the scale and scope of the development proposal or stage in the planning process. SWM-related studies should reflect existing and proposed land use(s) and the scale and scope required to support the planning application or planning studies under other legislation (e.g., Environmental Assessment Act). Studies should also be in-keeping with higher-level studies (e.g., Subwatershed Plans, Environmental Implementation Reports/Functional Servicing Studies, Master Environmental Servicing Plans, Environmental Assessments, etc.), where applicable.

The following provides an overview of the SWM-related studies required to support various planning documents and applications under the *Planning Act* or other legislation. As the scale and scope of land development varies widely, pre-consultation with CH and the municipality, as well as relevant Provincial ministries, is strongly recommended.

Watershed Studies (WSs) and Subwatershed Studies (SWSs) are valuable resources and supporting studies for municipalities when developing and updating their Official Plans (OPs) and Secondary Plans. A comprehensive Terms of Reference (TOR) guides the scope and components of these studies. Typically, TOR are developed collaboratively to ensure the technical requirements of both the municipalities and CH are met. Typically, WSs are carried out to gain a broad understanding of the ecosystem’s functions and status, including the role and appropriate management of stormwater. SWSs build upon the recommendations made within the higher-level WS following the same ecosystem approach but at a greater level of detail for a smaller area (typically Secondary Plan).

In addition to other matters such as ecology and hydrogeology, a SWS should demonstrate how SWM planning will:

- Ensure systems are optimized, feasible, and financially viable over the long term;
- Minimize, or where possible, prevent increases in contaminant loads in the receiving watercourse or wetland;
- Minimize changes in water balance and erosion;
- Prepare for the impacts of a changing climate;
- Minimize, or where possible prevent, increases in peak surface water flows in the receiving watercourses;
- Mitigate risks to human health and safety, property, and the environment; and,
- Promote SWM best practices, including stormwater attenuation and re-use, water conservation and efficiency, and Low Impact Development (LID) techniques.

When reviewing a SWS, CH will only comment on SWM with respect to impacts on natural hazards or the hydrologic function of wetlands (for works proposed within regulated areas). The SWS should identify management and implementation strategies to meet the above objectives and establish acceptable practices, applications, targets, and SWM facility location(s) at a conceptual level. The SWS should also provide guidance on the requirements of future studies.

An **Environmental Implementation Report (EIR)/Subwatershed Impact Study (SIS)/Municipal Environmental Servicing Plan (MESP)** or similar study typically supports Tertiary or “Block” Plans, Official Plan Amendments (OPA), Zoning By-law Amendments (ZBA), and Draft Plans of Subdivision/Condominium. An EIR/SIS/MESP involves a more detailed assessment of many components, including conceptual SWM designs and grading plans. Typically, an EIR/SIS/MESP is used to demonstrate how a specific development concept will comply with the applicable SWS recommendations while addressing/evaluating all lands within a given subcatchment area. TOR for these studies is key, and preferably determined at the SWS stage. CH should be involved in the development of the TOR, including when work is being scoped.

OPA, ZBA, and Draft Plans of Subdivision/Condominium, are normally also supported by a **Functional Servicing Report (FSR)** as outlined in this document. The FSR may be combined with an EIR or EIS/EIA. Detailed Subdivision/Condominium Designs and Site Plans are normally supported by a **SWM Brief/Design** Report as outlined in this document. The requirements for an FSR and other SWM reports are provided in Section 5.

CH typically defers SWM requirements and reviews for Consents (Severances), Minor Variances, and Single Lot Residential Development (<0.5 ha) to municipal staff; however, CH may recommend technical evaluations and SWM controls depending on the location, size and complexity of the site.

Environmental Assessments, under the *Environmental Assessment Act*, are generally undertaken to support municipal, provincial, and federal infrastructure projects. These documents should identify potential stormwater impacts of the evaluated alternatives as well as mitigation measures. The document should also outline the SWM requirements associated with the preferred alternative.

These guidelines apply to new projects proposed, following CH Board approval of these guidelines. For legacy projects that have remained active, CH encourages incorporation of the new criteria, requirements and recommendations, where appropriate. Otherwise, CH will be consistent with past direction for the duration of the *Planning Act*/Permit application or Environmental Assessment study as well as for subsequent planning and permitting stages for the same project. In cases where legislation or Federal/Provincial direction change; when it is necessary to protect public safety; or when required by updated technical reports and policies (e.g., 5-year Official Plan reviews, SWS updates, new CA regulations and associated policies), different approaches may be required.

Section 2 Stormwater Management Criteria and Objectives

A SWM strategy should assess the impacts of proposed development with respect to flooding and erosion/sediment transport. For development within an area regulated by CH, the SWM strategy should also assess the hydrological impacts to wetlands, where applicable. The recommended strategy should demonstrate how impacts will be mitigated and SWM objectives addressed.

The following is a list of some of the key documents that provide guidance to the proponent for SWM submissions:

- *Stormwater Management Planning and Design Manual*, Ministry of the Environment (March 2003)
- *Low Impact Development Stormwater Management Planning and Design Wiki Guide*, Credit Valley Conservation and Toronto and Region Conservation Authority
- Toronto and Region Conservation Authority, *Erosion and Sediment Control Guide for Urban Construction* (2019)
- *Erosion and Sediment Control Inspection and Monitoring (CAN/CSA-W202-18)*, CSA Group (October 2018)
- *Approaches to Manage Regulatory Event Flow Increases Resulting from Urban Development*, Toronto and Region Conservation Authority (2016)
- *Halton-Hamilton Source Water Protection Plan and Mapping*
- Municipal SWM/Engineering Guidelines/Standards (both local and Regional)
- Hamilton Harbour Remedial Action Plan

2.1 Treatment Train

CH encourages the use of a treatment train approach in addressing SWM volume requirements. The treatment train approach involves providing controls at multiple locations (i.e., treatment at source, along the conveyance system, and at the end-of-pipe outlet). A treatment train may be required to meet the multiple objectives of water quantity, water balance and erosion control as well as municipal requirements for water quality. Multiple methods could be used to achieve this goal.

2.2 Water Quantity

Stormwater quantity control is intended to protect life and property from increased flood risk, which could result from increased peak flows and/or increased runoff volume.

Quantity control requirements are typically established through a SWS, which assesses the effects of cumulative development impacts within the subwatershed. Where a current SWS is unavailable, site-specific stormwater quantity control criteria will be established through consultation with CH and the municipality. The applicant may be required to prepare a scoped SWS (i.e., a limited study) or other study that assesses cumulative impacts. The type of study and its limits would be determined through pre-consultation.

If the scale of development does not warrant a completion of a scoped SWS or SWS update, CH typically recommends that post-development peak flow rates not exceed corresponding pre-development rates for the 1:2-year, 1:5-year, 1:10-year, 1:25-year, 1:50-year and 1:100-year storms. If there is a known deficiency in the downstream conveyance system (e.g., undersized pipes, insufficient overland flow paths), an insufficient downstream outlet, or specific municipal requirements, additional quantity controls (i.e., over-controlling outflows to less than the existing conditions) may be required. This requirement should be identified through pre-consultation with the municipality.

Safe conveyance of the Regulatory flow from a SWM facility to a sufficient receiving system must be provided such that there will be no adverse effects on downstream lands. The Regulatory flow is the greater of the uncontrolled 100-year or Regional (Hurricane Hazel) flows. A sufficient receiver typically consists of a watercourse or lake, though a wetland may also be an acceptable discharge location for clean controlled runoff. A public right-of-way may also be an acceptable receiver, provided the applicant has written permission from the municipality.

2.2.1 Regulatory Storm Control

The need for Regulatory Storm control is typically determined at a watershed or subwatershed-level of study based on a flood risk assessment. Several studies have identified the requirement for quantity control for the Regulatory Storm within CH's jurisdiction. If not stated in a higher-level document, consultation with CH and the municipality is recommended to confirm if Regulatory Storm control is required. CH follows the approaches outlined in the document *Approaches to Manage Regulatory Event Flow Increases Resulting from Urban Development* (Toronto and Region Conservation Authority, 2016) except for flooding of internal roadways within additional storage areas and a minimum freeboard based on fetch length for off-line SWM facilities.

2.3 Stream Erosion Control

Development can alter the rate and quantity (i.e., flow and volume) of water that enters a receiving watercourse, as well as the amount of sediment transported in the system. The objective of stream erosion control is to prevent excess erosion or sedimentation (i.e., changes to the rate of natural or existing erosion) and associated risks to property/infrastructure.

An erosion threshold assessment will typically be required at the watershed, subwatershed, or EIR/FSS/SIS/MESP study level. The erosion assessment should be completed by a qualified professional using scientifically defensible models, and current industry standards. A field assessment of channel features, forms, and sensitivity should be done by walking the watercourse throughout the subject site and downstream to the extent reasonably anticipated to be impacted by proposed development (as feasible, recognizing site access constraints). Erosion assessments are typically terminated at the first major confluence or the point where the site represents approximately 10% of the contributing area of the system. Multiple methodologies should be used to establish thresholds and targets and should include the total work performed on the channel and not simply review/match duration of exceedance. More detailed information on CH submission requirements for erosion threshold assessments will be provided in future fluvial geomorphology guidelines.

In the absence of higher-level studies establishing erosion control requirements, a site-specific erosion study may be required. CH and the municipality should be consulted about the need and scope for an erosion study. The following are typical scenarios where an erosion study would likely be required to support large-scale new development:

- If development is proposed upstream of a known erosion area,
- If development is proposed to discharge to small watercourses, or
- If flow diversions are proposed.

Where higher-level studies have not specified requirements and a site-specific erosion study is not warranted, CH typically recommends that the runoff from a 25 mm design storm be retained or detained and released over a period of at least 24 hours for sites, even those sites that outlet directly to a storm sewer. For smaller sites, it is sufficient for submissions to demonstrate that the use of parking lot/pipe storage, infiltration, evapotranspiration, and on-site re-use of runoff has been applied to the extent feasible to reduce erosion potential.

2.4 Wetland Water Balance

Water balance requirements are to be considered when development within a CH regulated area has the potential to impact a wetland. the objective of a water balance is:

- To replicate as closely as possible existing hydrologic conditions by maintaining a balance between infiltration, runoff and evapotranspiration;
- To maintain as closely as possible groundwater and base flow regimes; and
- To ensure long-term sustainability of hydrological form and function of the wetland.

Increased impervious areas can result in increased runoff volumes and/or decreased groundwater flows directed to natural features such as wetlands. Grading and servicing can change drainage patterns. For example, the use of end-of-pipe SWM facilities transfer runoff to a single discharge point which may direct flows away from wetlands. These changes in runoff can impact the function of the wetland.

Wetland water balances establish a wetland's hydrological function(s) and demonstrate how these functions will be maintained during and post-development. Typically, the SWM strategy should maintain the existing quantity, timing, duration and frequency of surface water and groundwater contributions on a monthly, seasonal, and annual basis to maintain pre-development hydrologic functions of the wetland. CH is in the process of creating guidelines with respect to wetland water balance assessments. CH staff should be consulted prior to design.

2.5 Diversions

CH requires maintenance of existing watershed boundaries and drainage patterns unless there are extenuating circumstances or where a higher-level study supports a diversion (i.e., re-direction of flows from one drainage basin to another).

Should the applicant put forward a drainage diversion or modification of drainage basin boundaries, the impact of the proposed changes must be assessed holistically, considering both the 'losing' and 'gaining' systems. The impacts of water takings and land use changes must be evaluated relative to risk to flooding and erosion, including maintenance of geomorphic functions. The analysis should consider the anticipated changes in flow frequency, timing, duration, peak, and volume and should be supported through supporting analysis. Opportunities must be investigated to mitigate a diversion from one subwatershed to another through an equal offsetting diversion.

Given the inherent complexities, consultation with CH and the municipality is required to establish site specific requirements related to any proposed diversions.

2.6 Climate Change

Climate change is the long-term modification of weather conditions (e.g., temperature, precipitation, wind, etc.). It can involve changes in average conditions and changes in weather predictability. As a result of climate change, Ontario is experiencing more frequent variation in temperature, wind patterns, and precipitation events.

In recent years, southern Ontario has experienced intense storms that have caused flooding and resulted in large economic and physical damage to infrastructure. The frequency and severity of storm and flood events is anticipated to escalate in the coming years. Thus, stormwater infrastructure should be designed with due consideration of possible changes.

Anticipated impacts that will affect SWM strategies include:

- Shift in seasonal flows (e.g., reduced spring freshet, longer periods of low flow in summer, increased precipitation and flows in fall/winter);
- Reduced level of service provided by existing infrastructure due to more intense rainfall or blockage because of more frequent freeze/thaw cycles;
- Increased urban flooding (surcharging sewers, basements, roadways, and an inability to achieve design control levels within centralized facilities);
- Increased thermal impacts of stormwater on the receiving water body;
- Increased occurrence of algae blooms; and
- More sediment transport due to intense rainfall.

Provincial and municipal policies encourage consideration of climate change in stormwater management, including infrastructure design. Watershed studies, subwatershed studies and Master Plans, are important vehicles for considering the implications of climate change on SWM. These studies should assess the implications of climate change and include recommendations for climate resiliency for future developments and retrofits of existing SWM assets. The assessment/recommendations should demonstrate that the design performance of the SWM infrastructure is maintained over the lifespan of the asset. Due to the uncertainty of climate change on SWM, adaptive management is strongly encouraged.

Proponents are directed to consult with the municipality for direction on how to address climate change resiliency and adaptive management in their SWM design.

2.7 Summary – Criteria & Objectives

Table 2.1 provides a summary of CH's SWM criteria and objectives for water quantity, stream erosion and feature-based water balance. The proponent should follow the requirements of current higher-level studies (e.g., SWS) and in instances where a higher-level study is not available, consult with the municipality and CH.

TABLE 2-1: SUMMARY – SWM CRITERIA AND OBJECTIVES

Criteria / Objective	Key Information
Treatment Train	• Use of a treatment train approach is encouraged, and may be required, to meet multiple SWM objectives.
Water Quantity	• Use the targets and sizing criteria established in higher-level studies. • Confirm the need for Regulatory controls through higher-level studies or through consultation with CH/municipality. • In the absence of current higher-level studies, control post-development flows to pre-development levels for 1:2-year through 1:100-year storm events. Overcontrol may be required where downstream capacity constraints exist. • Provide safe conveyance of Regulatory Storm from a SWM facility.
Stream Erosion Control	• Use the erosion control criteria established in current higher-level studies. • Consult with CH and municipality to determine the need for site specific erosion study, where there are no higher-level studies. • Use 24-hour detention of the 25 mm storm, where an erosion study is not required.
Wetland Water Balance	• Consult with CH regarding wetland water balance requirements.
Diversions	• Maintain existing watershed boundaries and drainage patterns unless there are extenuating circumstances and supporting analysis is provided or where diversion is supported by a higher-level study. • Consult with CH to establish site specific SWM requirements for any proposed diversions.
Climate Change	• Watershed studies, subwatershed studies and Master Plans, should consider climate change and plan/design development for climate resilience. Consult with the municipality for direction on how to address climate change in SWM design.

Section 3 Stormwater Management Practices

This section summarizes CH's expectations related to infrastructure elements typically included as part of a stormwater management strategy. These expectations should also complement the requirements in the following documents:

- The guidelines and criteria set out in the Ministry of the Environment *Stormwater Management Planning and Design Manual* (March 2003), as well as any supporting documents such as the forthcoming Low Impact Development guidelines;
- Requirements/recommendations of relevant watershed/subwatershed studies; and
- Municipal guidelines and standards (both local and Regional).

This section does not provide a comprehensive list of SWM practices. CH will consider alternative methods/approaches through consultation, subject to approval by the municipality.

CH recommends SWM strategies for nearby projects be coordinated.

CH requires that SWM infrastructure be in accordance with CH's *Policies and Guidelines for the Administration of Ontario Regulation 162/06 and Land Use Planning Policy Document* (November 26, 2020). These policies require that most SWM infrastructure, excluding outfalls/spillways, be located outside of areas regulated by CH.

Where the placement of SWM infrastructure within CH's regulated area is necessary, permission is required from CH. The applicant must consult with CH to determine the feasibility/acceptability of the proposed location, as well as site-specific design requirements prior to applying for a permit under O. Reg. 162/06.

3.1 Low Impact Development Techniques

CH encourages the use of LID techniques in SWM strategies, where appropriate. Studies have shown that appropriately operated and maintained LID techniques have multiple positive impacts which are noted in the table below (not all benefits are experienced depending on the LID technique used or how it is considered in the SWM strategy).

TABLE 3-1: LID TECHNIQUE BENEFITS

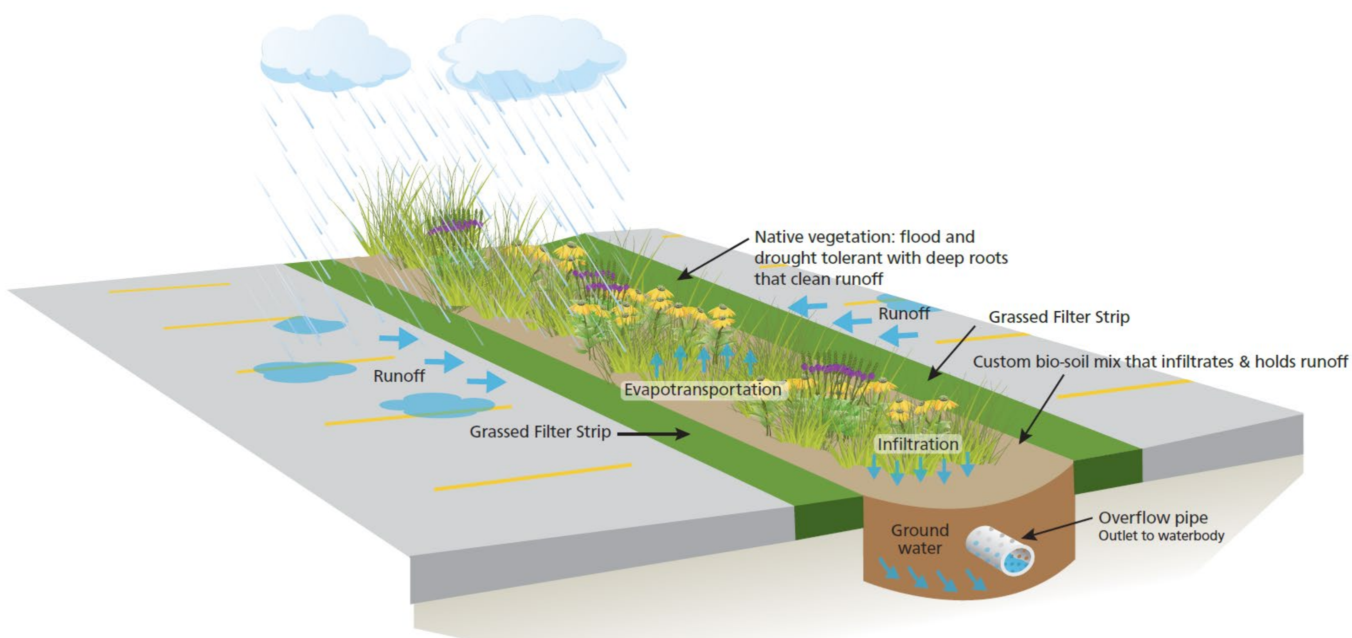
Category	Potential Benefit(s)
Infrastructure	• LID techniques reduce drawdown times in downstream end-of-pipe SWM facilities. • Retrofit areas lacking formal SWM controls. • Provides resiliency to adapt to the negative impacts of climate change. • Reduces volume of runoff and thermal loading of SWM facilities. • Reduces nuisance flooding related to poorly graded sites or lack of storm outlet.
Environmental	• Helps manage increased runoff volumes to wetlands. • Maintains hydrologic functions of streams and wetlands. • Protects downstream resources. • Mitigates increased runoff volumes resulting from proposed diversions. • Recharges groundwater. • Improves water quality. • Helps reduce potential erosion.

Category	Potential Benefit(s)
	• Reduces impacts to and promotes sustainability of ecological habitat. • Improves air quality. • Mitigates the heat island effect through increased vegetation which provides shading of impervious surfaces, deflects radiation from the sun, and releases moisture into the atmosphere.
Social	• Improves human well-being through increased green space, reduced noise levels, and enhanced aesthetics. • Increases road safety through traffic calming and aligns with objectives of creating 'Complete Streets' in urban areas https://www.completestreetsforcanada.ca/ • Boosts property values.

Source: Sustainable Technologies Evaluation Program; USEPA.

Of value are LIDs techniques that provide lot level controls as they retain rainfall where it falls (e.g., rain gardens/bioretention cells, green roofs, and water reuse; see Figure 3-1). Nevertheless, it is recognized that the use of infiltration techniques may not be suitable in certain instances, due to land use (e.g., gas stations), soil conditions (e.g., high water table) or area sensitivity (e.g., Vulnerable Areas as defined under the Clean Water Act, 2006 – municipal wellhead protection areas and water quality issue contributing area).

FIGURE 3-1: EXAMPLE OF LOT LEVEL CONTROL (BIOSWALE)



Source: Conservation Halton.

It is strongly recommended that the applicant consult with CH and the municipality to assess where and what LID techniques will be supported by all parties and if/how they may be credited in any SWM analysis.

There are many manuals available which can assist in informing the location and design of LID techniques. CH currently uses the Toronto and Region Conservation Authority (TRCA) and Credit Valley Conservation

(CVC) *Low Impact Development Stormwater Planning and Design Wiki Guide* (https://wiki.sustainabletechnologies.ca/wiki/Main_Page) to guide LID techniques technique.

Information to be provided within the SWM report includes a description of the design objectives (i.e., water quality, erosion and/or quantity control) and confirmation of site appropriateness such as land use and existing site conditions. Of note, the applicant should ensure that the LID technique design is supported by geotechnical and hydrogeological investigations following the TRCA/CVC guide. Calculations supporting the LID technique designs must also be provided by a qualified engineer.

3.2 Rooftop Storage

Flat building roofs, such as on commercial or industrial buildings, can be designed to store runoff and dampen/reduce the structure's peak flow rate. Where rooftop storage is proposed and permitted by the municipality, controls should be integrated with the building's design to prevent/discourage removal.

The type of control to be installed should be specified in the SWM report/brief with supporting manufacturer's design information provided in the appendix. Sizing calculations should be provided outlining the number and placement of the controls, release rate, ponding volume, and drawdown time. These must be for individual structures as well as for the entire roof. Clogging of the control structures (typically 50% blockage) should be considered in the design.

3.3 Parking Lot and Underground Storage

Sites can use aboveground/parking lot ponding or underground storage for the purpose of quantity control. Underground storage can consist of oversized pipes (super pipes), precast or cast-in-place concrete tanks, or individual pre-manufactured units.

The system should be designed to minimize the opportunities for controls to be removed and, where possible and allowed, the controls providing quantity control (i.e., orifice tube, maintenance hole, etc.) should be located such that it is partly on public lands.

Sizing calculations for any orifice/pipe restrictions should be provided. A stage-storage-discharge chart indicating all storm events is recommended and should contain elevations, equations used, coefficients of discharge, orifice and weir details, tailwater, surface area and resulting volume, and drawdown times.

If underground storage is proposed to provide Regulatory Storm control, it must be supported by the municipality and CH and must meet the requirements of Section 3.7.5. Sizing for the facility must take into consideration the potential for tailwater effects and storm stacking, as outlined in Sections 3.5.1 and 3.5.2.

The design drawings should provide details of these restrictions and their outlet. The maximum ponding extent, elevation, and storage volume should be provided at each ponding location and shown on a drawing.

3.4 Consideration of New Technologies

To foster innovation in stormwater management, new products and emerging technologies are encouraged. New technologies should be supported through background documentation, pilot studies, monitoring and adaptive management. Consult with municipalities and CH early in the design process to establish requirements for approval.

3.5 Stormwater Management Ponds

Stormwater management ponds (SWMPs) may be designed to provide water quantity, water quality, and erosion control. Depending on the requirements of the study area and the specific systems, as well as municipal design standards, SWMPs can be configured as a dry pond, wet pond, wetland, or hybrid wet pond/wetland. The majority of SWMPs are in municipal ownership.

Table 3-2 provides a summary of common SWMP design elements and areas of municipal and CH interest.

TABLE 3-2: SWMP DESIGN ELEMENTS and REVIEW INTERESTS

Design Element	CH (1)	Municipality
Stage-Storage-Discharge Curve & Supporting Calculations	✓	✓
Pond Grading	✓ (2)	✓
Outlet Control Structure	✓	✓
Outfall / Erosion Protection	✓ (2)	✓
Emergency Spillway	✓	✓
Freeboard	✓	✓
Geotechnical Considerations	✓	✓
Thermal Mitigation		✓
Landscaping	✓ (2)	✓

(1) CH reviews design elements and supporting calculations for water quantity and erosion controls only.
(2) CH reviews grading, landscaping and outfall details within regulated areas only. CH may review grading plans for pond berms outside of our regulated area if the facility provides Regulatory storm controls.

In general, all SWMPs must be supported by a design report and detailed drawings. Calculations supporting the stage-storage-discharge curve (i.e., elevations, equations used, coefficients of discharge, orifice and weir details, tailwater, surface area and resulting volume, storm events, drawdown times, etc.) should be provided. The figures/drawings must show the emergency spillway, erosion protection, pond outlet control structure details, the outfall and at least one cross-section through the facility. The amount of detail required for a SWMP design directly corresponds to the scope of work for the project/study.

3.5.1 Outlet Control Structure

The details of the outlet control structure should be provided within the SWM report as well as on an appropriate engineering drawing. The outlet control components should be designed in such a way that they cannot be readily removed or altered (see Figure 3-2).

FIGURE 3-2: EXAMPLE OF DESIRED OUTLET CONTROL COMPONENTS

Source: Conservation Halton.

The pond design should consider potential blockage of all low flow and grated outlet structures (typically 50%); however, if there is a potential for larger debris being transferred through the system, additional blockage considerations may need to be analyzed.

Analysis must be provided that demonstrates the facility is able to meet the required level of quantity control under both free-flowing conditions and under submerged outlet conditions (i.e., tailwater conditions) resulting from flooding within the receiving watercourse system. It should further be demonstrated that the facility operation provides sufficient capacity under both conditions (i.e., the emergency spillway at the facility outlet would not convey flows under either condition). Tailwater effects can be analyzed assuming Regulatory Storm flood elevations within the channel for the full range of storm events controlled within the SWMP. The analysis may alternatively assume a static tailwater condition at the outlet whereby the water surface elevation within the receiving watercourse corresponds to the return period of the design storm being assessed. Other analytical methods can be considered.

3.5.2 Emergency Spillway and Freeboard

The emergency overflow spillway for a SWMP should be designed to safely convey the greater of the uncontrolled 100-year peak or Regional Storm flow to the receiving system. If the required spillway size is considered infeasible due to local constraints, additional discussions with the municipality and CH will be required to determine the acceptable conveyance capacity of the emergency spillway, and any additional flood protection which may be required for properties adjacent to the facility during an overflow condition. A piped system may be considered/required for valleys with high and/or unstable slopes.

The proposed design should be supported with calculations demonstrating the full length of the flow path has been designed with adequate capacity including freeboard and erosion resistance along the entire flow path. Drawings must include details for the proposed spillway through plan, profile, and cross-sectional views.

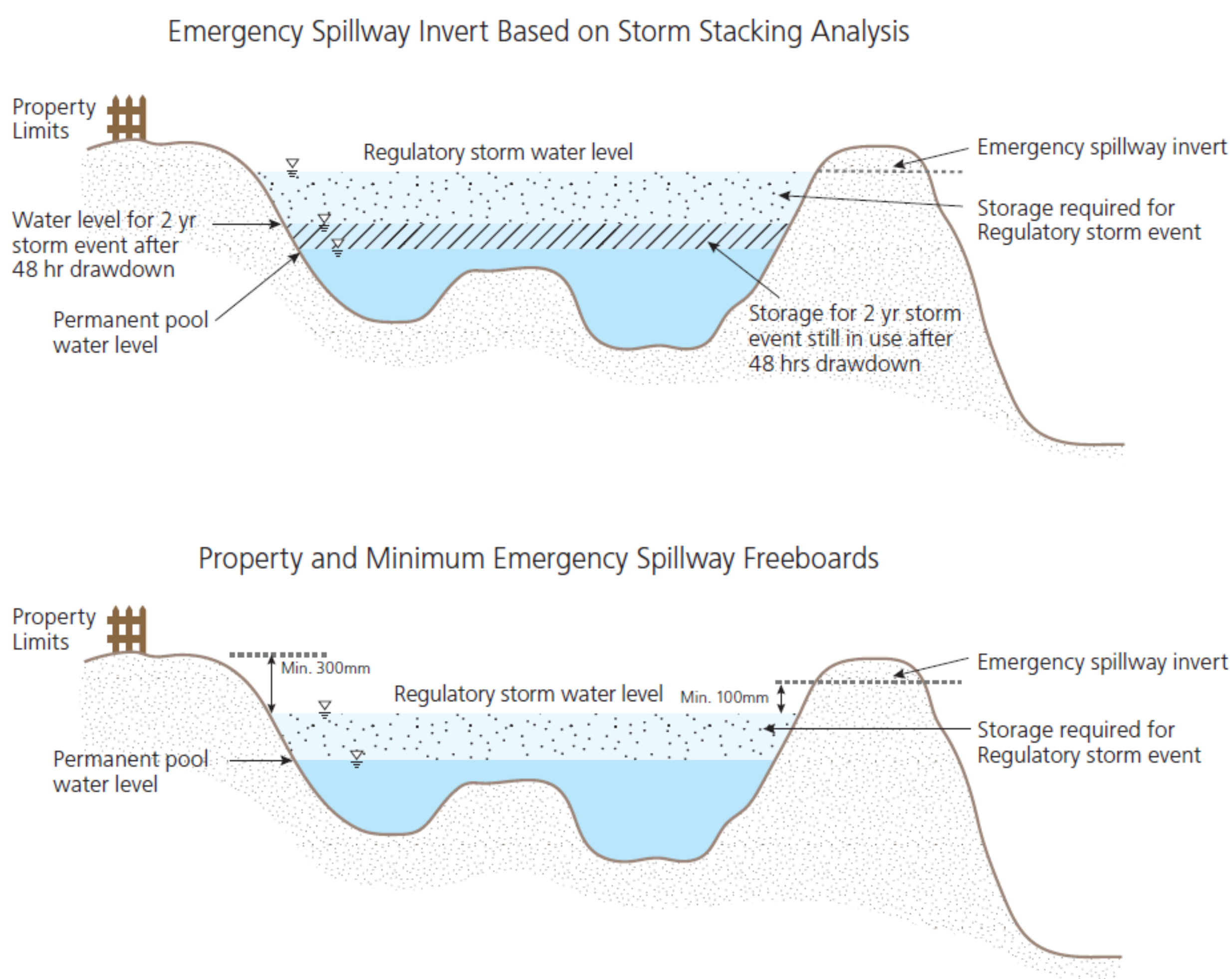
A minimum of 0.3 m of freeboard should be provided above the greater of the Regional Storm or 100-year designed operating water surface elevation in the pond to the edge/limit of the pond block. This requirement applies to all SWMP, including those not designed specifically for Regulatory Storm quantity control.

Where higher-level studies, such as the North Oakville Creeks Subwatershed Study or the Sixteen Mile Creek Areas 2 and 7 Subwatershed Update Study, credit Regulatory Storm Control facilities in land use planning and regulatory flood hazard mapping:

- Storage calculations for the Regulatory Storm should presume a 2-year design storm occurred 48 hours prior to the Regulatory Storm, with the emergency overflow invert elevation set above the resulting Regulatory Storm maximum water surface elevation; and,
- The emergency overflow invert elevation must also be a minimum of 100 mm above the normal Regulatory Storm water surface elevation (i.e., the water surface elevation calculated based on an assumption that all flood storage above the permanent pool was available prior to the Regulatory Storm occurring). CH recommends that this criterion apply to all SWM ponds.

Figure 3-3 provides a visual representation of the above.

FIGURE 3-3: FREEBOARD and EMERGENCY SPILLWAY PLACEMENT FOR REGULATORY STORM CONTROL PONDS



Source: Conservation Halton.

3.5.3 Geotechnical Considerations

A geotechnical report is required to support the SWMP design at the detailed design stage. For Regulatory Storm control facilities with berm heights more than 0.5 m (either on pond or valley sides) and/or berm top widths less than 7.5 m, the supporting geotechnical (i.e., slope stability) analysis should verify that the structure has been designed to withstand all static and dynamic forces and conditions (including groundwater) anticipated for all foreseeable conditions (e.g., during construction (undrained); permanent pool (drained); steady state full pond (undrained); and rapid drawdown (undrained)). This analysis should be based on a geotechnical site investigation considering an adequate number of representative boreholes and standpipe piezometers/monitoring wells. The need for seismic analysis is to be determined by the qualified professional based on standard industry practices and an understanding of the project's risks.

Construction notes for the SWMP berms, slopes and liners must be included on the engineering drawings (e.g., material composition, compaction percentage, moisture, lift thickness, etc.).

It is recommended that the excavated pond subgrade be inspected by qualified professionals to confirm geotechnical design recommendations and/or provide design refinements prior to pond completion.

3.5.4 Ownership of Regulatory Storm Control Ponds

For Regulatory Storm control ponds (and tanks) that have been identified by municipalities and CH in higher-level studies for downstream flow reductions in land use planning and regulatory flood hazard mapping, CH requires either public ownership of the facility or demonstration by the municipality that sufficient mechanisms are in place to ensure the proper operation and maintenance of a privately-owned facility.

3.6 Outfalls

Outfalls provide the discharge point for SWM facilities, typically to a receiving watercourse or drainage feature (e.g., storm sewer, ditch, etc.). All outfalls proposed within regulated areas will require a permit from CH under O. Reg. 162/06. Figure 3-4 provides examples of outfalls within regulated areas. An outfall permit checklist should be obtained through permit pre-consultation with CH staff.

CH discourages the construction of new outfalls within regulated areas unless required to support the flow regime of the natural heritage system and justified to CH's satisfaction in accordance with O. Reg. 162/06. However, greenfield development will typically require a new outfall to the natural system. Where permitted, storm outfalls should be sited and designed to minimize impacts to the regulated features, address valley slope stability, protect watercourse embankments and ensure no wetland interference as per CH Board-approved policies.

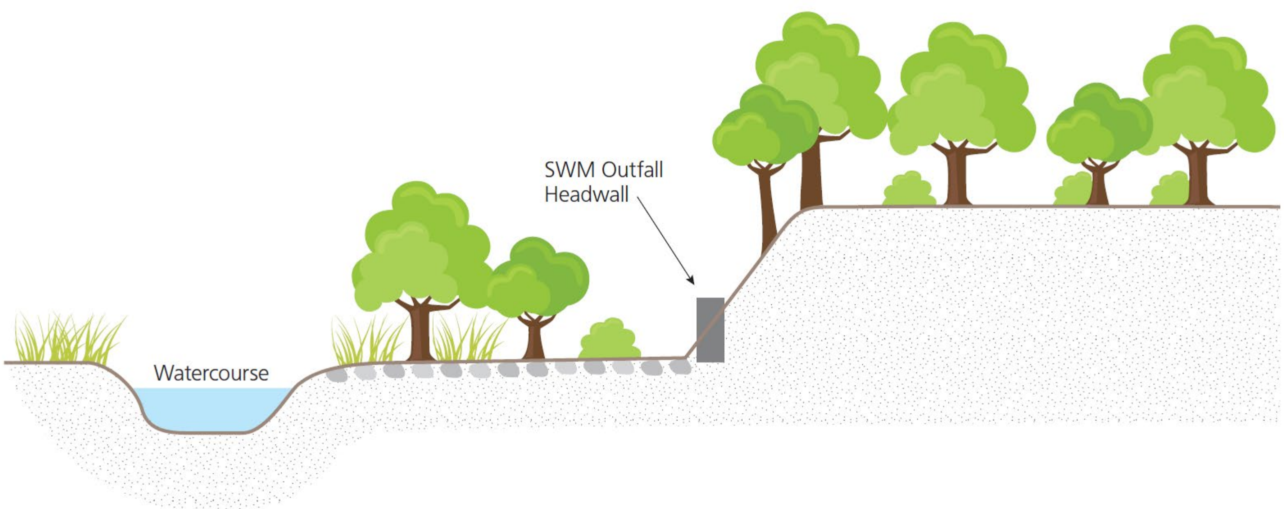
Where feasible, outfall entry points into a valley should generally be placed co-incident with the valley toe, minimally above the bankfull channel (i.e., above the 2-year flood elevation) and outside of the 100-year erosion limit (see Figure 3-5). The outfall (and where required any constructed conveyance channel) should be positioned such that flows are directed down current with the receiving watercourse. A site visit with CH staff and the designer is recommended to confirm any new outfall locations.

New storm sewer outfalls proposed within valley systems with slopes greater than 6 metres in height should be designed to protect the natural integrity of the valley slope (i.e., slope stability). This normally includes the use of a drop shaft and tunneling but other methods will be considered depending on site circumstances. The outfall may also be designed to accommodate emergency flows. Where the outfall construction impacts a valley slope (even when installed utilizing trenchless technologies), the outfall permit application must be supported with a geotechnical analysis demonstrating the outfall will not negatively impact stability of the existing slope. Refer to CH's *Slope Stability Assessment Submission Guidelines* for additional information in this regard.

FIGURE 3-4: EXAMPLES OF OUTLETS WITHIN CH REGULATED AREAS

Source: Conservation Halton.

FIGURE 3-5: DESIRED OUTFALL LOCATION



Source: Conservation Halton.

The outfall design must include calculations demonstrating adequate erosion protection under maximum discharge velocity conditions. All analysis supporting the design must be included within the submission.

Restoration plans should be included for any areas disturbed by the installation of the outfall or conveyance channel.

3.7 Landscaping

CH has specific requirements for planting within area regulated by CH which can be found in the *Guidelines for Landscaping and Rehabilitation Plans* (February 2024). CH has endorsed alternate landscaping criteria that should be used instead of CH's guidelines in select areas within the watershed. CH staff should be consulted in this regard.

3.8 Monitoring

Monitoring of the SWM practices implemented is key in ensuring that the desired criteria (e.g., quantity control, etc.) have been met by the SWM strategy and to provide insight for future designs. Monitoring protocols are set by each municipality, generally through higher-level studies, in consultation with CH as well as part of the MECP Environmental Certificate of Approval. Until the end of the monitoring period, CH requires monitoring reports to be provided within 3 months of the end of the reporting period (e.g., annual monitoring reports within 3 months of year-end). Additional monitoring of SWM works within a regulated area may be established through the permit approval process.

3.9 Summary – Stormwater Management Practices

Table 3.3 provides a summary of CH's recommendations related to SWM practices/infrastructure elements typically included in a SWM strategy for quantity and erosion controls. Additional practices for water quality controls, such as oil/grit separators and filtration units, may be required by the municipality.

TABLE 3-3: SUMMARY – SWM PRACTICES

SWM Practice	Key Information
Low Impact Development Techniques	• Use LID techniques where appropriate and feasible to do so. • Refer to the TRCA / CVC LID Stormwater Planning and Design wiki guide. • Consult with CH and municipality. • Describe design objectives, confirm site appropriateness, and provide design calculations.
Rooftop Storage	• Integrate controls with the building's design to prevent/discourage alteration or removal, where allowed by the municipality. • Include sizing calculations outlining number and placement of the controls, release rate, ponding volume, and drawdown time. • Include the type of control proposed and supporting manufacturer's design information.
Parking Lot and Underground Storage	• Design system to minimize opportunities to remove controls. • Include sizing calculations for all orifice/pipe restrictions (stage-storage-discharge chart). Design drawings showing locations of restrictions, outlets and maximum ponding elevations are needed.

SWM Practice	Key Information
Consideration of New Technologies	• CH is supportive of pilot projects and experimental approaches provided there is monitoring and adaptive management. • Final acceptance of these technologies will require consultation and approval of the municipality as well as CH.
SWM Ponds	• Include calculations supporting the design and detailed drawings (e.g., calculations supporting the stage-storage-discharge curve). • Show the emergency spillway, erosion protection, pond outlet control structure details, the outfall and at least one cross-section through the facility in figures/drawings. • Provide the level of detail for a SWM plan that directly corresponds to the scope of work for the project/study. • Include the specific requirements for control structure, emergency spillway, and geotechnical evaluation.
Outfalls	• Site and design outfalls to address valley slope stability, protect watercourse embankments and ensure no wetland interference. • Position, where feasible, the outfall such that it is co-incident with the valley toe, outside the 100-year erosion limit, and above the bankfull channel with flows directed downstream along the receiving watercourse. • Provide calculations demonstrating adequacy of erosion protection measures under maximum discharge velocity.
Landscaping	• For CH regulated areas, follow CH's *Guidelines for Landscaping and Rehabilitation Plans* (February 2024) and municipal guidelines.
Monitoring	• Follow the protocols outlined by a higher-level study, the municipality, and MECP or as established through the permit approval process. Submit monitoring reports within 3 months of the end of the monitoring period (including annual reports within 3 months of the year end).

Section 4 Hydrologic Modelling Requirements

This section discusses hydrologic modelling and associated hydraulic calculations. This section should be read in conjunction with the most up-to-date municipal requirements.

Hydrologic modelling is used to approximate the runoff response of a watershed to various climatic conditions under varying land use scenarios (e.g., pre-development, post-development, etc.). The results from hydrologic analyses are used to demonstrate the adequacy of a SWM strategy for erosion and quantity controls.

This section provides limited direction with respect to hydrologic analysis in support of regulatory flood hazard mapping. While it is encouraged that the same parameters be used to support both SWM and floodplain mapping assessments within the same study, different parameters may be required to meet the needs/circumstances of both assessments. Further information will be provided in CH's Guidelines for Floodplain Alterations and Mapping Submissions.

This section presents procedures, computational methods, and parameters that are commonly accepted industry standards supported by CH; however, it is the consulting engineer's responsibility to select an appropriate method and/or justify the parameters used. If the consulting engineer selects an alternative computational method or parameter, an explanation for its use should be provided. In these situations, consultation should be undertaken with CH and municipal staff.

4.1 Software and Documentation

Commonly available hydrologic modelling software should preferably be used. The use of open source (Public Domain) software is recommended. Use of specific software (or model) may be required by a higher-level study. Where appropriate, different models may be considered to achieve different objectives (e.g., subwatershed model, SWM pond design). Modelling should be completed using the most current version of the software unless otherwise requested or agreed upon. For sites less than 5 hectares in total area, a manual calculation method, such as the Rational Method, may be used.

All input parameters should be tabulated within the design report with their sources cited. All model input and output files shall be submitted to CH in digital format (pdf and executable). A model schematic should be provided to facilitate interpretation of the model input and output files. Documentation within the model is recommended. At a minimum, the model should provide the name of the modeller, company, date of the model, purpose of model run (e.g., existing, proposed uncontrolled, proposed controlled, etc.), and the source of topographic data. If there are many digital files, a README file or equivalent is required.

The technical submission should contain enough information such that a qualified professional can replicate the results of the submission. Submitted modelling, calculations, drawings, and reports should be stand-alone documents and contain all key information including documentation obtained from other approved reports that is necessary to support the analysis.

For large or complex areas, applicants should obtain municipal and CH's support of the existing/pre-development conditions models before advancing to post-development analyses.

4.2 Hydrologic Analysis Components

There are several key components that a hydrologic analysis should include as a minimum.

4.2.1 Catchment Delineation

Catchments should be delineated under both pre- and post-development surface drainage conditions. Key features such as ponds, railways, roads, culverts, undrained depressions, wetlands, etc., must be included. The discretization process should be based on field reconnaissance, topographic mapping, aerial photography, and site survey. The best level of topographic data available should be used. LIDAR/DTM data is recommended for watershed/subwatershed studies while total station site survey or equivalent is recommended for subdivision or site plan level modelling. There may be additional information available within approved reports such as watershed/subwatershed studies, EIR/SIS/MESPs, and Area Specific Plans.

Sources must be documented for all topographic and survey data used in the analysis. Reference information should include map title, author, publisher, scale, datum, publishing date and date flown or surveyor name and survey date.

Separate pre- and post-development (interim and ultimate conditions) catchment plans should be submitted in support of the modelling. Catchment plans should be consistent with the modelling completed. Catchment areas should be plotted over pre- or post-development contours and be labelled with catchment ID (consistent with modelling), catchment area, and % impervious/runoff coefficient. Flow direction arrows and the location(s) of outlets should also be shown. Post-development catchment area plans should include proposed land use conditions. A detailed digital (pdf) copy of the labelled catchment drainage area plan(s) should be included as part of the digital submission. A copy of the drainage area plan(s) suitable for insertion into CH's Geographic Information System should be submitted.

4.2.2 Rainfall Input

When assessing hydrology as part of a SWS or other higher-level study, a variety of rainfall distributions for Design Storms should be modelled, and justification provided for the temporal rainfall distribution(s) recommended for use in the study. For continuous modelling, actual historical rainfall records at the nearest available station should be used. A minimum record of 20 years is required.

The rainfall simulation (i.e., single event modelling with Design Storms or continuous modelling with flood frequency analysis) used in the higher-level planning studies should generally be used in subsequent studies (e.g., SWM report for a subdivision). Should an alternate rainfall method be selected, the rationale for the selection must be validated and justified. It is recommended a rainfall sensitivity analysis be undertaken to support this justification. For the sizing of SWMPs, the 24-hour Chicago design storm distribution should be considered with a suite of storm lengths and distributions in accordance with municipal guidelines to demonstrate peak flow control and calculate required storage volumes.

Rainfall amounts should be based on the Intensity-Duration-Frequency (IDF) curves for the precipitation station identified within the municipality's requirements. IDF information is provided in Appendix A1 through A6. Municipalities should be contacted to confirm the most current IDF data to use and determine if the modeler will need to consider specific historical storm events.

The Regional Storm (Hurricane Hazel) must also be modelled. CH preference is to model the last 12 hours of the Hurricane Hazel storm event assuming pre-saturated soils. However, the full 48-hour storm event could be used if the results are properly assessed (e.g., rainfall distribution and reasonable runoff volume). Depending on the size of the catchment area, areal reduction factors may be applicable. The Hurricane Hazel distribution and areal reduction factors are provided within Appendix A7.

The rainfall time step should be no larger than 1/5 (20%) of the smallest basin's approximate time to peak.

4.2.3 Hydrologic Parameters

Sources and rationale for the selection of all hydrologic parameter values should be provided, especially those factors affecting runoff generation (i.e., percentage impervious coverage, soil infiltration method and related parameters, etc.), and factors affecting hydrograph shape (i.e., flow length, Manning's Roughness Coefficients, etc.). All hydrologic parameters should be compared to the applicable higher-level planning study(s) or confirmed through consultation.

Values/approaches typically acceptable to CH are found in Appendix B1 through B12; however, while approaches and values are given, it is recognized that the values are not uniformly applicable. Typical values may need to be refined for several reasons (e.g., to represent watershed topography, software model, routing approach, event return period, model purpose, etc.). Model calibration and validation using local data, completed during the higher-level study to improve accuracy of the model results, may have adjusted parameters. References and justification should be provided for values selected.

<u>Imperviousness</u>

An accurate estimate of the percentage of imperviousness within catchments is very important as hydrologic models are generally sensitive to this parameter. This parameter will impact the proposed stormwater runoff volumes and consequently the land requirements and volume of the SWM facilities.

Impervious areas should be determined by sampling a representative area in each catchment for higher-level studies. For detailed level studies, they should be calculated by using the draft plan to calculate an overall imperviousness based on estimated maximum development envelopes and road configuration. Conservative assumptions for future amenity areas should be applied. Typical values for imperviousness are found in Appendix B1.

<u>Rainfall Abstractions</u>

Initial Abstraction (Ia) should be set for both the impervious and pervious areas within modelled catchments.

Three methods for determining infiltration have commonly been applied within CH's jurisdiction: 1) the Horton method, 2) the Soil Conservation Service (SCS) curve number method, and 3) the Green-Ampt method. To allow for a direct comparison of impacts between existing and future conditions, consistent infiltration approaches should be applied during both pre-development and post-development model scenarios. Typical values for rainfall abstractions are found in Appendix B2 through B6. Modelling for the 1:2 through 1:100-year storm events should consider average soil moisture; however, saturated conditions must be considered when modelling the Regional Storm event. For example, using the SCS method, AMC II should be used for 1:2 through 1:100 year and AMC III should be used for 12-hr Hurricane Hazel.

A thorough understanding of these methodologies is required to ensure their proper application within hydrologic modelling. This is especially important where the hydrologic modelling has not been validated against suitable monitoring data.

<u>Time of Concentration</u>

Hydrograph time of concentration values can be determined based on the Airport Method (for catchments with a runoff coefficient less than 0.40) or the Bransby-Williams Equation (for catchments with a runoff coefficient greater than or equal to 0.40). The equations and design charts for these methods are provided within Appendix B7 and B8. Other technically sound and well documented methods, such as the Uplands Method, are also acceptable as the standardized equations may not accurately represent site conditions or be consistent with municipal criteria.

The time to peak should be calculated as two-thirds of the time of concentration (or $t_p = 0.67\ t_c$).

The hydrograph computation time step (DT) should be no greater than 1/5 of the catchment time to peak (i.e., $DT = 0.2\ t_p$) but not less than the rainfall time step.

<u>Overland Flow Length & Catchment Widths</u>

Various hydrologic software requires that overland flow length and/or catchment widths be provided as an input parameter for each subcatchment. Overland flow length for pervious areas in an un-calibrated watershed can generally be estimated using the equation available in Appendix B9. Other approaches can be used where justified to CH staff satisfaction.

4.2.4 Channel Routing

Channel routing elements should be considered in the hydrologic model as determined by site conditions. Channel routing is most applicable to large-scale watershed and subwatershed hydrologic modelling. Rating curves and travel times used in the routing should be determined by hydraulic calculations of the backwater profile or by procedures available in the approved model software (e.g., Modified Pulse, Muskingum method, etc.). Alternatively, a stage-storage relationship can be generated using HEC-RAS. The routing methodology applied and technical justification for the associated routing parameters should be included in the report text of the submission.

Cross-section information used to define channel routing elements should be obtained from sufficiently detailed DTM data or field surveys. Cross-sections should be extended such that flows do not exceed the rating curve; however, cross-sections should not be substantially larger than the wetted width associated with the largest modelled storm.

The routing time step must be determined relative to the smallest channel section and be equal to the hydrograph time step at a maximum. Selected Manning's Roughness Coefficients for overland flow should be in accordance with the values in Appendix B10 and supported in the submission documentation.

4.2.5 Reservoir Routing

Many hydrologic modelling packages include several reservoir/storage routing tools, including modelling for natural storage areas and SWMP. When modelling natural features such as wetlands, reservoir routing commands are typically applied over the full range of storms, up to the Regional Storm. Routing/storage elements associated with SWMPs are generally applied only when modelling the 1:2 year through 1:100-year events. These however may be applied when modelling the Regional Storm, if the pond has been designed specifically to provide Regional Storm controls and meets all CH, municipal and provincial criteria for such a pond (see Section 3.6).

Where routing has been used, documentation should be provided discussing the routing used, the source data for the routing element, and any assumptions made when determining the routing of flows, especially for natural storage areas.

Outlet orifice and emergency spillway details should be provided along with a stage-storage-discharge table. The table should include the following for each storm event: maximum water surface elevation; maximum storage volume used; peak discharge rates; and approximate drawdown time.

Discharge equations should be used for free-flowing hydraulic structures such as orifices, weirs and spillways and are provided in Appendix B11. When calculating orifice discharge in an outlet structure, the orifice equation should only be applied for water levels above the centroid of the orifice. Flow rates for water levels below the orifice centroid should be calculated using the weir equation. Typical discharge coefficients are provided in Appendix B11.

4.3 Rational Method

The Rational Method can be used for developments which are less than 5 hectares in total area and consideration for the effects of detention/SWM are not required (the methodology is limited in this regard). The rainfall intensity should be based on the IDF curves and time of concentration identified within the municipality's SWM standards/guidelines. The municipality should be contacted to confirm the most current IDF data to use. The Rational Method equation and runoff coefficients are provided in Appendix B12.

4.4 Summary – Hydrologic Modelling Requirements

Table 4.1 provides a summary of the requirements for hydrologic modelling undertaken to support the SWM strategy proposed.

TABLE 4-1: SUMMARY – HYDROLOGIC MODELLING REQUIREMENTS

Modelling Component	Key Information
Software & Documentation	• Use software (or model) required by a higher-level study or use a commonly available modelling software in the absence of higher-level study requirements. • Tabulate all input parameters within the design report with their sources cited. • Submit all model input and output files in both digital and hard copy formats. • Include summary tables demonstrating that targets will be met. • Provide a model schematic to facilitate interpretation of the model input and output files. • Obtain municipal and CH approval of pre-development condition models before submitting post-development analyses for large or complex areas.
Hydrologic Analysis Components	• Delineate catchments under both pre- and post- development conditions. • Include base topographic mapping, flow direction arrows, the location(s) of outlets and key features in the catchment depictions. • Use the rainfall distribution included in higher-level planning studies. • Base rainfall amounts on municipal IDF curves. • Model the Regional Storm. • Provide sources and rationale for the selection of all hydrologic parameter values and compare them to the applicable higher-level planning studies or confirm them through pre-consultation with the municipality and CH. • Include channel routing in the hydrologic model as determined by site conditions and include the routing methodology applied and technical justification for the associated routing parameters. • Provide documentation where routing has been used, including the assumptions, especially for natural storage areas.
Rational Method	• The Rational Method may be acceptable for developments less than 5 hectares in area. • Base the rainfall intensity on the IDF curves and time of concentration identified within the municipality's SWM standards/guidelines.

Section 5 Submission Document Requirements

This section outlines the information needed to satisfy CH with respect to SWM for specific *Planning Act* applications. The items listed below do not replace municipal or provincial requirements. While the following components and format are suggested for inclusion, the report may follow a different format, or a component may be presented in a separate report and referenced in the subject report. Additional details are provided within Sections 2.0 to 4.0 of this document.

CH Permit Application Checklists should be used for submission requirements for infrastructure and grading works proposed within an area regulated under O. Reg. 162/06.

5.1 Functional Servicing Report (OPAs, ZBAs, Draft Plan of Subdivision/Condominium)

A Functional Servicing Report (FSR) will be required to support the issuance of conditions for Subdivision Draft Plan Approval as well as to support approval of Official Plan and Zoning By-law Amendments. The FSR may be combined with an EIR. The purposes of these reports are to show, at a conceptual level, the following:

- Location/design criteria for SWM infrastructure and LID techniques;
- SWM blocks are sufficiently sized to address the required level of control;
- SWM facilities drain to appropriate outlets; and
- Development lots/blocks do not encroach into natural hazards and regulated areas in accordance with CH policies.

While other information such as water and sanitary servicing are contained within an FSR, the components listed in Table 5.1 are related to CH's review for SWM. Additional components such as storm water quality controls and site water balances may also be required by the municipality.

TABLE 5-1: FUNCTIONAL SERVICING REPORT (OPAS, ZBAS, DRAFT PLAN OF SUBDIVISION/CONDOMINIUM)

<table>
<tr><th>Item Number</th><th>Components</th></tr>
<tr><td>1</td><td>Project Description

This section of the FSR should include a description of the development that is proposed for the site.</td></tr>
<tr><td>2</td><td>Referenced Drainage Studies/Background Reports

This section of the FSR should outline all background reports relevant to the development, including but not limited to:

• Approved Watershed, Subwatershed Studies
• Approved Subwatershed Impact Study/Environmental Implementation Report/Master Environmental Servicing Plan
• Approved SWM reports for same site and nearby developments (for peak flow analysis)</td></tr>
<tr><td>3</td><td>List of Design Criteria (refer to Section 2.0 for details)

This section of the FSR should list the design criteria for the development, including but not limited to:

• Erosion control
• Water quantity control
• Wetland water balance *
• Other municipal criteria</td></tr>
<tr><td>4</td><td>Site Conditions

This section should provide a description of existing and proposed site conditions, including but not limited to:

• Identified limits of development
• Hazard & Wetlands constraints mapping
    ○ Topographic details
    ○ Meander belt allowance for unconfined[1] systems – fluvial geomorphic study
    ○ Slope stability allowance for confined[1] systems – geotechnical engineering study or conservative stable slope assessment based on acceptable principles
    ○ Floodplain delineation/refinement
    ○ Areas of unstable bedrock or soils
    ○ Wetlands
    ○ Adjacent regulated allowances
• Preliminary grading plans</td></tr>
</table>

Item Number	Components

5	**Site Hydrology and Hydraulics (Pre- and Post-Development) (refer to Section 4.0 for details)**
	
	This section should characterize site hydrology and hydraulics under both pre- and post-development conditions and should include the following:
	
	• Topographic maps showing the following for pre-development and post-development (interim and ultimate) conditions:
	  o Sub-basin boundaries
	  o External contributing drainage areas
	  o Development drainage area
	  o Preliminary major and minor drainage patterns
	  o Land use
	  o Watercourses and drainage features
	  o Points of discharge from the site
	  o Existing on and off-site drainage facilities, including overland swales
	• Input parameters (hydrologic analysis) in tabular format
	• Output summary (hydrologic analysis) in tabular format
	• Hydrologic calculations (Appendix)
	• Detailed hardcopy of any modelling as well as digital copy (Appendix)

6	**Stormwater Management Strategy (refer to Section 3.0 for details)** The section of the FSR should outline the functional stormwater management strategy for the site, including but not limited to: • Proposed technologies • Justification for choice of proposed technologies • Summary table(s) demonstrating that erosion and quantity design criteria will be met • Preliminary calculations (Appendix) • Preliminary design plans in accordance with municipal requirements
7	**Hydrogeology (For development in CH regulated area that may impact the hydrologic function of wetlands)** This section should characterize the site's hydrogeologic conditions within the regulated area and identify any requirements and constraints. • Refer to CH's Guidelines for Wetland Water Balance Assessments (forthcoming) • Detailed water balance including identification of any mitigation measures and locations • Confirmation that preliminary LID technique & SWMP designs are appropriate for existing groundwater, soil and bedrock conditions (e.g., depth to seasonally high-water table; depth to bedrock; disruption of shallow groundwater flow to areas of groundwater discharge, etc.) and the requirement for any specific mitigation measures

Item Number	Components
8	**Wetland Water Balance *** This section of the FSR should provide water balance requirements and the proposed strategy for specified wetlands. • Preliminary water balance to specific wetlands (evaluating impacts of changes to hydrologic functions including flow rate, volume, timing, duration, etc.) • Identification of mitigation measures and potential locations
9	**Baseline Monitoring Program (if applicable)** This section should outline the final detailed baseline monitoring program, including but not limited to: • Reference applicable higher-level planning studies • Outline detailed baseline monitoring required prior to any Site Alteration, if applicable • Identify monitoring plan components to be finalized during detail design
10	**Future Study Requirements** This section of the FSR should outline any commitments for detailed design.
11	**Summary and Conclusions**

Notes:

- All reports and engineering plans must be signed, stamped and dated by a Professional Engineer, except for any fluvial geomorphological reports which should be signed, stamped and dated by a Professional Geoscientist.

- Contact CH for current digital drawing submission requirements.

* Pre-consultation with CH before design is strongly recommended

[1] Confined systems mean those systems where the watercourse is contained within valleys greater than or equal to 2 metres in height. Unconfined systems mean those systems where the watercourse is contained within valleys less than 2 metres in height.

5.2 SWM Design Report (Subdivision Detailed Design)

The purpose of this report is to provide detailed calculations, methodology, background criteria, and engineering drawings to support the detailed subdivision design. Typically, the report is an expansion of the earlier FSR. This is required to obtain clearance of draft plan conditions to support Registration of a Plan of Subdivision. This information is also required for permit issuance, where applicable. The same report and relevant drawings should be provided through both approval processes. Additional components such as water quality controls and site water balances may be required by the municipality.

TABLE 5-2: SWM DESIGN REPORT (SUBDIVISION DETAILED DESIGN)

Item Number	Components
1	**Project Description** This section of the SWM Design Report should include a description of the development that is proposed for the site.
2	**Referenced Drainage Studies/Background Reports** This section of the SWM Design Report should outline all background reports relevant to the development, including but not limited to: • Approved Watershed, Subwatershed Studies • Approved Subwatershed Impact Study/Environmental Implementation Report/Master Environmental Servicing Plan • Functional Servicing Report. • Approved SWM reports for same site and near by developments (for peak flow analysis)
3	**List of Design Criteria (refer to Section 2.0 for details)** This section of the SWM Design Report should list the design criteria for the development, including but not limited to: • Erosion control • Water quantity control • Wetland Water balance * • Other municipal criteria

Item Number	Components

4	**Site Conditions**
	
	This section should provide a description of existing and proposed site conditions, including but not limited to:
	• Identified limits of development
	• Hazard constraints mapping
	    o Topographic details
	    o Meander belt allowance for unconfined systems[1] – fluvial geomorphic study
	    o Slope stability allowance for confined systems[1] – geotechnical engineering study or conservative stable slope assessment based on acceptable principles
	    o Floodplain delineation/refinement
	    o Adjacent regulated allowances
	• Detailed grading plans

5	**Site Hydrology and Hydraulics (Pre- and Post-Development) (refer to Section 4.0 for details)**
	
	This section should characterize site hydrology and hydraulics under both pre- and post-development conditions and should include the following:
	• Topographic map showing the following for pre-development and post-development (interim and ultimate) conditions:
	    o Sub-basin boundaries
	    o External contributing drainage areas
	    o Development drainage area
	    o Major and minor drainage patterns
	    o Land use
	    o Watercourses and drainage features
	    o Points of discharge from the site
	    o Existing on and off-site drainage facilities, including overland swales
	• Input parameters (hydrologic analysis) in tabular format
	• Output summary (hydrologic analysis) in tabular format
	• Detailed hydrologic calculations (Appendix)
	• Detailed hardcopy of any modelling as well as digital copy (Appendix)

6	**Stormwater Management Strategy (refer to Section 3.0 for details)** The section of the SWM Design Report should outline the detailed stormwater management strategy for the site, including but not limited to: • Proposed technologies • Justification of proposed technologies • Summary table(s) demonstrating that erosion and quantity design criteria will be met • Detailed calculations (Appendix) • Detailed design plans in accordance with municipal requirements sufficient for construction

Item Number	Components
7	**Hydrogeology (for development in CH regulated areas that may impact the hydrologic function of wetlands)** This section should characterize the site's hydrogeologic conditions within the regulated area and identify any requirements and constraints. • Refer to CH's Guidelines for Wetland Water Balance Assessments (forthcoming) • Detailed design of any infiltration facilities required to maintain pre-development water balance • Confirmation that SWM and infiltration facilities are designed appropriately for hydrogeological conditions (e.g., soil types and depth to seasonally high-water table)
8	**Wetland Water Balance** * This section of the SWM Design Report should provide water balance requirements and the proposed strategy for specified wetlands. • Detailed water balance to specific wetland (evaluating impacts of changes to flow rate, volume, timing, duration, etc.) • Identification of mitigation measures and locations
9	**Erosion and Sediment Control Plans** The proposed erosion and sediment control measures to be used on-site should be outlined in this section and supported with drawings. • *Erosion and Sediment Control Guide for Urban Construction (TRCA 2019)* • *Erosion and Sediment Control Inspection Guide (TRCA, 2008)*
10	**Revegetation/Landscape Plans** While not a section of the report, landscape drawings will need to be provided with the document. • Refer to Conservation Halton's *Guidelines for Landscaping and Rehabilitation Plans (July 2021).* • Refer to any specific municipal restoration guidelines.
11	**Monitoring Plan** This section should outline the proposed monitoring program, if required, including but not limited to: • Provide detailed information on items to be monitored and the process to be followed or reference relevant documents • Location plans for all monitoring sites

Item Number	Components
12	**Summary and Conclusions**

Notes:

- All reports and engineering plans must be signed, stamped and dated by a Professional Engineer, except for any fluvial geomorphological reports which should be signed, stamped and dated by a Professional Geoscientist.

- Contact CH for current digital drawing submission requirements.

* Pre-consultation with CH before design is strongly recommended

[1] Confined systems mean those systems where the watercourse is contained within valleys greater than or equal to 2 metres in height. Unconfined systems mean those systems where the watercourse is contained within valleys less than 2 metres in height.

5.3 SWM Brief (Site Plan)

The purpose of this submission is to obtain approval for individual site plans. The type of report(s) and level of detail will be dependent on the complexity of the project. This information is also required for permit issuance, where applicable. The same report and relevant drawings should be provided through both approval processes. Additional components such as water quality controls and site water balances may be required by the municipality.

TABLE 5-3: SWM BRIEF (SITE PLAN)

Item Number	Components
1	**Project Description** This section of the SWM Brief should include a description of the development that is proposed for the site.
2	**Referenced Drainage Studies/Background Reports** This section of the SWM Brief should outline all background reports relevant to the development, including but not limited to: • Approved Watershed, Subwatershed Studies • Approved Subwatershed Impact Study/Environmental Implementation Report/Master Environmental Servicing Plan • Approved SWM reports for same site and nearby developments (for peak flow analysis)

Item Number	Components
3	**List of Design Criteria (refer to Section 2.0 for details)** This section of the SWM Brief should list the design criteria for the development, including but not limited to: • Erosion control • Water quantity control • Wetland Water balance * • Other municipal criteria

4	**Site Conditions**
	This section should provide a description of existing and proposed site conditions, including but not limited to:
	• Identified limits of development
	• Hazard constraints mapping
	    o Topographic details
	    o Meander belt allowance for unconfined systems[1] – fluvial geomorphic study
	    o Slope stability allowance for confined systems[1] – geotechnical engineering study
	    o Floodplain delineation/refinement
	    o Adjacent regulated allowances
	• Detailed grading plans

5	**Site Hydrology and Hydraulics (Pre- and Post-Development) (refer to Section 4.0 for details)**
	This section should characterize site hydrology and hydraulics under both pre- and post-development conditions and should include the following:
	• Topographic map showing the following for pre-development and post-development (interim and ultimate) conditions:
	    o Sub-basin boundaries
	    o External contributing drainage areas
	    o Development drainage area
	    o Major and minor drainage patterns
	    o Land use
	    o Watercourses and drainage features
	    o Points of discharge from the site
	    o Existing on and off-site drainage facilities, including overland swales
	• Input parameters (hydrologic analysis) in tabular format
	• Output summary (hydrologic analysis) in tabular format
	• Detailed hydrologic calculations including Rational method modelling (Appendix)

Item Number	Components
6	**Stormwater Management Strategy (refer to Section 3.0 for details)** The section of the /SWM Brief should outline the stormwater management strategy for the site, including but not limited to: • Proposed technologies • Justification for choice of proposed methods • Summary table(s) demonstrating that erosion and quantity design criteria will be met • Detailed calculations (Appendix) • Detailed design plans in accordance with municipal requirements sufficient for construction
7	**Hydrogeology (for development in CH regulated areas that may impact the hydrologic function of wetlands)** This section should characterize the site's hydrogeologic conditions within the regulated area and identify any requirements and constraints. • Refer to CH's Guidelines for Wetland Water Balance Assessments (forthcoming) • Detailed design of any infiltration facilities required to maintain pre-development water balance • Confirmation that SWM and infiltration facilities are designed appropriately for hydrogeological conditions (e.g., soil types and depth to water table)
8	**Wetland Water Balance *** This section of the SWM Design Report should provide water balance requirements and the proposed strategy for specified wetlands. • Detailed water balance to specific wetland (evaluating impacts of changes to flow rate, volume, timing, duration, etc.) • Identification of mitigation measures and locations
9	**Erosion and Sediment Control Plans** The proposed erosion and sediment control measures to be used onsite should be outlined in this section and supported with drawings. • *Erosion and Sediment Control Guide for Urban Construction (TRCA 2019)* • *Erosion and Sediment Control Inspection Guide (TRCA, 2008)*
10	**Revegetation/Landscape Plans** While not a section of the report, landscape drawings will need to be provided with the document. • Refer to Conservation Halton's *Guidelines for Landscaping and Rehabilitation Plans (July 2021).* • Refer to any specific municipal guidelines.

Item Number	Components
11	**Monitoring Plan** This section, if required, should outline the proposed monitoring program, including but not limited to: • Provide detailed information on items to be monitored and the process to be followed or reference relevant documents
12	**Summary and Conclusions**

Notes:

- All reports and engineering plans must be signed, stamped and dated by a Professional Engineer, except for any fluvial geomorphological reports which should be signed, stamped and dated by a Professional Geoscientist.

- Contact CH for current digital drawing submission requirements.

* Pre-consultation with CH before design is strongly recommended

[1] Confined systems mean those systems where the watercourse is contained within valleys greater than or equal to 2 metres in height. Unconfined systems mean those systems where the watercourse is contained within valleys less than 2 metres in height.

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Appendix A Rainfall Data

Provided below are available rainfall data for municipalities within Conservation Halton's watershed taken from their municipal engineering standards; however, **consult with the municipality to confirm the current information.**

A1 City of Burlington

Source: *City of Burlington Stormwater Management Design Guidelines*, City of Burlington, 2020).

IDF curves derived from 54 years of historical rainfall data from the RBG meteorological station with a +15% climate change adjustment.

TABLE A-1: CITY OF BURLINGTON, 2100 PROJECTED RAINFALL INTENSITIES

5-year Event					
	Existing	Historic*	RCP 2.6	RCP 4.5	RCP 8.5
	88.09	88.2	95.01	97.20	102.37
% Increase compared to Existing	N/A	0.12	7.85	10.34	16.21
	141.89	141.11	151.92	153.82	163.11
% Increase compared to Existing	N/A	-0.88	10.56	8.4	14.85

FIGURE A-1: CITY OF BURLINGTON, INTENSITY-DURATION-FREQUENCY CURVES

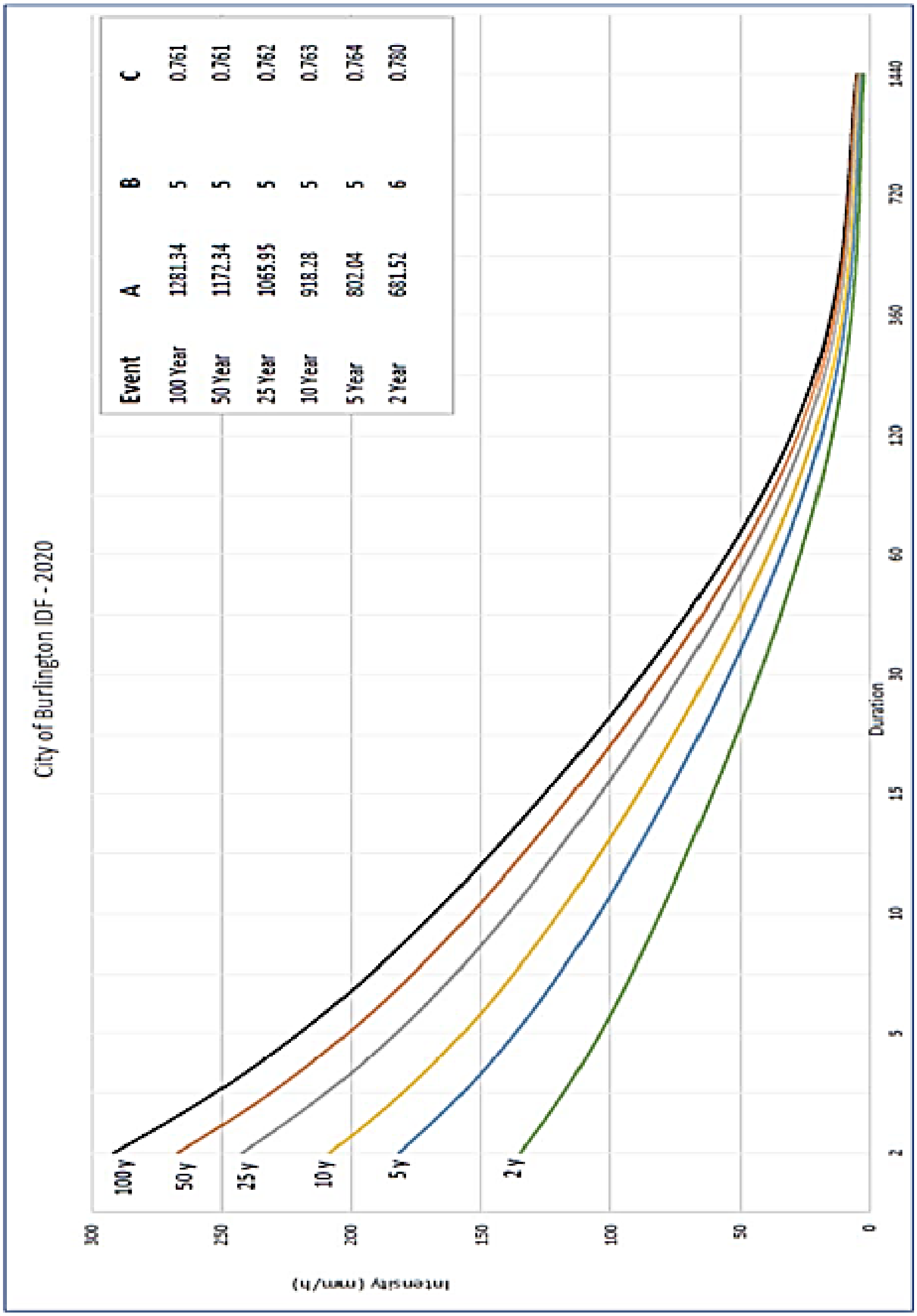


TABLE A-2: CITY OF BURLINGTON, RAINFALL INTENSITY EQUATION COEFFICIENTS

	A	b	c
2	681.52	6.0	0.780
5	802.04	5.0	0.764
10	918.28	5.0	0.763
25	1065.95	5.0	0.762
50	1172.34	5.0	0.761
100	1281.34	5.0	0.761

$$i = \frac{A}{(t_d + b)^c}$$

Where: i = Rainfall intensity (mm/hr)
t_d = Duration (hr)
A, b and c = constants

A2 Town of Halton Hills

Source: Town of Halton Hills, *Town of Halton Hills Subdivision Manual,* 1999.

TABLE A-3: TOWN OF HALTON HILLS, INTENSITY-DURATION-FREQUENCY VALUES

Compilation of AES Hydrometeorological Division data for Toronto International Airport, Fergus Shand Dam and Heart Lake (weighted by total years of record)

Duration min	2 Year mm/hr (mm)*	5 Year mm/hr (mm)*	10 Year mm/hr (mm)*	25 Year mm/hr (mm)*	50 Year mm/hr (mm)*	100 Year mm/hr (mm)*
5	104.64 (8.72)	135.36 (11.28)	155.64 (12.97)	181.44 (15.12)	200.40 (16.70)	219.36 (18.28)
10	73.08 (12.18)	94.68 (15.78)	109.02 (18.17)	127.08 (21.18)	140.46 (23.41)	153.78 (25.63)
15	61.60 (15.40)	82.88 (20.72)	97.04 (24.26)	114.84 (28.71)	128.08 (32.02)	141.24 (35.31)
30	41.22 (20.61)	56.96 (28.48)	67.40 (33.70)	80.58 (40.29)	90.32 (45.16)	100.06 (50.03)
60	24.23 (24.23)	35.32 (35.32)	42.68 (42.68)	51.97 (51.97)	58.85 (58.85)	65.69 (65.69)
120	14.73 (29.45)	21.23 (42.45)	25.54 (51.07)	30.98 (61.97)	35.01 (70.01)	39.02 (78.03)
360	6.51 (39.05)	9.11 (54.63)	10.83 (64.96)	13.00 (78.00)	14.61 (87.67)	16.22 (97.29)
720	3.76 (45.16)	5.21 (62.49)	6.17 (73.98)	7.37 (88.49)	8.27 (99.25)	9.16 (109.95)
1440	2.44 (58.49)	3.01 (72.21)	3.56 (85.50)	4.26 (102.26)	4.78 (114.69)	5.29 (127.05)

* The bracketed value is the total precipitation over the time interval

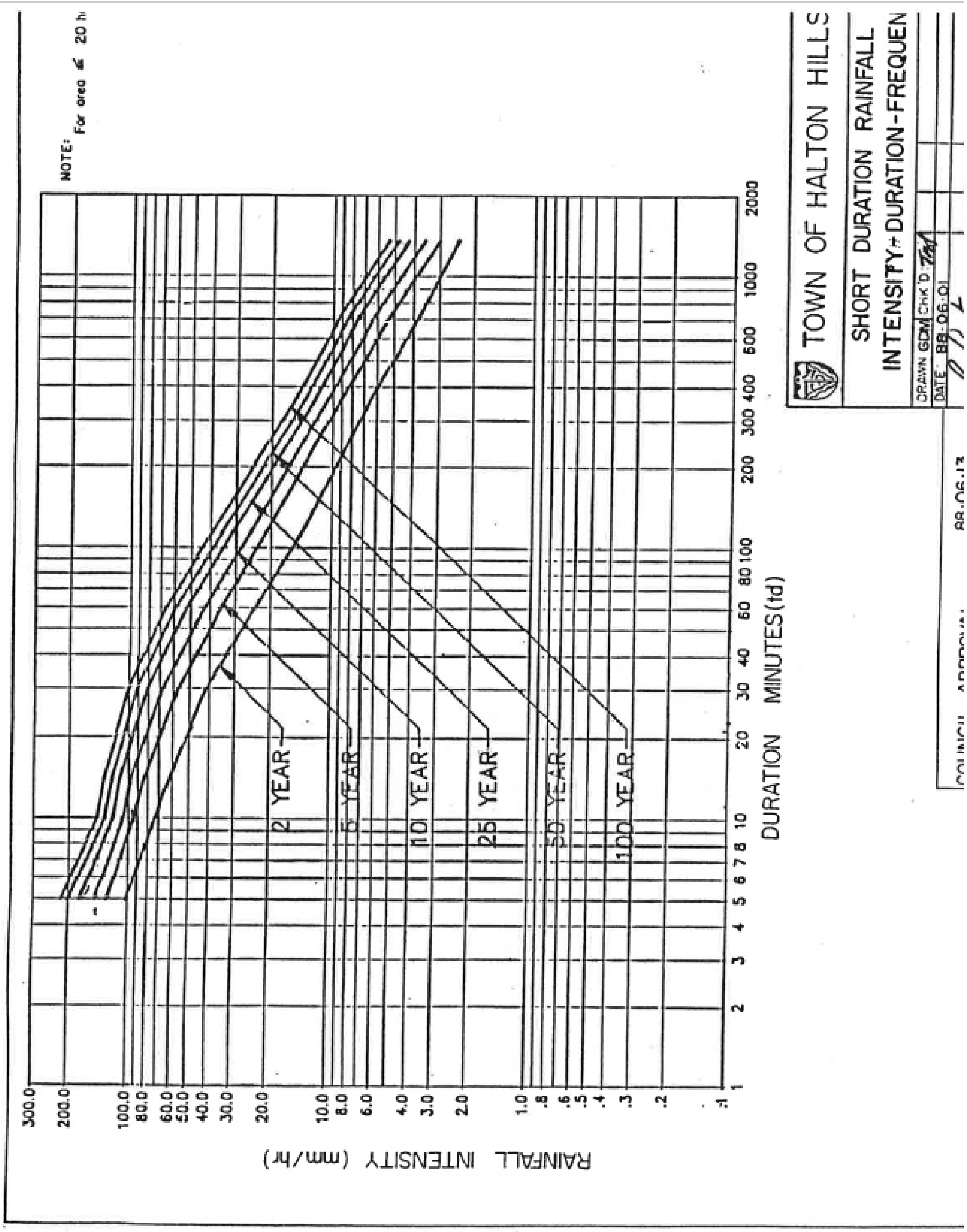
TABLE A-4: TOWN OF HALTON HILLS, RAINFALL INTENSITY EQUATION COEFFICIENTS

	A	b	c
2	586.10	6.0	0.760
5	946.46	7.0	0.788
10	1173.48	8.0	0.794
25	1363.91	8.0	0.789
50	1622.45	9.0	0.797
100	1777.20	9.0	0.795

$$i = \frac{A}{(t_d + b)^c}$$

Where: i = Rainfall intensity (mm/hr)
t_d = Duration (hr)
A, b and c = constants

FIGURE A-2: TOWN OF HALTON HILLS, SHORT DURATION INTENSITY-DURATION-FREQUENCY CURVES



A3 City of Hamilton

Source: City of Hamilton, *Comprehensive Guidelines and Financial Policies Manual,* 2018.

TABLE A-5: CITY OF HAMILTON, INTENSITY-DURATION-FREQUENCY VALUES, MOUNT HOPE

Duration min	2 Year mm/hr	5 Year mm/hr	10 Year mm/hr	25 Year mm/hr	50 Year mm/hr	100 Year mm/hr
5	102.7	140.1	165.0	196.3	219.6	242.4
10	72.1	100.4	119.1	142.8	160.4	177.8
15	58.4	81.2	96.3	115.4	129.5	143.6
30	39.5	55.2	65.6	78.6	88.3	97.9
60	24.7	36.2	43.8	53.4	60.6	67.7
120	15.0	22.2	26.9	33.0	37.4	41.9
360	6.6	9.4	11.3	13.6	15.3	17.0
720	3.7	5.2	6.2	7.5	8.4	9.3
1440	2.2	3.0	3.5	4.2	4.6	5.1

TABLE A-6: CITY OF HAMILTON, RAINFALL INTENSITY EQUATION COEFFICIENTS, MOUNT HOPE

	A	b	c
2	646.0	6.0	0.781
5	1049.5	8.0	0.803
10	1343.7	9.0	0.814
25	1719.5	10.0	0.823
50	1954.8	10.0	0.826
100	2317.4	11.0	0.836

$$i = \frac{A}{(t_d + b)^c}$$

Where: i = Rainfall intensity (mm/hr)
t_d = Duration (hr)
A, b and c = constants

TABLE A-7: CITY OF HAMILTON, INTENSITY-DURATION-FREQUENCY VALUES, ROYAL BOTANICAL GARDENS

Duration min	2 Year mm/hr	5 Year mm/hr	10 Year mm/hr	25 Year mm/hr	50 Year mm/hr	100 Year mm/hr
5	94.6	122.2	140.6	163.7	180.9	198.0
10	68.3	89.2	100.2	120.8	133.8	146.7
15	55.7	74.3	86.7	102.2	113.8	125.2
30	36.2	47.2	54.5	63.7	70.5	77.3
60	22.1	27.6	31.2	35.7	39.1	42.5
120	14.3	18.6	21.4	25.0	27.7	30.4
360	6.0	8.5	10.2	12.3	13.9	15.4
720	3.5	4.9	5.8	7.0	7.8	8.6
1440	2.1	2.8	3.3	3.8	4.3	4.7

TABLE A-8: CITY OF HAMILTON, RAINFALL INTENSITY EQUATION COEFFICIENTS, ROYAL BOTANICAL GARDENS

	A	b	c
2	595.5	6.0	0.778
5	688.2	5.0	0.753
10	748.0	4.5	0.740
25	867.0	4.5	0.737
50	947.3	4.5	0.733
100	1036.1	4.5	0.733

* Please note the following: The City of Hamilton has adopted the Mount Hope IDF relationship. The Royal Botanical Gardens IDF relationship has been provided in addition to the Mount Hope IDF relationship for the purpose of Watershed and Subwatershed Studies and Master Drainage Plans.

TABLE A-9: CITY OF HAMILTON, 3-HOUR CHICAGO DISTRIBUTION DESIGN STORM HYETOGRAPHS, MOUNT HOPE

Time Step min	Rainfall Intensity mm/hr					
	2 Year	5 Year	10 Year	25 Year	50 Year	100 Year
10	2.85	3.90	4.57	5.46	6.03	6.61
20	3.20	4.41	5.20	6.23	6.89	7.57
30	3.67	5.10	6.04	7.76	8.04	8.89
40	4.32	6.07	7.23	8.74	9.69	10.77
50	5.29	7.55	9.06	11.02	12.24	13.70
60	6.93	10.08	12.20	14.96	16.65	18.78
70	10.32	15.37	18.80	23.26	25.95	29.53
80	21.58	32.79	40.38	50.04	56.09	63.97
90	73.99	103.04	122.29	146.10	164.61	181.81
100	22.24	33.80	41.62	51.58	57.82	65.94
110	10.92	16.31	19.98	24.74	27.61	31.44
120	7.38	10.77	13.06	16.04	17.86	20.17
130	5.64	8.09	9.72	11.85	13.16	14.76
140	4.60	6.51	7.76	9.41	10.44	11.62
150	3.91	5.47	6.48	7.82	8.66	9.59
160	3.42	4.73	5.58	6.70	7.42	8.17
170	3.04	4.18	4.91	5.87	6.49	7.13
180	2.75	3.75	4.39	5.24	5.79	6.33

TABLE A-10: CITY OF HAMILTON, 6-HOUR CHICAGO DISTRIBUTION DESIGN STORM HYETOGRAPHS, MOUNT HOPE

Time Step (min)	Rainfall Intensity (mm/hr)					
	2	5	10	25	50	100
10	1.59	2.10	2.41	2.83	3.12	3.35
20	1.68	2.22	2.56	3.01	3.31	3.56
30	1.77	2.36	2.72	3.20	3.53	3.81
40	1.89	2.52	2.91	3.43	3.78	4.09
50	2.02	2.70	3.13	3.70	4.08	4.42
60	2.17	2.92	3.39	4.02	4.43	4.81
70	2.35	3.18	3.71	4.40	4.86	5.28
80	2.58	3.50	4.09	4.87	5.38	5.87
90	2.85	3.90	4.57	5.46	6.03	6.61
100	3.20	4.41	5.20	6.23	6.89	7.57
110	3.67	5.10	6.04	7.26	8.04	8.89
120	4.32	6.07	7.23	8.74	9.69	10.77
130	5.29	7.55	9.06	11.02	12.24	13.70
140	6.93	10.08	12.20	14.96	16.65	18.78
150	10.32	15.37	18.80	23.26	25.95	29.53
160	21.58	32.79	40.38	50.04	56.09	63.97
170	73.99	103.04	122.29	146.10	164.51	181.81
180	22.24	33.80	41.62	51.58	57.82	65.94
190	10.92	16.31	19.98	24.74	27.61	31.44
200	7.38	10.77	13.06	16.04	17.86	20.17
210	5.64	8.09	9.72	11.85	13.16	14.76

TABLE A-10: CITY OF HAMILTON, 6-HOUR CHICAGO DISTRIBUTION DESIGN STORM HYETOGRAPHS, MOUNT HOPE

Time Step (min)	Rainfall Intensity (mm/hr)					
	2	5	10	25	50	100
220	4.60	6.51	7.76	9.41	10.44	11.62
230	3.91	5.47	6.48	7.82	8.66	9.59
240	3.42	4.73	5.58	6.70	7.42	8.17
250	3.04	4.18	4.91	5.87	6.69	7.13
260	2.75	3.75	4.39	5.24	5.79	6.33
270	2.51	3.41	3.98	4.73	5.22	5.70
280	2.32	3.13	3.64	4.32	4.77	5.18
290	2.15	2.89	3.36	3.98	4.39	4.76
300	2.01	2.69	3.12	3.69	4.07	4.40
310	1.89	2.52	2.92	3.44	3.79	4.10
320	1.79	2.37	2.74	3.23	3.56	3.84
330	1.69	2.24	2.59	3.04	3.35	3.61
340	1.61	2.13	2.45	2.88	3.17	3.41
350	1.54	2.03	2.33	2.73	3.01	3.23
360	1.47	1.93	2.22	2.60	2.86	3.07

TABLE A-11: CITY OF HAMILTON, 3-HOUR CHICAGO DISTRIBUTION DESIGN STORM HYETOGRAPHS, ROYAL BOTANICAL GARDENS

Time Step min	Rainfall Intensity mm/hr					
	2 Year	5 Year	10 Year	25 Year	50 Year	100 Year
10	2.70	3.85	4.66	5.55	6.27	6.86
20	3.04	4.30	5.19	6.17	6.97	7.52
30	3.47	4.88	5.87	6.97	7.87	8.61
40	4.09	5.69	6.81	8.08	9.12	9.97
50	5.00	6.88	8.19	9.71	10.94	11.96
60	6.54	8.86	10.46	12.38	13.92	15.23
70	9.71	12.84	14.97	17.69	19.84	21.70
80	20.22	25.81	29.53	34.75	38.75	42.38
90	68.88	89.56	103.39	120.81	133.42	145.92
100	20.84	26.57	30.38	35.74	39.84	43.58
110	10.28	13.54	15.76	18.62	20.87	22.82
120	6.96	9.39	11.06	13.09	14.71	16.09
130	5.33	7.31	8.68	10.29	11.58	12.67
140	4.36	6.04	7.22	8.57	9.66	10.56
150	3.70	5.19	6.23	7.40	8.35	9.13
160	3.24	4.57	5.50	6.54	7.39	8.08
170	2.88	4.10	4.95	5.88	6.65	7.27
180	2.61	3.72	4.51	5.37	6.07	6.64

TABLE A-12: CITY OF HAMILTON, 6-HOUR CHICAGO DISTRIBUTION DESIGN STORM HYETOGRAPHS, MOUNT HOPE

Time Step min	Rainfall Intensity mm/hr					
	2 Year	5 Year	10 Year	25 Year	50 Year	100 Year
10	1.51	2.22	2.72	3.24	3.68	4.02
20	1.59	2.33	2.86	3.41	3.86	4.23
30	1.69	2.46	3.01	3.59	4.07	4.45
40	1.79	2.61	3.19	3.80	4.31	4.71
50	1.92	2.78	3.39	4.04	4.58	5.01
60	2.06	2.98	3.63	4.33	4.90	5.36
70	2.24	3.22	3.91	4.66	5.27	5.77
80	2.44	3.50	4.25	5.06	5.72	6.26
90	2.70	3.85	4.66	5.55	6.27	6.86
100	3.04	4.30	5.19	6.17	6.97	7.62
110	3.47	4.88	5.87	6.97	7.87	8.61
120	4.09	5.69	6.81	8.08	9.12	9.97
130	5.00	6.88	8.19	9.71	10.94	11.96
140	6.54	8.86	10.46	12.38	13.92	15.23
150	9.71	12.84	14.97	17.69	19.84	21.70
160	20.22	25.81	29.53	34.75	38.75	42.38
170	68.88	89.56	103.39	120.81	133.42	145.92
180	20.84	26.57	30.38	35.74	39.84	43.58
190	10.28	13.54	15.76	18.62	20.87	22.82
200	6.96	9.39	11.06	13.09	14.71	16.09

TABLE A-12: CITY OF HAMILTON, 6-HOUR CHICAGO DISTRIBUTION DESIGN STORM HYETOGRAPHS, MOUNT HOPE

Time Step min	Rainfall Intensity mm/hr					
	2 Year	5 Year	10 Year	25 Year	50 Year	100 Year
210	5.33	7.31	8.68	10.29	11.58	12.67
220	4.36	6.04	7.22	8.57	9.66	10.56
230	3.70	5.19	6.23	7.40	8.35	9.13
240	3.24	4.57	5.50	6.54	7.39	8.08
250	2.88	4.10	4.95	5.88	6.65	7.27
260	2.61	3.72	4.51	5.37	6.07	6.64
270	2.38	3.42	4.15	4.94	5.59	6.12
280	2.20	3.17	3.85	4.59	5.19	5.68
290	2.04	2.96	3.60	4.29	4.86	5.31
300	1.91	2.77	3.39	4.03	4.57	5.00
310	1.80	2.62	3.20	3.81	4.32	4.72
320	1.70	2.48	3.03	3.61	4.10	4.48
330	1.61	2.36	2.89	3.44	3.90	4.27
340	1.53	2.25	2.75	3.28	3.73	4.07
350	1.46	2.15	2.64	3.14	3.57	3.90
360	1.40	2.06	2.53	3.02	3.42	3.75

A4 Town of Milton

Source: Town of Milton, *Engineering and Parks Standards,* 2019.

TABLE A-13: TOWN OF MILTON, INTENSITY-DURATION-FREQUENCY VALUES

AES Toronto Pearson International Airport, 39 years of Record, 1950 – 1990

Duration min	2 Year mm/hr	5 Year mm/hr	10 Year mm/hr	25 Year mm/hr	50 Year mm/hr	100 Year mm/hr
5	107.4	141.5	164.2	192.7	213.9	235.0
10	79.0	103.5	119.8	140.3	155.5	170.6
15	65.3	86.5	100.7	118.5	131.7	144.8
30	43.0	57.0	66.3	78.0	86.7	95.4
60	24.3	32.2	37.5	44.1	49.0	53.9
120	14.2	19.2	22.5	26.7	29.8	32.8
360	6.2	8.5	10.1	12.1	13.5	15.0
720	3.5	4.9	5.9	7.1	7.9	8.8
1440	2.0	2.8	3.3	4.0	4.6	5.1

TABLE A-14: TOWN OF MILTON, RAINFALL INTENSITY EQUATION COEFFICIENTS

	A	b	c	Correlation Coefficient
2	779	6	0.8206	0.99985036
5	959	5.7	0.8024	0.99982256
10	1089	5.7	0.7955	0.99978510
25	1234	5.5	0.7863	0.99976364
50	1323	5.3	0.7786	0.99976825
100	1435	5.2	0.7751	0.99974784

$$i = \frac{A}{(t_d + b)^c}$$

Where: i = Rainfall intensity (mm/hr)
t_d = Duration (hr)
A, b and c = constants

A5 City of Mississauga

Source: City of Mississauga Transportation and Works Department, *Development Requirements Manual*, 2020.

TABLE A-15: CITY OF MISSISSAUGA, RAINFALL INTENSITY EQUATION COEFFICIENTS

	A	b	c
2	610	4.6	0.78
5	820	4.6	0.78
10	1010	4.6	0.78
25	1160	4.6	0.78
50	1300	4.7	0.78
100	1450	4.9	0.78

$$i = \frac{A}{(t_d + b)^c}$$

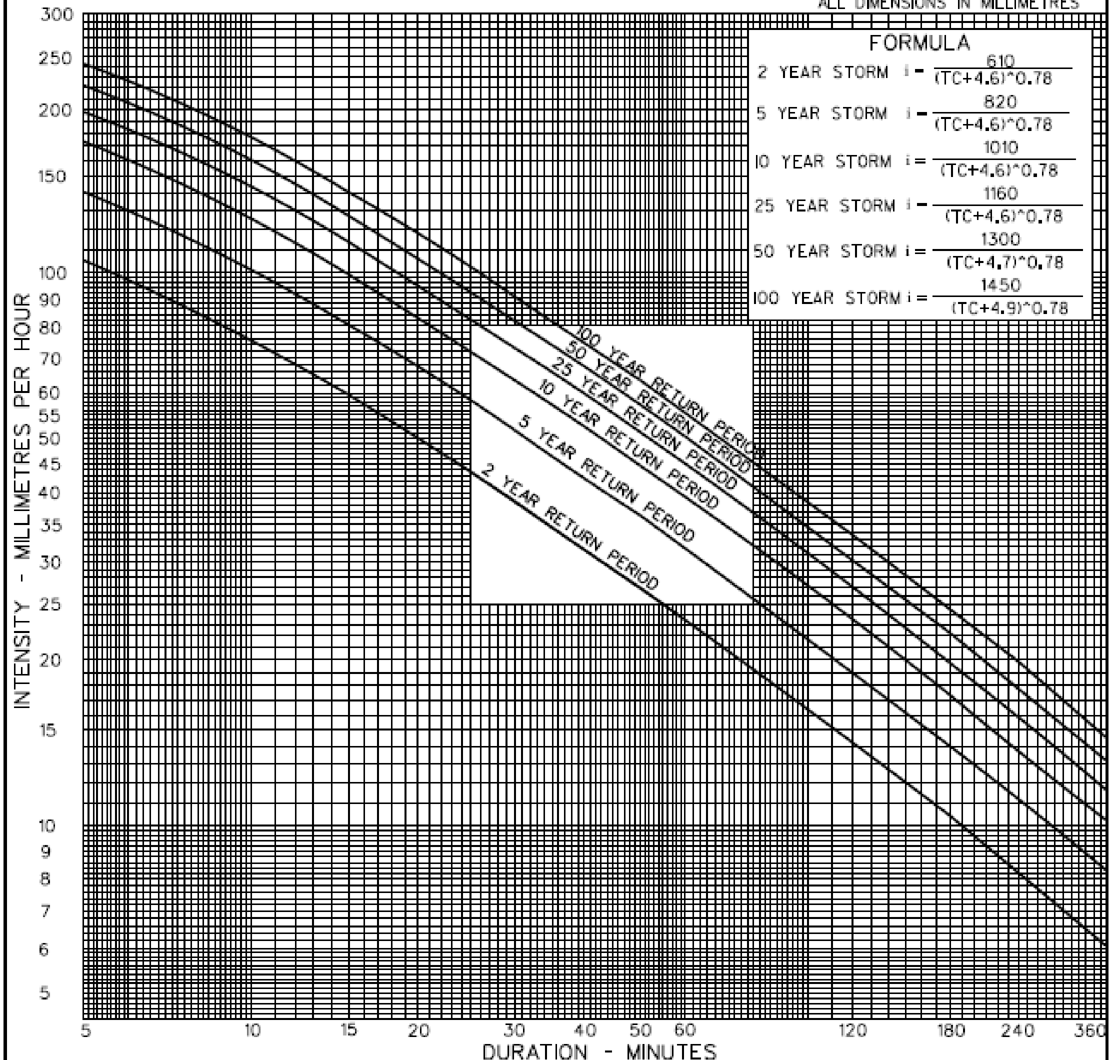
Where: i = Rainfall intensity (mm/hr)
t_d = Duration (hr)
A, b and c = constants

TABLE A-16: CITY OF MISSISSAUGA, INTENSITY-DURATION-FREQUENCY VALUES

Duration min	2 Year mm/hr	5 Year mm/hr	10 Year mm/hr	25 Year mm/hr	50 Year mm/hr	100 Year mm/hr
5	104.51	140.49	173.04	198.74	220.93	242.53
10	75.36	101.30	124.77	143.31	159.75	176.31
15	58.89	80.51	99.17	113.89	127.13	140.69
30	38.45	51.68	63.66	73.11	81.75	90.77
60	23.62	31.76	39.11	44.92	50.28	55.95

FIGURE A-3: CITY OF MISSISSAUGA, STANDARD INTENSITY-DURATION-FREQUENCY RAINFALL CURVES

METRIC
ALL DIMENSIONS IN MILLIMETRES



NOTES

1. ALL CALCULATIONS TO BE DONE ASSUMING FULL DEVELOPMENT AS SHOWN ON CITY OF MISSISSAUGA ZONING MAPS.
2. TO BE USED WITH RATIONAL FORMULA:

$$Q = \frac{CIA}{360}$$

Q-QUANTITY OF RUNOFF (M^3/S)
C-RUNOFF COEFFICIENT
A-AREA (ha)
I-RAINFALL INTENSITY (mm/hr)

MISSISSAUGA

STANDARD
INTENSITY-DURATION-FREQUENCY
RAINFALL CURVES

EFF. DATE		2002-01-01	SCALE	N.T.S
REV.		2016-07-22	STANDARD No.	2111.010

A6 Town of Oakville

Source: Town of Oakville Development Engineering Department, *Development Engineering Procedures and Guidelines.*

TABLE A-17: TOWN OF OAKVILLE, INTENSITY DURATION FREQUENCY VALUES

AES Toronto Pearson International Airport, 39 years of Record, 1950 - 1990

Duration min	2 Year mm/hr	5 Year mm/hr	10 Year mm/hr	25 Year mm/hr	50 Year mm/hr	100 Year mm/hr
5	117.0	164.0	194.0	233.0	262.0	291.0
10	80.0	108.0	126.0	149.0	166.0	183.0
15	65.0	90.0	107.0	129.0	145.0	160.0
30	41.0	58.0	69.0	83.0	93.0	103.0
60	25.0	35.0	41.0	48.0	54.0	60.0
120	15.0	20.0	23.0	27.0	30.0	33.0
360	6.1	8.1	9.4	11.0	12.0	13.0
720	3.6	4.6	5.3	6.2	6.8	7.5
1440	2.0	2.5	2.9	3.4	3.7	4.1

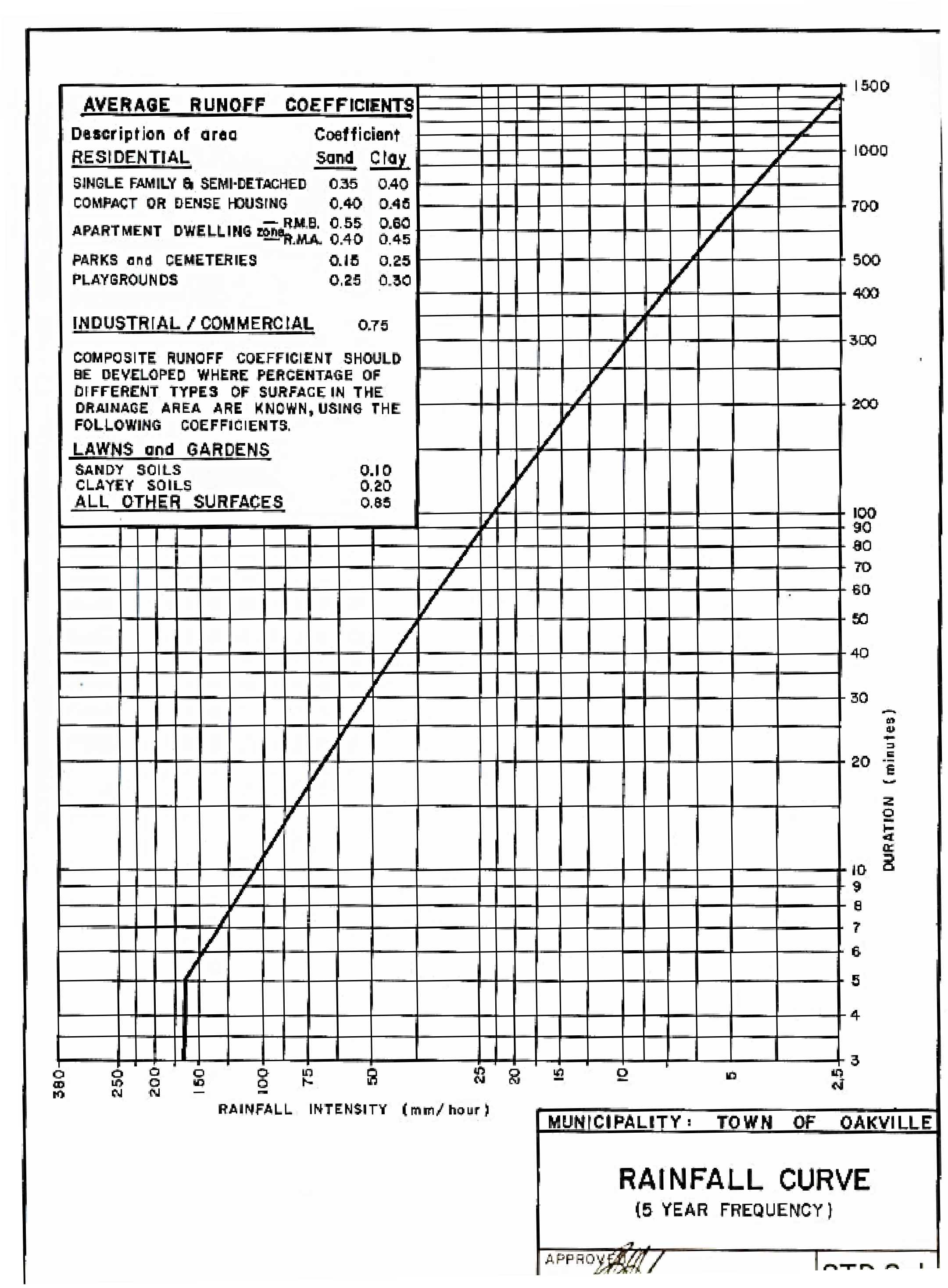
TABLE A-18: TOWN OF OAKVILLE, RAINFALL INTENSITY EQUATION COEFFICIENTS

	A	b	c
2	725	4.8	0.808
5	1170	5.8	0.843
10	1400	5.8	0.848
25	1680	5.6	0.851
50	1960	5.8	0.861
100	2150	5.7	0.861

$$i = \frac{A}{(t_d + b)^c}$$

Where: i = Rainfall intensity (mm/hr)
t_d = Duration (hr)
A, b and c = constants

FIGURE A-4: TOWN OF OAKVILLE, RAINFALL CURVE (5-YEAR FREQUENCY)



A7 Hurricane Hazel Distribution and Areal Reduction

Source: O. Reg. 162/06

TABLE A-19: HURRICANE HAZEL DISTRIBUTION

	Depth mm	Percent of 12 hour
First 36 hours	73	
37th hour	6	3
38th hour	4	2
39th hour	6	3
40th hour	13	6
41st hour	17	8
42nd hour	13	6
43rd hour	23	11
44th hour	13	6
45th hour	13	6
46th hour	53	25
47th hour	38	18
48th hour	13	6
Total	285	100

TABLE A-20: AREAL REDUCTION

Drainage Area km^2	Percentage	Drainage Area km^2	Percentage
0 to 25	100.00	2501 to 2700	69.0
26 to 45	99.2	2701 to 4500	64.4
46 to 65	98.2	4501 to 6000	61.4
66 to 90	97.1	6001 to 7000	58.9
91 to 115	96.3	7001 to 8000	57.4
116 to 140	95.4		
141 to 165	94.8		
166 to 195	94.2		
196 to 220	93.5		
221 to 245	92.7		
246 to 270	92.0		
271 to 450	89.4		
451 to 575	86.7		
576 to 700	84.0		
701 to 850	82.4		
851 to 1000	80.8		
1001 to 1200	79.3		
1201 to 1500	76.6		
1501 to 1700	74.4		
1701 to 2000	73.3		
2001 to 2200	71.7		
2201 to 2500	70.2		

Appendix B Typical Hydrologic/Hydraulic Parameters and Equations

B1 Total Impervious Area and Directly Connected Impervious Area

Total Impervious Area (TIMP) – The percentage of the total impervious area. Directly Connected Impervious Area (XIMP) – The percentage of the directly connected impervious area.

TABLE B-1: TIMP & XIMP VALUES

Land Use	XIMP	TIMP
Parks		
Village Square/Parkette	28	35
Neighbourhood Park	16	20
Open Space		
NHS	0	5
Utility Corridor	0	2
SWM Ponds[1]	50	50
Institutional		
School	60[2] / 30[3]	75
Church	60[2] / 30[3]	75
Employment / Commercial	85	85
Industrial	90	90
Mixed Use	80	80
Impervious Surfaces (i.e., roads, parking)	99	99
Residential[4]		
Rural Estate (> 0.3 ha lot)	16	20
Detached	50	70
Townhouses / Medium	55	75
Condominiums / High	65	85

* Public roads are included as part of other land uses within development blocks.

1 While the permanent pools of SWM ponds are impervious, this value includes the entire pond block. However, if impermeable liners are included that extend beyond the permanent pool, this number may need revision.

2 Roof leaders connected to impervious areas (e.g., driveway) and to storm sewer for XIMP calculations.

3 Roof leaders are connected to pervious area (e.g., lawn) for XIMP calculations.

4 Numbers within older developments may need refinement.

Source: Developed in house

B2 Initial Abstraction Values

TABLE B-2: INITIAL ABSTRACTION VALUES

Land Use	Ia (mm)
Impervious	2
Open Space / Green Space / Lawns	5
Crop / Cultivated	7
Pasture / Meadow	8
Woods/Woodlot/Forest	10
Wetlands	15

* Please note that if grade lot control is implemented, initial abstractions can be adjusted accordingly
Source: Technical Guidelines for Flood Hazard Mapping, (EWRG for CA Steering Committee, 2017)

B3 Horton's Infiltration Equation Parameters

TABLE B-3: HORTON'S PARAMETERS

Soil Group	f_o (mm/hr)	f_c (mm/hr)	K (1/hr)
A	250	25	2
B	200	13	2
C	125	5	2
D	75	3	2

Source: SWMHYMO User's Manual (J.F. Sabourin and Associates Inc., December 1998) – Note these parameters may not be appropriate for use in floodplain mapping studies. Further direction will be provided in CH's Guidelines for Floodplain Alterations and Mapping Submissions.

B4 Soil/Land Use Curve Numbers

TABLE B-4: SCS CURVE NUMBERS

Land Use	Soil Group			
	A	B	C	D
Agriculture / Nursery[1]	67	78	85	89
Buildings[2]	98			
Bedrock[3]	98			
Cemetery / Golf Course	49	69	79	84
Commercial & Business District (85% imp.)[4]	89	92	94	95
Dirt Areas (e.g., Confinement Yard)	72	82	87	89
Extraction	98			
Field / Meadow / Pasture	49	69	79	84
Forest / Plantation[1]	36	60	73	79
Grass / Highway Median	49	69	79	84

TABLE B-4: SCS CURVE NUMBERS

Land Use	Soil Group			
	A	B	C	D
Hedge Row / Orchard	45	66	77	83
Industrial (72% imp.)[4]	81	88	91	93
Institutional (50% imp.)[4]	71	80	88	90
Open Water	98			
Residential[4]				
High Density	89	92	94	95
Medium / Low Density[5] (65% imp.)	77	85	90	92
Trailer Park	71	80	88	90
Rural	51	69	79	84
SWM Pond	50			
Transportation (Roads, Railway, Parking)	98			
Wetland / Marsh	50			

1 Values should be refined further based on hydrologic condition as per the MTO Design Chart, if warranted by the nature of the study/available information.
2 Building footprints
3 100% bedrock
4 Represents a composite value. For solely pervious areas, use “Grass” values.
5 Values can be refined for older neighbourhoods.

Source: Developed in house

B5 SCS Curve Number Relationships for Different Antecedent Moisture Conditions

AMC I – A condition of soils where the soils are dry but not to the wilting point. This is the lowest runoff potential.

AMC II – The average case.

AMC III – Heavy or light rainfall and low temperatures having occurred during the previous five days. This is the highest runoff potential.

TABLE B-5: SCS CURVE NUMBER RELATIONSHIPS

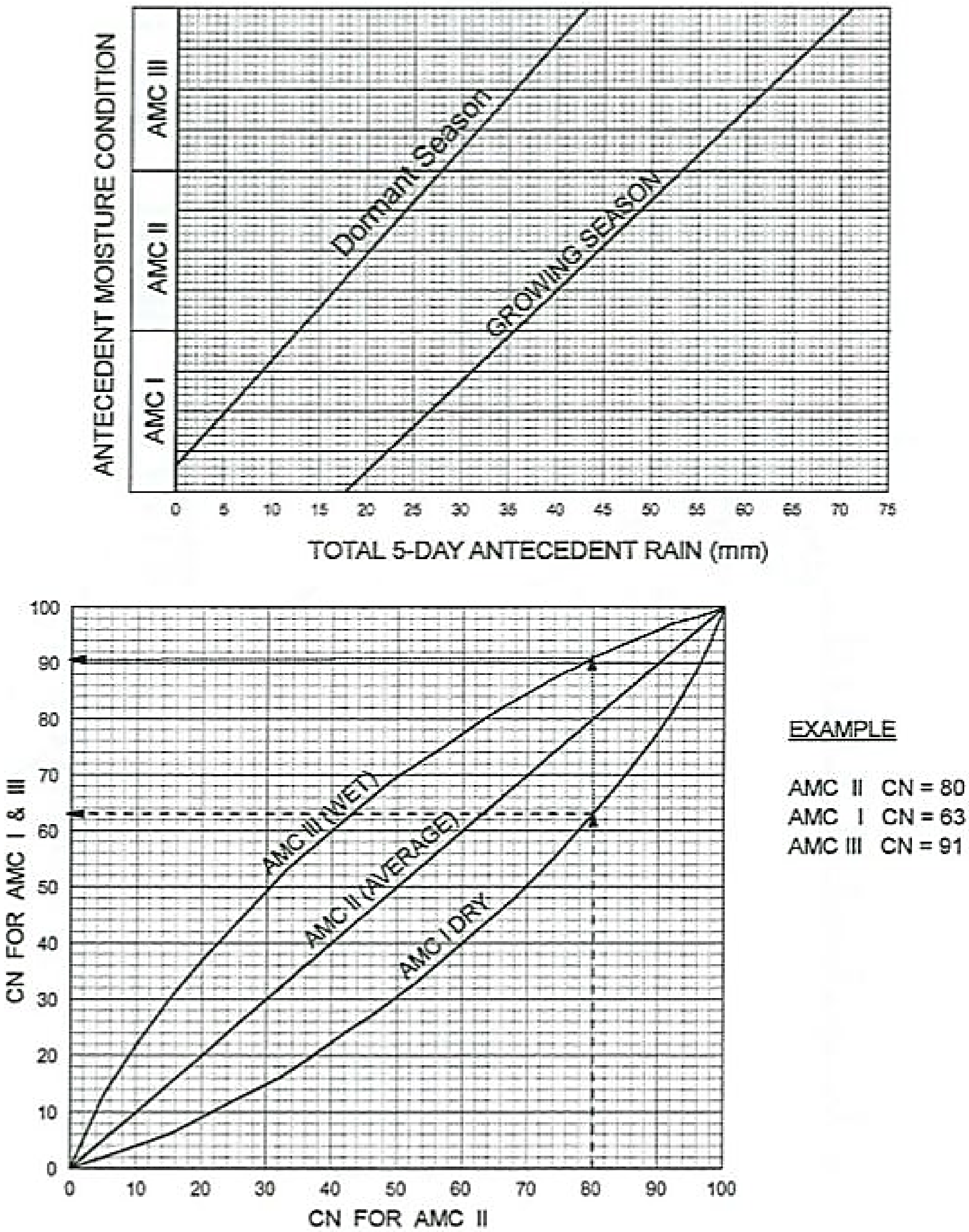
CN @ AMC II	AMC I	AMC III	CN @ AMC II	AMC I	AMC III
100	100	100	60	40	78
99	97	100	59	39	77
98	94	99	58	38	76
97	91	99	57	37	75
96	89	99	56	36	75
95	87	98	55	35	74
94	85	98	54	34	73
93	83	98	53	33	72
92	81	97	52	32	71
91	80	97	51	31	70
90	78	96	50	31	70
89	76	96	49	30	69
88	75	95	48	29	68
87	73	95	47	28	67
86	72	94	46	27	66
85	70	94	45	26	65
84	68	93	44	25	64
83	67	93	43	25	63
82	66	92	42	24	62
81	64	92	41	23	61

TABLE B-5: SCS CURVE NUMBER RELATIONSHIPS

CN @ AMC II	AMC I	AMC III	CN @ AMC II	AMC I	AMC III
80	63	91	40	22	60
79	62	91	39	21	59
78	60	90	38	21	58
77	59	89	37	20	57
76	58	89	36	19	56
75	57	88	35	18	55
74	55	88	34	18	54
73	54	87	33	17	53
72	53	86	32	16	52
71	52	86	31	16	51
70	51	85	30	15	50
69	50	84	25	12	43
68	48	84	20	9	37
67	47	83	15	6	30
66	46	92	10	4	22
65	45	82	5	2	13
64	44	81	0	0	0
63	43	80			
62	42	79			
61	41	78			

Source: Modern Sewer Design, Corrugated Steel Pipe Institute (1996)

FIGURE B-1: ANTECEDENT MOISTURE CONDITIONS



Source: Drainage Design Standards (MTO, 1995-1997)

B6 Green-Ampt Method Parameters

TABLE B-6: GREEN-AMPT PARAMETERS

Soil Group	IMD (mm/mm)	S_u (mm)	K_s (mm/hr)
A	0.34	100	25
B	0.32	300	13
C	0.26	250	5
D	0.21	180	3

Source: Drainage Design Standards (MTO, 1995-1997)

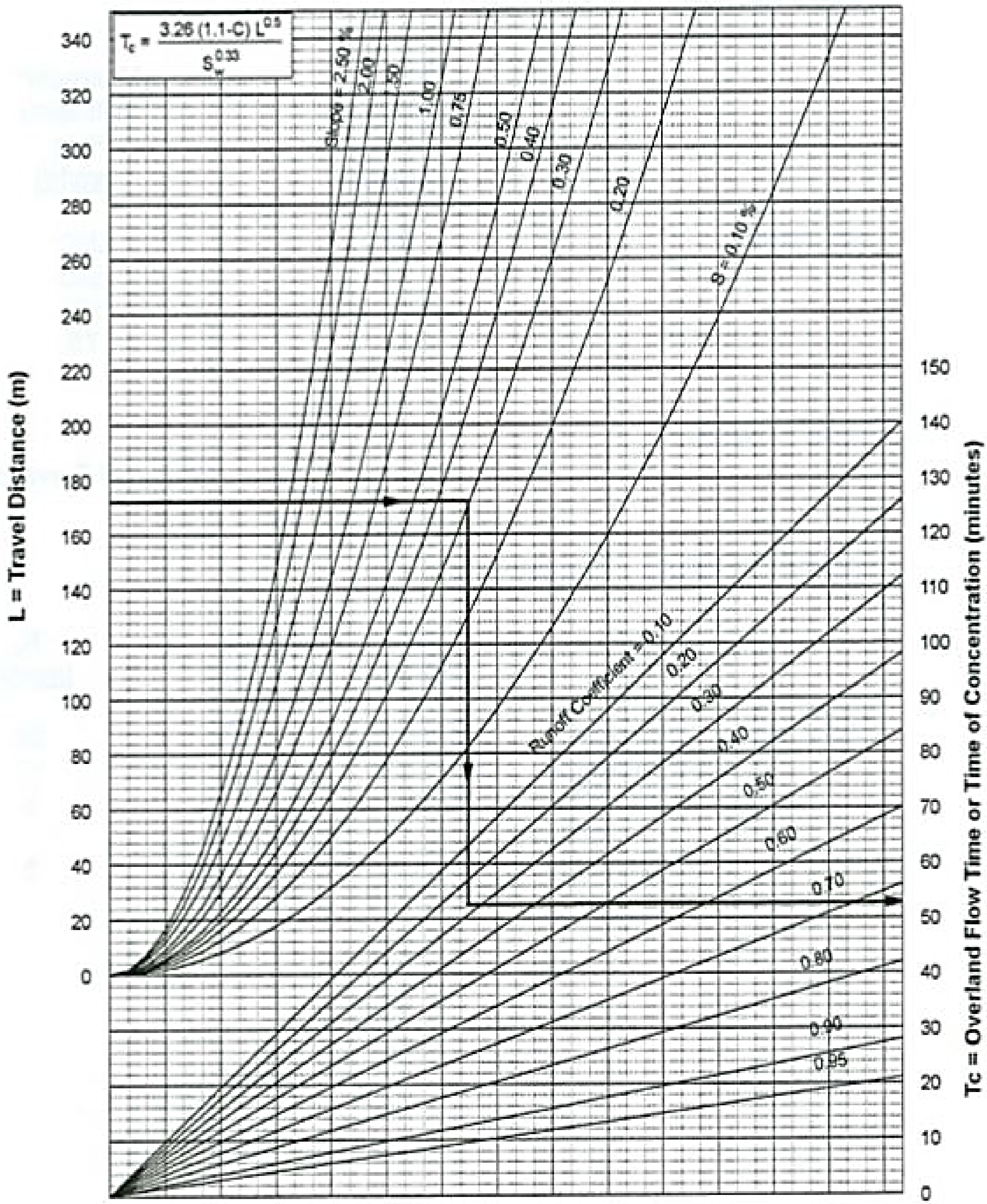
B7 Airport Equation

Generally applicable for subcatchments with runoff coefficients less than 0.4

$$Tc = 3.26(1.1 - C)L^{0.5}Sw^{-0.33}$$

Where:
Tc = Time of Concentration (min)
C = Runoff Coefficient
L = Catchment Length (m)
Sw = Catchment Slope (%)

FIGURE B-2: TIME OF CONCENTRATION – AIRPORT METHOD



Source: Drainage Design Standards (MTO, 1995-1997)

B8 Bransby-Williams Equation

Generally applicable for subcatchments with runoff coefficients greater than 0.4.

$$Tc = 0.057LSw^{-0.2}A^{-0.1}$$

Where: Tc = Time of Concentration (min)
L = Catchment Length (m)
Sw = Catchment Slope (%)
A = Catchment Area (ha)

Source: Drainage Design Standards (MTO, 1995-1997)

B9 Overland Flow Length & Catchment Widths

$$\mathrm{LGI} = \sqrt{(\mathrm{A} / 1.5)}$$

Where: LGI = overland flow length (m)
A = catchment area (m^2)

$$\mathrm{SW} = (2 - \mathrm{Sk})\mathrm{L}$$

Where: SW = catchment width (m)
Sk = skew factor = (A2 – A1) / At
A2 = largest area to one side of channel (ha)
A1 = area to the other side of the channel (ha)
At = total catchment area (ha)
L = length of main drainage channel (m)

Example – For a perfectly symmetrical watershed, Sk = 0 as A2 = A1

Source: Visual OTTHYMO v.2.4 Reference Manual (December 2011).

B10 Manning's Roughness – Overland Flow (i.e., non-channelized flow)

TABLE B-7: MANNING'S ROUGHNESS

Land Use	n
Impervious areas	0.013
Crop / Cultivated	0.300
Meadow	0.350
Woodlot	0.600
Lawns	0.250

Source: Technical Guidelines for Flood Hazard Mapping (EWRG for CA Steering Committee, 2017)

B11 Weir and Orifice Equations and Coefficients

Orifice

$$Q = CA\sqrt{2g\Delta h}$$

Where:
- Q = discharge / flow rate (m^3/s)
- C = discharge coefficient
- A = orifice area (m^2)
- g = acceleration due to gravity (9.81 m/s^2)
- Δh = differential head measured from the centroid of the orifice (m)

Sharp Crested Weir with End Contractions (used for example on DICB inlets operating under weir flow)

$$Q = C(L - 0.2\Delta h)\Delta h^{1.5}$$

Where:
- Q = discharge / flow rate (m^3/s)
- C = discharge coefficient
- L = crest length of the weir (m)
- Δh = differential head measured from the centroid of the weir crest (m)

Rectangular Broad Crested Weir and Sharp Crested Weir without End Contractions

$$Q = CL\Delta h^{1.5}$$

Where:
- Q = discharge / flow rate (m^3/s)
- C = discharge coefficient
- L = weir length (m)
- Δh = differential head measured from the centroid of the weir (m)

<u>Trapezoidal Broad Crested Weir (Emergency Spillways)</u>

$$Q = C(L - 0.1n\Delta h)\Delta h^{1.5}$$

Where: Q = discharge / flow rate (m^3/s)
C = discharge coefficient
L = length of weir (bottom length + side slope * Δh)
n = number of side contractions
Δh = differential head measured from the centroid of the weir (m)

<u>Partial Pipe Flow</u>

To sufficiently model the hydraulics of a SWM pond outlet control structure, partial pipe flow should be considered. Partial pipe flow below the orifice centroid should be included in the calculations.

TABLE B-8: HYDRAULIC EQUATION COEFFICIENTS (METRIC UNITS)

Application	Coefficient
Orifice	0.63
Orifice Tube	0.80
Sharp Crested Weir	1.7
Rectangular Broad Crested Weir (SWMP and Dam Spillway)	1.5 (or using equation)
Rectangular Broad Crested Weir (Road Crossing)	1.5

Source: CH standard values

<u>Rectangular Broad Crested Weir Coefficient Equation (applicable until H/L = 0.6)</u>

$$C = \frac{(-1.04E^{04} + 3.42E^{06}x)}{(1 + 2.13E^{06}x - 2.35E^{05}x^{2)}}$$

Where: C = Discharge Coefficient
χ = Head Divided by the Downstream Length of the Weir (H/L)

<u>Triangular Broad Crested Weir Coefficient (applicable until H/L = 0.6)</u>

$$C = \frac{(-1.01E^{-05} + 1.44E^{02}x)}{(1 + 1.15E^{02} - 4.77x^2)}$$

Where: C = Discharge Coefficient
χ = Head Divided by the Downstream Length of the Weir (H/L)

B12 Rational Method

$$Q = \frac{CiA}{360}$$

Where:
- Q = discharge / flow rate (m^3/s)
- C = runoff coefficient
- i = rainfall intensity (mm/hr)
- A = contributing drainage area (ha)

TABLE B-9: RUNOFF COEFFICIENTS

Land Use		RC (Urban)	Soil Group, where applicable (Rural)		
			A-AB	B-BC	C-CD-D
Agriculture / Nursery[1]	Rolling (5-10%)		0.30	0.45	0.60
	Flat (0-5%)		0.22	0.35	0.55
Buildings[2]		0.95			
Bedrock[3]		0.95			
Cemetery / Golf Course			0.10	0.15	0.20
Commercial & Business District (85% imp.)		0.90			
Dirt Areas (e.g., Confinement Yard)		0.50			
Extraction		0.95			
Field / Meadow / Pasture	Rolling (5-10%)		0.15	0.35	0.45
	Flat (0-5%)		0.10	0.28	0.40
Forest / Plantation	Rolling (5-10%)		0.12	0.30	0.42
	Flat (0-5%)		0.08	0.25	0.35
Grass / Highway Median			0.10	0.15	0.20
Hedge Row / Orchard	Rolling (5-10%)		0.12	0.30	0.42
	Flat (0-5%)		0.08	0.25	0.35

TABLE B-9: RUNOFF COEFFICIENTS

Land Use		RC (Urban)	Soil Group, where applicable (Rural)		
			A-AB	B-BC	C-CD-D
Industrial		0.90			
Institutional		0.90			
Low Impact Development	Refer to manufacturer specifications and consultation with Conservation Halton and municipal staff				
Residential					
High Density		0.80			
Medium / Low Density[4]		0.70			
Estate		0.40			
Trailer Park		0.55			
Rural Residential		0.40			
Transportation (Roads, Railway, Parking)		0.95			
SWM Pond		0.05			
Open Water		0.05			
Wetland / Marsh		0.05			

1 Corn system
2 Building footprints
3 100% bedrock
4 Conservation Halton would consider alternate values, particularly in older residential neighbourhoods

Source: Developed in house

To account for a decrease in available perviousness during major storms, the recommended factors as identified within the Ministry of Transportation Drainage Design Standards (1995-1997) shall be used. For storms having a return period of more than 10 years, runoff coefficients shall be increased as follows. Note that RC cannot exceed 1.0.

- 25-year event – add 10%
- 50-year event – add 20%
- 100-year event – add 25%

Conversion Equation (Runoff Coefficient to Percent Impervious)

$$i = \frac{(C - 0.2)}{0.7} X\ 100$$

Where: i = Percent Impervious
C = Runoff Coefficient