Submitted to:

SGL Planning & Design

Welland Northwest Area Secondary Plan

Stormwater Management Plan

Aquafor Beech Limited

2600 Skymark Avenue

Bldg 6, Suite 202

Mississauga, Ontario

Reference: 66295

February 30, 2020

CONTENTS

APPENDICES

TABLES

FIGURES

1 Introduction

The City of Welland has initiated a Secondary Plan for the Northwest Area in order to create a strategy for the future development of these lands in a way that is sustainable and integrated with the existing urban infrastructure. The Northwest Area of the City is not currently within the urban development boundary but, per the RFP for this assignment, "over the course of recent years, City of Welland Councils have supported the inclusion of the lands in the Northwest Area of the City within its urban area boundary so that urban development of these lands could proceed. The Northwest Area has significant potential to accommodate growth by permitting urban land uses within this Area. The Northwest Area of the City is a prime candidate area for boundary expansion."

Aquafor Beech Limited was retained as part of an overall project team headed by SGL Planning to complete the Subwatershed and Stormwater Management Plan.

1.1 Study Objective

The overall objective of this study is to develop an integrated Subwatershed Plan which ties into the findings and objectives of the Secondary Plan. The specific objectives are:

- Review of Relevant Background Information;
- Definition of Existing Conditions;
- Evaluation of management strategies to offset the impact of future landuse
- Development of a Stormwater Management Plan based on environmental targets (volume control, water quality, quantity, erosion, and water balance/infiltration);
- Provide direction as to the types of future studies required for the successful implementation of the Subwatershed Strategy; and
- Provide recommendations with respect to the phasing of proposed work.

1.2 Study Area

The study area, illustrated in **Figure 2-1**, is generally centered around the intersection of Quaker Road and Rice Road in the northwest part of the City of Welland.

There are three branches of Towpath Drain which provide drainage for the Northwest Area, with surface water flowing from West to East, outletting to the Welland Canal at Egerter Rd. The three (3) branches are characterized as relatively flat and shallow in nature, with wide floodplains.

2 Existing Conditions

This chapter provides an overview of the current state of the environmental features of the Welland Northwest Area subwatershed. The intensity of human activity has increased in the last 150 years to the detriment of environmental features. Therefore, before establishing realistic goals for the protection, enhancement and/or restoration of the Subwatersheds environmental features can be developed, it is necessary to describe the current condition of these features, the functions they perform and their inter-relationship.

2.1 Landuse

The area includes approximately 189 ha of land, the majority of which is currently zoned for agriculture. The area also includes existing single-detached residential properties (primarily in the northwest portion of the area), institutional properties (e.g., schools), and recreational/open space (e.g., the former Welland Soccer Club). Lands to the immediate north are located within the urban area boundary of the Town of Pelham (including the East Fonthill Secondary Plan study area) and City of Thorold (including the Port Robinson West Secondary Plan study area).

2.2 Drainage Boundaries

The subcatchment area is the drainage area that drains to a particular point. For the Welland Northwest area, the subcatchments were initially assigned based on the previous study of Central Welland River Floodplain Mapping Study (Aquafor, 2012). In the next step, the topographic map together with orthophotos were used to refine the subcatchment discretization. The delineation exercise was performed in ArcGIS (**Figure 2-2**).

In order to develop the model to assess both development impacts as well as flood hazard assessment, the subwatershed was divided into a greater number of subcatchments than would generally be required for solely the evaluation of flood hazards.

In the case of the hydrologic model development, both urban and rural subcatchments are present and many of the subcatchments are irregularly shaped and relatively large in size. Subcatchments discretization was completed recognizing that the model is not intended to be used for detailed pipe-by-pipe and /or dual drainage assessment design, but rather for peak flow estimation at key conveyance points within the watershed.

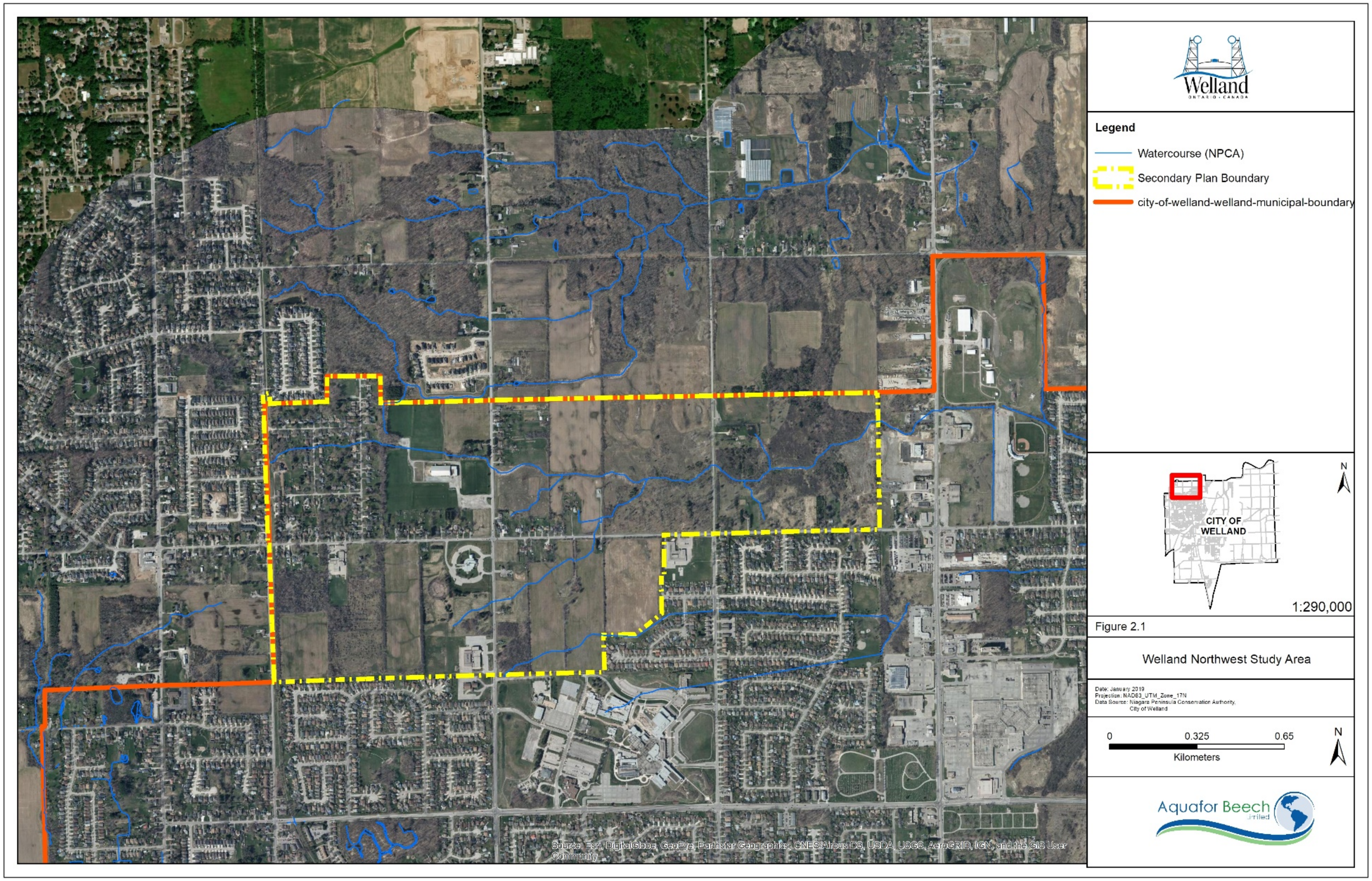

Figure 2-1: Welland Northwest Area Location

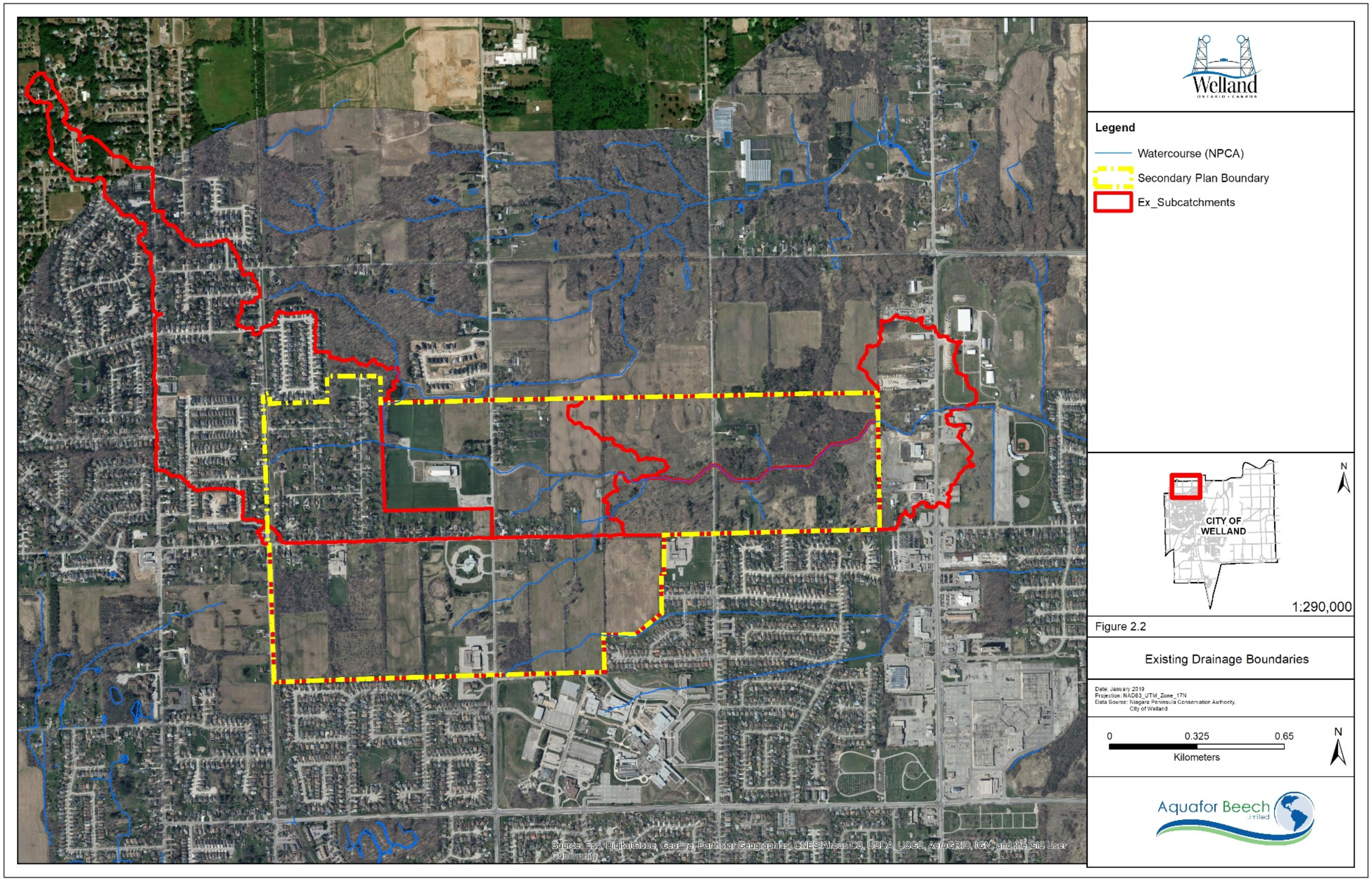

Figure 2-2: Existing Drainage Boundaries

2.3 Hydrology

Hydrology is the science which deals with the interaction of water and land, and the processes by which precipitation is transformed into runoff to the receiving watercourses or infiltrated into the groundwater system. These processes are generally called the hydrologic cycle.

One of the most dramatic changes brought about by urbanization is the change in hydrological cycle and stream hydrology. These changes can result in increases in flooding, channel erosion, sediment transport, and pollutant loadings which can cause deterioration in natural channel morphology, fish and wildlife habitats, recreational opportunity and aesthetics.

It is important that the existing hydrologic characteristics of the study area and its watercourses be established. This information is critical in defining existing flood characteristics, defining regulatory floodplain limits, and providing key information on the selection and design of stormwater management facilities for future urban development lands.

2.3.1 Hydrologic model setup

A hydrologic model is used to simulate predevelopment and post development conditions and evaluate the Stormwater Management alternatives. Ultimately, the hydrologic model is a tool to evaluate how proposed stormwater infrastructure solutions can mitigate the impacts of urbanization.

Appendix A provides the technical inputs/details of the hydrologic model setup for the study are in Welland.

2.3.1.1 Design Storm

The design storm is a critical precipitation event which is used for assessing the flood hydrology for a certain return period (frequency). Design storms are created based on statistical analysis of historical storm data and are usually region specific.

The design storm was obtained from the previous study of floodplain mapping (Aquafor, 2012). Therefore, a 12-hour AES storm distribution was provided by NPCA for use in the PCSWMM model for this study area. The 12-hour duration is considered reasonable given the size, travel time, and predominantly rural nature of the subwatershed.

Design storm depths were derived from an IDF curve generated by averaging IDF values from a set of four rain gauges throughout the Welland River watershed. The modelling for the Welland River Main Branch used rainfall statistics from the Hamilton Airport, Vineland RCS, St. Catharines, and Port Colborne rain gauges distributed over the Welland River watershed to derive an Average Welland River IDF curve (Perdikaris, 2012). The 12-hour rainfall depths for the 2, 5, 10, 25, and 100-year return period storms, are applied in the PCSWMM model for the Welland River Tributaries were 42, 56, 64, 75, and 92 mm. hydrograph information is provided in Appendix A.

2.3.2 Flow Estimation

The Welland Northwest Existing Model was used to estimate stormwater flow rates at key locations throughout (**Figure 2-3**) the Towpath Drain and tributaries watercourses at various return periods. The regulatory flood event in the study area for floodplain management purposes is the 100-year storm.

A design storm approach was selected to estimate peak flow rates for the 2-year through 100-year return periods on Welland River Tributaries and Welland Canal Tributaries within the study area.

With a design storm approach, a rainfall input (i.e. duration, return period depth, and temporal distribution) is selected and design flows are determined using specified antecedent moisture conditions and a computational technique such as hydrologic model. It is assumed with this approach that the peak flows which are generated are of the same return period as the applied design storm

Table 2-1 summarizes the estimated flow rates at key locations along the Towpath Drain. The flow nodes are presented in **Figure 2-3**. The modelled flows are also compared with estimates from previous study (Aquafor, 2012). In general, the flows were found to be very close to the previous estimates.

Table 2-1: Flow Rates at Key Locations Along the Towpath Drain

Junction Name	PCSWMM	HECHMS (Aquafor, 2012)
	Peak flow (m^3/s)	Peak flow (m^3/s)
Node 1	6.1	-
Node 2	7.5	-
Node 3 (TP2)	8.3	8.3

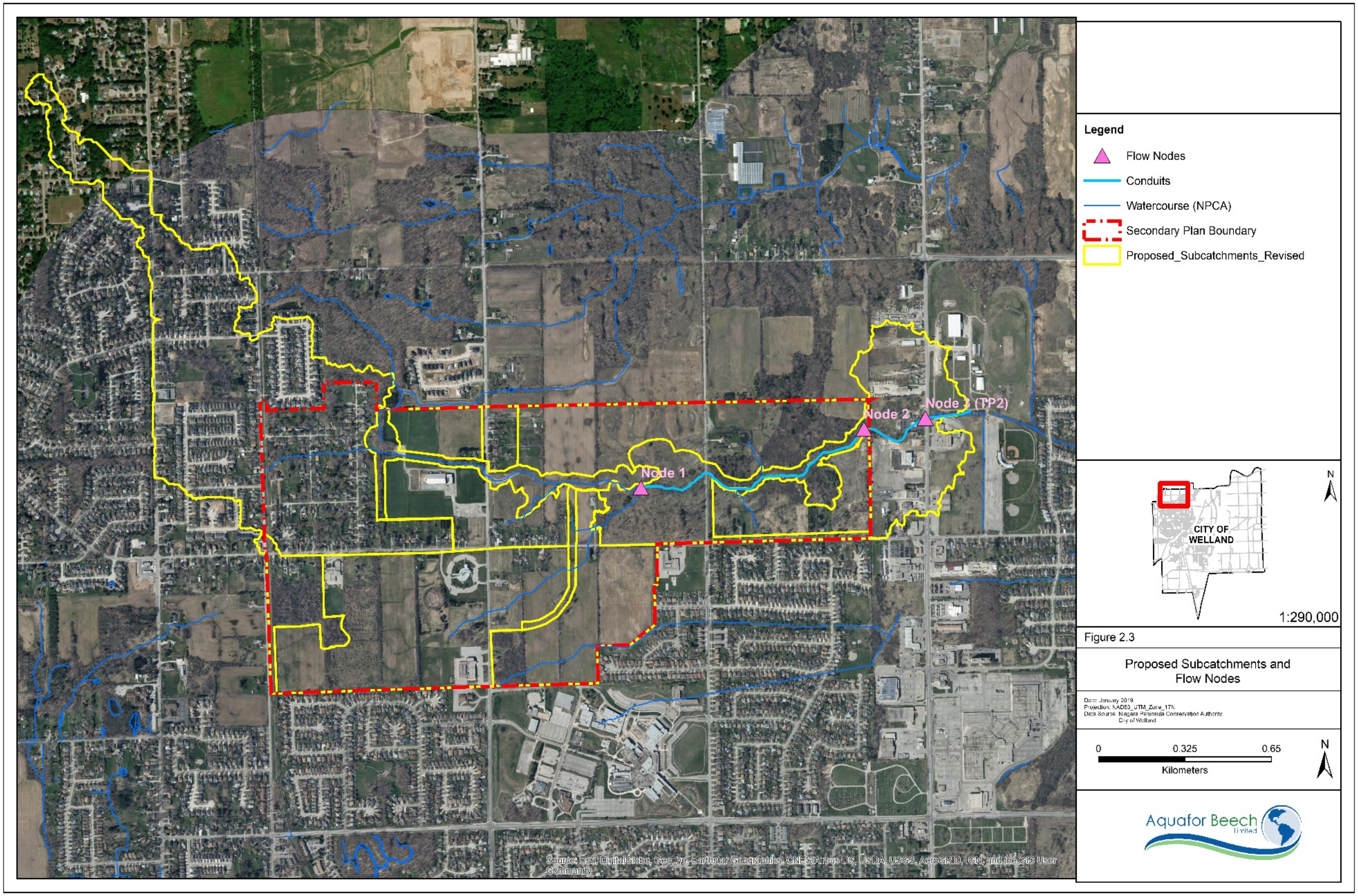

Figure 2-3: Proposed Subcatchments and Flow Nodes

3 Stormwater Alternatives

Three potential stormwater management control approaches were considered as part of the Stormwater Plan process:

1. Do Nothing;
2. Traditional (Conventional) Stormwater Management; and
3. Traditional Stormwater Management and LID.

A general description of each alternative is provided below:

3.1 Do Nothing Approach

For this study, the "Do Nothing" approach refers to not providing any form of water quality, water quantity, or erosion control for new development within the Welland Northwest study area. Development using this approach would cause significant environmental and ecological degradation, contravene municipal, provincial and federal policy as well as fail to meet the study purpose.

3.2 Traditional (Conventional) Stormwater Management

The traditional stormwater management approach involves establishing an end-of-pipe stormwater management facility (i.e. a wet pond or hybrid wetland-wet pond) within each new development area (**Figure 3-1**). It is most technically and economically feasible to site stormwater management facilities at site locations that are conducive to gravity drainage without excessive land grading. Stormwater management facilities typically discharge to natural drainage features (creeks, rivers, wetlands and lakes) or engineered conveyance structures such as ditches, swales, channels or pipes.

Wet ponds or hybrid wetland-wet ponds use active storage detention and elongated flow paths through the facility to settle suspended sediments and associated pollutants. Both facility types require a forebay for pre-treatment and easier maintenance. While both facilities can be designed to meet MECP's enhanced level of water quality treatment corresponding to a long-term sediment removal efficiency of 80%, the wetland component of a hybrid design provides enhanced biological removal during the summer months.

Figure 3-1: A wet pond SWM facility provides water quality treatment via the settlement of suspended pollutants and flood control via the temporary detention and peak flow reduction

3.3 Traditional Stormwater Management & Low Impact Development (LID)

LID stormwater management practices used together with conventional stormwater management as part of an overall holistic treatment train approach have been shown to better meet stormwater management targets and objectives, provide better performance, are more cost effective, has lower maintenance burden, and are more protective during extreme storms than conventional stormwater practices alone. The underlying concept is that each LID stormwater management and traditional practice within the treatment train provides successive storage, attenuation and water quality benefits. **Figure 3-2** illustrates the generalized impact of a holistic approach to stormwater management on the four (4) primary and most common stormwater management objectives when LID and conventional stormwater management solutions are used.

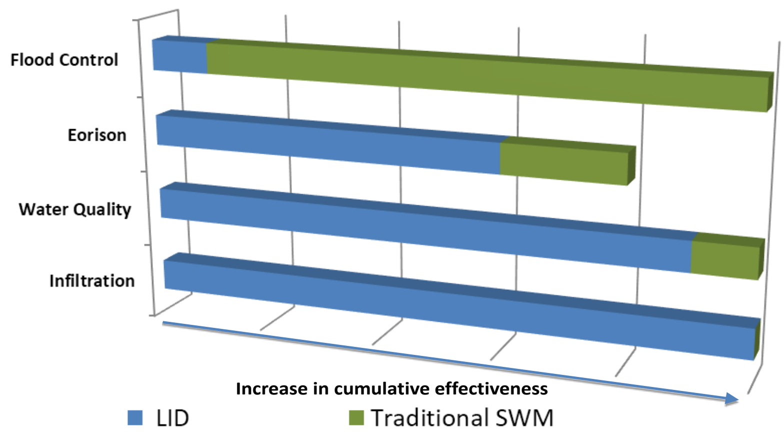

Figure 3-2: The Rationale for the Traditional Stormwater Management and LID Approach

The LIDs are incorporated into new development areas to provide water quality control via runoff volume reductions and filtration. Where these LIDs can treat the runoff generated up to the 90th percentile event, the end of pipe facilities can be designed to provide water quantity control only. For these catchment scenarios, a dry stormwater management pond and/or multi-use flood storage facility may be feasible. Hydrologic modelling undertaken at the development stage may take runoff volume reductions achieved via LIDs into account when designing for quantity control. In new development areas where LIDs can treat only a portion of the runoff, the end-of-pipe facilities (i.e. dry pond) will need to provide a volume of water quality storage (**Figure 3-3**). In this situation, the water quality volume can be reduced by subtracting the drainage area fully treated by LIDs before calculating the required water quality volume.

Figure 3-3 – Left: A dry SWM facility provides flood control; but little water quality treatment; Right: A dry SWM facility provides flood control as well as recreational opportunities Aurora, Ontario)

3.3.1 Low Impact Development (LID)

Low Impact Development (LID) is a stormwater management strategy that seeks to mitigate the impacts of increased runoff volume and stormwater pollution by managing runoff as close to its source as possible. LID comprises a set of site design strategies that minimize runoff and distributed, small scale structural practices that mimic natural or predevelopment hydrology through the processes of infiltration, evapotranspiration, harvesting, filtration and detention of stormwater. These practices can effectively remove nutrients, pathogens and metals from runoff, and they reduce the volume and intensity of stormwater flows. The key principles for Low Impact Development Design are to "soak it up or slow it down":

1. **Use existing natural systems as the integrating framework for planning;**
   - Consider regional and watershed scale contexts, objectives and targets;
   - Look for stormwater management opportunities and constraints at watershed/subwatershed and neighbourhood scales;
   - Identify and protect environmentally sensitive resources; and,
   - Restore, enhance, and expand natural areas.
2. **Focus on runoff prevention**
   - Minimize impervious cover through innovative site design strategies and application of permeable surfaces;
   - Incorporate green roofs and rainwater harvesting systems in building designs;
   - Drain roofs to pervious areas with amended topsoil or stormwater infiltration practices; and,
   - Preserve existing trees and design landscaping to create urban tree canopies.
3. **Treat stormwater as close to the source area as possible**
   - Utilize decentralized source and conveyance stormwater management practices as part of the treatment train approach;
   - Flatten slopes, lengthen overland flow paths, and maximize sheet flow; and,
   - Maintain natural flow paths by utilizing open drainage (e.g., swales).
4. **Create multifunctional landscapes**
   - Integrate stormwater management facilities into other elements of the development to conserve developable land;
   - Utilize facilities that provide filtration, peak flow attenuation, infiltration and water conservation benefits;
   - Design landscaping to absorb runoff, decrease need for irrigation, urban heat island effect and enhance site aesthetics.

To provide both water quality, water quantity and erosion targets, an aggressive LID approach would be required. This approach would see LID practices integrated on municipal property (Road ROWs, parks, municipal buildings, etc.) and on private property (residential, commercial, institutional and industrial properties).

Specific types of LID practices that are generally appropriate for different land uses are listed in **Table 3-1** .

Table 3-1:LID Applicability by Land Use

LID Type		Single Family Residential (Low Density)	Multi-Family (Medium Density)	Multi-Family (High Density)	Industrial, Commercial & Institutional
Soil Amendments		☑	☑	☑	☑
Perforated Pipe (PP)	PP as Storm Sewer	☑	☑	☑	☑
	Parallel PP ("3rd Pipe")	☑	☑	☑	☑
	Grassed Swale PP System	☑	☑	☑	☑
Permeable Pavements			☑	☑	☑
Bioretention, Bioswales and Enhanced Swales			☑	☑	☑
Green Roofs				☑	☑
Rainwater Harvesting				☑	☑

3.3.1.1 LID Approach for Single Family Residential (Low Density) Landuse

LID SWM practices that would be incorporated into an overall municipal stormwater management approach include:

Soil Amendments - Compost amendments are tilled or mixed into existing soils thereby enhancing or restoring soil properties by reversing the loss of organic matter and compaction (**Figure 3-4**). They also are used to make Hydrologic Group C and D soils suitable for on-site stormwater BMPs such as downspout disconnection, filter strips, and grass channels etc. Soil amendments benefits include increased infiltration, stormwater storage in the soil matrix, survival rate of new plantings, root growth and stabilization against erosion, improved overall plant/tree health and decreased need for irrigation and fertilization of landscaping. Amended soils are suitable for any pervious area where soils have been or will be compacted by the grading and construction process. While soil amendments will never be used solely to meet stormwater management objectives, they are effective in reducing the overall runoff volume, will contribute to a lower peak discharge, and can help improve water quality by reducing contaminate loads. Soil amendments can be applied on private property and do not require ongoing maintenance activities.

Perforated Pipe Systems - Perforated pipe systems, also called exfiltration systems, can be thought of as long infiltration trenches that can be designed for both conveyance and infiltration of stormwater runoff (**Figure 3-4**). They are underground stormwater systems composed of perforated pipes installed in gently sloping granular stone beds lined with geotextile fabric that allows infiltration of runoff into the granular bed and underlying native soil. Perforated pipe systems can be used in place of almost any conventional storm sewer pipes where topography, water table depth, and runoff quality conditions are suitable. They are capable of handling runoff from roofs, walkways, parking lots, and roads. For roads applications, these systems can be located within boulevard areas or beneath the roadway surface itself.

There are three configurations of perforated pipe systems that are feasible within residential road right-of-ways. The first is a perforated pipe system that functions as the minor system conveyance. The second is a perforated pipe that runs parallel and discharges to the conventional storm sewer. Because the conventional storm sewer meets conveyance requirements, the parallel pipe (also known as a "3rd pipe system") can be sized to infiltrate smaller volumes. This configuration is shown in the associated figure and is consistent with the PCSWMM modeling approach used for this study. The third configuration is a catchbasin lead to either a perforated or solid pipe that conveys flows to an infiltration chamber within the municipal ROW. There are also perforated pipes available up to 1200mm in diameter that can be used instead of a solid walled storm sewer to promote infiltration.

Soakaway Pits, Infiltration Trenches and Chambers - Soakaways, infiltration trenches and chambers can be used to reduce runoff volume and maintain or enhance recharge (**Figure 3-4**). Most surface areas can be directed to infiltration practices without pre-treatment. Roads and parking lots should be provided with pre-treatment devices to prevent clogging and extend their lifecycle.

These practices are also known as infiltration galleries, trench drains and / or dry wells, and are excavations in the native soil that are lined with geotextile fabric and filled with clean granular stone. They are typically designed to accept runoff from a relatively clean water source such as a roof or pedestrian area. Where possible, they should be installed where native soils allow for infiltration; however, like other infiltration techniques, underdrains can be installed where poorly drained soils are present. These practices can be designed in a broad range of shapes and sizes.

Infiltration chambers are a variant that use prefabricated modular plastic or concrete structures (as opposed to only aggerates) installed over a granular base to provide maximum void space (up to 90%) and provide structural support. These systems provide more storage capacity than equivalently sized soakaways and have minimal footprints. Infiltration chambers are ideal for heavily urbanized sites because they can be installed below parking lots or other impervious surfaces. Infiltration chambers have also been successfully installed below recreational fields and public urban courtyards. They can be designed in many configurations to suit site constraints.

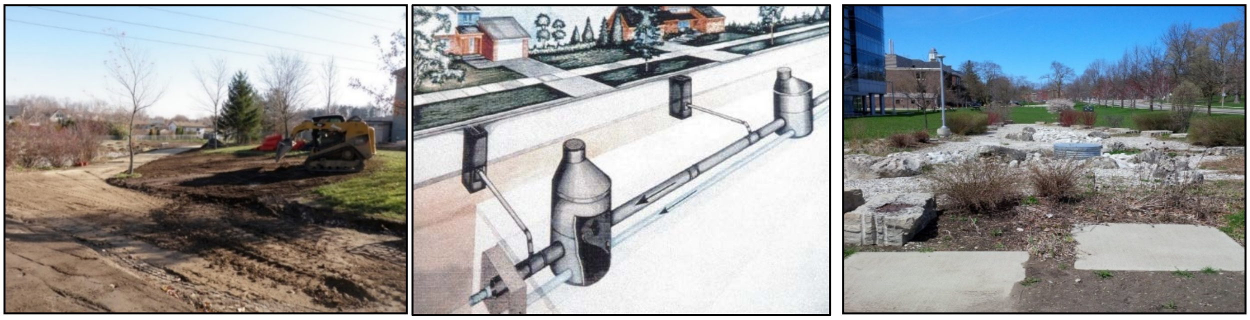

Figure 3-4: Example LID Practices, from Left to Right: Soil Amendment, Perforated Pipes and Soakaway Pits

3.3.1.2 LID Approach for Multi-Family Residential (Medium Density) Landuse

In addition to LID approaches mentioned in above section for single family areas two below LID types are applicable to the medium density areas.

Permeable Pavements - Permeable pavement is a collective term that describes LID BMPs that can be used in place of conventional asphalt or concrete pavement. These alternatives contain pore spaces or joints that allow stormwater to pass through to a stone base for infiltration into underlying native soil or temporarily detained for flood control purposes (**Figure 3-5**). Typical types of permeable pavement include:

- pervious concrete;
- porous asphalt;
- permeable interlocking concrete pavers (PICP) (i.e., block pavers);
- plastic or concrete grid systems (i.e., grid pavers or grass pavers); and
- rubberized granular surfaces, bricks and pads.

Permeable Pavements can be implemented as sidewalks, driveways, multi-use pathways, on-street (lay-by) parking, alleyways, road shoulders and even minor or local roadways themselves but are most commonly applied in parking lots. When implemented as within a parking lot, permeable pavement can be implemented as:

- Full permeable pavement parking surface (drive lanes and parking stalls); and
- Partial permeable pavement parking surface where permeable pavement is strategically constructed within the parking stall areas only and the central drive-lanes remain as

conventional asphalt. In this manner, the permeable pavement systems can accept runoff from impervious areas (i.e. drive lanes).

Bioretention, Bioswales and Enhanced Grass Swales - As a stormwater filtration and infiltration practice, bioretention temporarily stores, treats and infiltrates runoff. The primary component of the practice is the bioretention soil media (**Figure 3-5**). This component is comprised of specific ratio of sand, fines and organic material. Another important element of bioretention practices is vegetation, which can be either grass or a more elaborate planting arrangement such as an ornamental garden.

Bioretention can be integrated into a diverse range of landscapes including as roadside practices, open space, and as part of parking lots and landscaped areas a perimeter control. Perimeter controls are placed adjacent to the impermeable surface (i.e. parking lot) typically at the low point where it can efficiently collect runoff. Bioretention practices are commonly referred to as “rain gardens”. Depending on the native soil infiltration rate and site constraints, bioretention practices may be designed without an underdrain for full infiltration, with an underdrain for partial infiltration, or with an impermeable liner and underdrain for filtration only (commonly called a biofilter) where infiltration is not desired or where contaminated soils are encountered.
Bioswales are similar to bioretention cells. They include a filter media bed, gravel storage layer and optional underdrain components. The main difference is that bioswales are also designed to provide linear conveyance via their swale-like surface geometry and slope. Pre-treatment and rock check dams are often included in the design. In general, bioswales are open channels designed to convey, treat and attenuate stormwater runoff. Vegetation or aggregate material on the surface of the swale slows the runoff water to allow sedimentation, filtration through the root zone and engineered soil bed, evapotranspiration, and infiltration into the underlying native soil. Bioswales may be planted with grasses or have more elaborate landscaping. They are implemented to provide water quality treatment and water balance benefits beyond those of a conventional ditch. Bioswales are sloped to provide conveyance, but due to their permeable soil media and gravel, surface flows are only expected during intense rainfall events. Bioswales are the most commonly applied LID as part of complete streets and parking lots. The photo above is of the Waterloo Street Raingarden in SOHO, London, Ontario.

The photo is below in 3.5

Enhanced grass swales are vegetated open channels designed to convey, treat and attenuate stormwater runoff (also referred to as enhanced vegetated swales). Check dams and vegetation in the swale slows the water to allow sedimentation, filtration through the root zone and soil matrix, evapotranspiration, and infiltration into the underlying native soil. Simple grass channels or ditches have long been used for stormwater conveyance, particularly for roadway drainage. Enhanced grass swales incorporate design features such as modified geometry and check dams that improve the contaminant removal and runoff reduction functions of simple grass channel and roadside ditch designs. Enhanced grass swales are not capable of providing the same water balance and water quality benefits as dry swales, as they lack the engineered soil media and storage capacity of that best management practice.

Figure 3-5: Example LID Practices from Top Left to Right: Permeable Pavements, Bioswales, Bioretention (Bostwick Community Centre, London, ON), and Raingarden (Waterloo Street, SOHO, London, ON)

3.3.1.3 LID Approach for Multi-Family Residential (High Density), Industrial, Commercial and Institutional Landuse

The BMPs already described in **section 3.3.1.2** (Soil Amendments, Perforated Pipe, Permeable Pavements, Bioretention & Bioswales, Enhanced Swales, Soakaway Pits, Infiltration Trenches and Chambers) have been selected as suitable LID alternatives for low and medium density residential areas. These systems can be inspected and maintained to ensure the intended level of service is maintained. However, there are other LID SWM practices such as green roofs and rainwater harvesting which require more rigorous operation and maintenance works. There are opportunities to adopt these practices on properties with high density residential, industrial, commercial and institutional areas where there are maintenance or landscaping staff (e.g. maintenance contracts with commercial properties or condominium blocks).

Green Roofs **-** Green rooftops, also known as “living roofs” or “rooftop gardens” consist of a thin layer of vegetation and growing medium installed on top of conventional flat roofs or modestly sloped roofs

(**Figure 3-6**). Green roofs are touted for their multiple benefits to cities, as they improve energy efficiency, reduce heat island effects, and can create urban green space for passive recreation, aesthetics and habitat. To a water resources manager, they are attractive for their water quality, water balance, and geomorphic benefits. Hydrologically speaking, a green roof acts like a lawn or meadow by storing rainwater in the growing medium and ponding areas. Excess rainfall enters the underdrain and is conveyed through a typical building drainage system and onto the next LID BMP in the treatment train, if one exists. After the storm, stored water is transpired by the plants or evaporates. Green roofs are particularly useful in developments with a high percentage of lot coverage sites where space for ground level BMPs is limited. Equally beneficial from a SWM perspective is to attenuate runoff volume using storage on the rooftop without any vegetation. This can be achieved with minor adjustments to the building structure and will provide a SWM benefit by slowing down the flow.

Rainwater Harvesting **-** Rainwater harvesting is the process of intercepting, conveying and storing rainwater for future use (**Figure 3-6**). Harvesting rainwater for domestic purposes has been practiced in rural Ontario for well over a century. Roof runoff is the ideal source for this practice due to the large surface area and minimal exposure to contaminants. Rainwater harvesting not only reduces the volume of runoff that is conveyed offsite, but also reduces the onsite usage of potable water for irrigation and associated costs.

Rainwater harvesting systems convey runoff to a storage tank or cistern. Prefabricated storage units can range in size from a simple rain barrels that tie into downspouts to precast concrete tanks capable of storing tens of thousands of litres or more from much larger catchment areas. Cisterns can be located inside a building or outside. Rainwater that is collected in a cistern can be used for non-potable indoor or outdoor uses. Sufficient pre-treatment options include gravity filtration or first flush diversion. The irrigation of landscaped areas and washing of site features and vehicles are common uses of harvested rainwater. The 2006 Ontario Building Code explicitly allows the use of harvested rainwater for toilet and urinal flushing.

Figure 3-6: Example LID Practices from Left to Right: Green Roofs and Rainwater Harvesting

3.3.2 Provincial Stormwater Guidance Manuals

The “state-of-the-art” in stormwater management has been evolving rapidly. The MECP’s 2003 Stormwater Management Planning and Design Manual (SWMPDM) provides an integrated approach to stormwater management that has been utilized across the province since its publication. The SWMPDM incorporates water quantity and erosion considerations. The SWMPDM provides technical and procedural guidance for the planning, design, and review of stormwater management practices. The focus of the manual was broadened to incorporate the current multi-objective approach to stormwater facility planning to address targets related to hazards, water quality, fish habitat and recreation. Fundamental stormwater management objectives which are included in the 2003 SWMPDM include:

- Groundwater and baseflow characteristics are preserved;
- Water quality will be protected;
- Watercourses will not undergo undesirable and costly geomorphic change;
- There will not be any increase in flood damage potential; and ultimately,
- That an appropriate diversity of aquatic life and opportunities for human uses will be maintained.

A central theme of the SWMPDM is the application of a “treatment train”, a term that is used to describe the combination of controls – source, conveyance and end-of-pipe controls - usually required in an overall stormwater management strategy to ensure that objectives are achieved. The SWMPDM states that:

> “the recommended strategy for stormwater management is to provide an integrated **treatment train approach** to water management that is premised on providing control at the lot level and in conveyance (to the extent feasible) followed by end-of-pipe controls. This combination of controls is the only means of **meeting the multiple criteria for water balance, water quality, erosion control and water quantity**.”

The 2003 SWMPDM remains the go-to reference material for end-of-pipe stormwater management criteria and design requirements for wet ponds, constructed wetlands, hybrid wet pond/wetland systems, dry ponds and centralized infiltration facilities.

Since the publication of the 2003 SWMPDM, advancements have been made in the approaches used to manage stormwater and the technologies available to the stormwater practitioner. It is now understood that to effectively mitigate the impacts from urbanization, stormwater strategies must include a means to **reduce runoff volume** with the objective of maintaining the pre-development water balance. To meet the multiple objectives of stormwater management on a broad-scale, it is expected that a combination of source, conveyance and end of pipe controls will be required within Ontario’s stormwater systems. To encourage stormwater solutions that treat stormwater as a resource and provide a high level of stormwater quality control, the MECP is in the process of finalizing a *LID Stormwater Management*

Guidance Manual (G:\MOE\65732.PO - LID Manual\TOC\MARCH 2018 Final Draft). The draft manual outlines a Runoff Volume Control Target (RVCT) to be used for new development.

4 Stormwater Management Strategies (Model Development)

For the purpose of estimating and comparing impacts of various stormwater control approaches, a PCSWMM model was used to establish flows and runoff volumes for the 100-year storm.

To meet the water quality and water quantity (including flood and erosion control) requirements three (3) stormwater management strategies were evaluated. The PC SWMM model defines the impact of each alternative on flooding, erosion and water balance. This section describes the strategies and compares their ability to mitigate the impact of new development on within the Welland Northwest Subwatershed. The three (3) alternative strategies are:

1. The "**Do Nothing**" Approach
2. A "**Traditional Stormwater Management**" approach relying primarily on end-of-pipe facilities for water quality and water quantity control.
3. A "**Traditional Stormwater Management and LID**" approach relying primarily on source and conveyance controls to provide water quality control while relying on end-of-pipe facilities for flood mitigation requirements.

4.1 Alternative 1 - Do Nothing

Alternative 1 represents the "Do Nothing" scenario in which future development proceeds without any stormwater management controls. For this purpose, the long-term land use (**Figure 4-1**) which has been provided by SGL was used in the model. All the proposed ponds were taken out of the model and flows were defined.

4.2 Alternative 2 – Traditional SWM Strategy

In this alternative, the SWM ponds are in place where development is proposed. **Figure 4-2** illustrates the preliminary location and approximate size of the proposed stormwater management facilities (SWM Ponds). The light blue lines illustrate the approximate drainage areas to each SWM pond.

It should be noted that SWM facilities SWMF 2.1 and SWMF 2.3 have been located in such a manner to avoid a higher density node at the intersection of Rice Road and Quaker Road. An overland/below ground drainage easement of approximately 20 m (see Figure 4.2) will be required to convey flows from the outlet of SWMF 2.3 to the receiving stream.

4.3 Alternative 3 - Traditional plus Low Impact Development

In this alternative, the impact of proposed development will be addressed through the use of LID measures as well as dry storage stormwater ponds to control 100-year post-development peak flows to pre-development levels.

A perforated pipe system was modeled for all proposed land uses. The PCSWMM model schematic is presented in **Figure 4-3**. The PCSWMM model does not have a perforated pipe algorithm, the infiltration trench algorithm was selected as a surrogate based on the alternatives available in the PCSWMM model. Infiltration trenches are excavations backfilled with stone aggregate used to capture runoff and infiltrate it into the ground (Guo, 2001). From our extensive LID modelling experience and past projects, infiltration trenches have been used to represent perforated pipe systems and to appropriately simulate response times, as well as the allocation of infiltration, filtration, and detention mechanisms.

Generally, there are two (2) approaches for placing LID controls within subcatchments:

1. place the LID control in an existing subcatchment that will replace an equal amount of non-LID area from the subcatchment,
2. create a new subcatchment devoted entirely to just a single LID practice.

The first approach which is a simplified approach, consistent with the requirements of the EA process (at this stage) was used. The "LID Controls" option within the PCSWMM model was used to define the LID values for the model. The values of the key parameters which have been used in the model and the default values in PCSWMM model are presented in **Table 4-1**.

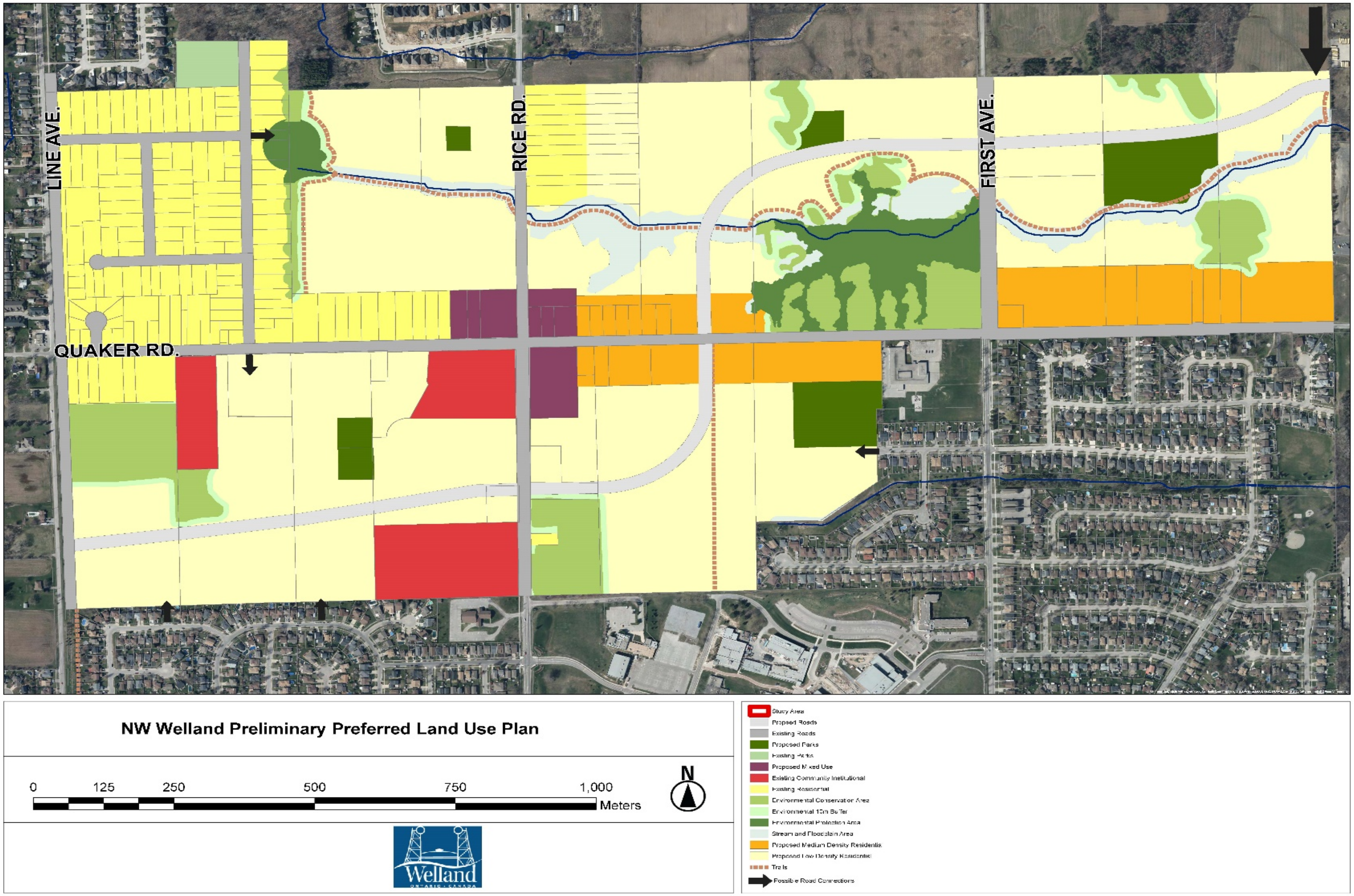

Figure 4-1: Proposed Landuse

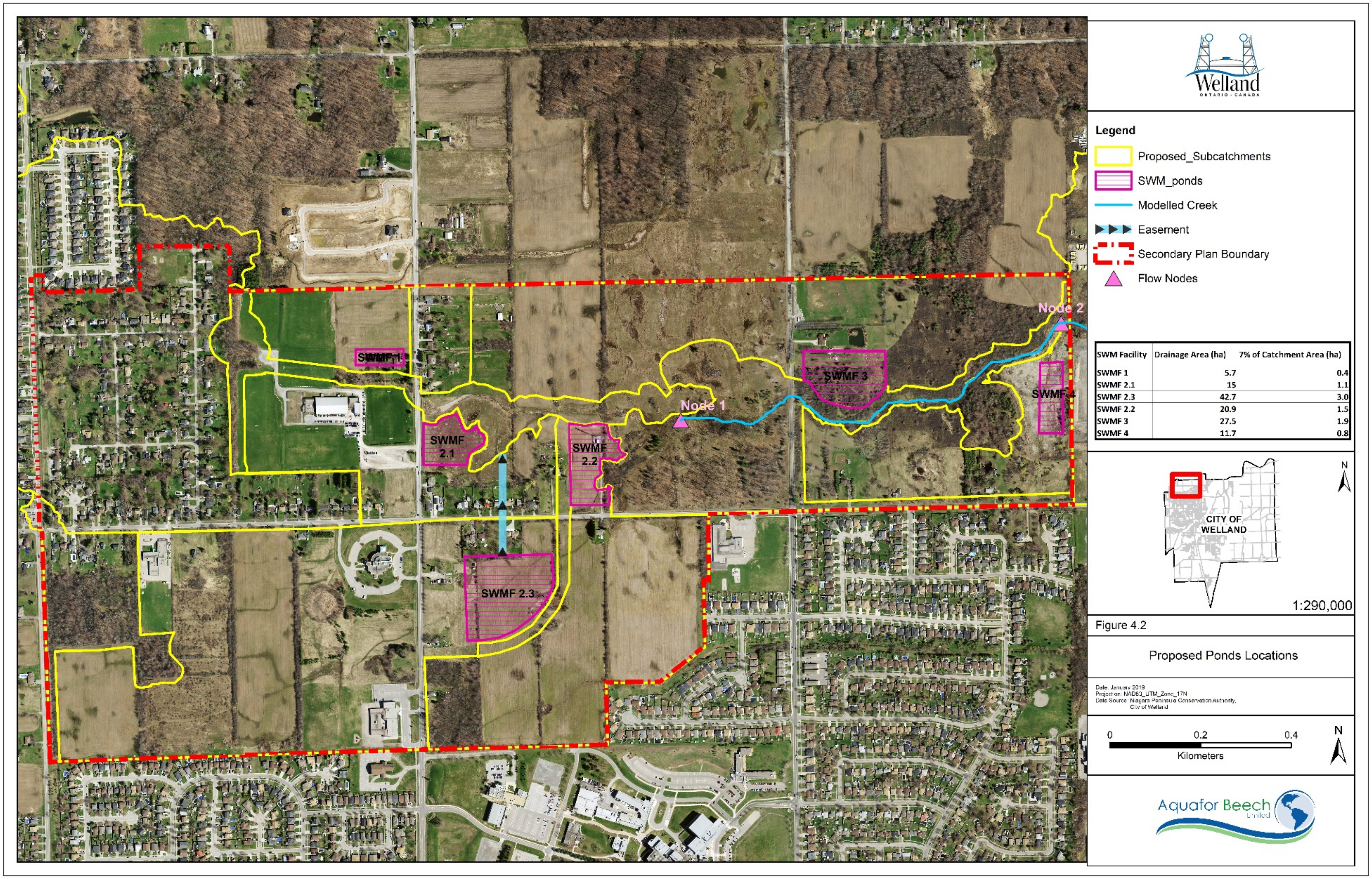

Figure 4-2: Proposed Ponds Locations

Table 4-1: LID key parameters (Non-calibrated)

Parameters	**Value in the Model**	**Default**	**Unit**	**Description**
Berm height	100	N/A	mm	Maximum depth to which water can pond within the unit before overflow occurs (in inches or mm).
Vegetation Volume (fraction)	0.0	N/A	-	The fraction of the volume within the storage depth filled with vegetation. Assuming perforated pipes are in the road way.
Surface roughness	0.3	0.1	-	Manning's n for overland flow over the surface.
Surface slope (%)	0.25	1.0	(%)	Slope
Thickness of Storage	400	N/A	(mm)	Thickness of the storage
Void Ratio of Storage	0.45	0.75	-	The volume of void space relative to the volume of solids. Typical values range from 0.35 to 0.75.
Seepage Rate	Varies (2.5-18)	0.5	(mm/hr)	The maximum allowable rate at which water infiltrates into the native soil below the layer (in inches/hour or mm/hour). This would typically be the Saturated Hydraulic Conductivity of the surrounding area.

4.4 Alternatives Model Results

Table 4-2 compares the results on a peak flow and volume basis for each of the potential development scenarios. The PCSWMM model schematic is presented in **Figure 4-3**.

Table 4-2: Summary of Estimated Flows for Alternative Scenarios within the Future Development Lands

Nodes	Existing		Alternative 1 Do Nothing		Alternative 2 Traditional		Alternative 3 Traditional + LID	
	Peak Flow (m^3/s)	Volume (ML)	Peak Flow (m^3/s)	Volume (ML)	Peak Flow (m^3/s)	Volume (ML)	Peak Flow (m^3/s)	Volume (ML)
Node 1	6.1	83.7	7.0	110	5.8	110	5.4	107
Node 2	7.5	102	9.1	142	7.5	142	6.9	138
Node 3 (TP2)	8.3	115	10.0	155	8.1	155	7.3	151

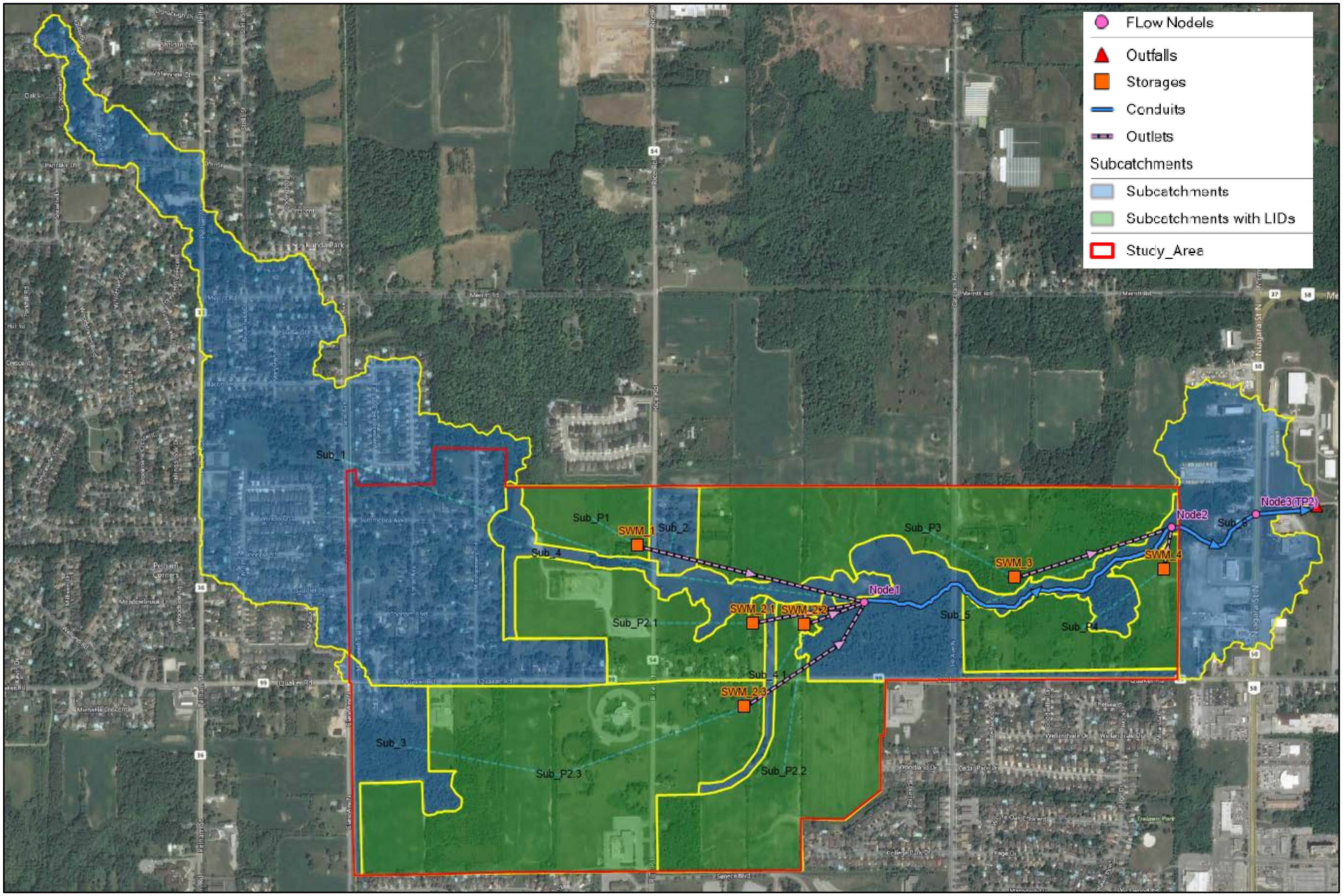

Figure 4-3: PCSWMM Model Setup

5 Stormwater Management Targets

This section outlines the recommended stormwater management target criteria to be applied to mitigate the potential water balance, water quality, flood and erosion impacts from future land use changes with the Welland Northwest study area.

5.1 Stormwater Management (Surface Water)

The Runoff Volume Control Target (RVCT) corresponds to the runoff generated from the regionally specific 90th percentile rainfall event. As a result, new projects in the Welland Northwest area will have a **water quality** target corresponding to the runoff volume generated from the local 90th percentile event (i.e. the runoff generated from approximately a 28 mm event). The runoff generated from a 28 mm rainfall event should be controlled using a control hierarchy whereby retention via LID retention technologies which utilize the mechanisms of infiltration, evapotranspiration and or re-use are preferred. The control hierarchy is shown below in **Figure 5-1**.

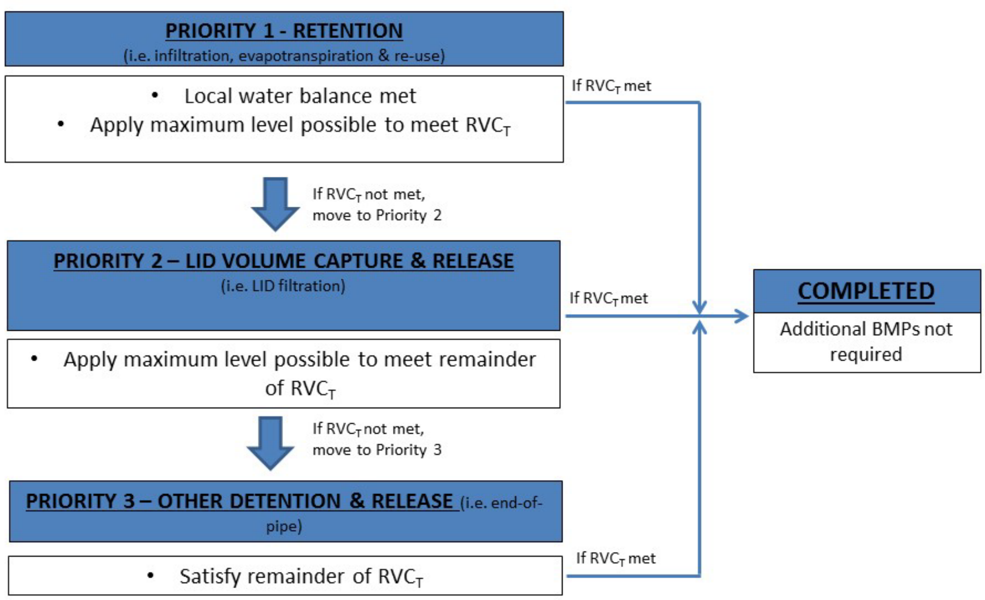

Figure 5-1: The runoff control hierarchy from the MECP's LID Stormwater Management Guidance Manual

Following the approach outlined in **Figure 5-1**, new development areas within the Welland Northwest Subwatershed are recommended to follow the following stormwater control strategy:

- The local water balance of the development area will be maintained at pre-development conditions by providing infiltration opportunities at source and/or conveyance control measures (Discussed further in **Section 3.3.1**).

- The water quality target will not vary and will remain as control of the runoff generated from a 28 mm event. Where new development areas are designed to meet the pre-development water balance and the water balance target meets or exceeds an event capture depth corresponding to the runoff generated from a 28 mm event, additional end-of-pipe water quality measures will not be required unless intended to address a project specific water quality concern identified by the City or regulatory agency. SWM quantity controls to control peak flows will still be required at the end-of-pipe.

Where the water balance targets do not meet an event capture depth corresponding to the runoff generated from a 28 mm event, the remainder of the runoff volume generated from the 28 mm rainfall event will be treated using capture and release LID filtration before discharging to the conventional storm sewer system or outlet. SWM quantity controls to control peak flows will still be required at the end-of-pipe.

5.1.1 Water Quality

The MOE Stormwater Management Planning Manual, 2003, defines specific water quality control storage targets for stormwater facilities. The targets are based on:

- The type of the facility (i.e., stormwater pond, infiltration facility, etc.);
- The landuse within the contributing area (in terms of an impervious component); and
- The level of control required

Regarding the first point above, a number of alternative stormwater measures may be used to achieve the water quality target.

Regarding the last point, a “level 1” or “enhanced” level of protection as defined in the MOE Manual (i.e., 80% long-term suspended solids removal) has been selected for use in the study area.

5.1.1.1 If LID is Not Applied:

If no LID is utilized, the water quality control storage targets for stormwater facilities (i.e. wet pond in Welland NW) will be defined based on the MOE Stormwater Management Planning Manual, 2003 as noted above. To provide control for anticipated future developments within the Welland NW study area, the MOE Stormwater Management Planning Manual indicates the following target storage volumes for level 1 water quality control:

- Low density residential development (approx. 40% impervious) - 150 m^3/hectare;
- Medium density residential development (approx. 50% impervious) - 175 m3/hectare;
- High density residential development (approx. 60% impervious) - 200 m3/hectare;
- Commercial (approx. 70% impervious) – 225 m3/hectare;

- Industrial (approx. 80% impervious) - 240 m3/hectare;

Of these targets, 40 m^3/ha is provided as extended detention or “active” storage, while the remainder is provided as permanent pool storage (MOE, 2003).

5.1.1.2 If LID is Applied:

LID source controls are recommended primarily to achieve the water balance objectives. However, many of the LID source and conveyance control techniques also provide water quality control benefits through the reduction of runoff volumes and/or filtration of runoff.

The water quality target will not vary and will remain as control of the runoff generated from a 28mm event. Where new development areas are designed to meet the pre-development water balance and the water balance target meets or exceeds an event capture depth corresponding to the runoff generated from a 28 mm event, additional end-of-pipe water quality measures will not be required unless intended to address a project specific water quality concern identified by the City or regulatory agency. SWM quantity controls to control peak flows will still be required at the end-of-pipe.

Where technical constraints prevent infiltration and filtration practices from treating the runoff generated from the 28mm event, conventional end-of-pipe systems including oil and grit separators and stormwater management facilities will be implemented to provide the appropriate level of treatment (enhanced-level corresponding to a log-term TSS load reduction of 80%). SWM quantity controls to control peak flows will still be required at the end-of-pipe.

5.1.2 Water Balance Target

5.1.2.1 If LID is Not Applied:

Nothing is applicable.

5.1.2.2 If LID is Applied:

As noted in Section 4.1, the impervious surfaces associated with future urban development will reduce the capacity of the site to infiltrate rainfall events into the groundwater system, creating an increase in the volume of surface runoff instead. For the Welland Northwest subwatershed Thornthwaite and Mather model was used to estimate existing infiltration values on a yearly basis.

The water budget analysis is a comprehensive examination of the hydrological cycle based on the following expression:

$$\text{Precipitation (P)} = \text{Evapotranspiration (ET)} + \text{Runoff (R)} + \text{Infiltration (I)}$$

A basic water budget was prepared for the existing land use condition using monthly values of precipitation and temperature for the Welland Airport meteorological station (Environment Canada).

As presented in **Table 5-1**, on average, the area receives approximately 1029.4 mm of precipitation per year. Evapotranspiration (ET) was calculated according to the Thornthwaite and Mather model (Thornthwaite and Mather, 1957) which uses an accounting procedure to analyze the allocation of water among various components of hydrologic system. This has been done with the help of a computer program which allows the calculation of the parameters to be accomplished in a more efficient and timely manner. Inputs to the model are monthly temperature and precipitation.

Table 5-1: Thornthwaite Evapotranspiration Components

Month	**Average Precipitation (mm)**	**Average Temperature (^oC)**	**Potential ET (mm)**	**Actual ET (mm)**
January	87.7	0.2	0.3	0.3
February	47.9	0.0	0.0	0.0
March	63.7	1.5	5.7	5.7
April	74.2	7.8	35.5	35.5
May	95.5	13.5	76.1	75.6
June	69.1	19.4	119.6	107.0
July	106.5	21.9	138.8	122.7
August	90.7	21.5	120.9	98.5
September	107.7	17.7	87.4	80.9
October	93.9	10.6	43.2	42.8
November	101.3	5.8	17.7	17.7
December	91.3	0.8	2.0	2.0
Average/Total	1029.4	10.0	647.1	588.7

Note: *when mean monthly temperatures fall below 0^oC, the Thornthwaite and Mather assumes the evapotranspiration does not occur.*

Using a water retention value of 250 mm (corresponding to moderately deep-rooted vegetation in a silt loam soil) the estimated annual predevelopment evapotranspiration over the Welland NW area is approximately 558.7 mm (**Table 5-2**).

The computed evapotranspiration values were then used to estimate annual and monthly water surplus. The results of the water budget analysis highlight the importance of infiltration and evapotranspiration in the natural hydrological cycle (i.e. predevelopment) of the study area. Considering the flat topography and silty clay soil type of the Welland NW area, the infiltration factor of the 0.3 was used to estimate the infiltration value.

Table 5-2: Water Budget for the Dingman Study Area

Water Budget Component	Source of Information	Value (mm/year)
Annual Precipitation (P)	Environment Canada	1029.4
Actual Evapotranspiration (ET)	Thornthwaite & Mather monthly calculation	588.7
Water Surplus	P – ET	440.7
Infiltration	-	132.2
Runoff	-	308.5

The period of 2000-2006 was selected specifically with this objective in mind, as this period of rainfall data contained annual rainfall depths ranging from 843-1227 mm per year and was selected to represent wet, dry and average years and represent a real-world approach for infiltration target development.

The Thornthwaite methods provide an annual infiltration rate of 132.2 mm/year on a watershed basis. Given that there are approximately 56 rainfall events per year the average infiltration rate per event is relatively modest (2-3 mm per event). The actual values on a site by site basis will vary depending on soil type, slopes, vegetation cover and depth to water table.

The above recharge targets can be achieved by incorporating appropriate LID source and conveyance control measures as outlined in **Section 4** together with the requirements to meet the Water Quality targets as noted above in **Section 5.1.1** above. Collectively the LID measures should ensure that post development infiltration rates equal or exceed pre development levels.

5.1.3 Flood Control Target

This section will address the flood control strategy for up to the 100-year design storm to ensure that proposed development does not increase flows within the Welland NW study area.

As noted in **Section 4.3.2**, without appropriate stormwater controls, the impervious surfaces associated with future urban development will result in increased runoff volumes rates, which in turn can result in increased flooding and erosion in downstream receiving streams. Therefore, it is understood that future land use changes within the Welland NW study area will require stormwater detention facilities to control future runoff rates to pre-development levels.

The necessary stormwater detention can be provided within the end-of-pipe stormwater ponds as recommended as part of the preferred stormwater strategy (**Section 5.2.5**), or within traditional on-site controls generally applicable for small sites less than 5 hectares (Alternate stormwater management strategy).

The PCSWMM model which was used to estimate flow rates along the Tow Path creek, was also applied to estimate storage requirements for future stormwater detention facilities. For this analysis, a design storm approach was applied. The 12-hour AES storm distribution derived from Central Welland River Floodplain Mapping Study (Aquafor, 2012) was found to produce the highest runoff rates and was therefore used in the stormwater facility sizing analysis.

The modelling steps used in the stormwater facility sizing analysis are summarized below:

- The hydrologic model was used to estimate the pre-development flows for catchments within the future development lands.
- The model was then adjusted to include proposed future development, using imperviousness values.
- The Water Quality Capture Volume (WQCV) was estimated using drainage area and the imperviousness based on the MOE recommendations (Low Impact Development Stormwater Management Guidance Manual, 2019). The storage volume was assumed to be equal to the RVCT.
- The storage was connected to the drainage system (and the depth was expanded) to simulate proposed stormwater facilities.
- For flood (quantity) control, storage volumes were increased within the model reservoirs until the runoff rates for the 100-year storm events were controlled back to pre-development rates (see **Table 4-2**).

There are 5 SWMF facilities proposed. The list of the proposed ponds and stormwater control facilities and their storage volumes are presented in **Table 5-3**.

Table 5-3: Summary of Conceptual Stormwater Management Ponds

SWM Facility	Drainage Area (ha)	7% of Catchment Area (ha)	Storage Volume (m^3)	Volume (m^3/ha)
SWMF 1	5.7	0.4	3312.0	581.1
SWMF 2.1	15	1.1	11760.0	784.0
SWMF 2.3	42.7	3.0	37661.4	882.0
SWMF 2.2	20.9	1.5	15277.0	731.0
SWMF 3	27.5	1.9	17527.0	637.3
SWMF 4	11.7	0.8	8372.3	715.6

5.1.4 Erosion Target

5.1.4.1 If LID is Not Applied:

If the LID is not applied in the drainage area, then the Distributed Runoff Control (DRC) approach (MOE, 2003) will be used to evaluate the traditional SWM erosion control targets. This method deals with design for end-of-pipe facilities with the primary objective to release stored water at a rate which is consistent with meeting established erosion control targets.

Detention storage volumes for erosion control will be estimated using the "Distributed Runoff Control", as outlined in 2003 MOE Stormwater Management Planning and Design Manual. This approach is required for the following:

- Outflows from the detention facilities for the 2-year storm were controlled to predevelopment rates; and
- Outflows from smaller storm events were over controlled to a target equal to (20-30) % of 2-year release rate in order to minimize potential in-stream erosion from these more frequent storm events.

5.1.4.2 If LID is Applied:

As was shown in Section 4.4, implementation of LID measures on a tributary basis will maintain or reduce runoff volumes to predevelopment levels.

As presented in **Table 4-2**, given the balancing of flow volumes and based on the LID measures which are required to meet water quality and water balance targets, the recommended preferred alternative for SWM is expected to meet the erosion control requirements.

6 Implementation

6.1 General

The focus of this chapter is to provide guidance for the future work required to implement the concept plan for Welland Northwest area. This includes direction with respect to future studies, timing/phasing of the works, policy/design guidance, and approvals.

6.2 Stormwater Management Controls

Stormwater management controls consist of the recommended works required to mitigate the impacts from proposed future development. This includes:

- Traditional stormwater management strategy which provides flood, water quality and erosion but not water balance control;
- Dry ponds with Low Impact Development (LID) source control techniques which provides flood, water quality and erosion and water balance control. Adding LIDs will help to meet water quality, water balance and erosion requirements.

The PCSWMM model was used to define flows for existing and proposed development conditions. **Table 5-3** of this document summarizes the names, type, drainage area and flood storage requirements for each of the proposed facilities. The location of the proposed facilities is shown in **Figure 4-3**.

6.2.1 The City of Welland Municipal Standards

The City of Welland Municipal Standards – Chapter 11 Stormwater Management (August 2013) provides direction with respect to a number of items that are required to undertake conceptual and detail design of stormwater measures. Provided below is an overview of each of the major sections within the design document together with cross-referencing to this study.

Chapter 11.2 – Storm Drainage Policies

This section summarizes policies and guidelines affecting Stormwater Management in the City of Welland (see Table 11.2 of the Municipal Standards. The design references that are provided are sufficient for undertaking the conceptual and design components for stormwater works.

One additional reference that can be utilized is the pending MECP Climate Change Low Impact Development Stormwater Management Guidance Manual https://municipalclassea.ca/files/7_DRAFT_MOECC_LID%20SWM%20Manual.pdf).

This section also provides direction with respect to the City of Welland's expectations related to the water quality and water quantity controls as well as an introduction to a runoff control hierarchy to satisfy water quality, erosion, quantity and water balance requirements.

Furthermore, the section also outlines details with respect to catchment delineation, overland flow routes and hydrologic modelling.

The approach used in this study is generally consistent with the approach and associated values used in the City of Welland document. The PCSWMM model was used to define flows and calibration of the model was carried out based on the flow and meteorological data that was available.

Chapter 11. 3 -Stormwater Quantity and Quality Management

This section provides guidance on current stormwater management practice advocates the consideration of SWMP's on a hierarchical basis, whereby more pro-active techniques are considered first. In this section, the SWMP's are grouped under the following headings in order of preferred application:

i) Lot level techniques, and Source Controls, and Alternative Development Standards
ii) Transport or Conveyance Controls
iii) End-of Pipe Management Techniques

Table 11.2 of the Municipal Standards constitutes a comprehensive list of currently available techniques associated with each of the foregoing categories. It is recognized that stormwater management remains an emerging science, hence this list will change over time. It will be the responsibility of the proponent to demonstrate that any technique, not currently approved by the City, will address the intended function within expected maintenance and cost parameters, to the satisfaction of the City of Welland.

As documented in section 4 of this report, Alternatives I and iii were selected as preferred means to provide the required stormwater management works for new development.

In Ontario, the Toronto Region Conservation Authority (TRCA), Credit Valley Conservation (CVC) and Lake Simcoe Conservation Authority (LSRCA) are supporting a Wiki based "living design manual" on the Sustainable Technologies website: https://wiki.sustainabletechnologies.ca/wiki

This is a key resource for consultants as well as the public with respect to general information and design considerations surrounding LID systems.

Chapter 11.5 Stormwater Information Requirements

This section summarizes different planning studies which has been identified for the City of Welland including: Watershed Plans, Sub-watershed Plans, Sub-watershed Impact Studies and Stormwater Management Plans.

6.2.2 Future Study Requirements

This report outlines the requirements for future studies to be completed in support of the implementation of various components of the recommended Stormwater Management strategies.

For instance, the stormwater management requirements for the Welland Northwest area will be identified at a conceptual level of detail. The implementation of these recommendations will require further, progressively more detailed studies at both the "catchment" and "site" level, as development planning proceeds.

Stormwater Management Plans are prepared in support of individual development applications. The plans complement the planning process associated with draft plans of subdivision or individual site plans. Stormwater management reporting associated with this planning stage would be the "Functional Design" plan. Subsequently, in support of final subdivision design, a "Detailed Design" plan is required.

Consistent with the City of Welland 2013 Municipal Standards these types of studies have been classified according to their level of design:

Functional Design

This level of design typically involves demonstrating the feasibility of providing storm water management for a particular development. In areas where no Sub-watershed Plan has not completed, the stormwater Management Plan will be required to address additional issues such as environmental baseline conditions and screening of various storm water management strategies and techniques.

Detailed Design

The detailed design submission shall demonstrate how the required information, outlined in Functional Design report, has been integrated as well as addressing details related to minor system design detail, landscaping, safety and maintenance aspects of facility design, and monitoring requirements.

7 References

Earth Tech Canada. (2003). *Northwest Area Planning and Servicing Review Class Environmental Assessment - Environmental Impact Study.*

Earth Tech Canada. (2008). *City of Welland Northwest Area Planning and Servicing Study Municipal Class Environmental Assessment.*

Environment and Climate Change Canada. (2016). *Management Plan for the Monarch (Danaus plexippus) in Canada.*

Environment Canada. (2010). *Recovery Strategy for the Butternut (Juglas cinerea) in Canada.*

Heagy, A., Badzinski, D., Bradley, M., Falconer, M., McCracken, J., Reid, R., & Richardson, K. (2014). *Recovery Strategy for the Barn Swallow (Hirundo rustica) in Ontario. Ontario Recovery Strategy Series.*

MNRF. (2015). *Significant Wildlife Habitat Criteria Schedule for Ecoregion 7E.*

Niagara Region. (2014). *Regional Official Plan.*

NPCA. (2010). *Central Welland River Watershed Plan.*

NPCA. (2011). *Policies, Procedures, and Guidelines for the Administration of Ontario Regulation 155/06 and Land Use Planning Policy Document.*

Oldham, M. J. (2010). Checklist of the Vascular Plants of Niagara Regional Municipality, Ontario. In NPCA, *Natural Areas Inventory, 2006-2009.* Welland: NPCA.

Ontario Ministry of Municipal Affairs and Housing. (2014). *Provincial Policy Statement.*

Ontario Ministry of Municipal Affairs and Housing. (2017). *Growth Plan for the Greater Golden Horseshoe.*

Welland, C. o. (2013). *City of Weland Municipal Standards.* City of Weland: City of Weland.