PROJECT FILE REPORT

DON MILLS CHANNEL FLOOD REDUCTION STUDY

FINAL REPORT ▪ JULY 2018

REPORT PREPARED FOR

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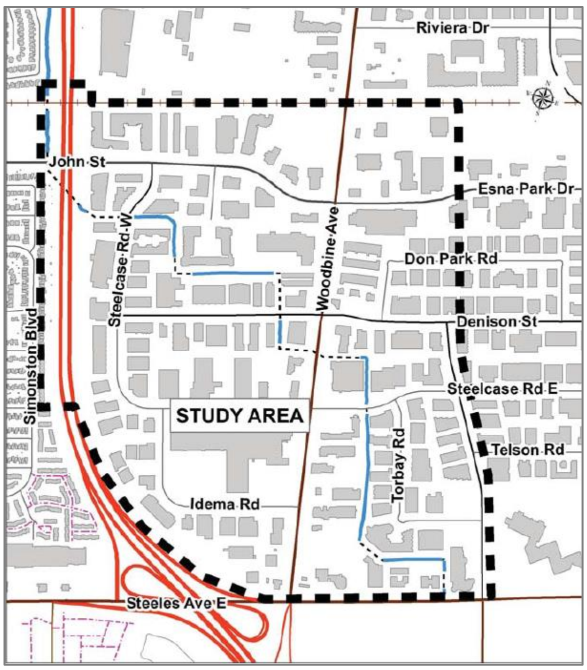
EXECUTIVE SUMMARY

The Municipal Infrastructure Group Limited (TMIG) was retained by the City of Markham to determine the most appropriate means of reducing flooding along the Don Mills Channel. The Don Mills Channel emerges as an open channel system at Steeles Avenue, and flows in a northerly and westerly direction to cross under Highway 404 south of John Street. From there, the channel continues north along the west side of Highway 404 for a short distance before flowing west to join German Mills Creek near Leslie Street and Green Lane. The study area, illustrated in **Figure ES-1**, represents the lands adjacent the Don Mills Channel that are potentially impacted by flooding or could potentially impacted by any solutions to reduce flooding. The study area is generally bound by Steeles Avenue to the south, the CNR corridor to the north, Victoria Park Avenue to the east and Highway 404 to the west.

Figure ES-1 Study Area



The Don Mills Channel study area was developed in the 1960's, prior to the adoption of modern stormwater management practices to control the quantity and quality of storm runoff. As part of the development of the area, the Don Mills Channel was transformed from a natural watercourse through agricultural lands to the realigned and confined system of channels and culverts that exist today. Consistent with practices at the time of development, the realigned Don Mills Channel was designed to convey the runoff from a 5 year storm event, with no provision for flows from larger, less frequent events. A number of sections of the channel were subsequently enclosed in culverts to facilitate industrial development. These enclosures, combined with the lack of planning for conveyance of storm runoff for storms greater than the 5 year event, have resulted in frequent flooding in the study area.

The first well documented occurrence of flooding from the Don Mills Channel occurred in August 1985 from a storm estimated to be between a 10 year and 25 year return period event. The study area was impacted by another severe storm on August 19, 2005 that dropped roughly 100 mm of rainfall over a study area in a little over 2 hours (Clarifica, 2005). That storm, estimated to be in excess of a 100 year event, resulted in severe flooding of many properties near the Don Mills Channel. The Don Mills Channel again experienced flooding from moderate return period storm events on July 27th and August 1st, 2014.

Previous studies to mitigate flooding from the Don Mills Channel concluded that any feasible flood reduction solutions would be extremely expensive and challenging, and no adequate funding sources available for their construction. In response, the City of Markham completed its Stormwater Funding Study to identify annual funding requirements to remediate areas in the City at risk of flooding, including the Don Mills Channel, and began charging a new City-wide Stormwater Fee in 2015 to fund flood remediation works. With a source of funding established, the City of Markham initiated the Don Mills Channel Flood Reduction Municipal Class EA study to determine the preferred solution to reduce flooding and flood damages from the Don Mills Channel and plan for its implementation.

The study area is fully developed for commercial and industrial development, and is designated as Commercial and Employment (several categories) in the City of Markham Official Plan. The past development of the area, prior to emergence of modern environmental protections and stormwater management practices, has resulted in very limited and degraded terrestrial and aquatic habitat through the study area. Numerous portions of the channel have been impacted by erosion, and several of the culverts along the Don Mills Channel are nearing the end of their serviceable life.

A detailed PCSWMM 2D model of the Don Mills Channel and catchment area was developed as part of this study to better understand flooding conditions through the study area. The PCSWMM 2D simulates hydrologic conditions and routes the generated runoff through representations of the existing on-site peak flow controls, storm sewers and overland flow routes leading to the Don Mills Channel, and the hydraulics of the Don Mills Channel itself. The 2D component of the model simulates flow paths and flooding through the study area when water overtops the banks of the Don Mills Channel during severe storm events. The model was validated against observed high water levels from the severe storms of 2005 and 2014, and was used to predict flooding conditions for the 2 year through 100 year return period storm events. The PCSWMM model confirmed that the channel cannot contain runoff from the 2 year storm event, and predicts that 8 buildings will be flooded in a 5 year storm (flood levels above finished floor elevations) and 18 buildings flooded in a 100 year storm. Average annualized damages, representing the product of risk x damages, is estimated at approximately $1.7 Million per year.

A number of different solutions were developed to reducing flooding and/or flood damages from the Don Mills Channel and are briefly summarized below.

- <u>Status Quo</u>: The City would continue to regularly inspect and maintain the Don Mills Channel, and continue to require redevelopment in areas draining to the Don Mills Channel to significantly over-control storm runoff.
- <u>Enhanced Channel Maintenance</u>: All woody vegetation would be cleared and the Don Mills Channel would be maintained with regularly mown side slopes
- <u>Channel Widening with Culvert Replacements</u>: Up to 24 properties abutting the existing Don Mills Channel would be acquired, and the channel would be reconstructed as an approximately 60 m wide natural watercourse and valley corridor. The existing culverts at Steelcase Road East, Woodbine Avenue, Denison Street and Steelcase Road West would be replaced with much larger structures, and all other piped sections would be replaced by the natural channel corridor
- <u>Acquisition of Flood Prone Properties</u>: Up to 16 properties at risk of flooding in a 5 year storm event would be secured in public ownership, the existing structures would be demolished and the properties would be restored as parks or open space.
- <u>Underground Flood Control Storage</u>: Approximately 40,000 m^3 of storage would be created through construction of storage tanks under parking lots or other portions of existing developed sites at appropriate locations in the study area. The underground storage tanks would reduce the rate and potentially also reduce the volume of water delivered to the Don Mills Channel during flood events, and also improve water quality and baseflow in the Don Mills Channel by infiltrating runoff from small storm events.
- <u>Central Municipal Flood Control Storage</u>: Several properties upstream (south) of Steelcase Road East would be acquired to allow construction of a large flood storage facility immediately adjacent the Don Mills Channel. A flow control structure would be constructed across the channel to restrict flow rates and back stormwater up into the facility during severe storm events.

- Flow Diversion: A large storm sewer would be constructed on Steelcase Road East and West to capture high flows and divert them away from the most flood prone areas, returning the flow to the Don Mills Channel just upstream of Highway 404.
- Flood Proofing and Education: Instead of reducing flooding from the Don Mills Channel, flood damages would be reduced by retrofitting buildings to prevent water from entering during flood events, and by encouraging implementation of best management practices to reduce damages to both indoor and outdoor areas on private property.
- Combined Alternative: This alternative would include the central municipal flood storage facility, replacement of the culverts at Steelcase Road East, Woodbine Avenue, Denison Street and Steelcase Road West, and a flood proofing and education program.

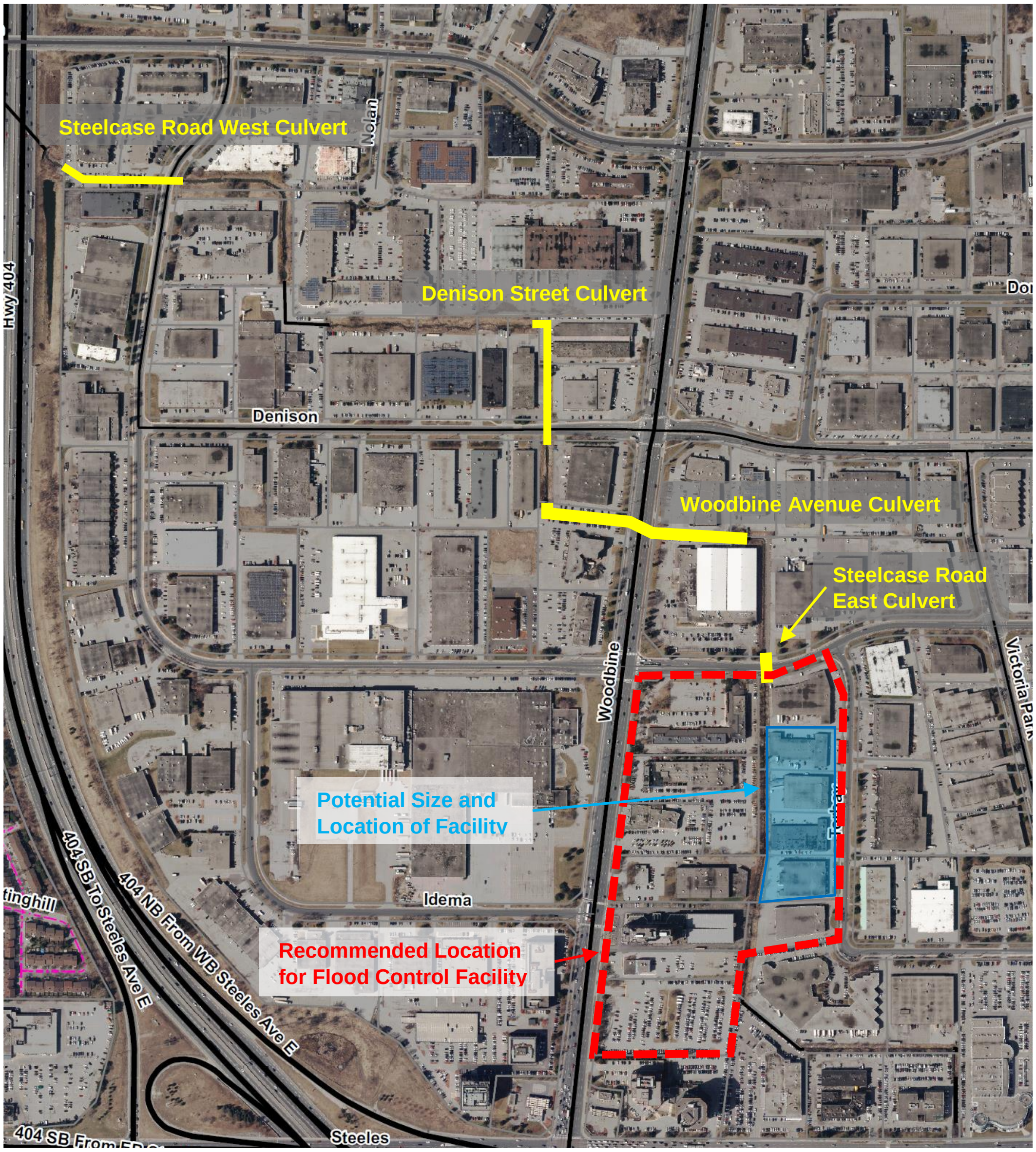
The alternative solutions were evaluated against a number of criteria considering the natural environment, social and cultural impacts, technical effectiveness and challenges and cost. The preferred solution to reduce flooding and flood damages from the Don Mills Channel is the Combined Alternative. This solution involves the construction of a central municipal flood storage facility upstream (south) of Steelcase Road East with a storage volume of approximately 37,000 m^3, replacement of the existing corrugated steel pipe culverts at Steelcase Road East, Woodbine Avenue, Denison Street and Steelcase Road West with 12 m to 15 m open span concrete structures, and implementation of a flood proofing and education program that can be expanded to other flood vulnerable areas in the City of Markham. The works are expected to cost approximately $69 Million to implement and will reduce average annualized flood damages from $1.7 Million to $0.2 Million.

Table ES-1 Evaluation Summary

Alternative	Capital Cost	Operation and Maintenance Costs	Resulting Average Annualized Flood Damages	Selection Notes
Status Quo	None	Low	$1.7 Million (no reduction)	Not selected. There is no reduction in flood damages in the short and medium terms
Enhanced Channel Maintenance	Very Low	Low-Medium	$1.7 Million (no reduction)	Not selected. The existing culverts govern the overall system capacity, and removal of channel vegetation will have no impact on flooding
Channel Widening with Culvert Replacements	Very High	Low	$0	Not selected. The cost and challenges to acquire up to 24 properties are prohibitive
Acquisition of Flood Prone Properties	Very High	Low	$0.5 Million	Not selected. The cost and challenges to acquire up to 16 properties are prohibitive, and it will not reduce flooding on roadways and the non-acquired properties
Underground Flood Control Storage	Medium	High	$0.6 Million	Not selected. There are significant challenges to construct and maintain storage facilities on existing developed private properties
Central Municipal Flood Control Facility	Low-Medium	Low-Medium	$0.9 Million	Not selected. The facility does not reduce flooding sufficiently to prevent damages in a 5 year storm event
Flow Diversion	Low	Medium	n/a[1]	Not selected. The diversion would result in unacceptable increases in the depth and frequency of flooding on Highway 404
Flood Proofing and Education	Low	Medium	$0.9 Million	Not selected. There are significant challenges to implement flood proofing measures at all flood vulnerable properties, and it will not reduce flooding on roads and parking lots
Combined Alternative	Medium	Low-Medium	$0.2 Million	**Selected**. The combined works will prevent damages in a 5 year storm event and can be reasonably implemented in a relatively short period of time

[1] Flood damages were not calculated as the alternative in not reasonable/feasible

Figure ES-2 Preferred Solution – Combined Alternative



It is recommended that the central municipal flood storage facility be constructed first, as it can be implemented relatively quickly and achieves over half of the total reduction in flood damages associated with the combined alternative. The culvert replacements should proceed from downstream (Steelcase Road West) to upstream (Steelcase Road East) if feasible, but additional analyses have confirmed that, if warranted due to condition or timing for other roadway improvements, any culvert can be replaced in isolation with no concerns for upstream or downstream flood impacts.

A number of additional studies are recommended to facilitate implementation of the preferred solution, including detailed topographic surveys, geotechnical and hydrogeological investigations, utility investigations, Environmental Site Assessments for any acquired properties and an Environmental Impact Statement to ensure that the central municipal flood storage will achieve a net overall benefit to the natural environment.

A permanent flow and/or water level monitoring station is recommended in the vicinity of Steelcase Road East to refine the calibration of the PCSWMM model, and to allow comparisons to flood levels following construction of the central municipal flood storage facility.

Considerable consultation with the public, agencies and other stakeholders has taken place throughout the Don Mills Channel Flood Reduction Study. A Liaison Committee, comprised of City of Markham councillors and staff, TRCA staff and landowners, provided oversight of the project. Two Public Information Centres provided opportunities for the landowners and the public to provide feedback regarding existing conditions through the study area, input to the development of alternative solutions and feedback on the preliminary preferred solution. Numerous additional meetings took place with individual affected landowners and staff from the TRCA, York Region and MTO. All concerns raised by the public, landowners and agency staff have been considered in the evaluation of alternative solutions and have been addressed in this final Project File Report.

CONTENTS

APPENDICES

FIGURES

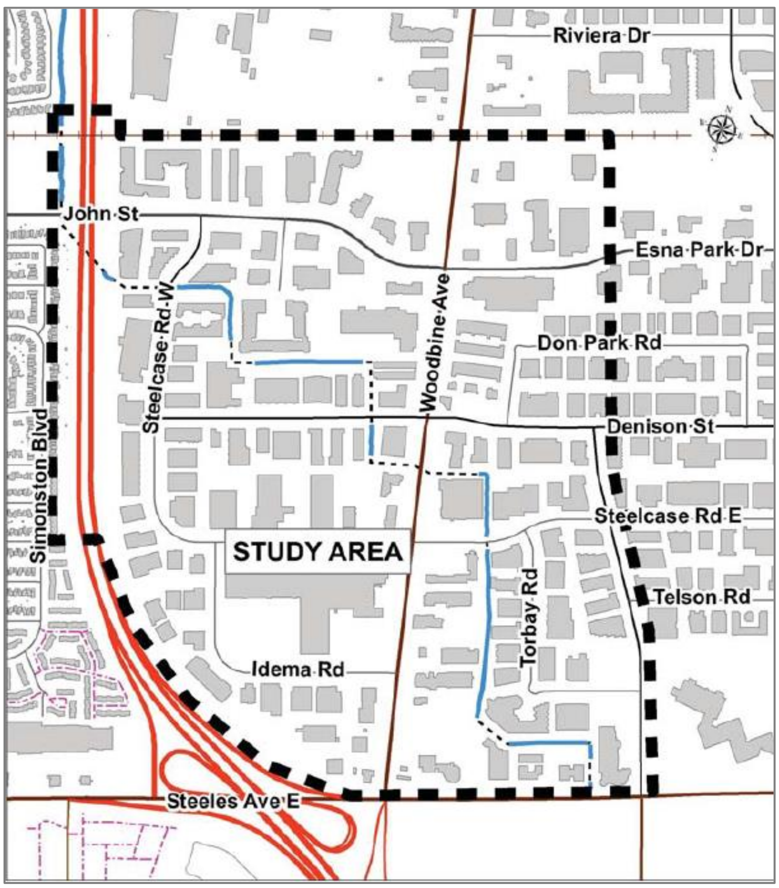
TABLES

1 INTRODUCTION AND BACKGROUND

1.1 Study Overview and Purpose

The Municipal Infrastructure Group Limited (TMIG), along with team members CHI, PECG, Archeoworks and Hunt Surveys, were retained by the City of Markham to determine the most appropriate means of reducing flooding along the Don Mills Channel. The Don Mills Channel emerges as an open channel system at Steeles Avenue, and flows in a northerly and westerly direction to cross under Highway 404 south of John Street. From there, the channel continues north along the west side of Highway 404 for a short distance before flowing west to join German Mills Creek near Leslie Street and Green Lane. The study area, illustrated in **Figure 1-1**, represents the lands adjacent the Don Mills Channel that are potentially impacted by flooding or could potentially impacted by any solutions to reduce flooding. The study area is generally bound by Steeles Avenue to the south, the CNR corridor to the north, Victoria Park Avenue to the east and Highway 404 to the west.

Figure 1-1 Study Area



Urban development though the study area has significantly altered the Don Mills Channel from its natural state. The majority of the system through the study area has been realigned and confined to a relatively narrow corridor or enclosed in culverts. The current system of culverts and channels does not have adequate capacity to convey storm runoff from large storm events, and the areas surrounding the channel have been flooded numerous times since the lands developed, beginning in the late 1960's.

This study report documents the development and evaluation of a range of potential alternative to reduce flooding along the Don Mills Channel, and sets out the funding, approvals and other activities needed for implementation of the recommended works.

1.2 Project Background

The Don Mills Channel was initially transformed from a natural state to its current alignment in the 1960's. Prior to that, the area was used for agriculture and the Don Mills Channel was a small watercourse within a broad, shallow valley. The channel and adjacent industrial lands were developed prior to the adoption of modern stormwater management practices to control the quantity and quality of storm runoff. At that time, the objective was to get stormwater off the landscape as quickly as possible. According to the design report for the channel (MMM, 1964), the system was sized for a 5 year return period storm and applied a runoff coefficient of 0.7 to the planned industrial development. The 5 year design flow ranged from 553 ft^3/s (16 m^3/s) at Steeles Avenue to 983 ft^3/s (28 m^3/s) at the then proposed Highway 404. The report proposed a trapezoidal channel with a uniform depth of 6.5 ft (2.0 m), 2H:1V side slopes and a flat base ranging from 10 ft (3.0 m) wide at Steeles Avenue to 18 ft (5.5 m) wide at Highway 404. Hydraulic calculations assumed a smooth, grassed channel with a Manning's roughness value of 0.025. The 1964 design report did not include any discussion on how runoff from storms greater than the 5 year return period event would be conveyed from Steeles Avenue to Highway 404.

The Don Mills Channel was deliberately aligned at the rear of the properties through the study area to minimize the number of crossings for driveways and laneways. With the exception of public road crossings, the channel corridor was maintained in private ownership with easements for the city to perform various functions. With the Don Mills channel generally removed from public view and largely in private ownership, a number of sections of the channel were subsequently enclosed in culverts to facilitate industrial development. These enclosures, combined with the lack of planning for conveyance of storm runoff for storms greater than the 5 year event, have resulted in frequent flooding in the study area.

The first well documented occurrence of flooding from the Don Mills Channel occurred in August 1985 from a storm estimated to be between a 10 year and 25 year return period event. A study completed in response to that storm event (CPW, 1986) concluded that some reaches of the Don Mills Channel did not have capacity for even a 2 year return period storm. Capacity was primarily governed by a number of culverts installed along the Don Mills Channel. In response, the City of Markham began requiring over-control as part of the stormwater management plans for new and re-development in the Don Mills Channel catchment area in the late 1980's.

A subsequent analysis of the Don Mills Channel was completed using the OTTHYMO computer program instead of the Rational Method to estimate the peak flows in the system (Dillon, 1989). The OTTHYMO model predicted even larger peak flow rates than the Rational Method hydrology, and similarly concluded that a number of undersized culverts limited the capacity of the channel to a fraction of the 2 year return period storm. The study then investigated several alternatives to reduce flooding, but did not generate any cost-effective solutions. Instead, the report recommended that the channel be regularly maintained and suggested limited berming to better contain the flow along particularly flood prone reaches.

The study area was hit by another severe storm on August 19, 2005 that dropped roughly 100 mm of rainfall over a study area in a little over 2 hours (Clarifica, 2005). That storm resulted in severe flooding impacting many properties near the Don Mills Channel. Following the storm, a Municipal Class Environmental Assessment (EA) was initiated to further investigate the causes of flooding and identify potential flood mitigation measures. The study included an inspection and topographic survey of existing culverts and channel sections, fish and invertebrate sampling and assessments of the vegetation and habitat along the channel. A significant component of the study was the development of an InfoWorks hydrologic/hydraulic model of the Don Mills Channel subwatershed. The InfoWorks model generated more accurate representations of the depth, direction and velocity of flow in the system once the capacity of the culverts and channels are exceeded and floodwaters spread through the surrounding development areas. The Class EA study generated two technical memoranda. The first memorandum documented the existing characteristics of the Don Mills Channel and presented the extent of flooding under existing conditions (Clarifica, 2006). The second memorandum presented and evaluated a number of alternatives to reduce the frequency and severity of flooding (Cole, 2010). Solutions examined included flood proofing existing buildings, underground storage, culvert and channel improvements, and diversion of runoff from a portion of the study area away from the most flood prone reaches of the channel. The study did not select a preferred alternative. All of the alternative solutions that could potentially reduce flooding in the system were expensive, with significant constructability and implementation challenges and no funding source available for their construction. The Municipal Class EA was not brought to completion, and priorities at the City of Markham shifted to the development and implementation of new funding tools to improve the Don Mils Channel and other areas at the City prone to flooding. The City of Markham completed its Stormwater Funding Study to identify annual funding requirements to remediate areas in the City at risk of flooding and began charging a new City-wide Stormwater Fee in 2015 to fund flood remediation works.

The Don Mills Channel again experienced flooding from large storm events on July 27th and August 1st, 2014. These events served as a reminder of the Don Mills Channel flood risks, and also provided an opportunity for City of Markham staff to observe and record high water marks and gather additional information to allow a better understanding of flooding through the study area. New hydrologic and hydraulic modelling tools are available to more accurately predict the extent of flooding from storm events and assess the effectiveness of different flood reduction solutions that weren't available when the Clarifica study was concluded in 2010.

This Municipal Class EA has been initiated to make use of the observations from the 2014 flood events and new tools to generate effective flood reduction alternative solutions that are technical feasible, can be reasonably implemented and can be funded through the City's new Stormwater Fee program.

1.3 Municipal Class Environmental Assessment Process

The planning of major municipal projects or activities is subject to the Ontario Environmental Assessment (EA) Act, R.S.O. 1990, and requires the proponent to complete an Environmental Assessment, including an inventory and description of the existing environment in the area affected by the proposed activity.

The Class EA process was developed by the Municipal Engineers Association and approved by the Ministry of the Environment, now Ministry of the Environment, Conservation and Parks (MECP), as an alternative method to Individual Environmental Assessments for recurring municipal projects that were similar in nature, usually limited in scale and with predictable ranges of environmental effects which were responsive to mitigating measures. The latest Municipal Class EA document (October 2000, amended 2007, 2011 & 2015) has been used for this study.

The Class EA provides for the following designations of projects depending upon potential impacts:

Schedule A: Projects are limited in scale, have minimal adverse environmental effects and include a number of municipal maintenance and operational activities. These projects are pre-approved. Schedule A projects generally include normal or emergency operational and maintenance activities.

Schedule A^{+}: Projects are within existing buildings, utility corridors, rights-of-way, and have minimal adverse environmental effects. These projects are pre-approved; however, the public is to be notified prior to project implementation.

Schedule B: Projects have the potential for some adverse environmental effects. The proponent is required to undertake a screening process, involving mandatory contact with directly affected public and relevant review agencies, to ensure they are aware of the project and that their concerns are addressed. If there are no outstanding concerns, then the proponent may proceed to implementation.

Schedule C: Projects have the potential for significant environmental effects and must proceed under the full planning and documentation procedures specified in the Class EA document.

Schedule C projects require that an Environmental Study Report be prepared and filed for review by the public and review agencies.

The Don Mills Channel project has the potential for some adverse environmental impacts, and therefore follows the planning procedure for Schedule B activities. The following Class EA planning phases apply:

Phase 1: Identify the problem (deficiency) or opportunity.

Phase 2: Identify and evaluate alternative solutions to address the problem or opportunity by taking into consideration the existing environment, and establish the preferred solution taking into account public and review agency input.

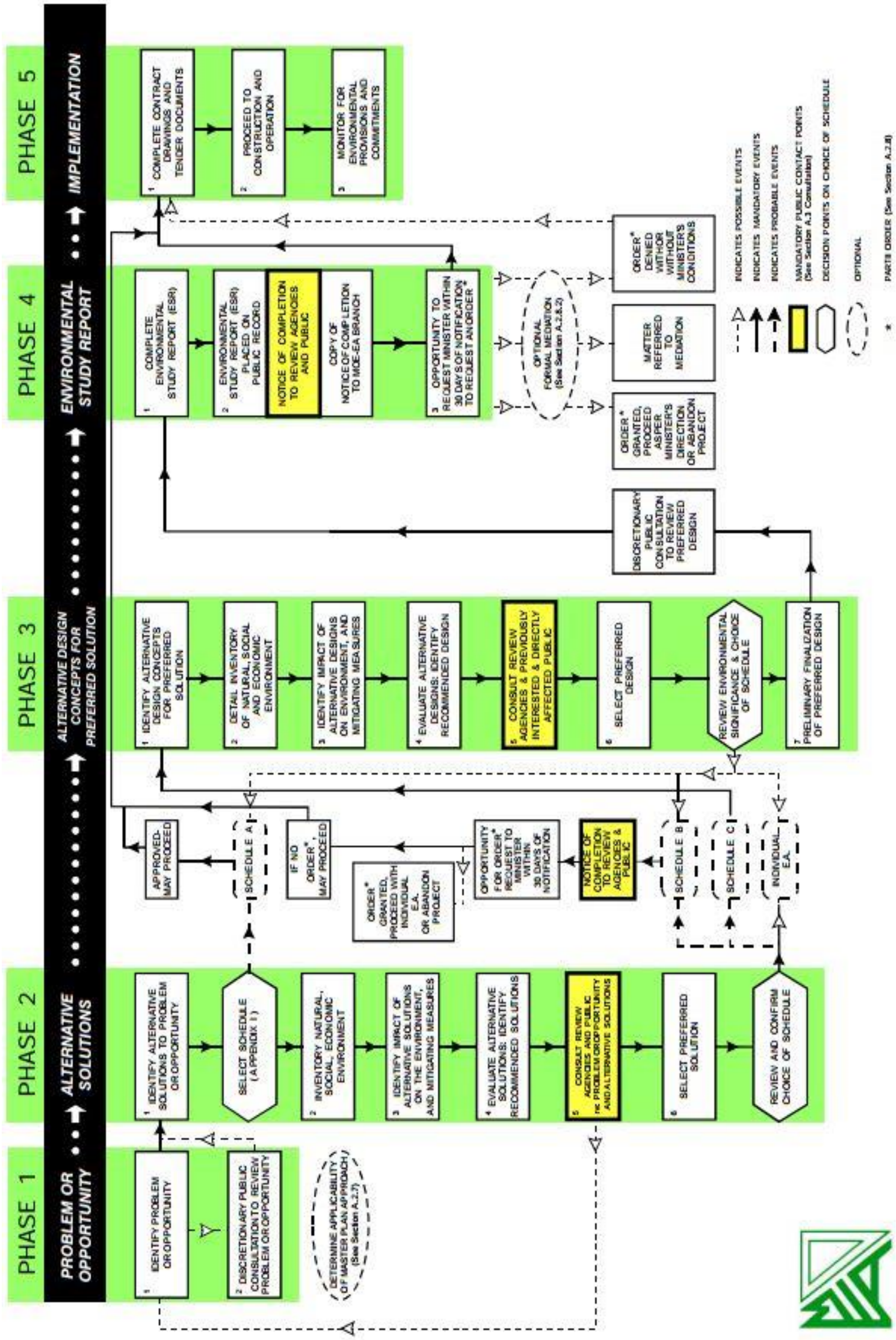
Phase 5: Complete contract drawings and documents, and proceed to construction and operation; monitor construction for adherence to environmental provisions and commitments. Where special conditions dictate, also monitor the operation of the completed facility.

The Class EA process also provides an appeal process to change the project status. Under the provisions of subsection 16 of the amended EA Act, there is an opportunity under the Class EA planning process for the Minister to review the status of a project. Members of the public, interest groups and review agencies may request the Minister to require a proponent to comply with Part II of the EA Act, before proceeding with a proposed undertaking. This is known as a “Part II Order” (formerly called “Bump-Up Request”). The Minister determines whether this is necessary with the Minister’s decision being final. The procedure for dealing with concerns which may result in the Minister, by order, requiring the proponent to comply with Part II of the Act is outlined in the Municipal Class Environmental Assessment document.

Following the end of the 30 day public review period, if there are no outstanding Part II Order Requests, the project may proceed to Phase 5 of the Class EA process to complete design and the contract drawings and tender documents, and then move on to construction.

A flow chart describing the Class EA planning and design process is shown in **Figure 1-2.**

Figure 1-2 Municipal Class EA Planning Flow Chart



1.4 Project Team Organization

The project was completed by a multi-disciplinary team led by TMIG. Key staff involved in the Study are listed in **Table 1-1**. The project was completed under the direction of a technical working group comprised of City of Markham staff from various City departments.

Table 1-1 Study Team

Name	Organization	Role
Steven Hollingworth, P.Eng.	TMIG	Project Manager
David Ashfield, P.Eng.	TMIG	Quality Assurance/Quality Control
Sumera Yacoob P.Eng	TMIG	Water Resources Engineer
Karen Finney	CHI	Model Developer
Nicola Lower	PECG	Senior Aquatic Biologist
Dirk Janas	PECG	Terrestrial Ecologist
Doug Hunt	Hunt Surveys	Surveyor
Kim Slocki	Archeoworks	Archeologist

1.5 Problem and Opportunity Statement

The majority of the existing development within the Don Mills Channel catchment area occurred prior to the adoption of modern stormwater quality and quantity control practices. Standards in place at the time of development did not consider the control of peak flow rates nor the conveyance of storm runoff beyond the capacity of the minor drainage system, which was designed for the 5 year return period storm. As a result, the Don Mills Channel does not have sufficient capacity to safely convey storm runoff from moderate to large storm events. Buildings and property within the study area have been impacted by flooding numerous times over the last three decades. Historic development within and adjacent the Don Mills Channel has also significantly impaired the natural environment associated with the channel corridor. The problem and opportunity statement is as follows:

> *To determine the preferred method(s) of managing storm runoff to reduce flooding and/or flood damages from the Don Mills Channel, while maintaining or improving water quality, erosion and aquatic and terrestrial habitat associated with the Don Mills Channel.*

2 EXISTING ENVIRONMENTS

2.1 Planning Environment

The Don Mills Channel study area is located within the City of Markham, and land use within the study area is predominantly employment. The channel corridor itself is narrow with many enclosed sections, and other open areas in the study area are limited to undeveloped industrial lots. The study area lies outside of the Greenbelt and Oak Ridges Moraine, but a number of other planning documents are relevant to the study.

2.1.1 Provincial Policy Statement

The Provincial Policy Statement (PPS) (April 2014) provides broad land use planning and development policy direction, particularly as it relates to matters of provincial interest including but not limited to the natural environment and natural hazards. The Natural Hazard policies (Section 3.1 of the PPS) generally prohibit development in areas at risk of flooding from riverine systems as well as areas that could not be safely accessed due to excessive flood depths and velocities during severe storm events. The PPS contains some exemptions to these policies, such as designated Special Policy Areas and flood fringe areas where separate policies apply. At this time, the Study Area is not designated as a Special Policy Area nor managed as a two-zone area where new development in the flood fringe could be permitted.

The PPS also includes policies to protect and preserve employment areas, particularly in proximity to major transportation corridors (Section 1.3), and policies generally promoting intensification and redevelopment in existing built-up area (Section 1.1)

2.1.2 Growth Plan for the Greater Golden Horseshoe

The Growth Plan for the Greater Golden Horseshoe (GPGGH) (May 2017) is another provincial policy document intended to guide future growth in the area. The plan is generally intended to direct future population and employment growth to existing urban areas. The plan identifies Markham Centre as an Urban Growth Centre. Markham Centre, generally located on the north side of Highway 407 between Rodick Road and Kennedy Road, is a short distance from the study area. Given the proximity to Markham Centre, major transportation corridors Highway 404 and Highway 407, and availability of transit on Woodbine Avenue, the Don Mills Channel study area plays a significant role in achieving the employment growth targets for the City of Markham and Region of York set out in the GPGGH.

2.1.3 York Region Official Plan

The York Region Official Plan is intended to guide growth at the Regional scale and provide planning direction to local municipalities including the City of Markham. The plan was adopted in 2010, but was subject to a number of appeals at the Ontario Municipal Board (OMB). The plan is in effect, and was consolidated in April 2016 with all OMB decisions and amendments.

The Don Mills Channel study area is designated ‘Urban’ in the Region’s Official Plan, and the various maps included with the Official Plan do not show any wetlands, woodlands, greenlands, or other significant natural features within the study area. Portions of the study area are designated ‘Highly Vulnerable Aquifers’ on Map 14 of the Official Plan, though it is not close to any wellhead protection areas or significant groundwater recharge areas. The policies pertaining to Highly Vulnerable Aquifers in the Official Plan (Section 2.3) state that ‘*An application for major development within highly vulnerable aquifers (as shown on Map 14) involving the manufacturing, handling and/or storage of bulk fuel or chemicals (activities prescribed under the Clean Water Act), shall be accompanied by a Contaminant Management Plan, as deemed necessary by the local municipality’*.

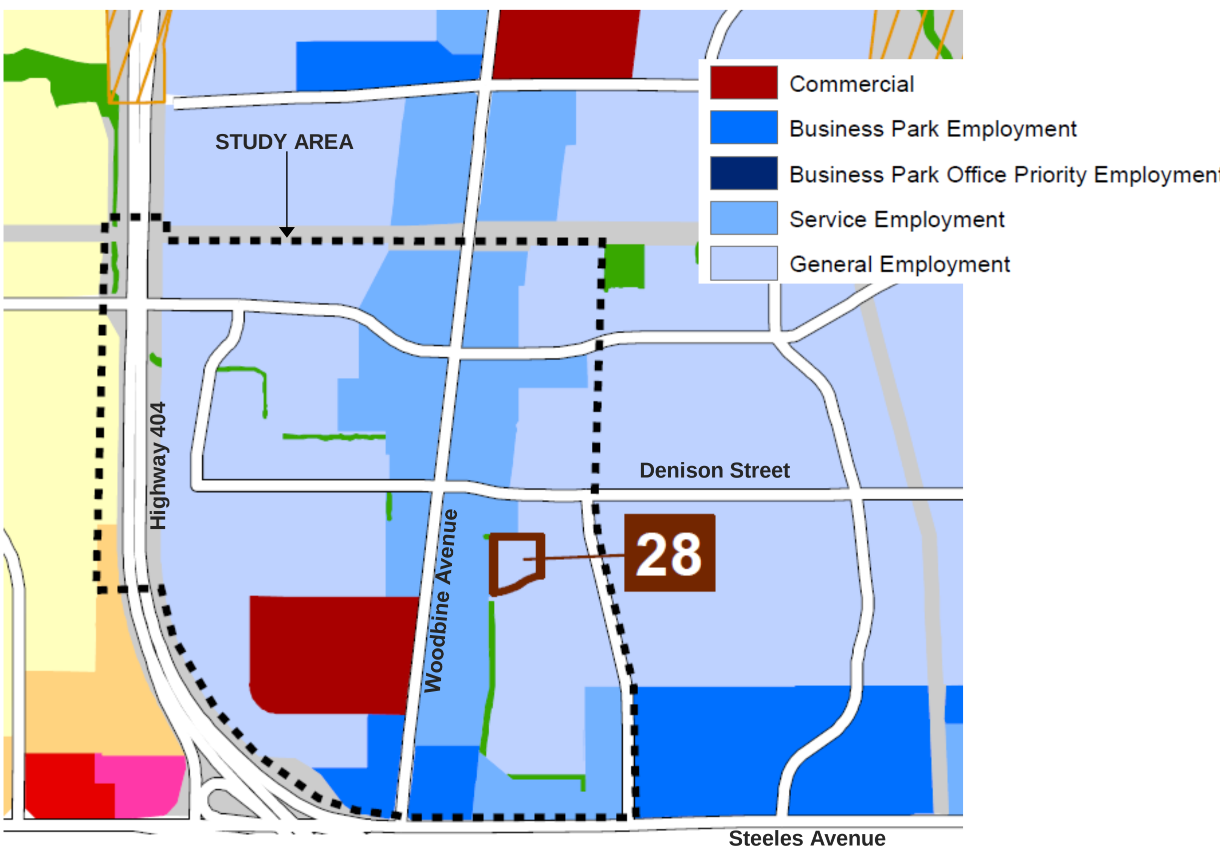
2.1.4 City of Markham Official Plan

The City of Markham Official Plan contains both broad and site-specific land use policies. The plan was adopted by the City in 2013 and approved by York Region in 2014, but has been appealed to the Ontario Municipal Board (OMB). The OMB issued a partial approval of the Official Plan in April 2017, bringing parts of the plan in force. Until an OMB decision to approval all or part of the new Official Plan, the City's 2987 Official Plan will continue to remain in force.

The Don Mills Channel study area is generally designated as an employment area in the City's Official Plan. An excerpt from the Land Use Map from the Official Plan is included as **Figure 2-1**. The majority of the study area is designated 'General Employment', with the lands adjacent Woodbine Avenue and Steeles Avenue designated 'Service Employment' and 'Business Park Employment'. There is also a parcel designated 'Commercial' between Steelcase Road West and Idema Road. Service Employment lands are intended to accommodate uses that support other businesses and their employees, and this designation also applies to lands that are transitioning from older industrial and warehousing to small scale office and retail uses. Service Employment provides for a very wide range of business uses, and is geared toward multiple unit buildings with smaller floor areas. Business Park lands are intended for higher profile offices and prestige industrial development.

The open sections of the Don Mills Channel are also designated 'Greenway' in the Official Plan, along with some isolated parcels abutting the CNR corridor near Rodick Road. The Official plan includes a number of policies intended to protect and enhance the natural features associated with Greenway systems. Finally, Woodbine Avenue is designated as 'Regional Transit Priority' in the Official Plan.

Figure 2-1 Land Use



Excerpt from Map 3 from the City of Markham Official Plan

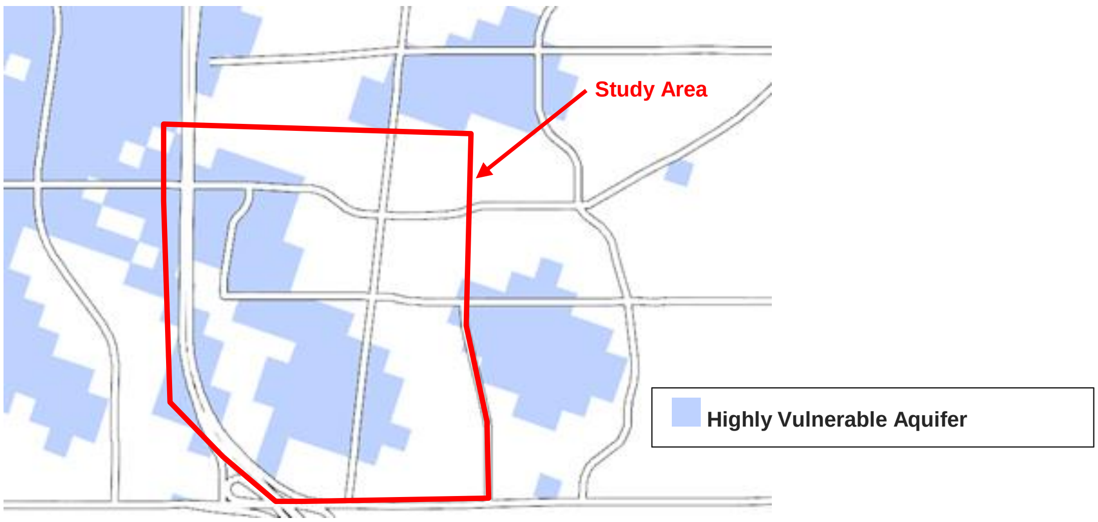
As with the York Region plan, the City of Markham Official Plan designates portions of the study area as Highly Vulnerable Aquifers, and includes the following policies to protect groundwater resources.

3.3.2.3 To work with provincial agencies, York Region, adjacent municipalities and private landowners to manage activities which pose potential contamination risks on highly vulnerable aquifers as identified on Appendix J – Clean Water Act Highly Vulnerable Aquifers including salt management and the manufacturing, handling and storage of organic solvents and dense non-aqueous phase liquids (DNAPLS) in accordance with industry and provincial standards.

3.3.2.4 That applications for development approval within highly vulnerable aquifers identified on Appendix J – Clean Water Act Highly Vulnerable Aquifers involving the manufacturing, handling and/or storage of bulk fuel or chemicals (activities prescribed under the Clean Water Act), shall be accompanied by a contaminant management plan, as deemed necessary by Markham.

An excerpt from Appendix J of the Official Plan showing the HVA in relation to the study area is included as **Figure 2-2**.

Figure 2-2 Highly Vulnerable Aquifers

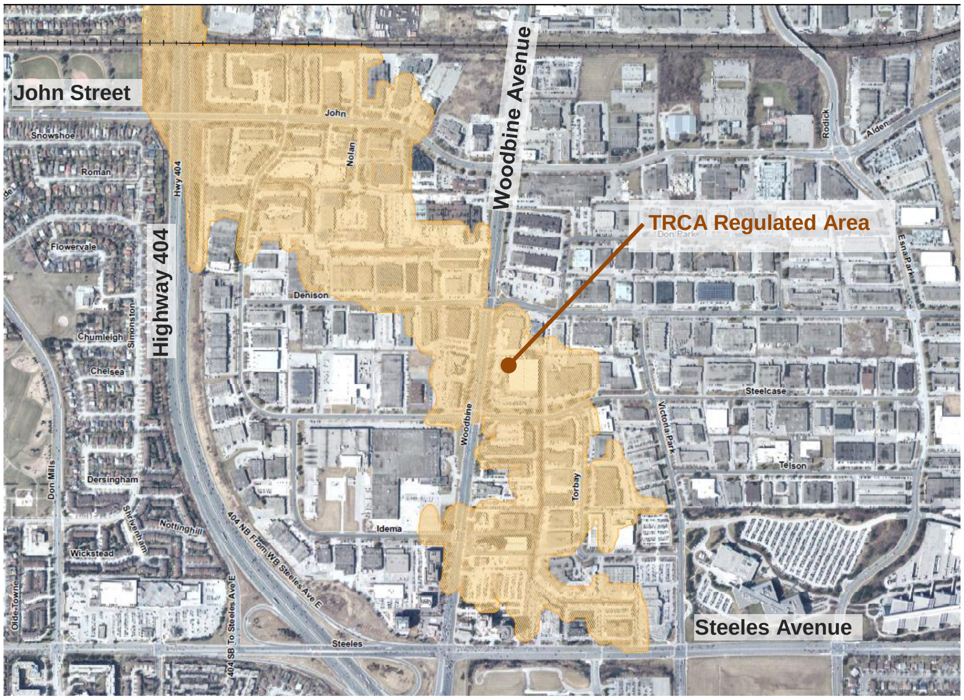


2.1.5 Toronto and Region Conservation Authority

The Toronto and Region Conservation Authority (TRCA) regulates works within and adjacent rivers and streams, wetlands, and shorelines under Ontario Regulation 166/06 (Development, Interference with Wetlands and Alterations to Shorelines and Watercourses). The regulation limit extends 15 m beyond the regulatory flood plain or top of bank associated with defined watercourses such as the Don Mills Channel. An excerpt of the TRCA's Regulation limit mapping is presented in **Figure 2-3**. The regulatory flood is not confined to the Don Mills Channel. As a result, the TRCA regulation limit covers a considerable portion of the study area including 68 buildings.

A permit is required from TRCA for any site alteration within their regulated area, and TRCA policies and regulations generally prohibit new development in existing flood prone areas, consistent with the Provincial Policy Statement (**Section 2.1.1**). There are some exceptions to these policies to allow for minor building expansions and site alterations, subject to meeting flood protection criteria, but the policies generally discourage intensification or other works that would significantly increase the number of people and/or amount of property at risk of flooding during severe storm events.

Figure 2-3 TRCA Regulation Limit



2.1.6 Source Water Protection

As noted in **Section 2.1.3**, portions of the study area are considered 'Highly Vulnerable Areas', even though it is a considerable distance removed from any wellhead protection areas or significant recharge areas. Highly Vulnerable Aquifers (HVA) are defined in the CTC Source Protection Plan (2015) as areas where there is some potential for groundwater contamination due to proximity to the ground surface and/or permeability of the soil between the ground surface and local water table. Source Protection Plan policies pertaining to HVA are related to the storage, handling and application of road salt and the handling and storage of potentially hazardous substances These policies have been incorporated into the York Region and City of Markham Official Plans, as described in **Sections 2.1.3** and **2.1.4**, respectively.

2.2 Physical Environment

2.2.1 Physiography and Topography

The study area lies within the Peel Plain physiographic region (Chapman and Putnam, 1984). The Peel Plain is a relatively flat shelf of land south of the Oak Ridges Moraine and South Slope, characterized by shallow depths of poorly drained clay soils.

Locally, the landscape has been highly altered through past development. The land generally falls to the north and west towards Highway 404 and John Street, and continues in a north-westerly direction west of Highway 404 to join the main branch of German Mills Creek, a tributary of the Don River watershed.

2.2.2 Soils and Groundwater

Available soils mapping show the soils through the Don Mills Channel catchment area are predominantly Peel Clay and Cashel Clay. Both are relatively impermeable clay soils with limited infiltration capacity, and the depth to bedrock is relatively shallow through the study area. The relatively slow rate of movement through the clay soils and shallow depth to bedrock can result in the local groundwater table close to the ground surface.

There is typically some baseflow in the Don Mills Channel throughout the year, but it is suspected that the source of water, estimated to be less than 1 L/s, is from building and roadway foundation drains rather than natural groundwater discharge.

2.3 Natural Heritage

A detailed review of background information related to the natural heritage features of the study area was completed. The current study builds upon work conducted by Clarifica Inc. in 2006 for the previous flood remediation study of the Don Mills Channel.

The Toronto and Region Conservation Authority (TRCA) and Ministry of Natural Resources and Forestry (MNRF) were contacted by the project team for relevant natural heritage information or records for the study area. The background review included a search of available documents and online databases (e.g., the MNRF's Natural Heritage Information Centre) for existing information on flora, fauna, wetlands, fish and wildlife habitat in the area.

2.3.1 Field Methods

Field investigations were subsequently carried out to inventory the flora and fauna of the site, assess habitat characteristics, and to provide an assessment of the ecological features and functions within the study area. The field surveys were carried out on August 9 and September 7, 2016. The survey methods and findings are summarized in the following sections.

2.3.1.1 Fish Habitat Surveys

Upon completing the secondary information review, a qualified fish ecologist conducted field investigations on September 7th, 2016, along the 3 km stretch of the Don Mills Channel. The following key aquatic habitat features and conditions were documented: in-stream cover, aquatic vegetation, fish passage barriers; and, any specialized habitat features such as areas for spawning or rearing. Considering the availability of fish community data from secondary sources (including that documented in Cole Engineering (2010), fish community surveys were not conducted for this assessment.

2.3.1.2 Terrestrial Surveys

Vegetation Communities and Flora: Vegetation communities were mapped and described following the Ecological Land Classification (ELC) System for Southern Ontario (Lee et al. 1998). Information collected included dominant species cover, community structure, presence of indicator species, and other notable features. Botanical surveys were completed in conjunction with ELC by walking the creek alignment and recording species observed. The area on the west side of Highway 404 to the west side of Summerdale Park at Leslie Street was also walked to provide additional information on local site conditions. Provincial plant status was based on the Provincially Rare Flora of Ontario (Oldham and Brinker, 2009) and the Natural Heritage Information Centre (NHIC, 2016).

Wildlife: Given the urban and disturbed nature of the site, wildlife surveys focused on identifying any sensitive habitat features (e.g., amphibian breeding habitat) and noting the general character of the habitat along the creek alignment. The surveys were conducted in conjunction with ELC surveys. All culverts were examined for Barn Swallow nests and any other wildlife observations were recorded.

2.3.2 Fisheries and Aquatic Habitat

Habitat conditions to the northwest of Highway 404 outside of the current study area were characterized to provide context for the local area. During studies in 2010, the only fish in the entire study area were caught in this reach – two Creek Chub, *Semotilus atromaculatus*, although benthic invertebrate sampling at the same time indicated degraded water quality (Cole Engineering, 2010). Habitat conditions were therefore assessed to provide confirmation of these previous assessments, as well as a comparison to the downstream reaches.

Downstream of the study area in Summerdale Park, the channel flows through a naturalized area. The stream provides fair to good fish habitat in this reach, with a mix of sand substrate (70 %), gravel (15 %), and boulder (15 %). Riparian cover (primarily Manitoba maple) provides some overhanging shade, and undercut banks provide potential fish refuge. There is evidence of bank erosion in multiple places, with exposed tree roots in some areas, and debris from flooding visible in the trees. The channel wetted width ranges from 2 m to 4 m, with about 1 m water depth, with full clarity to the substrate. Upstream of Summerdale Park the channel has been straightened, as it runs alongside the Highway 404. There is additional evidence of exposed banks, and debris from flooding events at the high water mark. No aquatic vegetation was present in the main channel, and overhanging shade was limited to riparian trees. Substrate consisted of 90% sand and 10% gravel. Flow was low during the habitat assessment, and water depth was approximately 50 cm.

Once the channel re-emerges on the east side of the Highway 404 within the current study area, aquatic habitat conditions deteriorate. There was no flow during the time of assessment, and the water was stagnant, with thick algae and aquatic vegetation present. The water was turbid and it was not possible to see to the substrate in sections. The wetted width is approximately 10 m at this location. Gabion baskets and rip-rap have been added as bank stabilization, with some boulders observed in the main channel substrate.

Upstream of Steelcase Road West, the channel has been constrained as it flows through an industrial complex. There is garbage dumped in the channel, with stagnant water, and an abundance of green algae. There was little flow, and water depth was less than 1 m, and wetted width approximately 7 m. There are some sections of more natural channel conditions within this reach, with some overhanging shrubs and trees. Water quality conditions remain degraded however, with stagnant water and garbage present in multiple locations.

Upstream of Woodbine Avenue, the channel has been altered (straightened) and it flows through a culvert and concrete lined channel. There is little to no flow, and the water is choked with green algae. Upstream of Steelcase Road East, the channel is no longer concrete lined, and the substrate is natural, primarily consisting of sand. The channel wetted width is approximately 1 m, and less than 20 cm depth, with little to no flow observed. Storm sewers inputs were observed further downstream which contributed to some observed flow, but overall the aquatic habitat characteristics remained similar to the culvert at Steeles Avenue East.

Overall, the aquatic habitat assessment indicated a highly degraded, urbanized, and impaired environment. The available records from MNRF did not indicate any fish species of concern, and no fish were observed during the habitat survey. The only fish caught in 2010 were upstream of the Highway 404 (Cole, 2010), outside of the current study area. It is unlikely that any of the reaches upstream of Highway 404 support consistently viable fish habitat. Water quality is degraded, and the numerous storm flows would alter aquatic conditions (temperature and velocity fluctuations), further degrading the habitat suitability for fish. The numerous culverts and flood events also likely provide barriers to fish migration. The existing conditions observed in 2016 are consistent with those observed in 2010 (Cole Engineering), and 2006 (Clarifica).

2.3.3 Vegetation and Terrestrial Habitat

The Don Mills channel is a highly modified channel constrained by surrounding industrial and commercial uses, with generally only a thin band of riparian habitat along its length. In general, vegetation conditions along the creek alignment are consistent with those reported by Clarifica (2006). The majority of the creek riparian habitat is represented by relatively steep and narrow ditch habitat dominated by common and/or weedy herbaceous vegetation (Cultural Meadow). Varying proportions of shrubs and trees are present, generally as planted linear or isolated occurrences. In-stream wetland vegetation was rare, and when present, confined to sparse, isolated occurrences along the channel banks.

Conditions northwest of Highway 404 (adjacent to, but outside of, the current study area) provide the higher quality natural habitat within the general area, including pockets of lowland forest and marsh wetland, the latter of which showed some evidence of groundwater contribution.

2.3.3.1 Vegetation Communities

In total, five vegetation community types were observed within the study area for Don Mills channel, with descriptions provided below. Vegetation community mapping is shown in **Appendix A** (Figures 1.1 - 1.3).

Cultural Meadow (CUM1-1): This community type is the most widespread throughout the study area, occupying the channel banks from Steelcase Road West to Steeles Avenue. These communities are characterized by open herbaceous layers of common and non-native herbaceous species, with the most abundant species being Awnless Brome (*Bromus inermis ssp. inermis*), Tall Goldenrod (*Solidago canadensis var. scabra*), swallow-wort species (*Cynanchum sp*.), Reed-canary Grass (*Phalaris arundinacea*), Riverbank Grape (*Vitis riparia*) and Wild Carrot (*Daucus carota*). Scattered, infrequent shrubs and woody species predominantly include Manitoba Maple (*Acer negundo*), Red-osier Dogwood (*Cornus sericea ssp. sericea*), Green Ash (*Fraxinus pensylvanica*) and willow species (*Salix sp*). Trees (singly or in linear rows) are present along many upper bank portions of the riparian habitat. Species include Manitoba Maple, Norway Maple (*Acer platanoides*), Freeman's Maple (*Acer x freemanii*), willows, and Siberian Elm (*Ulmus pumila*).

Cultural Thicket (CUT1): This community type occurs in one location in a complex with cultural meadow habitat. Shrub and young tree cover, represented by a mix of species including Manitoba Maple, Green Ash, Red-osier Dogwood, and Staghorn Sumac (*Rhus hirta*), is sufficiently dense to completely shade much of the available ground area. In non-woody cover areas, cultural meadow species predominate.

Cattail Mineral Shallow Marsh (MAS2-1): This community occurs in one location directly east of Highway 404 within its ditch, north of the Don Mills channel and SWT2-2 community. Given its location, it is assumed to be of anthropogenic origin and likely collects runoff and drainage from adjacent areas. Built forms for vegetation stabilization are visible on the banks surrounding the community. The community is dominated by a very dense herbaceous layer of Narrow-leaved Cattail (*Typha angustifollia*). Property access was not possible in this area and observations were made from the edge only.

Willow Mineral Thicket Swamp (SWT2-2): This small community occurs along the banks of the creek directly east of the Highway 404. The dominant vegetation is willow shrubs (*Salix sp*), which occupy the channel bottomland and banks. Property access was not possible in this area and observations were made from the edge only. The community appears to be the result of reconstruction and restoration activities, given the presence of large cobbles within the stream and along its banks and the constructed nature of the surrounding area.

Open Aquatic (OA): This community occurs in one location, directly east of Highway 404 within the ditch, south of the channel and the SWT2-2, and consists of open water habitat. Built forms for vegetation stabilization are visible on the banks surrounding the community. Like the MAS2-1, it is assumed to be of anthropogenic origin and likely collects runoff and drainage from adjacent areas.

2.3.3.2 Vascular Flora

A total of 46 species were observed in the study area during the field surveys. Of these, 23 (50%) are non-native. All of the native species have S-Ranks of S5 or S4, indicating they are common and secure, or apparently secure, in the province. Additionally, all of the native species have CC values of 1 - 5, indicating a high to moderate tolerance to disturbance (Oldham et al. 1995). These results are as expected given the urban and highly modified character of the site. A vascular plant list is provided in **Appendix A**.

2.3.4 Wildlife and Wildlife Habitat

No wildlife was observed within the study area during the field surveys and no nests were located in any culverts during field surveys. Wildlife habitat opportunities within the study area are restricted to urban-adapted species of open or edge habitats. Some areas of the stream may have potential to support limited frog breeding of species that utilize streams, such as Green Frog (*Lithobates clamitans*), but no frogs were observed during field surveys. More suitable breeding opportunities may be provided by the wetland marsh habitat in Summerdale Park northwest of the study area as it is better buffered from adjacent land uses. The channel likely provides only very limited movement or foraging opportunities for turtles. The riparian vegetation is interrupted in several locations by expanses of parking lot and major or minor road crossings and as such it may provide only very limited linkage or corridor functions for wildlife along its route. Road noise is severe throughout the study area.

2.3.5 Species at Risk

For the purposes of this report, Species at Risk (SAR) are those species listed as Endangered or Threatened under the Ontario Endangered Species Act (ESA, 2007). Such species and their habitats are afforded protection from harm or destruction under the Act. Correspondence with MNRF and the background review identified the potential of occurrences for Barn Swallow (*Hirundo rustica*, listed as Threatened), Blanding's Turtle (*Emydoidea blandingii*, listed as Threatened), and Butternut (*Juglans cinerea*, listed as Endangered) within the study area. Searches for these species or suitable habitat were conducted during field surveys. No Butternut trees or Barn Swallow were observed (including nests or foraging / flight activity) within the study area. Barn Swallow nests were observed on the Leslie Street Bridge at the west end of Summerdale Park, outside of the study area. No wetlands suitable for Blanding's Turtle were observed and it is considered unlikely that Blanding's Turtles would be found within the study area. No other flora or fauna SAR were observed during field surveys.

2.3.6 Significant Natural and Environmentally Sensitive Areas

The Don Mills stream corridor is designated as part of the Greenway System of the City of Markham Official Plan, but no Provincially Significant Wetlands, Areas of Natural and Scientific Interest, Environmentally Significant / Sensitive Areas, or other provincially designated environmental features are present within the study area. One unevaluated wetland is present within Summerdale Park, northwest of the current study area.

2.4 Cultural Environment

The Don Mills Channel study area is within a predominantly commercial and industrial area, with no public park, recreational facilities or other significant public amenities.

The City's *Register of Property of Cultural Heritage Value or Interest* was consulted, and it was confirmed that there are no heritage resources in or near the study area.

2.4.1 Archaeology

The Don Mills Channel study area lies within a region that was first inhabited about 15,000 years ago, following the last ice age. Europeans began settling the study area in the 1790's, and several historic structures are indicated on atlases and maps from the 1860's. Land use through the study area remained agricultural until the late 1960's when the lands were developed for commercial and industrial uses.

One registered archaeological site is located in the study area (AkGu-22). Unfortunately, no reports or any other information is available for this site. Given that the location of the registered site is completely developed, it is expected that the site was mitigated or removed prior to development of the site.

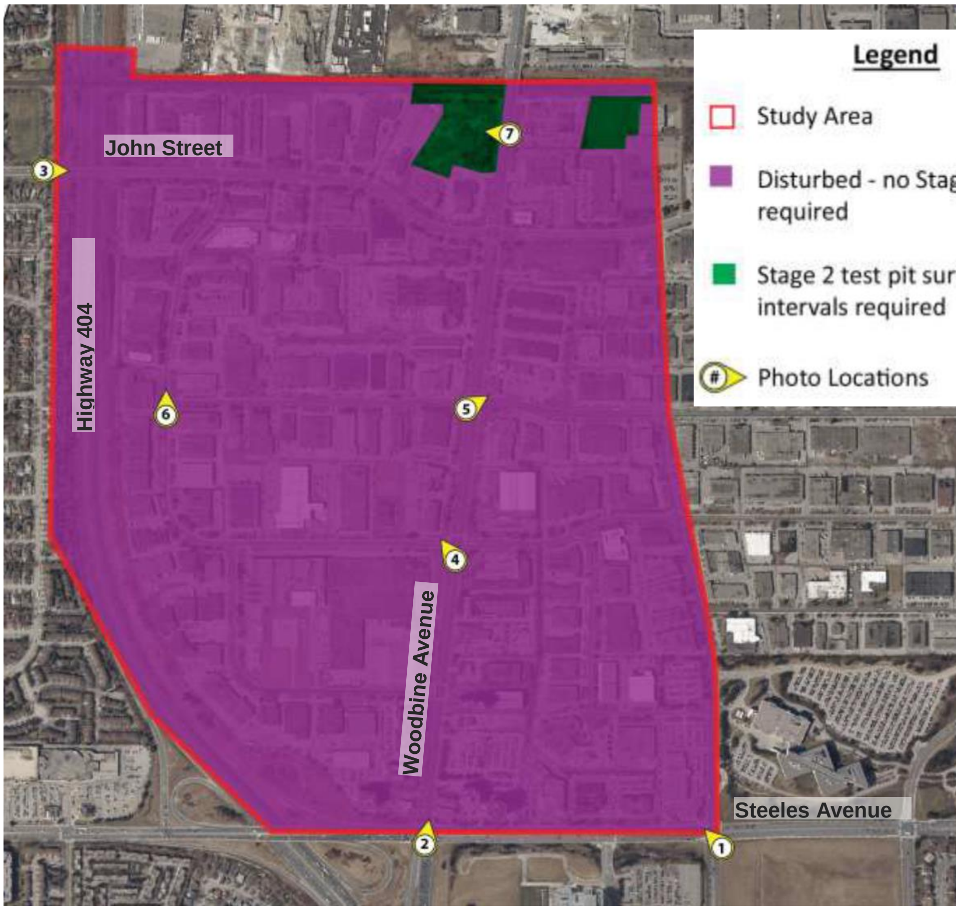
The study area has archaeological potential due to its proximity to water (i.e. the Don Mills Channel and German Mills Creek to the east) and the presence of known archaeological sites in and surrounding the study area.

The majority of the study area has been previously disturbed for construction of the commercial and industrial sites, roads, rail lines and other infrastructure. The past construction would have resulted in severe damage to the integrity of any archaeological resources which may have been present, and therefore no further archaeological investigations are warranted for these disturbed areas.

Two locations within the study area do not appear to have been extensively disturbed in the past, and therefore retain some archaeological potential. These two areas are located immediately south of the CNR tracks, on either side of Woodbine Avenue. Test pits are recommended to further assess these areas prior to any excavation or other works on these sites that could disturb any potentially present archaeological resources.

The complete Archaeological Assessment study report is included as **Appendix B,** and **Figure 2-4** shows the location of the two sites with archaeological potential.

Figure 2-4 Archaeological Potential



Refer to the complete report in Appendix B for photos

2.5 Engineering Environment

2.5.1 Channel and Culvert Characteristics

The size and condition of both the open and enclosed sections of the Don Mills Channel within the study area have been assessed through field inspections by TMIG staff. Observations by TMIG staff have been augmented with findings from the following earlier studies:

- Don Mills Ditch Capacity Remediation Class EA Study – Existing Conditions Summary (Clarifica, November 2006). The previous EA for the Don Mills Channel included visual inspections of the culverts along the Don Mills Channel and surveyed cross sections at representative locations along each reach of open channel through the study area.
- Detailed Visual Inspection of Storm Sewer Culverts (Andrews Infrastructure, June 2011). This study assessed the condition of a number of culverts throughout the City of Markham, including the Don Mills Channel culvert under and extending north from Denison Street
- Don Mills Storm Channel Condition Assessment (Andrews Infrastructure, August 2013). This study assessed the physical condition of the open channel and several of the culverts between Steeles Avenue and Steelcase Road West.
- Don Mills Channel Culverts Debris Observations (Andrews Infrastructure, October 2014). Andrews Infrastructure re-inspected a number of culverts along the Don Mills Channel to determine if the

recommendations from the 2013 report had been implemented and to gauge the rate of sediment and debris accumulation in the culverts

- City of Markham Inspection Program: City of Markham staff completed inspections of the Don Mills Channel and all storm outfalls discharging to the channel in 2016. The 2016 inspections results were logged in a GIS database which was provided to TMIG.

Each culvert and open reach of the Don Mills Channel through the study area is described below.

2.5.1.1 Upstream of Steeles Avenue

Upstream (south) of Steeles Avenue in the City of Toronto, the storm drainage system has been completely urbanized and no open channels remain. A linear open water feature is evident along the south side of Steeles Avenue between Woodbine Avenue and Victoria Park Avenue, but no information is available to determine if this feature provides any control of storm runoff.

2.5.1.2 Enclosed Reach through 3190 Steeles Avenue (CU 10)

The Don Mills Channel originates on the north side of Steeles Avenue approximately 100 m west of Victoria Park Avenue. However, there is only approximately 20 m of open channel before the channel is enclosed in a culvert under a parking area at 3190 Steeles Avenue. There is evidence of erosion in the form of downcutting in this reach, which may have contributed to damage to a storm sewer outfall on the west side of the channel immediately north of Steeles Avenue.

The 3730 mm x 2290 mm corrugated steel pipe-arch (CSPA) culvert under the parking area at 3190 Steeles Avenue is approximately 50 m long, with gabion basket headwalls at both the upstream and downstream ends. The CSPA culvert was installed in the mid 1980's, and remains in good condition with minor corrosion. The Condition Assessment (Andrews, 2013) noted some slight buckling along the joint at the top of the culvert, but concluded that this likely occurred during installation and was not a concern.

2.5.1.3 Open Channel North of Steeles Avenue (Segment 1)

Downstream of Culvert CU10, the channel flows northward for a distance of approximately 30 m. The channel is confined by an older gabion basket retaining wall on the west side, and a newer (and higher) block retaining wall on the east side. The width of the open channel between the retaining walls is approximately 7 m.

2.5.1.4 Enclosure North of Steeles Avenue (CU 9)

The channel makes a 90 degree bend north of Steeles Avenue via a short length of 1.9 m diameter CSP culvert, with sheet pile headwalls and wingwalls. The CSP is in relatively good condition with minor corrosion. A 200 mm diameter sanitary sewer is installed through the culvert on a south-west to north-east alignment. Such installations through culvert commonly contribute to debris jams, but no significant accumulations of sediment and debris were observed in the Andrews Infrastructure inspections.

2.5.1.5 Open Channel North of Steeles Avenue (Segment 2)

West of the Culvert CU9, the channel flows westward for a distance of approximately 190 m in a trapezoidal shaped channel, with a top width of approximately 10 m. The channel is heavily vegetated with some larger trees within the channel corridor. During a site visit by TMIG staff in July 2016, several larger branches were observed within the channel corridor (See **Figure 2-5**). Debris such as branches could potentially mobilize and contribute to debris jams in culverts during severe storm events, worsening flooding conditions.

Erosion, in the form of downcutting, was observed along this reach. Downcutting was moderate at the east (upstream) end of this reach, but more severe at the west limit of the reach, south of the property at 205 Torbay Road.

Figure 2-5 Open Channel North of Steeles Avenue

Outlet of Culvert CU10 at 90º Bend **Looking upstream (east) at rear of 205 Torbay Road**

2.5.1.6 Enclosed Section through 3120 Steeles Avenue (CU8)

The Don Mills Channel is enclosed in a 4.7 m x 3.1 m CSPA culvert through the property at 3120 Steeles Avenue. The approximately 100 m long culvert is located at the rear of the property, which is at an angle relative to Steeles Avenue. There is a bend in the culvert to transition from the east-west channel alignment upstream to the angled alignment at the rear of the property, and another bend from the angled section to discharge to the north-south alignment of the Don Mills Channel downstream of the site. There are concrete headwalls at both the inlet and outlet (**Figure 2-6**). The culvert is in good physical condition with minor corrosion, although the previous condition assessments noted up to 450 mm deep sediment deposits in isolated areas within the culvert.

Figure 2-6 Culvert under 3120 Steeles Avenue

Culvert Inlet **Culvert Outlet**

2.5.1.7 Open Channel South of Steelcase Road East (Segment 3)

At more than 400 m long, the Don Mills Channel between 3120 Steeles Avenue and Steelcase Road East is the longest reach of continuous open channel in the study area. It flows from south to north, and is aligned behind the rear of the buildings on Woodbine Avenue and Torbay Road. The top width of the triangular shaped channel varies, but is typically 14 m to 15 m wide. The channel is densely vegetated, although most of the mature trees along this reach are at the rear of the properties backing onto the channel, rather than within the channel itself. During a site visit by TMIG staff in November 2015, a number of larger branches (which appeared to have been trimmed from the trees at the rear of 7225 Woodbine Avenue) were lying on the channel side slopes, and could contribute to debris jams and culvert blockages during severe storm events. These branches have been subsequently cleared from the channel.

At the commencement of this channel section downcutting was present at the storm outfall. At this point it was deemed that it would not be a threat to infrastructure however, it is recommended for this channel section to be monitored annually.

Moderate to significant downcutting was observed throughout this reach of the Don Mills Channel, contributing to over-steepened and potentially unstable slopes at the rear of several properties abutting the channel. TMIG staff also observed erosion and slumping of the side slope on the east side of the channel, at the rear of 85 Steelcase Road East (See **Figure 2-7**). The guard rail was leaning into the channel, and a portion of the asphalt surface had been lost due to the slope failure. A design was recently prepared for the stabilization of the slope and rehabilitation of the asphalt at 85 Steelcase Road East (Cole, September 2015), and construction was completed in 2017.

Figure 2-7 Open Channel South of Steelcase Road East

Looking North (Downstream) from 3120 Steeles Avenue

Looking South from Steelcase Road East

2.5.1.8 Steelcase Road East Culvert (CU7)

The Don Mills Channel crosses under Steelcase Road East via a 2.2 m high x 3.4 m wide elliptical concrete culvert that is approximately 25 m long. There are concrete headwalls and wingwall at both the upstream and downstream ends and a large storm sewer outlet is integrated into the downstream headwall (**Figure 2-8**).

The 2013 condition assessments found that significant deterioration of the concrete and reinforcing steel in the downstream third of the culvert (Andrews, 2013). The culvert was subsequently rehabilitated in 2014.

Figure 2-8 Steelcase Road East Culvert

Culvert Inlet

Culvert Outlet

2.5.1.9 Open Channel through 50 Steelcase Road East (Segment 4)

The Don Mills Channel continues north in an open channel at the east limit of 50 Steelcase Road East before turning 90 degrees and flowing west toward Woodbine Avenue. The trapezoidal channel has concrete lining along its base and the side slopes are vegetated with grasses and small shrubs. There are no mature trees within the approximately 15 m wide channel corridor. The concrete channel lining may be slightly undermined outside bend where the channel makes the 90 degree turn (**Figure 2-9**).

2.5.1.10 Woodbine Avenue Culverts (CU 6)

There are three distinct segments that make up the Don Mills Channel culvert under Woodbine Avenue. There is the original culvert installed within the Woodbine Avenue right-of-way, which is owned and maintained by York Region. The culvert was subsequently extended both upstream and downstream to enclose the channel through the private commercial properties on the east and west sides of Woodbine Avenue.

The approximately 40 m long, 3.9 m wide x 2.7 m high CSPA culvert under Woodbine Avenue was installed at an angle to the roadway to match the original channel alignment to the east and west at the time. This culvert continues to be owned by York Region. There is a bend where the culvert was extended approximately 120 m east under 50 Steelcase Road East with the same size CSPA. At the west limit of Woodbine Avenue, there is a rectangular concrete chamber at the interface between the Woodbine Avenue culvert and a 120 m long 4.4 m wide x 2.9 m high CSPA extension through 7270 Woodbine Avenue. There is a bend near the west end of the culvert extension to discharge to the north-south aligned channel at the outlet. All three culverts are reported to have concrete lined inverts (Andrews, 2013).

The 2013 and 2014 condition assessments by Andrews Infrastructure found the culverts in good physical condition with minor corrosion, but also found significant accumulations of sediment and debris in the culvert, including large automotive parts. The City of Markham removed the automotive parts from the culvert in November 2016. During the removal operations, City of Markham staff noted evidence of settlement of the Woodbine Avenue culvert (see **Figure 2-10**).

Figure 2-9 Open Channel behind 50 Steelcase Road East

Looking North from Steelcase Road East **90 Degree Bend East of Woodbine Avenue**

Figure 2-10 Woodbine Avenue Culvert

Culvert Inlet during Debris Removal

Road Settlement along Culvert Alignment

2.5.1.11 Open Channel South of Denison Street West (Segment 5)

There is a short length of open channel between the outlet of the Woodbine Avenue culvert extension (CU6) and the beginning of another enclosure at Denison Street. This reach of the Don Mills channel is approximately 75 m long, with a top width of approximately 15 m. The triangular channel is vegetated with grasses and small shrubs, but there are no mature trees along this reach (**Figure 2-11**). The land on the west side of the channel is approximately 1 m higher than the loading area on the east side of the channel (7310 Woodbine Avenue).

Figure 2-11 Open Channel South of Denison Street

Looking South to Denison Street **Looking North from Denison Street**

2.5.1.12 Denison Street Culvert (CU 5)

Similar to Woodbine Avenue, the Denison Street culvert was extended to enclose the Don Mills Channel through multiple development sites. A 4.2 m wide x 2.6 m high CSPA culvert was installed under Denison Street during its original construction. The culvert deteriorated over time, and in 2005 a new 3.97 m wide x 2.36 m high CSPA culvert was slipped inside the original pipe and grouted in place.

In the late 1970's, the Don Mills Channel was enclosed further south, under 7370 Woodbine Avenue, in a 4.4 m wide x 2.9 m high CPSA, including a 90º bend near the north end of the enclosure to discharge to the channel leading west from the site. Finally, in the early 1980's, the open reach between Denison Street and 7370 Woodbine was enclosed in a 4.4 m wide x 2.9 m high CPSA to facilitate the expansion of a parking lot at 230 Denison Street.

All three culvert segments, including the rehabilitated initial culvert under Denison Street, are in good physical condition with minor corrosion, and the inverts of all three segments are concrete lined with minimal sediment or debris.

2.5.1.13 Open Channel North of Denison Street (Segment 6)

From the outlet of the Denison Street culvert, the Don Mills Channel flows westward for a distance of approximately 270 m in a triangular shaped open channel with a top width ranging between 19 m and 21 m. Along most of this length, the channel is densely vegetated with grasses, shrubs and a few small trees.

The channel side slopes are very steep in areas, and a previous failure of the side slope within the 110 and 130 Denison Street properties was remediated in 2015 (**Figure 2-12**). Erosion is also evident near the outlet of Culvert CU5 at the upstream end of this reach, as the storm sewer outlet from 230 Denison Street appears to have been damaged by erosion. The outfall continues to convey runoff from the site to the channel, but erosion may soon impact the parking lot at the top of the slope. The storm sewer outfall and associated bank erosion is scheduled to be repaired later in 2018. Erosion is also evident on the south bank at 210 Denison Street, but this at may be related to previous unauthorized fill placement on this slope. The TRCA, which regulates fill placement in the flood plain, has been informed of the fill placement and has initiated enforcement activities for the potential violation.

Figure 2-12 Open Channel North of Denison Street

Steep, vegetated side slopes behind 210 Denison Street **Recent channel rehabilitation at 130 Denison Street**

2.5.1.14 Enclosed Section through 70 Denison Street (CU 4)

The Don Mills Channel is enclosed through 70 Denison Street, with a 90 degree bend near the middle of the culvert. The 4.4 m wide x 2.9 m high CSPA culvert is in poor condition due to corrosion, which has fully perforated the culvert invert in places. The Condition Assessment (Andrews, 2013) also noted scour and erosion at the culvert inlet as well as shifting of the gabion basket wingwalls at the inlet (**Figure 2-13**).

Figure 2-13 Culvert Enclosure through 70 Denison Street

Culvert Inlet – Note slope failure on left side of inlet **Culvert outlet and restoration works at 300 Steelcase Rd**

2.5.1.15 Open Channel East of Steelcase Road West (Segment 7)

There are two distinct reaches of the Don Mills Channel between the outlet of the enclosure through 70 Denison Street (Culvert CU 4) and the inlet of Culvert CU3 under Steelcase Road West. The initial 120 m long reach flowing northward is within the 300 Steelcase Road East property, and is a trapezoidal channel with a top with of 18 m to 20 m. The low flow channel is noticeably wider through this reach relative to the upstream channel segments, and the side slopes are well vegetated with some mature trees growing on the side slopes

(**Figure 2-14**). Restoration works were completed in late 2007 or early 2008 to repair scour and erosion near the outlet of Culvert CU 4 at the rear of the property at 300 Steelcase Road West. During a site visit by TMIG staff in July 2016, the restoration works at the culvert outlet appeared stable.

As the channel makes the 90 degree bend to flow another 130 m eastward to Steelcase Road West, the channel corridor widens to a top width of approximately 22 m, although part of this width includes a berm along the north limit of 300 Steelcase Road West, which is approximately 0.5 m higher than the top of bank on the north side of the channel. The channel banks are well vegetated with some mature trees growing within the side slopes. However, there are several storm sewer outlets in this reach that have failed or are in poor condition due to channel downcutting and/or under-controlled discharge from the storm sewer outlets. Repairs to the storm sewer outfalls in the worst condition are scheduled for repair later in 2018.

Figure 2-14 Open Channel East of Steelcase Road West

North-South Reach behind 300 Steelcase Road West **East-West Reach through 350 Steelcase Road West**

2.5.1.16 Steelcase Road West Culvert (CU 3)

The culvert under Steelcase Road West is a 4.27 m wide x 2.44 m high concrete box culvert, approximately 28 m long. In the early 1980's, the culvert was extended approximately 125 m westward through 351/361 Steelcase Road with a 5.1 m wide x 3.3 m high CSPA culvert. In 2011, minor repairs to the concrete box culvert were completed, gabion baskets at the inlet were removed and replaced with riverstone slope protection, and the gabion basket headwall at the culvert outlet was reinforced with riverstone protection at the base of the wall (**Figure 2-15**). The culvert interior was inspected in 2014 (Andrews, 2014) and was found to be in generally good condition with isolated areas of minor sediment accumulation.

2.5.1.17 Open Channel Downstream of Steelecase Avenue (Segment 8)

There is a relatively short length of open channel between the outlet of the Steelcase Road West culvert extension and the culvert under Highway 404. Two stormwater management ponds are also located on the east side of Highway 404, north and south of the Don Mills Channel (**Figure 2-16**). The ponds were constructed in the early 2000's, and were designed to control both the quantity and quality of storm runoff from Highway 404. The ponds outlet to the open channel immediately upstream of the Highway 404 culvert.

Figure 2-15 Steelcase Road West Culvert

Steelcase Road West Culvert Inlet

Figure 2-16 Highway 404 Drainage

Looking West to Highway 404 Culvert Inlet

South SWM Pond on the West Side of Highway 404

2.5.1.1 Highway 404 Culvert (CU2)

The 200 m long, 4.88 m wide x 2.44 m high concrete box culvert is installed on an angle under Highway 404, with a bend to outlet to the open on the west side of the highway north of John Street. Just south of John Street, a 1200 mm diameter storm sewer connects into the highway culvert. This storm sewer services a residential area between Don Mills Road and Highway 404, south of John Street.

2.5.1.2 West of Highway 404 (Segment 9/ CU1)

From the outlet of the Highway 404/John Street culvert, the Don Mills Channel continues northward in a 25 m to 30 m wide open, vegetated channel on the west side of Highway 404. The channel crosses under the CNR tracks via a 3.6 m wide x 3.2 m high elliptical corrugated steel culvert, which was twinned with a 3.7 m diameter CSP culvert in 1982.

Near the west limit of 14th Avenue, a 2.4 m wide x 2.1 m high concrete box culvert conveys runoff from a large area bounded by Woodbine Avenue, Highway 404, Highway 407 and the CNR tracks under Highway 404 to the Don Mills Channel. From the confluence with this culvert outlet, the Don Mills Channel continues west and crosses under Leslie Street before joining the main branch of German Mills Creek.

2.5.2 Watershed Hydrology and Hydraulics

A model that can accurately predict the flow rates, flood levels and flow velocities in the Don Mills Channel is critical for understanding the primary causes of flooding in the system and for evaluating the effectiveness of different solutions in reducing flooding. As noted in **Section 1.2**, a number of studies have been completed in the past to investigate flooding along the Don Mills Channel. A number of different modelling platforms have been used for the past studies, each with its own advantages and limitations. These previous modelling platforms were assessed along with other platforms to determine the most appropriate model to support the Don Mills Flood Reduction Study.

2.5.2.1 Model Selection

The primary models for the Don Mills Channel sub-watershed are those used by the TRCA to regulate the flood plain associated with the Don Mills Channel. The TRCA currently predicts the flow rates in the Don Mills Channel with an event-based Visual OTTHYMO (VO) model, and uses a HEC-RAS 1-dimensional hydraulic model to determine the flood levels associated with the calculated flow rates along the channel. The hydrology model was last updated in 2011 (Cole Engineering, December 2011) to more accurately refine the flow rates within the Don Mills Channel. The refined hydrology model was developed specifically for establishing the Regulatory flood plain along the Don Mills Channel, and therefore incorporates a number of conservative assumptions as mandated by provincial guidelines governing Regulatory flood plain mapping (MNRF, 2002). The VO model only simulates the 100 year and Regional (Hurricane Hazel) storm events, whereas it is known that the capacity of the Don Mills Channel is less than the 2 year return period storm event (refer to **Section 1.2**). The model does not take into account any of the on-site flow controls present on most of the more recent developments in the sub-watershed, and does not consider storage and attenuation of storm flows in areas flooded during severe storm events. The HEC-RAS 1-dimensional hydraulic model of the Don Mills Channel is based on a detailed topographic survey of the channel and culvert crossings, but does not take into account the different flow paths that water travels through the system once the capacity of the channel is exceeded.

While appropriate for the preparation of Regulatory flood plain mapping in accordance with provincial guidelines, the VO and HEC-RAS modelling platforms are not suitable for the Don Mills Flood Reduction Study. To accurately assess and understand actual existing flooding conditions and predict the effectiveness of different flood reduction solutions, a more sophisticated model is needed.

As noted in **Section 1.2**, a more detailed InfoWorks hydrologic/hydraulic model of the Don Mills Channel sub-watershed was developed as part of the earlier Class EA Study (Cole, 2010). The InfoWorks model is a dynamic model that takes into account the different flow paths and flooding areas beyond the channel itself, providing a greater understanding of the causes and extent of flooding for different storm events. However, there continue to be some limitations with the InfoWorks model. The sub-catchment delineation for the model included a mix of very large and very small drainage areas, which complicates the estimation and calibration of input parameters. Furthermore, the model did not represent the storm sewers and overland flow pathways that convey storm runoff to the channel. These systems govern the time it takes for storm runoff from individual sites to flow to the channel, which in turn influences peak flow rates and flood levels in the channel. There is generally more confidence in hydrologic/ hydraulic models that employ a relatively consistent sub-catchment drainage area and incorporate both the minor and major drainage conveyance systems upstream of the outlets to open systems. The previous InfoWorks model also appears to have represented the Don Mills Channel as a series of storage elements representing the different channel reaches and associated surface flooding routes as opposed to a fully dynamic hydraulic network of 2-dimensional grid elements. Finally, in a letter dated March 20, 2013 responding to an interim report from the earlier EA for the Don Mills Channel (Cole, 2010), the TRCA expressed some concerns with the InfoWorks model platform, set-up and calibration.

The PCSWMM 2D modelling platform has been selected for the Don Mills Channel Flood Reduction Study. The 2D extension of PCSWMM has been used for at least seven comparable modelling projects in Ontario and at least 20 projects across Canada in recent years. PCSWMM 2D can simultaneously represent the linear conveyance system of culverts and open channels and the 2-dimensional (2D) overland flow along the roadways and through development sites once the capacity of the channel is exceeded. It is also a hydrodynamic model, accounting for the storage and attenuation of storm runoff in the areas flooded during large storm events. Unlike the previous InfoWorks model, the PCSWMM 2D model represents both the storm sewers and overland flow routes that convey storm to the channel, and uses formal grids of 2-dimensional hydraulic elements to route overflow from the channel through study area. Finally, the PCSWMM 2D modelling software has been used by and is available to TRCA staff.

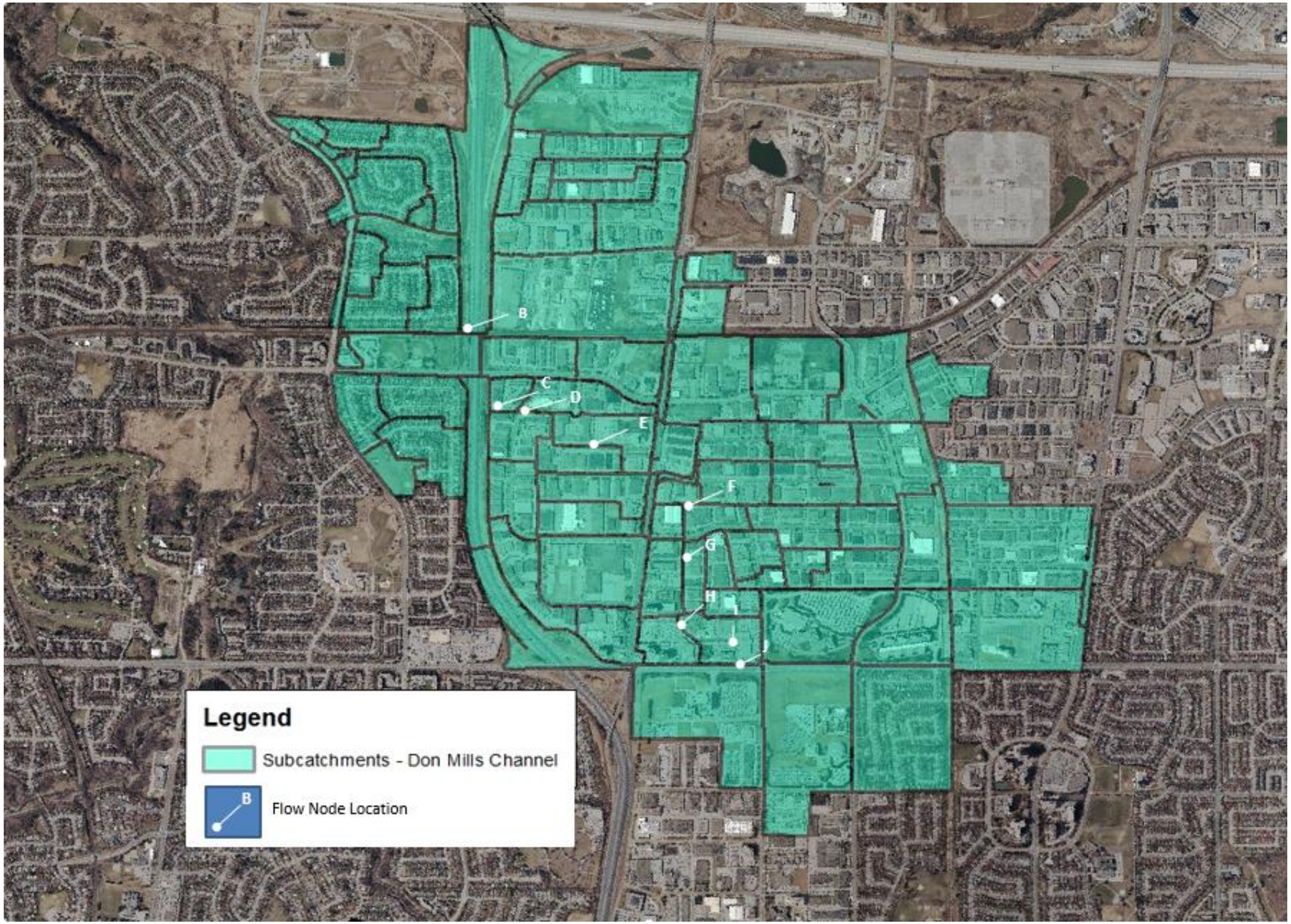
2.5.2.2 Model Set-up

The PCSWMM 2D model of the Don Mills Channel watershed was initially set up and calibrated by staff from Computational Hydraulics International (CHI).

The Don Mills Channel watershed extends as far south as Gordon Baker Road in the City of Toronto, and as far east as Warden Avenue. The PCSWMM 2D model represents the entire Don Mills Channel watershed to near its confluence with German Mills Creek at Leslie Street. The sub-watershed was discretized into 122 sub-catchment areas (**Figure 2-17**) to accurately characterize the different areas within the study area. A larger scape map showing the delineated sub-catchments is included in **Appendix C.**

Land use through the study area is predominantly commercial and industrial. Past development typically proceeded on a site-by-site basis, with each site having its own independent drainage design and graded accordingly. Sub-catchment boundaries were therefore derived using both topographic and property mapping, with sub-catchment boundaries co-incident with property boundaries where appropriate. The average sub-catchment area is 6 ha, with larger catchments representing portions of the watershed outside of the main study area (i.e. south of Steeles Avenue and west of Highway 404), and smaller catchment areas for sites with known on-site peak flow control measures.

Figure 2-17 Model Sub catchments and Flow Node Locations



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The hydrologic characteristics of the subcatchment areas such as percent impervious, flow path length and slope, initial abstraction and infiltration capacity were derived based on land use, aerial photography, soils mapping and anecdotal information from site visits and background documents. More information on the initial model parameters can be found in **Appendix C.**

The hydraulic elements of the PCSWMM model were then added to the model. To account for the differences in timing between piped flows and overland flow to the Don Mills Channel, both storm sewers and overland flow routes were represented in the model. Storm sewer information was imported from GIS datasets provided by the City and Region, and storm sewers smaller than 600 mm were generally excluded from the model to avoid unnecessary complexity.

Channel cross sections and culvert and bridge properties from the previous HEC-RAS hydraulic model (refer to **Section 2.5.2.1**) were used to initially represent the Don Mills Channel itself in the model, and were subsequently refined based on the previously completed topographic surveys and condition assessments as well as recent field observations.

Finally, the 2-dimensional conveyance elements were added to the model. These take the form of networks of grid elements to account for both the vertical and lateral movement of water through the study area once the capacity of the channel is exceeded. Only the flood prone areas near the channel were modelled for 2-dimensional flow. Roadways were represented with a directional (i.e. square) mesh, as overland flow on roadways is typically longitudinally (parallel to the road alignment), or laterally to the curbs on either side of the road. The open channel corridors were similarly represented by a directional mesh. Areas outside of the channels and roadways were represented by a hexagonal mesh, which better represents the movement of water across parking lots, between buildings and through the other open areas on the developed sites. The buildings were represented as obstructions in the 2D analysis such that the model accounted for floodwaters moving around, but not through, the buildings.

More information on the PCSWMM 2D model set-up can be found in **Appendix C.**

2.5.2.3 Model Validation

There are no active or historic streamflow gauges along the Don Mills Channel that could be used to calibrate the PCSWMM 2D model. However, there are a considerable number of photographs showing the depth and extent of flooding as a result of the severe storm events of August 2005 and July and August 2014. Following the floods of 2014, City staff located and measured high water marks at many locations through the study area. The resulting estimated flood depths from these relatively recent severe storm events have been used to confirm that the PCSWMM 2D model of the Don Mills Channel is accurately predicting the flow rates and flood levels in response to severe storm events. The locations of the rainfall gauges where records existing for these past storm events are shown in **Figure 2-18,** and the properties of the validation storm events are summarized in **Table 2-1**.

Figure 2-18 Rainfall Gauge Locations

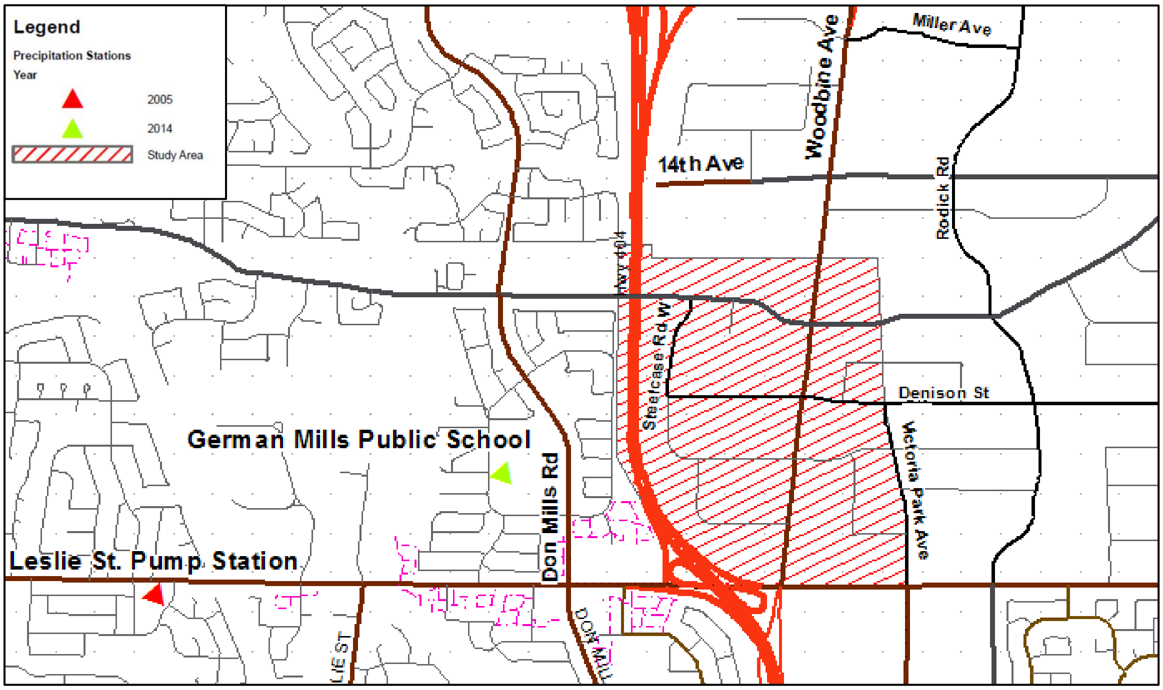

Table 2-1 Validation Storm Properties

Date	Rainfall Gauge	Total Storm Depth (mm)	Peak Rainfall Intensity (mm/hr)
August 19, 2005	Leslie Street Pumping Station	113 mm over 12 hours	191 mm/hour over 10 minutes
July 27, 2014	German Mills Public School	62 mm over 19 hours	167 mm/hour over 10 minutes
August 1, 2014	German Mills Public School	62 mm over 3 hours	206 mm/hr over 10 minutes

The above storm volumes and peak rainfall intensities were compared against Environment Canada's rainfall records for their gauge at Buttonville Airport (1986-2014). In terms of total storm volume or average intensity, the August 19, 2005 storm is in excess of a 100 year return period event, the July 27, 2014 storm is slightly greater than a 10 year return period event, and the August 1, 2015 storm is comparable to a 50 year return period event. For the peak 10 minute period, both the August 19, 2015 and August 1, 2014 storms correspond to a 100 year return period, while the July 27, 2014 storm peak intensity corresponds to between a 25 year and 50 year return period. All three events are considered rare and severe, and are adequate for the validation of the model for predicting flow rates and flood levels for other severe storm events.

The elevations corresponding to the recorded high water marks have been estimated by confirming the location where the measurement was recorded, estimating the ground surface at the location from the City's Digital Elevation Model (DEM), and adding the measured depth to the estimated ground surface elevation. At some locations, only photo documentation is available. For these records, the height of the water mark was estimated from the photograph and added to the estimated ground elevation.

All three storms were simulated in the PCSWMM 2D model of the Don Mills Channel, and some refinements were made to the model based on the initial model output. The predicted extent of flooding for the three different storm events are shown on **Figure 2-19**, **Figure 2-20** and **Figure 2-21,** and the model output is compared against the observed high water marks for the three storms in **Table 2-2**, **Table 2-3** and **Table 2-4**.

Table 2-2 PCSWMM Model Validation – August 19, 2005 Storm

Address	Estimated Maximum Flood Elevation (m)	Simulated Maximum Flood Elevation (m)	Difference in Elevation (m)
3120 Steeles Avenue	177.25	177.28	+0.03
7063 Woodbine Avenue - A	176.74	176.94	+0.20
7063 Woodbine Avenue - B	176.76	176.94	+0.18
7063 Woodbine Avenue - C	176.80	176.94	+0.14
50 Steelcase Road East	176.21	176.42	+0.21
7301 Woodbine Avenue	176.07	176.42	+0.35
7270 Woodbine Avenue – A (NW)	175.97	176.16	+0.19
7270 Woodbine Avenue – B (NE)	176.13	176.29	+0.16
7270 Woodbine Avenue – C	176.48	176.42	-0.06
7270 Woodbine Avenue – D (S)	176.72	176.76	+0.04

Table 2-3 PCSWMM Model Validation – July 27, 2014 Storm

Address	Estimated Maximum Flood Elevation	Simulated Maximum Flood Elevation	Difference in Elevation
85 Torbay Road	176.61	176.18	-0.43
55 Torbay Road	176.71	176.15	-0.56
50 Steelcase Road East	176.14	175.98	-0.16
7270 Woodbine Avenue	176.10	176.10	0.00
7310 Woodbine Avenue	176.06	175.19	-0.87
130 Denison Street	174.61	174.27	-0.34

Table 2-4 PCSWMM Model Validation – August 1, 2014 Storm

Address	Estimated Maximum Flood Elevation	Simulated Maximum Flood Elevation	Difference in Elevation
7310 Woodbine Avenue	175.95	175.3	-0.65
130 Denison Street	174.61	174.41	-0.20
300 Steelcase Road West - A	173.44	173.86	+0.43
300 Steelcase Road West - B	173.74	173.83	+0.09
351 Steelcase Road West	172.96	173.32	+0.36

The output from the PCSWMM model agrees closely with the observed flood levels during the August 2005 storm, with the simulated flood levels generally within 0.3 m of the observed values.

For the July 27, 2014 storm event, the flood levels predicted by the PCSWMM model agree closely with observed levels where the Don Mills Channel crosses under Woodbine Avenue north of Steelcase Road, but is generally under-predicting flood levels upstream of the Steelcase Road East culvert and upstream of the Denison Street culvert. Finally, for the August 1, 2014 storm, the PCSWMM model is generally under-predicting flood levels upstream of the Denison Street culvert, but over-estimating flood levels further downstream near the Steelcase Road West crossing.

The location on the upstream (south) side of Denison Street, west of Woodbine Avenue (7310 Woodbine Avenue) was examined further due to the large differences between observed and simulated flood levels. The PCSWMM model predicts that water spilled from the open channel on the south side of Denison Street can flow eastward and through the buildings at the north-west corner of Woodbine Avenue and Denison Street and return to the open channel north of Denison Street. The modelling also suggests that water can also flow westward along Denison Street and flow between the buildings to the west to return to the channel north of Denison Street. Along both routes, the available topographic information shows that water will spill and flow along both of the above described routes at elevations significantly lower than the observed water levels upstream of the Denison Road culvert. It is possible that there are small berms, high curbs/retaining walls or other small features obstructing flow that are not adequately represented in the DEM and/or PCSWMM grid cells. It is also possible that the Denison Street culvert was partially to significantly obstructed with debris during the 2014 storms. The PCSWMM model assumes that the culverts are unobstructed, and therefore would under-predict flood levels if the culvert was blocked. Culvert blockage could also explain the under-prediction of flood levels in the channel south of Steelcase Road East for the July 27, 2014 storm.

Overall, it is concluded that the PCSWMM model is sufficiently accurate to characterize existing flooding conditions through the study area and to form the basis for the evaluation of alternative solutions to reduce flooding and flood damages through the study area. While there are some differences between the simulated and observed flood levels, a considerable amount of error is inherent in estimating the flood levels from a combination of photographs of high water marks and a DEM. To improve the model accuracy for future studies, it is recommended that a detailed topographic survey be undertaken for the open channel, culverts and flood prone areas on either side of the channel. The survey information could be used to create a more detailed and accurate DEM 2D grid network for the PCSWMM model. Hydrometric monitoring is also recommended to more accurately measure flood depths in the open reaches of the Don Mills Channel during future severe storm events. This is discussed further in **Section 5.5**.

2.5.2.4 Design Storm Selection

In order to fully characterize existing flooding conditions through the study area and quantity the potential for future flood damages, it is necessary to predict the extent of flooding for a range of return period design storm events. A number of different distributions can be used to generate the return period design storms. An exercise was completed to determine the most appropriate storm distributions to use in simulating the 2 year through 100 year return period storm events.

Three different design storm distributions were investigated:

- 3 Hour Modified Atmospheric Environment Service (AES) Distribution: This is a relatively short duration, high intensity storm distribution. It has been included in the City of Markham's engineering standards and is used for the design of stormwater management facilities and other storm drainage infrastructure
- 4 Hour Chicago Storm Distribution: This is a synthetic storm distribution that mimics the peak intensities of a given intensity-duration-frequency (IDF) relationship over the duration of the storm event. This storm distribution typically yields results comparable to Rational Method hydrology, which is also based on an IDF relationship. For this study, the Chicago Storm distributions were generated using the IDF represented by the A, B and C values in the City of Markham's Engineering Design Criteria.
- 12 Hour Modified Soil Conservation Service (SCS) Type II Distribution: The TRCA developed this long duration / low intensity design storm distribution for their Don River watershed hydrology model.

The 2 year through 100 year design storms for all three distributions are included in **Appendix C.**

The PCSWMM model was used to simulate the 2 year through 100 year return period storms for each of the three different distributions. The 3 hour AES and 4 hour Chicago storms generated very similar flood levels and peak flow rates through the system, with the output from the 3 hour AES storms slightly higher than the 4 hour Chicago storms over the range of return periods simulated. The 12 hour SCS storms generated significantly lower peak flow rates and flood depths for the range of return period events simulated. This is reasonable, as low intensity, long duration storm events generally result in larger peak flow rates relative to short duration, high intensity storms for larger systems, such as the main branch of German Mills Creek and the Don River itself.

It was decided to adopt the 3 hour Modified AES storm distributions for the analyses of the Don Mills Channel. This distribution provided consistency with existing and future stormwater management infrastructure which has been or will be designed using the same distribution, and is comparable (but slightly greater) than the Chicago storm distribution, which mimics the Rational method hydrology used for the design of the storm sewer systems through the study area.

2.5.2.5 Model Output

The extent of flooding through the study area for the 5 year return period and 100 year return period, 3 Hour Modified AES storms are presented in **Figure 2-22** and **Figure 2-23**, respectively. The peak flow rates for the 2 year through 100 year at key locations in the study area are summarized in **Table 2-5**, and compared against the peak flow rates and flood levels from previous studies of the Don Mills Channel in **Table 2-6**, **Table 2-7, Table 2-8** and **Table 2-9**. Additional model output can be found in **Appendix D.**

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Figure 2-19 Predicted Extent of Flooding – August 19, 2005 Storm

Figure 2-20 Predicted Extent of Flooding – July 27, 2014 Storm

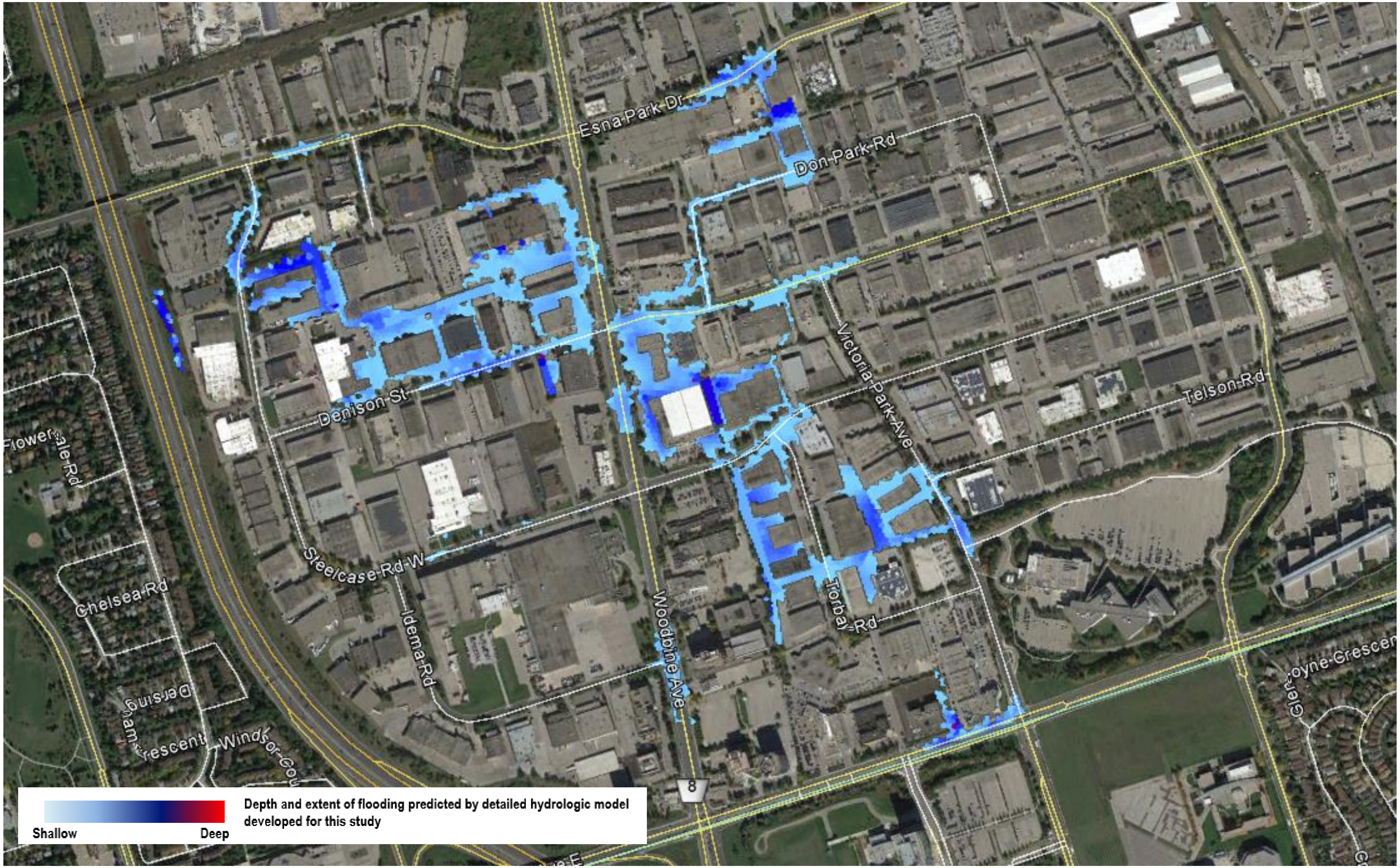

Figure 2-21 Predicted Extent of Flooding – August 1, 2014 Storm

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Figure 2-22 Predicted Extent of Flooding – 5 Year Storm

Figure 2-23 Predicted Extent of Flooding – 100 Year Storm

Table 2-5 Don Mills Channel Peak Flow Rates

Location (Flow Node) (See Figure 2-17)	**Peak Flow Rate (m^3/s)**					
	2 Year	**5 Year**	**10 Year**	**25 Year**	**50 Year**	**100 Year**
Leslie Street (A)	27.73	41.95	49.10	59.38	67.73	74.43
Highway 404 at the CNR Crossing (B)	18.73	21.43	23.46	25.38	26.73	28.26
Highway 404 at Steelcase Road W Culvert Outlet (C)	17.86	19.17	19.45	20.48	20.99	21.48
Steelcase Road West (D)	18.06	20.28	24.95	30.57	33.15	35.55
Open Channel North of Denison Street (E)	18.13	19.69	20.06	20.80	22.55	24.04
Woodbine Avenue (F)	10.58	12.20	12.88	15.76	18.19	20.10
Steelcase Road East (G)	5.66	7.51	9.76	11.21	13.21	15.13
Open Channel West of Torbay Road (H)	5.86	8.52	9.94	11.20	13.28	15.54
Open Channel North of Steeles Avenue (I)	8.04	11.07	12.38	13.94	14.69	15.11
Steeles Avenue (J)	7.74	10.58	11.99	13.81	15.91	16.27

Table 2-6 Comparison with Original Channel Design Flows (MMM, 1964)

Location (Flow Node)	**Peak Flow Rate (m^3/s)**			
	5 Year Storm		**50 Year Storm**	
	Original Design (1964)	**PCSWMM (2016)**	**Original Design (1964)**	**PCSWMM (2016)**
Highway 404 at Steelcase Road W Culvert Outlet (C)	27.84	19.17	n/a	20.99
Woodbine Avenue (F)	18.92	12.20	32.42	18.19
Steelcase Road East (G)	15.66	7.51	n/a	13.21

Table 2-7 Comparison with Ditch Capacity Study (Dillon, 1989)

Location (Flow Node)	Peak Flow Rate (m^3/s)			
	2 Year		100 Year	
	OTTHYMO (1989)	PCSWMM (2016)	OTTYHYMO (1989)	PCSWMM (2016)
Highway 404 at Steelcase Road W Culvert Outlet (C)	42.0	17.86	102.2	21.48
Open Channel North of Denison Street (E)	37.7	18.13	91.9	24.04
Woodbine Avenue (F)	22.1	10.58	53.6	20.10
Steelcase Road East (G)	14.2	5.66	34.4	15.13
Steeles Avenue (J)	11.5	7.74	27.9	16.27

Table 2-8 Comparison with Visual OTTHYMO (Cole, 2011)

Location (Flow Node)	100 Year Storm Peak Flow Rate (m^3/s)	
	Visual OTTHYMO (2011)	PCSWMM (2016)
Highway 404 at Steelcase Road W Culvert Outlet (C)	73.8	21.48
Open Channel North of Denison Street (E)	65.2	24.04
Woodbine Avenue (F)	57.8	20.10
Steelcase Road East (G)	34.3	15.13
Steeles Avenue (J)	16.8	16.27

Table 2-9 Comparison with InfoWorks Model (2010)

Location (Flow Node)	Flood Level (m)					
	5 Year		25 Year		100 Year	
	InfoWorks (2010)	PCSWMM (2016)	InfoWorks (2010)	PCSWMM (2016)	InfoWorks (2010)	PCSWMM (2016)
Highway 404 at the CNR Crossing (B)	171.78	172.78	172.03	172.78	172.21	172.78
Highway 404 at Steelcase Road W Culvert Outlet (C)	173.08	173.46	173.51	173.46	173.78	173.46
Steelcase Road West (D)	173.45	173.79	173.87	174.3	174.11	174.76
Open Channel North of Denison Street (E)	174.60	174.29	175.00	174.42	175.27	174.78
Woodbine Avenue (F)	176.47	175.94	177.04	176.28	177.42	176.38
Steelcase Road East (G)	177.06	176.22	177.59	176.36	177.92	176.46
Open Channel West of Torbay Road (H)	177.12	176.22	177.65	176.37	177.98	176.49
Open Channel North of Steeles Avenue (I)	177.42	176.56	177.93	177.35	178.24	177.74

Table 2-6 and **Table 2-7** show that the peak flow rates predicted by the PCSWMM model are significantly lower than the original design flow rates and less than 50% of the flow rates modelled in the Ditch Capacity Study (Dillon, 1989). The model developed for the 1989 was an event-based, non-dynamic hydrology model. The 2011 model was developed using Visual OTTHYMO, an event-based, steady state hydrologic model. The dynamic, 2D PCSWMM model developed for this study accounts for the storage and attenuation of storm runoff in the channel upstream of culverts and on surface areas adjacent the channel during large storm events. It is suspected that the storage and attenuation of flows in the channel and flooded areas adjacent the channel significantly reduce the flow rate in the Don Mills Channel.

This is particularly evident downstream of the Steelcase Road West culvert, where the PCSWMM model calculates much lower flows in the Highway 404 right-of-way relative to upstream of Steelcase Road West. This is due to a local high point west of Steelcase Road West that limits the conveyance of overland flow to Highway 404 once the capacity of the Steelcase Road West culvert is exceeded. Grades near the west limit of the properties west of Steelcase Road West in the vicinity of the Don Mills Channel are up to 1 m higher than the centreline of Steelcase Road west, and are also higher than much of the land east of Steelcase Road West. This high point governs flood levels for the majority of the area between Steelcase Road West and Woodbine Avenue, north of Denison Street (see **Figure 2-23**), such that this area acts as a single flood storage area governed by the discharge through the Steelcase Road West culvert. Water begins to spill over this high point and into the Highway 404 right-of-way only at the 50 year storm, and therefore the storage area, combined with the limited capacity of the Steelcase Road West culvert, significantly reduces the peak flow rates reaching the Highway 404 right-of-way.

Finally, the PCSWMM 2D model also takes into account the on-site controls that have been incorporated on new and re-development through the study area since the late 1980's, which reduce the peak flow rates in the channel system.

Relative to the previous hydrodynamic InfoWorks model of the Don Mills Channel, the PCSWMM model is predicting similar or slightly higher water levels at and downstream of Highway 404, and lower flood levels in the system at and upstream of Highway 404 (**Table 2-9**). It is suspected that the differences between the models is due to the finer sub-catchment discretization in the PCSWMM model, the representation of the minor drainage system and consideration of on-site controls in the PCSWMM model. These differences between the models affect the timing and rate of delivery of storm runoff from developed sites and roadways to the Don Mills Channel, which in turn affect peak flow rates through the system.

2.5.2.6 Flood Damages

Damages to buildings impacted by surface flooding are difficult to estimate. The Ontario Ministry of Natural Resources and Forestry (MNRF) and other agencies previously developed tables and curves to correlate flood depth against a structure to flood damages. However, there are many factors influencing potential flood damages other than water depth against a structure. In residential areas, the height of basement windows or other building openings above existing grades varies by structure, and therefore depth is not directly related to the potential for floodwater to enter a building. The degree to which a basement is finished would also significantly influence actual flood damages. The correlation between flood depth and flood damages is even weaker for commercial and industrial properties. In these instances, flood damages can be influenced by the value of inventory stored below flood depths, water damage to manufacturing equipment, the duration of any closure for flood clean-up and repairs, and countless other factors that aren’t directly correlated to the maximum water depth in a flood.

A number of flood reduction studies were completed for the City of Peterborough following severe storms in 2002 and 2004. The difficulties in estimating flood damages were identified during the initial City-Wide Flood Reduction Master Plan (AECOM, 2005). After careful consideration with a number of stakeholders, it was agreed to estimate flood damages as a percentage of the assessed value of the buildings partially and fully within the flood plain associated with any given return period storm event. This approach was simple and consistent in its application, allowed relatively simple updating of damage estimates in future studies, and avoided extensive inspections of homes and businesses that would be required to fully utilize a depth/damage approach. The same approach was more recently successfully applied to a flood reduction study for the City of Pickering (TMIG, 2015). Given its advantages, this approach has been adopted for this study to estimate damages from flooding along the Don Mills Channel.

The assessed values of the impacted properties through the study area were based on the 2014 property assessments completed by the Municipal Property Assessment Corporation (MPAC), which were provided by the City of Markham. Based on average insurance claims provided by the Institute for Catastrophic Loss Reduction and recent and pending flood damage claims against the City of Markham, it was determined that 10% of the assessed property value is a reasonable estimate for damages to buildings in the study area impacted by flooding

Flood inundation mapping was prepared and corresponding flood damage estimates were calculated for the 2, 5, 10, 25, 50 and 100 year return period storm events and the Regional storm. For the 100 year return period storm, a total of 18 buildings are predicted to be impacted by flooding, with a corresponding damage estimate of $10.3 Million. Note that this is considerably less than the 68 buildings partially or entirely within the TRCA’s Regulatory flood plain (refer to **Section 2.1.5**). While more than 50 buildings are within the flood extent for the 100 year storm, buildings with finished floor elevations above the 100 year flood level were assumed to not incur flood damages. Furthermore, the PCSWMM model developed for this study accounts for storage and attenuation of flows behind culverts and other obstructions, and accounts for on-site peak flow controls installed in the more recent development sites in the study area. These are conservatively ignored in the TRCA’s Regulatory hydrology and hydraulic models, as per MNRF guidelines for regulatory flood plain mapping, resulting in increased peak flow rates and flood levels relative to the PCSWMM model.

Average annualized flood damages were then calculated as the product of risk of flooding and corresponding flood damages. A 2 year storm has a 50% risk of occurring in any year. A 100 year storm is expected to result in much higher flood damages, but only has a 1% risk of occurring in any year. The sum of the product of risk x damages across all storm events is calculated as follows:

$$D_{TOT} = 0.50 * \frac{D_2}{2} + 0.30 * \frac{(D_2+D_5)}{2} + 0.10 * \frac{(D_5+D_{10})}{2} + 0.06 * \frac{(D_{10}+D_{25})}{2} + 0.02 * \frac{(D_{25}+D_{50})}{2} + 0.01 * \frac{(D_{50}+D_{100})}{2}$$

Where D_{TOT} = Average annualized flood damages, and;
D_N = Flood damages associated with *N*-year return period event

Note that the estimated damages from the Regional storm have not been included in the above calculation for average annualized flood damages. The probability of a Regional storm occurring in any year cannot be quantified, but is significantly less than the probability of a 100 year storm. When the extremely small risk of the Regional storm is multiplied by the anticipated damages, the product of risk x damage is negligible relative to the overall average annual damage estimate calculated using the 2 year through 100 year storm damages.

The average annualized flood damages along the Don Mills Channel are estimated to be approximately **$1.7 Million** per year. Flood inundation mapping and the flood damage calculations are included in **Appendix D**.

The above estimate of average annualized flood damages does not consider damages to cars parked in flood prone areas during storm events, nor does it account for any potential loss of revenue if businesses are closed while clean-up and repairs are completed. These damages vary significantly with the time of year, day of the week and even time of day that flood occurs, making it difficult to predict flood damage amounts with any certainty.

Note finally that this study only considers the potential for flooding and flood damages associated with surface flooding from the Don Mills Channel. Businesses in the study area could also potentially be at risk of back-up from the sanitary sewer system during severe storm events. The analysis of the sanitary sewer systems in the study area is beyond the scope of this project. However, sanitary flow monitoring data collected by the City of Markham from recent storm events did not show a high surcharge potential in the system. Furthermore, the majority of the buildings in the study area are 'slab-on-grade' commercial and industrial buildings that do not have basements. The risk of flood damages from sanitary sewer back-ups in the study area is therefore expected to be relatively low.

2.5.3 Utilities

All relevant utility owners that could potentially have existing or planned infrastructure in the study area were circulated information on the project in December 2015. Information on existing and planned utilities was obtained from the following organizations:

- Rogers Communications
- Bell Canada
- Power Stream
- Enbridge
- TransCanada Pipelines
- Telus
- Cogeco
- MTS Allstream
- Hydro One

Refer to **Appendix F8** for correspondence from utilities and locations of known utilities through the study area.

Responses were received from most potential utility owners. Utilities present in the study area include All Stream, Bell, Enbridge, Powerstream and Rogers. The City and Region also own storm sewers, sanitary sewers, sanitary forcemains and watermains throughout the study area.

3 DESCRIPTION OF ALTERNATIVE SOLUTIONS

Simply stated, flooding occurs when the runoff generated by a storm event exceeds the capacity of the drainage conveyance system. Flooding becomes a concern when water in excess of the conveyance system capacity flows onto private property, and flood damages result when floodwater enters structures or otherwise negatively impacts public and private infrastructure.

The analyses and investigations documented in **Section 2.5** demonstrate that flooding is a concern along the Don Mills Channel. Floodwater spills from the channel onto private property during a 2 year storm, and approximately 18 buildings are expected to be flooded during a 100 year storm.

Given the above simple definition of flooding, there are only three general approaches to reducing flooding and flood damages. The first option is to increase the capacity of the undersized drainage conveyance systems. This could include larger or additional storm sewers, improved or new overland flow routes, enlarging or improving open channel systems, and enlarging culverts and bridges.

The second option is to reduce the rate and volume of water entering the drainage systems. This could be achieved by reducing the amount of rainfall that is transformed to runoff (increased infiltration and evapotranspiration, capture for re-use in irrigation or greywater systems, etc.), creating flood attenuation storage in the system (stormwater management ponds, tanks, surface ponding, etc.), or diverting water away from the undersized segments of the drainage conveyance system.

The last option is to allow flooding to continue, and protect structures from damages during flood events. This could be achieved by constructing berms or otherwise re-grading around structures, or installing water-tight windows and doors at all openings to structures that lie below the anticipated maximum flooding elevation.

These general flood reduction and flood protection concepts were applied to the study area to generate a list of potential feasible solutions to address the problem of flooding along the Don Mills Channel.

Typically, the objective of flood reduction studies is to reduce flooding to minimize flood damages for up to the 100 year storm or Regulatory storm event. For the City of Markham, the regulatory event is the historical Hurricane Hazel storm. However, recall from **Section 1.2** that Don Mills Channel was originally designed to convey flows only up to the 5 year storm, and the numerous culverts and channel modifications that have taken place since the channel was originally constructed has reduced the system capacity to less than the 2 year return period storm. The previous flood reduction study of the Don Mills Channel (Cole, 2010) concluded that the works needed to improve the channel sufficient to convey the 5 year storm would be extremely expensive, and conveyance of the 100 year storm peak flow rate would be cost prohibitive.

A presentation was made to Markham Council in February 2013 regarding the Stormwater Fee, which was implemented to fund the City's Flood Control Program. Following the presentation, Council made the following resolution:

> *"That the City's flood control strategy adopt a 5 year level of service target for Don Mills Channel drainage system based on its original design and consider other options, subject to technical feasibility and approval as part of a future Class EA"*

In developing flood reduction alternatives for this study, the objective is to reduce flooding and flood damages to the extent feasible. Given the above described council resolution, the minimum target of protection to the 5 year storm has been considered in the development of the alternative solutions. The alternative solutions are described in the following sections.

3.1 Status Quo (Do Nothing)

The City of Markham and property owners in the study area have been aware of the potential for flooding along the Don Mills Channel for some time, and a number of initiatives are already in place to mitigate flooding. Redevelopment in the Don Mills Channel catchment area within the City of Markham is required to over-control peak flow rates from up to the 100 year storm to the 2 year storm in order to reduce flow rates in the Don Mills Channel.

The City has also initiated an enhanced inspection and maintenance program for the Don Mills Channel to clear vegetation and debris that could potentially obstruct culvert openings and contribute to flooding, and prepared a comprehensive erosion study of the Don Mills Channel in 2017 to identify erosion sites and prioritize the required channel rehabilitation works. The inspection and maintenance program will minimize the potential for flooding due to debris jams, and the area specific stormwater management criteria will reduce peak flow rates in the Don Mills Channel. Unfortunately, redevelopment in the Don Mills Channel catchment area is occurring at a relatively slow pace, and it will take a very long time before there is sufficient redevelopment with the more stringent stormwater management controls to have a measurable reduction in flow rates and flooding.

For the purposes of this EA study, the Status Quo alternative does not consider potential future redevelopment in the Don Mills Channel catchment area, and therefore the extent of flooding for the 2 year through 100 year storms and average annualized flood damages of $1.7 Million are unchanged from the existing conditions analyses documented in **Section 2.5.2**.

3.2 Enhanced Channel Maintenance

Section 3.1 described the City's current inspection and maintenance program for the Don Mills Channel. Under this program, any large dead tree branches or other debris that could potentially block a culvert or otherwise obstruct the flow in the channel are removed on at least and annual basis. However, healthy trees and shrubs within the Don Mills Channel corridor are not removed. The natural vegetation in the channel contributes to a high 'roughness' of the channel banks, which has the potential to reduce conveyance capacity and increase flooding relative to a perfectly smooth, unobstructed channel.

There is therefore some potential to reduce flooding from the Don Mills Channel by clearing all woody vegetation and maintaining the channel corridor as a manicured, grass lined channel. The PCSWMM model described in **Section 2.5.2** was used to evaluate the effectiveness of such an enhanced channel maintenance program. The removal of all woody vegetation in the channel was represented with a reduced roughness coefficient (Manning's 'n' = 0.035) for the channel segments.

The PCSWMM model output demonstrates that enhanced channel maintenance will have a negligible reduction in flooding along the Don Mills Channel and no reduction in average annualized flood damages. It is clear from the PCSWMM model that the existing culverts along the Don Mills Channel have much less conveyance capacity relative to the open channel segments. The PCSWMM model output associated with this alternative are included in **Appendix E.**

3.3 Channel Widening with Culvert Replacements

The analysis of the enhanced channel maintenance alternative described in **Section 3.2** concluded that clearing all debris and vegetation from the channel would have a negligible impact on flooding and flood damages from the Don Mills Channel. More significant works are needed to increase the capacity of the Don Mills Channel sufficient to mitigate flooding.

An alternative was developed to assess the effectiveness of widening the Don Mills Channel corridor. This would require acquisition of existing private property containing and abutting the existing channel corridor. Through the majority of the study area, the existing channel is located at the rear of commercial and industrial sites. There is already limited space for turning movements for trucks to access the loading bays at the rear of the buildings on these sites, and acquiring a portion of the property between the buildings and channel for the widening would effectively sterilize the existing building and business. This alternative therefore assumes that the entire property on one side of the channel would be acquired for the widening, and the full width of the acquired property could be used for the widened channel. Under this assumption, it is expected that the

Don Mills Channel could reconstructed as a 60 m wide channel corridor. **Figure 3-1** shows a potential alignment for the widened channel.

Figure 3-1 Channel Widening Concept Design

A total of **24** properties would need to be acquired, and then the existing buildings would need to be demolished and utilities relocated before construction of the widened channel corridor could commence.

The property acquisition and channel widening would open up the existing enclosed reaches on private property, but new culverts would be required at all road crossings in the study area. The existing culverts at Steelcase Road East, Woodbine Avenue, Denison Street and Steelcase Road West would be removed and replaced with 12.8 m span culverts. These are the largest spans that could reasonably be implemented at these crossings. There is limited distance between the existing road elevation and channel invert elevation, and the larger structure depths associated with larger spans would result in a smaller overall opening area.

The PCSWMM model of the Don Mills Channel was revised to reflect the 60 m wide channel corridor and replacement culverts. With these improvements, flooding would be contained to the widened channel corridor for up to the 100 year storm.

3.4 Acquisition of Flood Prone Properties

The risk of future flood damages can be eliminated by acquiring the flood prone properties and protecting them in public ownership. Such an approach to flood risk management was adopted following Hurricane Hazel in 1954, where a large number of private properties in the flood plain were acquired by what is now the TRCA, buildings were demolished and the lands were protected as open space or parkland.

For this study, the property acquisition alternative involves purchasing all properties at risk of flooding during a 5 year storm event. The buildings on these properties would be demolished and converted to park or open space. No other works would be undertaken to reduce the depth or extent of flooding through the study area.

Implementation of this alternative requires the acquisition of **16** properties that are currently at risk of flooding in a 5 year storm event.

3.5 Underground Flood Control Storage

The previously described alternatives highlight the significant level of effort needed to increase the capacity of the Don Mills Channel sufficient to reduce flooding and flood damages. As noted in **Section 3**, flooding can also be mitigated by reducing the flow rates in the channel.

There are no suitable open areas within the study area for construction of traditional end-of-pipe stormwater management facilities to reduce runoff peak flow rates delivered to the Don Mills Channel. However, underground storage facilities could be constructed under existing surface parking lots and other open areas to control storm runoff from both the host property and external upstream lands. Underground storage facilities emerged as a preliminary preferred alternative in the previous Don Mills Channel remediation study (Cole, May 2010).

Underground flood control storage could take the form of a relatively small number of very large storage facilities, or a larger number of smaller facilities distributed through the Don Mills Channel catchment area. Where soils and groundwater conditions allow, these facilities could integrate Low Impact Development (LID) and Green Infrastructure (GI) best management practices (BMPs) such as constructing the storage facilities with an open bottom to infiltrate pre-treated storm runoff and further reduce runoff volumes and peak flow rates.

Implementation of this alternative would need to be led by the City, as it is not appropriate to impose such flood storage facilities through redevelopment applications. Underground storage facilities could potentially manage storm runoff from areas external to the properties on which they are installed. Some redevelopment sites may not be well suited for such controls (i.e. sites at the upstream end of a sewershed would only be able to store runoff from the site itself), and it would take a very long time to fully implement, given the current pace of redevelopment in the study area. The City would need to enter into agreements and/or with landowners of suitable sites to allow for the construction and long term maintenance of on-site flood storage facilities.

Note that the flood control facilities associated with this alternative would be in addition to the storage required to achieve the current peak flow control criteria applied to redevelopment in the Don Mills Channel catchment area, described in **Section 3.1.**

This alternative was evaluated using the PCSWMM model by applying on-site flood storage uniformly through the Don Mills Channel catchment area within the City of Markham. A total storage volume of approximately 40,000 m^3 would be needed to reduce flows sufficient to prevent flooding in a 5 year storm. The PCSWMM model output, including the extent of flooding, is included in **Appendix E**.

3.6 Central Municipal Flood Control Storage

The previous alternative described how on-site flood control storage could be installed within existing developed properties to reduce peak flow rates and flooding in the Don Mills Channel. Another alternative to reduce peak flow rates is a centralized municipal flood control storage. This would take the form of a single large stormwater management facility integrated into the Don Mills Channel. High flows in the Don Mills Channel would fill the facility, which would limit the discharge delivered to the downstream channel reaches.

The most suitable location for such a central flood control facility is within the upper portion of the catchment area, such that flows are reduced upstream of flood prone areas. However, the facility must be located such that it will receive and control storm runoff from a significant fraction of the total drainage area to the Don Mills Channel. The facility should also ideally be located within a low-lying area to minimize the amount of excavation required for its construction. There are no suitable open, undeveloped areas adjacent the Don Mills Channel for such a facility, and therefore property must be acquired and buildings demolished to allow for its construction.

The most appropriate location for a centralized flood control storage facility is upstream of Steelcase Road East, as indicated in **Figure 3-2. Figure 3-2** also presents a potential location and approximate size of a facility within the larger preferred area. A large flood storage area would be created by excavating an area immediately adjacent the Don Mills Channel, and an on-line control structure would be constructed on the channel upstream of Steelcase Road East to back water up into the facility and control peak flow rates from the contributing areas.

Note that many of the properties adjacent the Don Mills Channel are at risk of flooding during severe storm events, and acquisition of such properties would eliminate flood damages associated these buildings and reduce the overall average annualized flood damages from the Don Mills Channel.

The centralized flood storage facility could incorporate a variety of different functions in addition to flood control. A storm sewer currently discharges to the Don Mills Channel via an easement between 115 and 135 Torbay Road. The centralized flood storage facility could incorporate a permanent pool of water and low flow control structure to improve the quality of storm runoff released to the Don Mills Channel. The facility could also provide recreational opportunities by integrating trails and other public amenities.

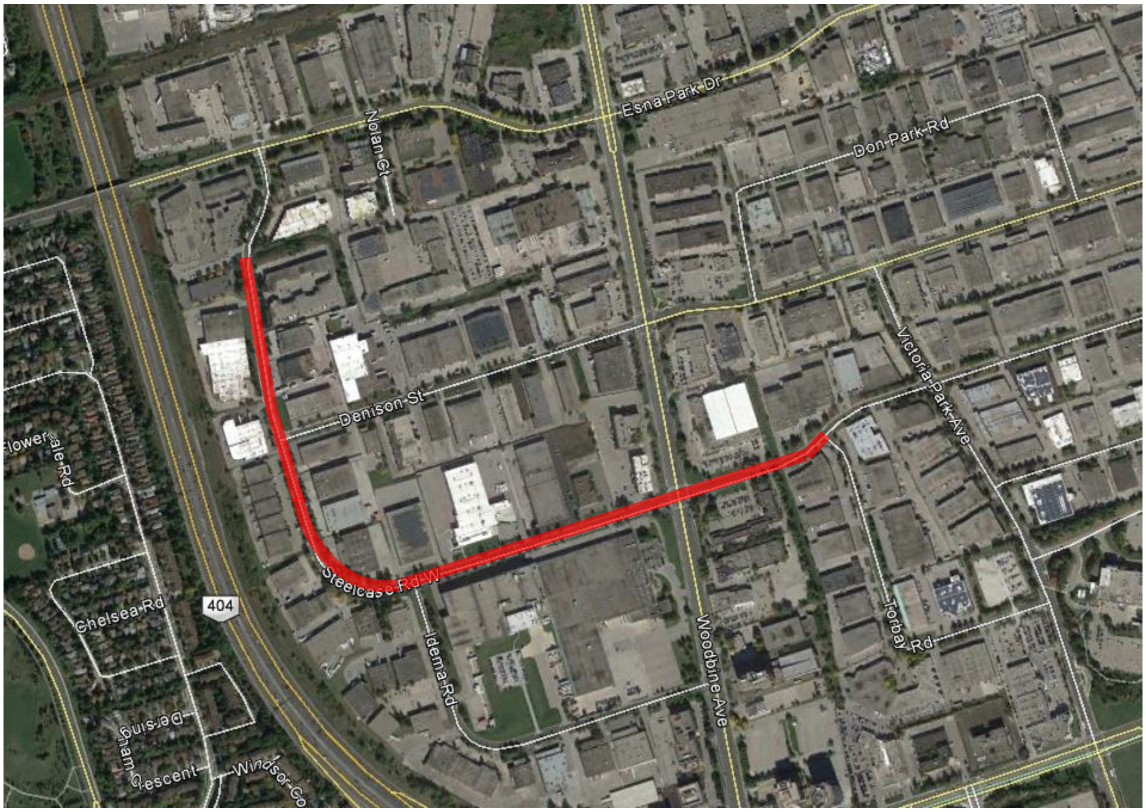
It is estimated that a centralized flood storage facility constructed in the area shown in **Figure 3-2** could provide a total storage volume of approximately 37,000 m^3, and would reduce flow rates in and flood levels in the downstream reaches of the Don Mills Channel. The PCSWMM model output, including the extent of flooding and corresponding flood damages are included in **Appendix E**.

Figure 3-2 Potential Size and Location of Flood Storage Facility

3.7 Flow Diversion

The final alternative explored to reduce peak flow rates in the Don Mills Channel is a flow diversion. A diversion would intercept some or all of the flows in the channel near the upstream end of the study area and safely convey them around the most flood prone areas before returning flows to the system. Within the study area, a diversion sewer could be constructed to intercept high flows in the Don Mills Channel at Steelcase Road East. The diversion sewer would carry flows west and continue on Steelcase Road West and outlet back to the Don Mills Channel at the Steelcase Road West Crossing. This alterative would also require replacement of the existing Steelcase Road West culvert and the existing culvert extension through the downstream property to accommodate the discharge from the diversion sewer. The alignment for the diversion sewer is highlighted in red on **Figure 3-3.** The diversion sewer would replace the existing storm sewer systems on Steelcase Road East and West along its alignment.

Figure 3-3 Potential Diversion Sewer Alignment



A conceptual design of the sewer was prepared to confirm that a continuous gravity diversion sewer could be constructed on Steelcase Road East and West with adequate cover. The concept design is based on a 3,000 mm wide x 1,800 mm high concrete box, which could be reasonably implemented on Steelcase Road. It is expected, however, that numerous utilities would need to be relocated for its construction.

The effectiveness of the flow diversion was assessed with the PCSWMM model. The model confirmed that, by intercepting high flows and diverting them around the flood prone areas between the Steelcase Road East and West crossings, flow rates and flood levels in the Don Mills Channel would decrease. However, the model also predicted that the diversion sewer would deliver flows to the Highway 404 right-of-way faster than under existing conditions, resulting in increases in flood depths and the frequency of flooding of the highway. Under existing conditions, Highway 404 would not be flooded for up to the 50 year return period storm event. With the flow diversion in place, the highway would experience flooding in a 10 year storm.

Several different refinements to this alternative were assessed in the PCSWMM model to mitigate the predicted increase in flooding of Highway 404, but no reasonable measures can fully offset the flooding impacts on Highway 404. The PCSWMM model output is included in **Appendix E**.

3.8 Flood Proofing and Education

The final alternative solution considered for the Don Mills Channel is to allow flooding to continue without mitigation, and instead prevent or minimize flood damages through implementation of a flood proofing and education program.

Flood proofing of individual buildings and properties could take a variety of forms, depending on the depth and extent of flooding surrounding a building. For buildings near the edge of the flood limit, re-grading or berming could contain the flood plain away from the building, preventing floodwater from reaching the structure. Where re-grading is not feasible, a flood prone building could be retrofitted with water-tight doors and windows or protected by an enclosure to prevent water from entering the building. **Figure 3-4** illustrates examples of flood proofing that have already been implemented in the study area.

Figure 3-4 Flood Proofing Examples

This alternative primarily considers protection of only the flood prone buildings. Protecting existing parking and loading areas from flooding is not feasible through most of the study area. Extensive regrading would be required, which could in turn worsen flooding elsewhere in the system. Raising grades in existing loading areas is also not feasible without also raising the loading bays internal to the building. As a result, any vehicles parked on flood vulnerable sites and any materials stored outside on flood vulnerable would continue to be at risk during flood events.

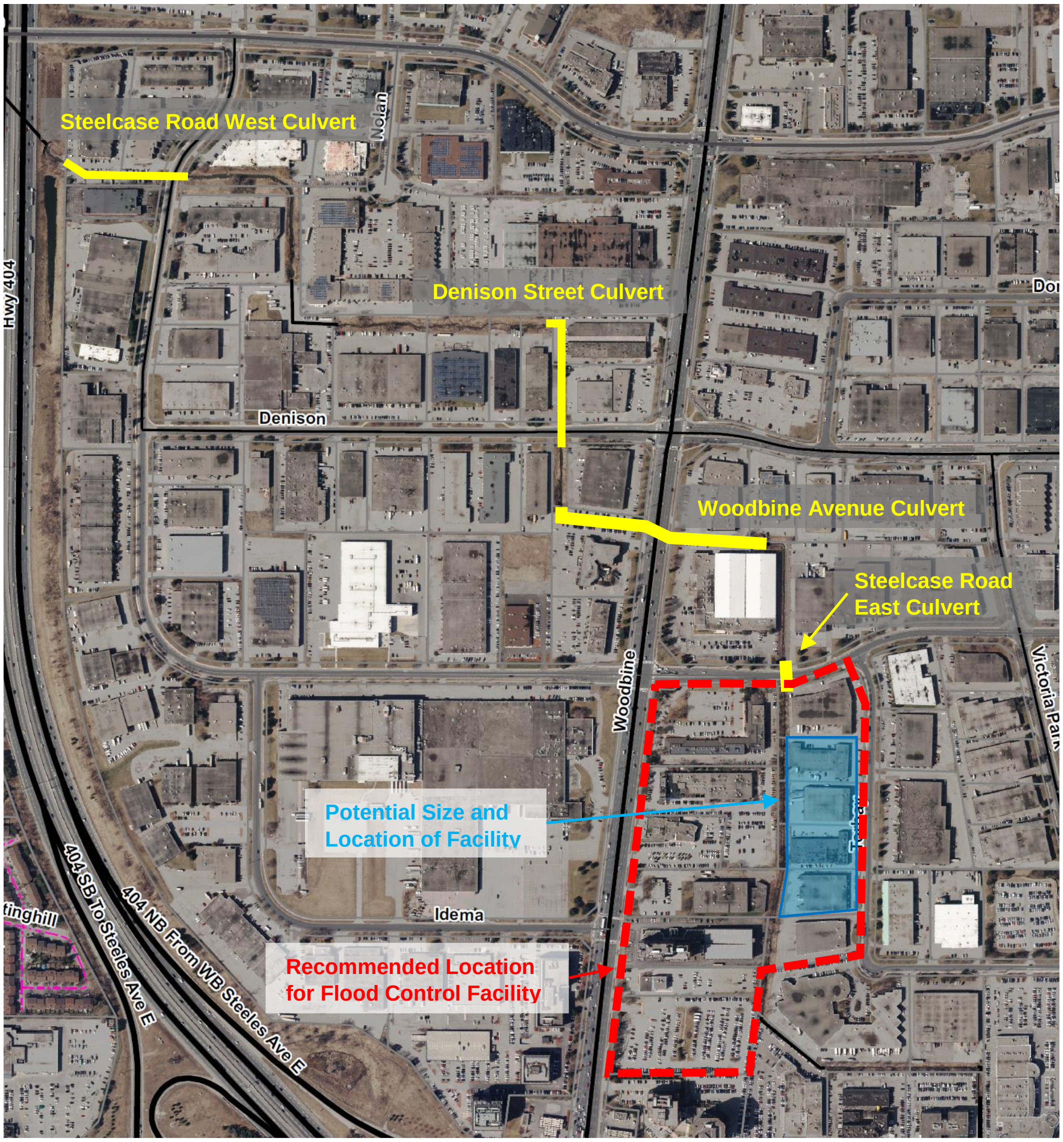
The education component of this alternative could include consultation with owners of flood vulnerable buildings to make them aware of the predicted maximum flood levels on their property and the range of suitable flood proofing measures available to prevent water from entering their buildings during flood events. The education program could also include outreach to property owners and tenants to implement best management practices to minimize damages during flood events. Such practices include but are not limited to elevating critical equipment to the extent reasonable, storing goods and materials above predicted flood levels inside buildings, locating outdoor storage areas to the least flood vulnerable areas of a property, preventing storage containers from being mobilized and carried off site during flood events, and implementing protocols to move vehicles to safe areas (on or off-site) when severe storms are predicted.

Note that this alternative was not evaluated with the PCSWMM model, as it would not have any impact on flow rates and flood levels.

3.9 Combined Alternative: Central Municipal Flood Storage, Flood Proofing & Education and Culvert Upgrades

A final alternative was developed by combining elements of different stand-alone flood reduction measures. The Centralized Municipal Flood Storage Facility (**Section 3.6**) has the potential to reduce flow rates and flood levels in the Don Mills Channel. Further improvements can be realized by replacing several of the culverts in the system, which was a component of the channel widening alternative described in **Section 3.3**. For this alternative, it is assumed that the existing culverts at Steelcase Road East, Woodbine Avenue, Denison Street and Steelcase Road West would be replaced, along with the extensions through private properties upstream and downstream of the municipal right-of-ways. This alternative assumed that the culverts located entirely within private properties (but with easements in favour of the City) would remain in place. The location and extent of the proposed replacement culverts are shown in **Figure 3-5**.

Figure 3-5 Combined Alternative Solution Elements



This alternative was modelled in PCSWMM, and was determined to be more effective in reducing flooding and flood damages relative to the centralized municipal flood storage facility alone, but would not be sufficient to fully eliminate flooding and flood damages for the 5 year storm. As a result, this alternative also considers the flood proofing and education program described in **Section 3.8** to prevent damages to at least the remaining buildings at risk of flooding during the 5 year storm. Note, however, that the flood proofing and education program could be easily expanded to cover all buildings at risk of flooding for up to the 100 year storm, and any retrofits implemented on flood vulnerable buildings would target the maximum amount of flood protection feasible rather than simply protect for up to the 5 year storm event.

The PCSWMM model output for this alternative, including the extent of flooding and flood damages, is included in **Appendix E**.

4 EVALUATION OF ALTERNATIVE SOLUTIONS

4.1 Evaluation Criteria

The alternative solutions described in **Section 3** were comparatively and qualitatively evaluated based on criteria developed within the following main categories, which represent the broad definition of the environment from the Municipal Class Environmental Assessment:

- Natural Environment, which relates to potential impacts and benefits to the natural and physical components of the environment (i.e., air, land, water and biota) including natural and/or environmentally sensitive areas.
- Social Environment, which relates to potential impacts and benefits to residents, neighbourhoods, businesses, community character, social cohesion and community features.
- Cultural Environment, which relates to potential impacts to historical/archaeological remains, and heritage features.
- Technical Environment, which relates to the technical feasibility, effectiveness, constructability, operation and maintenance, and other engineering aspects of the alternative solutions.
- Financial Environment, which relates to the capital and maintenance costs of the alternative solutions and potential reductions in future flood damages

Within each main category, project-specific evaluation criteria were developed based on a review of the Municipal Class EA, the existing conditions of the study area and the alternative solutions being considered. The resulting evaluation criteria are summarized in **Table 4-1**.

Table 4-1 Evaluation Criteria

Category	Evaluation Criteria
Natural Environment	Potential effects on fish habitat and aquatic ecosystems Potential effects on terrestrial wildlife and ecosystems Potential effects on known habitat for Species at Risk Potential effects on groundwater quality and quantity
Social/Cultural Environment	Potential impacts to public safety (emergency access) Potential impacts to the community during construction (noise, dust, traffic restrictions) Potential impacts to the public realm (aesthetics, trails, recreational amenities) Potential for requiring private property Potential impact to archaeological resources
Technical Environment	Potential to achieve technical objectives (minimum 5 year storm conveyance) Potential constructability of proposed infrastructure (technical feasibility, timing for implementation) Potential future maintenance requirements Potential conflicts with existing municipal services and utility Potential impacts on level of effort for approvals and permits
Financial Environment	Estimated costs of implementation Estimated operations and maintenance (O&M) costs Estimated reduction in future flood damages Potential impacts on municipal revenues (loss of tax revenue)

4.2 Status Quo

The Status Quo alternative, described in **Section 3.1**, does not involve any additional works to reduce peak flow rates or increase the capacity of the Don Mills Channel system. However, the City would continue to regularly inspect the channel, remove large vegetation and other debris, and complete erosion repairs where warranted under existing programs. Redevelopment in the Don Mills Channel catchment area would continue to require peak flow rates from up to the 100 year storm to be controlled to 2 year storm levels.

Natural Environment: As no works are proposed beyond current maintenance programs, there would be no direct impacts or benefits to the natural environment.

Social/Cultural Environment: As no works are proposed beyond current maintenance programs, there would be no direct impacts or benefits to the social or cultural environment, and there would challenges to provide emergency access to all properties in the study area during flood conditions

Technical Environment: If nothing is done beyond the status quo, floodwaters will continue to spill from the Don Mills Channel during a 2 year storm event. Continued application of the enhanced peak flow control criterion will reduce flows from redeveloped sites, but the pace of redevelopment in the study area is relatively slow. At the current rate, it will take a very long time to realize even a minor reduction in peak flow rates in the Don Mills Channel.

Financial Environment: There are no direct implementation or maintenance costs associated with this alternative beyond the City's existing funded maintenance program for the Don Mills Channel. Average annualized flood damages will remain at approximately $1.7 Million.

4.3 Enhanced Channel Maintenance

The Enhanced Channel Maintenance alternative, described in **Section 3.2**, involves clearing all woody vegetation from the Don Mills Channel and regularly mowing the channel to prevent any obstructions to flow from vegetation.

Natural Environment: Clearing all woody vegetation from the channel corridor would significantly degrade terrestrial habitat through the study area. The existing trees along the channel current shade the low flow channel, and their removal could contribute to increased water temperatures and negatively impact aquatic habitat.

Social/Cultural Environment: There would be minimal impact on existing businesses for vegetation removal, as it would be relatively short in duration and would not require any road closures. A regularly mown channel may be considered less aesthetically pleasing relative to the existing more natural vegetation in the channel to people that frequent the area.

Technical Environment: The PCSWMM model created for this alternative concluded that clearing vegetation to create a 'smoother' channel corridor would have no impact on flood levels and flood damages along the Don Mills Channel. The existing culverts through the system have much less capacity relative to the open channel sections and function as 'bottlenecks', backing flow up into the upstream open reaches.

There may be challenges securing permits from regulatory agencies for tree removals, and there may be issues accessing all areas of the channel with the heavy equipment needed to safely clear and dispose of larger trees.

Financial Environment: It is estimated that the initial works needed to clear all woody vegetation from the channel would cost approximately $150,000 to complete. Once complete, there would also be increased maintenance costs to mow the channel banks several times a year to prevent woody vegetation from re-establishing. The works would have a negligible impact on existing flood levels, and average annualized flood damages would remain at $ 1.7 Million.

4.4 Channel Widening with Culvert Improvements

The channel widening alternative, described in **Section 3.3**, would see the Don Mills Channel fully reconstructed as a 60 m wide natural channel corridor. All existing culverts would be removed, and large new culverts and bridges would be constructed at the four existing road crossings between Steeles Avenue and Highway 404.

Natural Environment: There would be short term impacts to the natural environment for construction of this alternative. Most of the existing vegetation in the channel corridor would be removed for excavation and grading of the new channel, and the flows in the system would need to be diverted around work areas. Upon completion, the widened channel corridor would significantly increase the size and quality of the natural heritage system through the study area. Terrestrial habitat would be improved through appropriate planting of the corridor, a natural low flow channel would improve aquatic habitat, and wildlife would be able to move easily through the system.

Social/Cultural Environment: Implementation of this alternative will require the City to acquire up to 24 properties. As noted in **Section 3.3**, the commercial and industrial uses through the study area would be sterilized if a widening was taken at the rear of the properties abutting the channel, and therefore full property acquisition is necessary. Construction of the widened channel corridor and culvert replacements would require road closures. There would also be potential for noise and dust impacts during construction, which could take several years to complete. The widened channel corridor would create opportunities for trails and other amenities that would enhance the social environment through the study area.

Technical Environment: The PCSWMM model was used to simulate the effectiveness of the widened channel corridor. Flows would be contained within the widened channel corridor for up to the 100 year storm event. However, there are a number of significant challenges associated with implementation of this alternative. It would be necessary for the City to acquire up to 24 properties, which could take very long time. Many utilities would need to be relocated away from the widened channel and new culverts, and there will also be challenges during construction of the channel widening to bypass storm flows around work areas.

Financial Environment: The total cost to implement this alternative is estimated at $350 Million. More than half of this cost is associated with property acquisition, and once acquired the City will no longer receive tax revenues from these properties. Once complete, there will be few long term maintenance costs associated with the Don Mills Channel, as it will function as a natural watercourse and valley system. Widening the Don Mills Channel will largely eliminate flood damages for up to the 100 year storm.

4.5 Acquisition of Flood Prone Properties

As described in **Section 3.4**, damages from future flood events can be eliminated by acquiring flood prone properties and removing the building and parking areas at risk of flooding. This alternative involves the acquisition of 16 properties that are at risk of flooding during the 5 year flood event and converting the properties to open space or parkland.

Natural Environment: There would be no direct impacts to the natural environment, as work would be primarily contained within existing developed sites. There could be some benefits to the natural environment if the acquired sites were restored, planted and managed as natural habitat.

Social/Cultural Environment: As identified in **Section 3.4**, this alternative would require the City to acquire 16 properties within the Don Mills study area, with significant impacts to the owners and tenants of those buildings who would be forced to relocate. There could be some benefits to the social environment if the acquired properties were restored and managed for passive or active recreation.

Technical Environment: This alternative would eliminate flood damages associated with buildings as well as outdoor parking and storage areas for up to a 5 year return period storm. However, there would be no reduction in the frequency and depth of flooding from the Don Mills Channel, and therefore no improvement to the existing flood prone roadways in the study area, and no reduction in flood damages for buildings at risk of flooding during less frequent storm events (which would not be acquired). There are considerable challenges to acquire the 16 properties prone to flooding in a 5 year return period storm.

Financial Environment: The total cost to implement this alternative would be $250 Million. This includes the cost of building acquisition and demolition. However, as with the previous option, the City will no longer receive tax revenues for these properties, and there may be additional long term costs to maintain the acquired properties, depending on how they are restored and managed after acquisition and demolition. Upon acquisition and demolition of the buildings on the 16 properties to be acquired, average annualized flood damages would be reduced to $ 0.5 Million.

4.6 Underground Flood Control Storage

The on-site flood control storage alternative involves construction of underground storage facilities within existing developed sites in the Don Mills Channel catchment area, as described in **Section 3.5**. The facilities would control peak flow rates from the properties on which they are located as well as off-site areas that could be directed to the facility. These distributed, local stormwater controls would also be considered LID and GI BMPs when designed to reduce runoff volumes and improve water quality.

Natural Environment: There would be no direct impacts to the natural environment, as work would be primarily contained within existing developed sites. There could be benefits to the natural environment if the storage facilities can be designed as LID/GI BMPs with open bottoms to promote infiltration, as this could reduce erosion and improve water quality and baseflow.

Social/Cultural Environment: Implementation of this alternative would require numerous agreements with private property owners to allow the City to construct, inspect and maintain underground storage units. It is expected that most of the parking area within a site would be temporarily removed during construction of a underground storage unit, with significant impacts on business operations. Once completed, the presence of the underground storage unit will restrict future redevelopment of the properties containing the units.

Technical Environment: The effectiveness of this solution in reducing flooding depends on the amount of on-site storage that can be implemented. Using the PCSWMM model, it was determined that a total storage volume of approximately 40,000 m^3 would be required to reduce peak flow rates in the Don Mills Channel sufficient to prevent flooding for up to the 5 year storm event. This could take the form of a small number of very large facilities or a larger number of smaller facilities. Regardless, there would be significant challenges to convince the owners of suitably located sites to accept underground storage units and the associated loss of parking and business during construction and it is expected that it would take a very long time to implement enough underground storage facilities to achieve significant peak flow reductions in the Don Mills Channel. There may also be challenges to work around or relocate existing utilities and service connections within existing developed sites.

Financial Environment: The cost to construct underground flood storage facilities on private properties with a cumulative storage volume of 40,000 m^3 is estimated to be $78 Million. This cost estimate includes the installation of underground storage as well as an allowance for compensation to property owners for loss of business during construction and long term constraints on redevelopment of the properties. Once constructed, there would be increased maintenance costs for the City to regularly inspect each storage facility and clean sediment and debris from the facilities and/or upstream pre-treatment devices. Average annualized flood damages would be reduced to $0.6 million following full implementation of this alternative.

4.7 Central Municipal Flood Control Storage

Section 3.6 described the centralized municipal flood control storage alternative, which would take the form of a large flood control facility located adjacent the existing Don Mills Channel. The preferred location is upstream (south) of Steelcase Road East, west of Torbay Road. Several properties would need to be acquired for implementation of this alternative. There is also the potential to integrate water quality treatment for an existing storm sewer system that discharges to the Don Mills Channel in this area.

Natural Environment: There would be temporary impacts to aquatic habitat in the Don Mills Channel during construction of the facility, when flows would be diverted around the work area for construction of the flow control structure and any works needed to safely direct the flow in the channel into the facility. The flow control structure also has the potential to impede fish movement to the limited aquatic habitat upstream of Steelcase Road East. Once complete and vegetated, the facility would increase the amount of open space in the study area and improve terrestrial habitat. If the facility integrated water quality treatment for the storm sewer system discharging through this area to the Don Mills Channel, aquatic habitat would benefit from the improved water quality.

Social/Cultural Environment: Implementation of this alternative requires acquisition of 4 properties. The concept design is based on acquiring properties on the west side of Torbay Road for the facility, but there is some flexibility in the location of the facility. There may also be localized noise and dust impacts during construction. The facility could incorporate trails, lookouts and other public amenities and serve as a recreational facility for the study area.

Technical Environment: The PCSWMM model created for this alternative determined that the centralized municipal flood storage facility would significant reduce peak flow rates and flood levels along the Don Mills Channel, but would not eliminate flooding for the 5 year storm. In addition to the challenges in acquiring the properties for the facility, there would be technical challenges to design the flow control structure to back storm flows up into the facility and regulate the discharge for moderate storm events while also preventing increases in upstream flood levels for the 100 year and regulatory storm events. The design of the flow control structure would be further complicated by the objective to preserve fish passage to the upstream reaches of the Don Mills Channel to the extent reasonable.

Once complete, the facility would require regular maintenance by the City to clear any accumulated debris from the flow control structures. If the facility incorporates a permanent pool to improve water quality from the storm sewer discharging to the Don Mills Channel in this area, this would require regular inspection and sediment removal once every 10 to 20 years, similar to other traditional stormwater management ponds in the City.

Financial Environment: The total cost to acquire property and construct the centralized municipal flood storage facility is estimated to be approximately $32 Million. There would also be increased annual costs to inspect and maintain the facility as part of the City's overall stormwater management facility asset management program. Acquisition of the 4 properties would also eliminate the tax revenue that the City currently receives from these properties. Once complete, average annualized flood damages would be reduced to $ 0.9 Million.

4.8 Flow Diversion

The Flow Diversion alternative, described in **Section 3.7**, would involved construction of a new concrete box storm sewer on Steelcase Road, intercepting high flows from the Don Mills Channel at Steelcase Road West and discharging back to the Don Mills Channel at Steelcase Road West. The sewer would divert flows around the flood prone areas between the Steelcase Road East and West crossings.

Natural Environment: Construction of this alternative would have a negligible impact on the natural environment, as the work would be primarily limited to existing road right-of-ways. The system would need to be designed to maintain baseflows and low flows in the Don Mills Channel to prevent impacts to the limited aquatic habitat in the system.

Social/Cultural Environment: The diversion sewer could be constructed entirely within public property, but it would be necessary to replace the existing culvert at Steelcase Road West and downstream extension through private property. There may be road closures along Steelcase Road East and West during construction, with potential impacts to businesses whose accesses would be cut off temporarily during construction. There would also be the potential for noise and dust impacts during construction. Note, however, that these impacts would be incurred regardless to replace the existing storm sewer systems on Steelcase Road East and West at the end of their serviceable life.

Technical Environment: While the PCSWMM model concluded that this alternative would be effective in reducing peak flow rates and flooding in the Don Mills Channel at and downstream of Steelcase Road East, it also predicted an increase in the frequency and depth of flooding on Highway 404 during severe storm events. The impacts to Highway 404 and related increase in risk to life and property are not acceptable, and this alternative has not been explored further.

Financial Environment: The diversion sewer is estimated to cost approximately $ 20 Million to construct. Maintenance costs would be similar to those for the existing storm sewers on Steelcase Road East and West. The potential reduction in average annualized flood damages has not be calculated as the alternative is not feasible due to the impact to flooding on Highway 404.

4.9 Flood Proofing and Education

This alternative, described in **Section 3.8**, does not involve any works to reduce flow rates or flood levels. Instead, buildings would be retrofit to prevent water from entering buildings and causing damages during storm events and other best management practices would be adopted by property owners and tenants to minimize damages during flood events.

Natural Environment: There would be no impacts to the natural environment, as all works would occur within existing developed sites.

Social/Cultural Environment: Existing businesses would be disrupted during construction of on-site flood proofing measures, and there would be restrictions on future expansion or renovations to ensure that the flood proofing measures remain effective. As flooding of local roadways would not be improved, there would continue to be challenges accessing properties in the study area during a severe storm event.

Technical Environment: There are significant challenges in implementing flood proofing. The City would need to provide incentive or rebate programs to assist property owners with construction of flood proofing measures, and/or enter into agreements with property owners to allow the City to construct flood protection works. Once completed, there would be challenges to ensure that property owners and businesses maintain the flood proofing measures, especially during building renovations or expansions. It may not be possible to adequately flood proof existing buildings due to existing building elevations and site grading restrictions, and vehicles and materials stored outside would continue to be at risk of damage during flood events at most properties. Finally, there would be no reduction in the frequency and depth of flooding on the existing flood prone roadways or parking areas through the study area.

Financial Environment: The cost of flood proofing measures is difficult to estimate, as each existing flood prone site would require unique measures to reduce or prevent flood damages during severe storm events. Based on recent flood proofing costs for representative buildings in the study area, the cost to implement flood proofing measures on all sites at risk of flooding in a 5 year storm is estimated to be approximately $2.1 Million. There would also be ongoing costs for property owners to maintain the flood proofing measures. With flood proofing implemented on all buildings at risk of flooding in a 5 year storm, average annualized flood damages would be reduced to $0.9 Million.

4.10 Combined Alternative: Central Municipal Flood Storage, Flood Proofing & Education and Culvert Upgrades

The final alternative considered for the Don Mills Channel combines elements from several of the alternative solutions previously described. It included the Centralized Municipal Flood Storage Facility described in **Section 3.6**, some of the culvert replacements associated with the Channel Widening alternative described in **Section 3.3**, and flood proofing of the remaining buildings at risk of flooding in a 5 year storm, as described in **Section 3.8**.

Natural Environment: Impacts to the natural environment would include the short term impacts to aquatic habitat for construction of the flood storage facility noted in **Section 4.7**, as well as short term impacts during construction of the culvert replacements at Steelcase Road East, Woodbine Avenue, Denison Street and Steelcase Road West. The flow control structure associated with the storage facility has the potential to impede fish passage, but the culvert replacements will improve aquatic habitat and fish passage through the system. There would also be benefits to aquatic habitat if the flood storage facility incorporates water quality treatment for a storm sewer system discharging to the Don Mills Channel at the suggested facility location.

Social/Cultural Environment: Implementation of this alternative requires acquisition of 4 properties, as described in **Section 4.7**. Roads would need to be closed temporarily for construction of the culvert replacements, and existing businesses would be impacted during and following implementation of flood proofing measures as noted in **Section 4.9**. The culvert replacements also require works on private property where the existing roadway culverts extend beyond the road right-of-way. Following construction, the flood storage facility could incorporate trails and other recreational amentias to benefit those that frequent the study area.

Technical Environment: The PCSWMM model created for this alternative determined that the combination of the centralized municipal flood storage facility and culvert replacements would reducing flooding and flood damages relative to the flood storage facility alone, but 2 buildings would remain at risk of flooding and require flood proofing measures. **Section 4.7** described the challenges associated with acquiring properties for the flood storage facility and associated with its design, and **Section 4.9** described the challenges to implement and maintain flood proofing measures on private properties within the study area. There may also be challenges to replace the existing culvert extensions on private property upstream and/or downstream of the roadway culverts.

Financial Environment: The total cost to acquire property and construct the centralized municipal flood storage facility, complete the culvert replacements and implement flood proofing measures on the remaining properties at risk of flooding during a 5 year storm is estimated to be approximately $69 Million. Of this, approximately $36 Million is associated with the replacement of the culverts at Steelcase Road East, Woodbine Avenue, Denison Street and Steelcase Road West. As noted in **Section 2.5.1**, several of these culverts have been recently repaired and have a limited remaining serviceable life. A significant fraction of the $36 Million associated with the culvert replacements will need to be spent regardless to replace the existing culverts at the end of their serviceable life.

Once complete, there will be ongoing costs for the City to inspect and maintain the flood storage facility, and for property owners to maintain flood proofing measures. Once all measures are implemented, average annualized flood damages would be reduced to $0.2 Million.

4.11 Evaluation

The evaluations of the alternatives described in **Section 4.2** through **Section 4.10** are summarized in **Table 4-2.**

The preferred solution is the Combined Alternative, which includes the centralized municipal flood storage facility, culvert replacements at municipal road crossings and flood proofing of buildings remaining at risk of flooding during a 5 year storm event. This alternative is the most effective at reducing flooding and flood damages that can reasonably be implemented in the study area. The centralized flood storage facility is not sufficient on its own to achieve the minimum 5 year storm level of protection established by City Council (see **Section 3**), but can meet this objective when combined with culvert replacements and flood proofing.

Neither the Status Quo or Enhanced Channel Maintenance alternatives are acceptable, as they do not address the flooding problems along the Don Mills Channel. Channel Widening, while very effective at reducing flooding, was not preferred due to the very significant costs and challenges associated with acquisition of 4 properties needed for the widening. The On-Site Flood Control Storage alternative was similarly not preferred due to the significant costs and very significant challenges to convince multiple property owners to allow their businesses to be disrupted for construction of underground storage facilities. The Flow Diversion alternative was not considered due to the unacceptable impacts on flooding of Highway 404, and Flood Proofing on its own is challenging to implement on such a large number of properties and does not flooding through the study area, which would remain a concern for the existing flood prone roadways through the study area.

Table 4-2 Evaluation Summary

Alternative	Natural Environment		Social/Cultural Environment		Technical Environment		Overall		Financial Environment
	Impacts	Benefits	Impacts	Benefits	Challenges	Performance	Cumulative Impact	Cumulative Benefit	
Status Quo	● No impacts, as no works are proposed	○ No benefits, as no works are proposed	● No impacts, as no works are proposed	○ No benefits, as no works are proposed	● No challenges, as no works are proposed	○ Negligible reduction in flooding due to improved stormwater management through future redevelopment	● **NOT RECOMMENDED** Does not reduce flooding or flood damages from Don Mils Channel	○	No capital costs, as no works are proposed Negligible reduction in flood damages
Enhanced Channel Maintenance	◔ Loss of woody vegetation and associated terrestrial habitat along the channel	○ No benefit to the natural environment	◕ Diminished aesthetics due to vegetation removal at rear of properties backing onto channel	○ No benefit to social or cultural environments	◕ Difficulties obtaining approvals for tree removals, challenges to access the channel for removals	○ Negligible reduction in flooding	◑ **NOT RECOMMENDED** Does not reduce flooding or flood damages from Don Mils Channel	○	Initial capital cost of $150,000 for vegetation removal, increased annual maintenance costs No reduction in flood damages
Channel Widening with Culvert Replacements	◕ Temporary impacts to vegetation and aquatic habitat during construction	● The widened channel will increase and improve aquatic and terrestrial habitat through the study area	◔ Impacts to owners of the acquired properties and their tenants, loss of businesses and employment	◕ Improved recreational opportunities if a trail system is integrated into the widened channel corridor	○ Challenges to acquire up to 24 properties, difficulties in managing storm flows during channel construction	● The widened channel corridor could largely contain the flow for up to the 100 year storm event	◔ **NOT RECOMMENDED** Significant challenges and costs to acquire up to 24 properties and construct the widened channel, and significant impacts to the business community	◕	$350 Million including construction and property acquisition, losses in tax revenues from acquired properties Elimination of flood damages for up to the 100 year storm
Acquisition of Flood Prone Properties	● No impacts, as all works would be on existing developed sites	◑ Potential improvements to terrestrial habitat if the acquired properties are restored as open space.	◔ Impacts to owners of the acquired properties and their tenants, loss of businesses and employment	◑ Acquired properties could potentially be restored to create opportunities for active or passive recreation	○ Challenges to acquire up to 16 properties	◑ Eliminates flood damages associated with 2 and 5 year storm events, but does not reduce flood levels	◔ **NOT RECOMMENDED** Does not reduce flooding, significant challenges and costs to acquire up to 16 properties	◑	$250 Million to acquire properties and demolish flood prone buildings, losses in tax revenues from acquired properties Damages reduced to $0.5 Million per year
Underground Flood Control Storage	● No impacts, as all works would be on existing developed sites	◔ Potentially reduced erosion and improved baseflow and water quality if the storage facilities could be designed to infiltrate the captured storm runoff	◑ Loss of business during construction, limitations on future redevelopment or expansion for properties with underground storage	○ No benefit to social or cultural environments	◔ Difficulties securing agreements for underground storage on private property, challenges to direct external storm runoff to storage facilities	◕ There would be no flood damages for up to the 5 year storm	◑ **NOT RECOMMENDED** Implementation of this alternative would be limited by the significant challenges to identify and secure agreements with many appropriately located properties	◔	$78 Million to construct the facilities and compensate property owners for loss of business and future development constraints Long term inspection and maintenance of underground storage units Damages reduced to $0.6 million per year

Alternative	Natural Environment		Social/Cultural Environment		Technical Environment		Overall		Financial Environment
	Impacts	Benefits	Impacts	Benefits	Challenges	Performance	Cumulative Impact	Cumulative Benefit	
Central Municipal Flood Control Storage	◕ Temporary impacts to the natural environment during construction	◑ The facility could potentially enhance terrestrial habitat in the study area and improve water quality	◑ Impacts to owners of the acquired properties and their tenants, loss of businesses and employment	◑ Improved recreational opportunities if a trail or other amenities are integrated into flood storage facility	◑ Challenges to acquire properties for facility, challenges to design the flow control structure to prevent upstream flood increases and allow fish passage	◔ Reduction in flooding and flood damages for the 2 year and 5 year storms	◕ **RECOMMENDED** Reduces flooding and flood damages and requires limited property for implementation	◑	$32 Million in estimated capital costs, limited additional costs for maintenance of the new SWM facility Damages reduced to $0.9 Million per year
Flow Diversion	◕ Temporary impacts to aquatic habitat during construction of the inlet and outlet	○ No benefit to the natural environment	◑ Disruptions to traffic and businesses on Steelcase Avenue during construction	○ No benefit to social or cultural environments	○ Increases in the frequency and severity of flooding on Highway 404, potential utility conflicts	◔ Reduction in flooding and flood damages for the 2 year and 5 year storms	◔ **NOT RECOMMENDED** This alternative would have unacceptable impacts on flooding at Highway 404	◔	$20 Million in estimated capital costs, increased maintenance and life cycle costs for the diversion sewer
Flood Proofing and Education	● No impacts, as all works would be on existing developed sites	○ No benefit to the natural environment	◕ Temporary impacts to businesses during construction of flood proofing measures	◔ Education program could be expanded to other flood prone areas in the City of Markham	◔ Challenges to convince property owners to install and maintain flood proofing measures, limitations due to building or site configurations	◔ Reduction in flood damages to protected buildings, but no reduction in flooding on roadways and parking areas	◕ **RECOMMENDED** Not recommended as a standalone solution due to implementation challenges, but recommended to complement other flood reduction solutions	◔	$2 million in estimated capital costs to protect buildings at risk of flooding in a 5 year storm Damages reduced to $0.9 Million per year if 5 year protection is achieved at all flood prone buildings
Combined Alternative – Central Municipal Flood Storage, Culvert Upgrades and Education Program	◕ Temporary impacts to the natural environment during construction of the storage facility and culvert replacements	◕ Potential use of the flood storage facility as terrestrial habitat, improved water quality and improved fish passage through replacement culverts	◑ Impacts to owners of the acquired properties, temporary impacts to businesses for flood protection works, temporary road closures for culvert replacements	◑ Improved recreational opportunities if a trail or other amenities are integrated into flood storage facility, education program could be expanded to other flood prone areas in the City of Markham	◔ Challenges to acquire properties for flood storage facility, implement and maintain flood protection works, and replace culvert extensions on private property	◕ Significantly reduces flood levels and eliminates flood damages for up to the 5 year storm.	◑ **RECOMMENDED** Achieves desired minimum flood protection for the 5 year storm, requires limited property acquisition and can be reasonably implemented	◕	$69 Million in estimated capital costs, but the existing culverts require replacement regardless in the near future Damages reduced to $0.2 Million per year

Least Impact or Greatest Benefit ● → ◕ → ◑ → ◔ → ○ Greatest Impact or Least Benefit

4.12 Financial Analysis

Section 4.11 and **Table 4-2** summarized the qualitative evaluation of the alternative solutions against the established criteria relating to the natural, social, cultural, technical and financial environments. The comprehensive evaluation resulted in the selection of the Combined Alternative as preferred solution.

An additional financial analysis of the alternatives has been undertaken to determine the amount of flood damage reduction achieved relative to the investment in capital upgrades and confirm that the preferred solution is justified economically. This evaluation considers the net financial benefits of each alternative after the associated operation and maintenance costs are subtracted from the expected average annualized flood damage reduction.

Table 4-3 summarizes the cost-effectiveness of the alternatives that achieve a measurable flood reduction benefit and identifies an approximate 'payback period' for net benefits (i.e., the number of years required for net financial benefits to reach the total capital cost). Status Quo and Channel Maintenance alternatives are excluded from **Table 4-3** as there are no flood reduction benefits associated with these alternatives. The Flow Diversion alternative was not included as it would increase the depth and frequency of flooding of Highway 404. Lastly, the Flood Proofing alternative is excluded as accurate estimates for capital implementation costs for individual properties are not available.

Table 4-3 shows that the Channel Widening and Property Acquisition alternatives, which have very high initial capital costs, have long payback periods of over 200 years. This suggests that despite the degree of flood reduction achieved, the return on investment associated with these alternatives is very limited.

Underground Storage is shown to have a payback period of 87 years once the operation and maintenance costs are considered. Operating costs for underground storage and infiltration facilities, including regular inspection and clean-out of pre-treatment devices, have been estimated by the City of Markham as part of its North Markham low impact development (LID) servicing evaluation and determined to be approximately 0.5% of capital costs. These relatively high operation and maintenance costs partially offset the average annualized flood damage reduction benefit of $1.1 M associated with this alternative.

The Central Municipal Flood Control Facility and the Combined Alternative both have more reasonable payback periods. On its own, the Central Facility is shown to be very cost effective, with a payback period of 28 years. Operation and maintenance costs for the large centralized storage facility has been estimated at approximately $50,000 per year based on the City of Markham's overall SWM facility maintenance program, which is very small relative to the average annualized flood reduction benefit of approximately $800,000. The Combined Alternative has a longer payback period of 48 years, suggesting that the addition of culvert upgrades has a smaller incremental benefit/cost than the storage facility alone. This can be expected as additional mitigation measures tend to become less efficient, offering a lower return on investment for the performance achieved at higher levels of service. For example, the annual flood damage reduction of the storage component of the Combined Alternative achieves $1.2 Million in damage reduction return for an investment of $32 Million, or $27 Million capital cost per $1 Million flood damage reduction. The Combined Alternative has a higher $46 Million capital cost per $1 Million flood damage reduction, which indicates a less efficient alternative and an overall reduced return on investment. Recall, however, that the more cost-effective Central Municipal Flood Control Facility does not eliminate flood damages during a 5 year storm event and therefore does not achieve the desired minimum level of flood protection.

The relative cost-effectiveness of alternatives is illustrated in the last column in **Table 4-3** which compares how cost effective each alternative is relative to the Central Municipal Flood Control Facility. The very high capital cost alternatives show the cost inefficiency associated with achieving their high level of service (i.e., 100-year). For example, the Channel Widening alternative is only 14% as efficient at reducing annual flood damages as the Central Facility alone. The Underground Storage alternative, consisting of multiple on-site storage facilities, is only 32% as cost-effective as the Central Facility at reducing flood damages. The Combined Alternative is less cost-effective than the Central Facility alone but represents the minimum requirement to achieve the City's flood risk reduction target.

Table 4-3 Return on Investment

Alternative	Capital Cost ($M)	Average Annualized Flood Damages ($M)	Reduction in Average Annualized Flood Damages ($M)	Annual Operation and Maintenance Costs ($M)	Net Annual Financial Benefits ($M)	Payback Period (Years)	Cost Effectiveness as a Percentage of the Combined Alternative
Channel Widening with Culvert Replacement	350	0	1.7	0	1.7	206	14%
Acquisition of Flood Prone Properties	250	0.5	1.2	0	1.2	208	13%
Underground Flood Control Storage	78	0.6	1.1	0.20[1]	0.90	87	32%
Central Municipal Flood Control Facility	32	0.9	0.8	0.05[2]	1.15	28	100%
Combined Alternative	69	0.2	1.5	0.05[2]	1.5	48	58%

[1] *routine maintenance of infiltration galleries estimated at 0.5% of capital cost (per North Markham LID strategy evaluation)*
[2] *central facility estimated annual inspection and maintenance cost (per City of Markham)*

5 DESIGN CONSIDERATIONS FOR THE PREFERRED ALTERNATIVE

5.1 Concept Designs

The preferred solution to address flooding from the Don Mills Channel includes a centralized municipal flood storage facility upstream of Steelcase Road East, replacement of the existing culverts at Steelcase Road East, Woodbine Avenue, Denison Street and Steelcase Road West (including replacement of the extensions on private property), and flood proofing for the remaining properties at risk of flooding in a 5 year storm event.

Concept designs have been prepared for the different elements of the preferred solution, and are described in the following sections.

5.1.1 Central Municipal Flood Control Facility

A concept design of the central municipal flood storage facility has been prepared based on acquisition of the properties at 55, 85, 115 and 135 Torbay Road. However, the location of the facility may be adjusted based on property availability and other factors as the project proceeds through preliminary design. However, a continuous block of properties upstream of Steelcase Road East is required.

The concept design of the facility is illustrated in **Figure 5-1** and **Figure 5-2**. The base of the facility is proposed at an elevation of 174.3 m, or 0.3 m above the existing channel invert to allow baseflows in the Don Mills Channel to continue unimpeded. The maximum design water level in the facility is proposed to be 176.4 m or 2.1 m above the base of the facility, creating a total flood storage volume of approximately 37,000 m^3. A 0.3 m freeboard is also provided above the design maximum water level to the top of the facility, and a 5 m shelf has been provided along the north and east edges of the facility for maintenance access and/or trails.

The concept design also illustrates how the existing storm sewer from Torbay Road could be truncated to outlet to a permanent pool of water for quality treatment if the facility were constructed at this location. This storm sewer services an 8.7 ha of primarily commercial and industrial development. Additional effort is needed during preliminary design to confirm the feasibility of incorporating water quality treatment, including the maximum depth of the permanent pool (dependent on sub-surface soil and groundwater conditions), the ability to incorporate extended detention storage (without reducing overall flood control storage) and mechanisms to prevent captured sediment from being scoured out of the pool when flooded from the Don Mills Channel.

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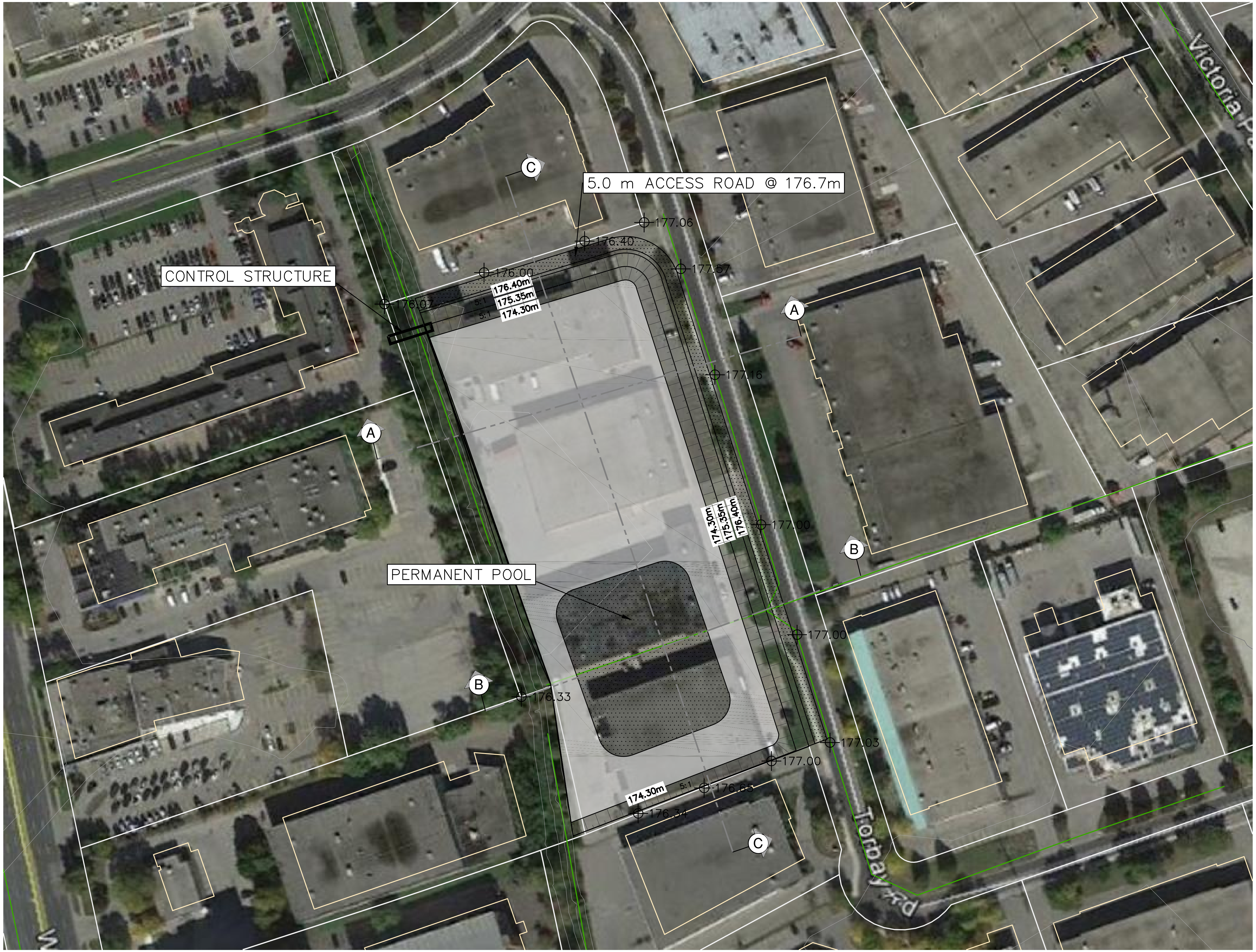

FOR ILLUSTRATIVE PURPOSES ONLY. ACTUAL SIZE AND CONFIGURATION OF CENTRAL MUNICIPAL FLOOD STORAGE FACILITY TO BE DETERMINED BASED ON AVAILABILITY OF PROPERTY AND ADDITIONAL STUDY

PROJECT : 15160
DATE : AUGUST 2017
SCALE : 1:1500

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DON MILLS CHANNEL FLOOD REDUCTION STUDY - ENVIRONMENTAL ASSESSMENT

FIGURE 5-1 CENTRALIZED MUNICIPAL FLOOD CONTROL FACILITY CONCEPT DESIGN

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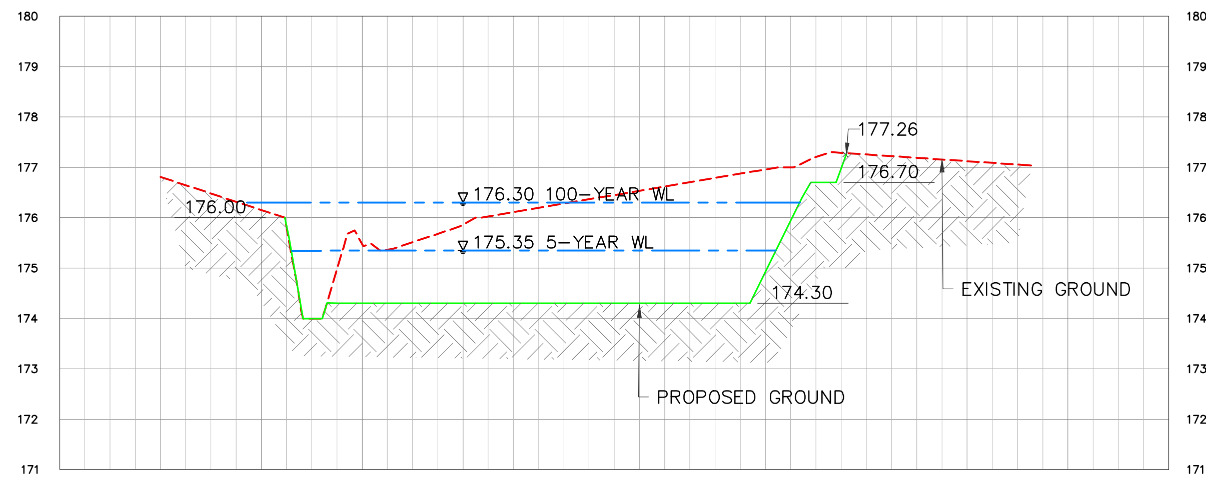

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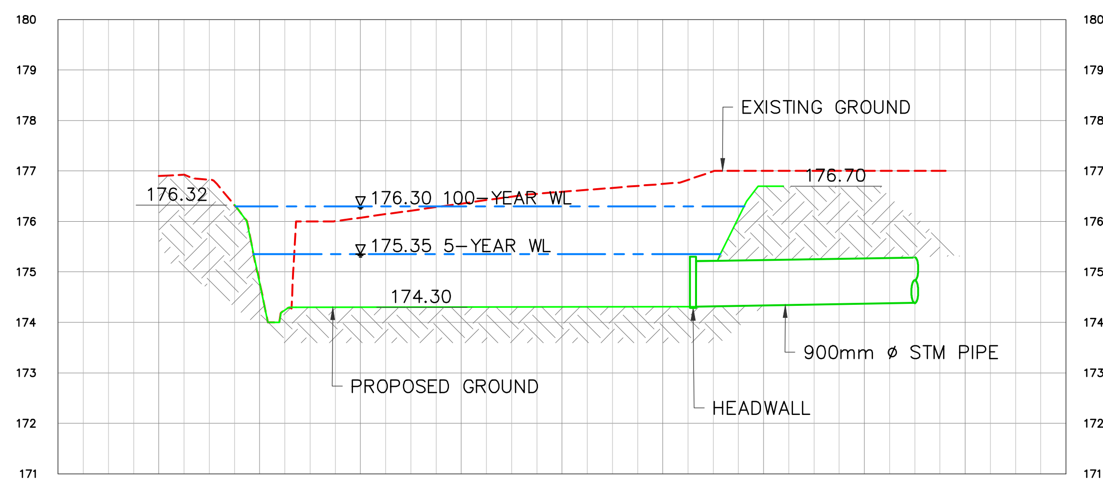

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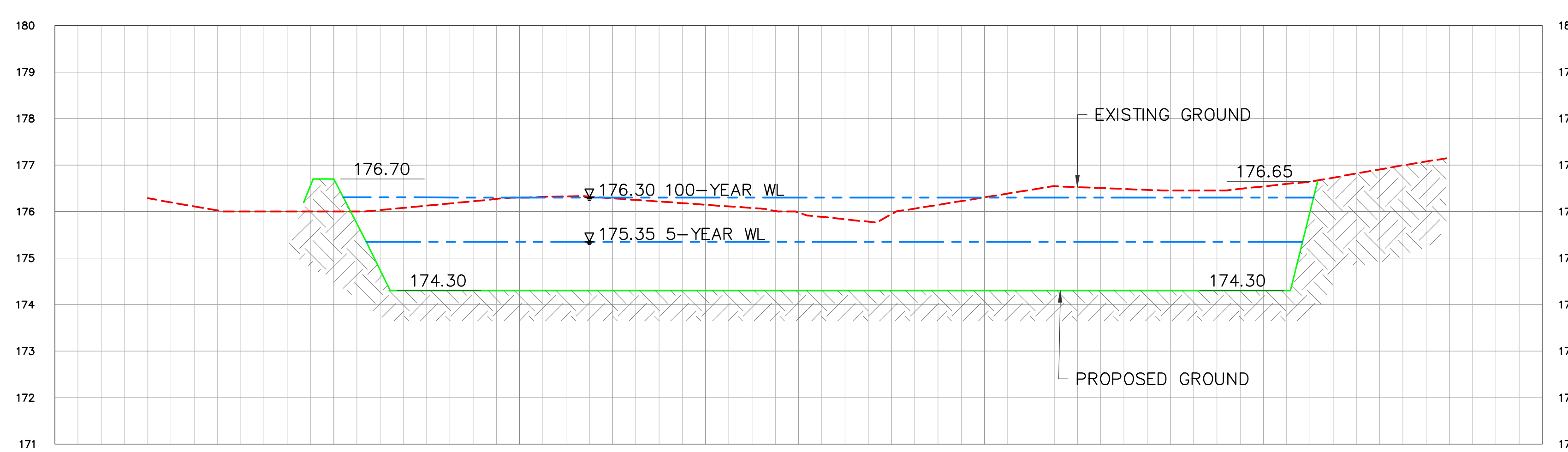

NOTE: FOR CROSS SECTION LOCATION SEE FIGURE 5-1

FOR ILLUSTRATIVE PURPOSES ONLY. ACTUAL SIZE AND CONFIGURATION OF CENTRAL MUNICIPAL FLOOD STORAGE FACILITY TO BE DETERMINED BASED ON AVAILABILITY OF PROPERTY AND ADDITIONAL STUDY

PROJECT : 15160
DATE : AUGUST 2017
SCALE : HOR 1:1500
VER 1:150

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DON MILLS CHANNEL FLOOD REDUCTION STUDY - ENVIRONMENTAL ASSESSMENT

FIGURE 5-2 - CROSS SECTION OF MUNICIPAL FLOOD CONTROL FACILITY

5.1.2 Culvert Replacements

The existing culverts at Steelcase Road East, Woodbine Avenue, Denison Street and Steelcase Road West are proposed to be replaced as part of the preferred alternative. Replacement of the Woodbine Avenue culvert would also include the upstream extension through 50 Steelcase Road East and the downstream extension through 7310 Woodbine Avenue. Similarly, the Denison Street culvert replacement would include the downstream extension through 230 Denison Street and 7370 and 7350 Woodbine Avenue and the Steelcase Road West culvert replacement would include the extension through 351 Steelcase Road West to the outlet to Highway 404.

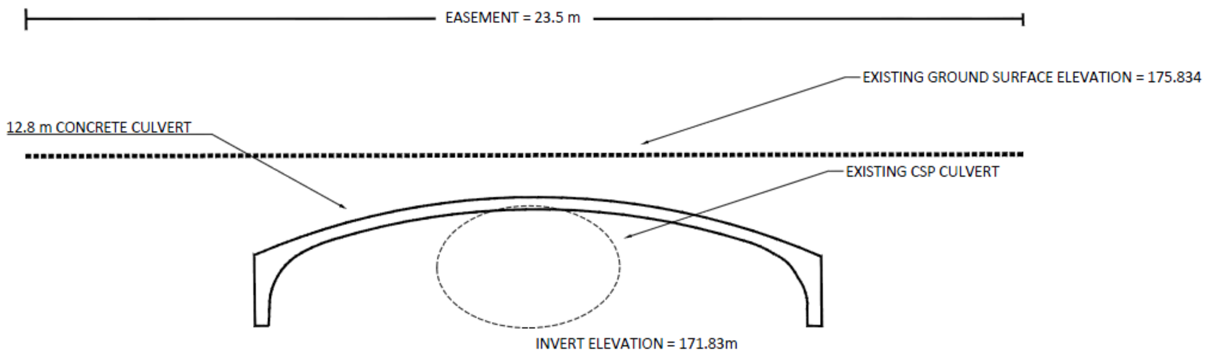
The recommended sizes of the replacement culverts are summarized in **Table 5-1**. The sizes of the proposed replacement culverts are limited by the available height from the channel invert to the top of the road. A typical section for Denison Street illustrating the existing culvert, proposed culvert and existing easement is illustrated in **Figure 5-3.**

Note that Woodbine Avenue is a Regional Road, and therefore the culvert section within the right-of-way is owned and maintained by York Region. Replacement of the Woodbine Avenue culvert and upstream and downstream culvert extensions through private property will need to be undertaken by and/or co-ordinated with York Region

Table 5-1 Recommended Replacement Culverts

Culvert Location	Existing Culvert	Culvert Length in Existing Right-of-way (m)	Culvert Length in Private Property (m)	Easement Width	Proposed Culvert
Steelcase Road East	2.2 m x 3.4 m concrete ellipse	33	0	-	12.8 m x 2.4 m Conspan or equivalent
Woodbine Avenue	3.9 m x 2.7 m CSP Arch	35	125 m upstream 107 m downstream	18	12.8 m x 2.7 m Conspan or equivalent
Denison Street	4.35 m x 2.9 m CSP Arch	12	127 m downstream	23.3	12.8 m x 2.7 m Conspan or equivalent
Steelcase Road West	4.27 m x 2.44 m concrete box + 5.5 m x 3.05 m CSP Arch extension	28	128 m downstream	22.5	14.6 m x 3.0 m Conspan or equivalent

Figure 5-3 Typical Culvert Section



5.1.3 Flood Proofing

Two properties in the study area will remain at risk of flooding in a 5 year storm following construction of the centralized municipal flood storage facility and culvert replacements. To achieve City Council's objective of fully preventing flood damages during a 5 year storm (refer to **Section 3**), works must be undertaken on these properties to protect them from damage during severe storm events. Depending on the depth of flooding, building configuration and on-site storm drainage infrastructure, this could be as simple as minor re-grading to prevent water from entering the property, or as extensive as structural modifications to the building to make it water-tight. Each site will have its own unique flood protection solution, and development of such solutions for each property at risk of flooding is beyond the scope of this study.

Similarly, there are a variety of different mechanisms for the City to aid with implementation of flood proofing measures on private property in the study area. This could include any one or combinations of the following:

- **General Education and Outreach**: The City could undertake an outreach program to educate all businesses and property owners in the study area about the risk of flooding (both prior to and following construction of the flood storage facility and culvert replacements), best practices to reduce flood damages (i.e. store goods and materials off the floor, move equipment and vehicles to higher ground when severe weather is predicted, etc.), and the range of flood proofing measures potentially applicable to protect the flood prone properties in the study area.
- **Site Specific Guidance**: The City could assist business and property owners by commissioning assessments of the remaining flood prone buildings in the study area and preliminary designs for the most appropriate flood proofing measures for each property. The assessments and preliminary designs would be prepared by a team of professionals qualified in water resources, structural and mechanical engineering and business processes, in partnership with business and property owners. Property owners would then be responsible for detailed design and construction of the recommended flood proofing measures.
- **Financial Incentives**: The City could facilitate implementation of flood proofing measures through a range of financial incentives. This could take the form of rebate programs to reimburse owners for a portion of the construction costs, or even 'front-ending' all costs and recovering them through a special charge or levy applied to property taxes for the benefitting property.

5.2 Construction Staging

The preferred solution to reduce flooding from the Don Mills Channel involves several different projects: the central municipal flood control storage facility, culvert replacements at Steelcase Road East, Woodbine Avenue, Denison Street and Steelcase Road West, and a flood proofing and education program. None of these works are dependent on each other, and therefore there are no constraints on the order in which the different projects are implemented. However, there are advantages to completing some works ahead of others.

The central municipal flood control storage facility represents slightly more than half of the total cost of the solution but achieves more than half of the reduction in average annualized flood damages. Recall from **Section 4.7** that the facility on its own will reduce average annualized flood damages from $1.7 Million (existing) to $0.9 Million. The central municipal flood control storage facility can also be implemented as a single project and constructed relatively quickly following property acquisition, whereas the culvert improvements are comprised of 4 different projects that must be planned and staged.

Analyses were completed to determine any constraints or advantages to the order in which the culvert replacements are phased, assuming that the central municipal flood control storage facility has already been constructed. Based on the analyses, it is recommended that the Steelcase Road West culvert be replaced first, followed by the Denison Street culvert, Woodbine Avenue culvert and Steelcase Road East culvert.

However, it is recognized that culverts may require replacement at any time due to structural condition, scheduled road rehabilitation or re-development of sites containing culvert extensions. The additional analyses concluded that replacing any culvert in isolation may increase flood levels slightly during the 5 year storm, but will not increase flood levels during a 100 year storm. Note also that despite the slight increases in flood levels at some locations during the 5 year storm, flood levels remain well below existing conditions, prior to construction of the central municipal flood control storage facility. Therefore, while it is preferable to replace culverts starting at the downstream end of the study area and proceeding upstream, any culvert can be safely replaced at any time with negligible impacts on downstream flooding. The additional analyses for the culvert replacements are summarized in **Appendix E**.

5.3 Additional Studies

A number of desktop and field investigations have been completed in support of the Don Mills Channel Flood Reduction Study. However, additional studies are required to better characterize and understand the existing conditions within the study area and support the detailed design of the recommended relocated centralized municipal flood storage facility, culvert replacements and flood proofing measures. These include

- Detailed topographic surveys for the properties to be acquired for the centralized municipal flood storage facility, the existing culverts to be replaced and, if access is granted, for the remaining properties at risk of flooding in a 5 year storm. The detailed topographic survey will include existing ground elevations, detailed channel elevations, relevant structures (culverts, roads, buildings, etc.), all visible utilities (manholes, hydro poles, lamp posts, etc.), and all markings for verified subsurface utilities
- Geotechnical and hydrogeological investigations to characterize soil and groundwater conditions in the vicinity of the flood storage facility and culvert replacements. The investigation should also determine groundwater levels and assess requirements for groundwater management (and permits) during construction
- Detailed utility investigations to identify the horizontal and vertical position of all utilities potentially impacted for construction of the flood storage facility and culvert replacements.
- Environmental Site Assessments (Phase 1 and Phase 2, if warranted) are recommended for the properties to be acquired for construction of the centralized municipal flood storage facility. These assessments will identify the potential for contamination and other potential environmental issues on the properties.
- An Environmental Impact Statement (EIS) should be completed during preliminary design to verify the environmental features potentially impacted for construction of the recommended works and their

ecological functions, determine appropriate mitigation measures and confirm that the project will achieve a net benefit to the natural heritage system.

5.4 Climate Change Adaptation

Adaptation and resiliency to future climate change are key considerations in any infrastructure project. The 2018 Companion Guide for the Municipal Class EA Manual encourages proponents to consider both climate change mitigation and adaptation in Municipal Class EA undertakings, but recognizes that the degree to which climate change is considered will vary depending on the type and complexity of the undertaking. Further direction is provided in the MECP on-line guide 'Considering Climate Change in the Environmental Assessment Process' (CC Guide) and Ontario's Long Term Infrastructure Plan (LTIP) (Ministry of Infrastructure, 2017). The LTIP includes the following guidance related to consideration of climate change:

- *'Infrastructure, both new and existing, should be resilient, support the resilience of the surrounding community, and be able to adapt to the impacts that Ontario experiences.'*
- *'Infrastructure investments require the application of a "risk lens" to protect their future. Infrastructure planning, design and construction require an understanding of future climatic conditions, vulnerabilities and potential risks to ensure that infrastructure, and infrastructure budgets, will not be compromised by climate change impacts.'*

The CC Guide reinforces this position with the following statement:

- *'In order to reduce future climate-related risks to the local environment, a proponent could consider climate change adaptation measures that increase resilience of any aspect of the proposed project's design, operation and function which could be susceptible to climate variability.'*

Climate change is also discussed in the 'Technical Guidelines for Flood Hazard Mapping' (EWRG, March 2017), a document that was prepared under the guidance of a steering committee comprises of staff from six Southern Ontario conservation authorities. The guideline notes that future climate change may impact local rainfall intensity-duration-frequency (IDF) curves, which form the basis for return period design storm events that are typically used for the design of water resources infrastructure.

The City of Markham has recently completed a review of past and current climate data and a number of other climate change resources in order to assess the resiliency of the City's wastewater collection systems. To assess IDF impacts the City of Markham first reviewed national and regional rainfall trends in Environment and Climate Change Canada's (ECCC's) Engineering Climate Datasets (version 2.3) and local research and determined that '*no historical changes in rainfall intensity are expected based on the analysis of national and regional (southern Ontario) datasets*' (Xu and Muir, 2018). This is consistent with extreme rainfall trends analysis by ECCC that indicate '*a general lack of a detectable trend signal'* nationally (Shephard et.al, 2014). As part of the assessment, the City of Markham updated local IDF curves for the long-term Toronto City climate station that its design standards are based on, as well as the Toronto International Airport (Pearson) and Markham Buttonville Airport stations IDF curves. The findings related to the wastewater system resiliency assessment, which are also relevant to storm drainage infrastructure, were as follows:

- *"The Pearson station 100-year data showed no change since the ECCC 2013 dataset, and a decrease since the 1990 dataset (average decrease of 3.2%). The Buttonville station 100-year data showed an average increase of only 1.1%. Therefore 100-year short-duration intensities are considered to be stationary for the purpose of the existing system capacity assessment under today's climate - past rainfall intensities (IDF data) maybe used to assess current wastewater system wet weather performance."*

City of Markham staff also reviewed the updated IDF data described above against the 3 hour AES design storm hyetographs from the City's Stormwater Management Guidelines (2016), which also form the basis for the analyses of the Don Mills Channel. The Markham 3 hour AES storm volume of 80 mm exceeds the updated 3 hour IDF volume of 73.6 m for the 100 year return period (i.e., 8.7% above). The peak 5 minute and 1 hour volumes from the Markham 3 hour AES storm are 2.1% and 15% above the updated 100 year IDF values, respectively.

These analyses of past and current precipitation data by the City of Markham do not reveal any current, discernable trends of increasing rainfall intensities, and indicate that the 3 hour AES design storms used for the analyses of the Don Mill Channel are conservative (i.e. larger intensities and volumes) relative to design storms based on the latest IDF values. While uncertainty exists regarding IDF values under future climate change scenarios, the flood mitigation measures designed on the basis of the more conservative Markham 3 hour AES design storms provide additional resiliency for both current and future rainfall extremes.

There are also a wide range of design storm shapes, or distributions, to which the IDF curves or historical rainfall statistics are applied to generate the synthetic storm events used for water resources infrastructure design. The type of storm used has as much or more influence on the resulting peak flow rates as the input IDF statistics. Recall from **Section 2.5.2.4** that several different design storm distributions were considered for analysis of the Don Mills Channel. The TRCA currently manages the Don River Watershed, which includes the Don Mills Channel, based on a hydrology that uses a modified 12 hour SCS design storm distribution. The PCSWMM model simulated flooding conditions in the Don Mills Channel with the TRCA design storms as well as the City of Markham 3 hour modified AES storm. While the 12 hour SCS storm has a longer duration and larger total storm volume, the City of Markham 3 hour AES storm has much larger peak rainfall intensities. For the 5 year storm, the TRCA's 12 hour SCS storm has a peak rainfall intensity of 49.8 mm/hr over a 15 minute time step. The City of Markham 5 year, 3 hour AES storm has a peak intensity of 144 mm/hr over a 5 minute time step, and an average intensity of 93 mm/hr over the peak 15 minutes of the design storm. As documented in **Section 2.5.2.4**, the PCSWMM model predicts larger peak flow rates and flood levels when using the more intense Markham 3 hour AES design storm compared to the TRCA 12 hour SCS storm. The recommended design therefore incorporates a degree of climate change resiliency by adopting the more conservative City of Markham 3 hour Modified AES storm for its design and analysis.

Note finally that, as opposed to greenfield development, the recommended works are not intended to entirely contain flooding to the channel corridor for up to the 100 year or Regional (Hurricane Hazel) storm event. The goal is to improve the current flooding issues in the study area, with a desire to prevent flood damages for up to the 5 year return period storm event (refer to **Section 3**). Implementing the recommended central municipal flood storage facility, culvert replacements and flood proofing and education program will significantly improve the Don Mills Channel system's resiliency to existing extreme weather stresses and future climate change relative to its current condition.

5.5 Monitoring

There are currently no permanent flow or water level monitoring stations established on the Don Mills Channel. Validation of the PCSWMM 2D model was completed with the aid of photographs taken during flood events and measurements of high water marks by City of Markham staff following sever storm events. One or more permanent water level and/or flow monitoring stations are recommended for the Don Mills Channel.

A permanent water level or flow monitoring station is recommended in the vicinity of Steelcase Road East to establish baseline flooding conditions prior to construction of the flood storage facility. Gauge data would be used to refine the calibration of the PCSWMM 2D model, and compared to post construction monitoring data to verify the effectiveness of the facility in reducing peak flow rates and flood levels. Water levels should also be monitored within the completed flood storage facility to verify that it operates as intended during severe storm events. Consideration should also be given to a permanent water level or flow monitoring station at the downstream end of the study area near Steelcase Road West.

6 POTENTIAL CONSTRUCTION IMPACTS AND MITIGATION

There is the potential for some environmental impacts during and following construction of the centralized municipal flood storage facility, replacement of the 4 culverts along the Don Mills Channel and implementation of flood proofing measures on remaining flood vulnerable sites. The potential impacts and recommendations to mitigate these impacts are summarized in the following sections. The proposed mitigation will be augmented with a construction monitoring program(s) that will be developed in consultation with the TRCA and other agencies during the detailed design and permitting stages.

6.1 Vegetation and Terrestrial Habitat

Construction of the centralized municipal flood storage facility will require removal of the existing vegetation on the east channel bank in this area, and limited vegetation removals may be required at the inlets and outlets of the culverts to be replaced to facilitate construction. Recall from **Section 2.3.3** that existing riparian vegetation along the Don Mills Channel is typically limited to a narrow strip of predominantly common and/or weedy herbaceous vegetation with limited trees and shrubs.

Regardless, detailed tree inventories and preservation plans will be prepared for all areas potentially impacted by construction of the municipal flood storage facility and culvert replacements. Comprehensive restoration plans will also be prepared to comply with the City of Markham's Tree Preservation By-Law and to achieve a net ecological gain for the Don Mills Channel natural heritage system.

6.2 Breeding Birds

As previously mentioned in **Section 6.1**, the construction of the centralized municipal flood storage facility and replacement of the existing culverts may require the removal of a limited vegetation and tree removals. During detailed design, the need for tree removals will be refined, and assessments will be carried out on any trees that may be removed. The Migratory Bird Convention Act restricts tree removals or any other activity that could be construed as impacting nesting or breeding of a range of bird species from April 15 to July 30. The nesting window should be confirmed during detailed design, and if tree removals cannot occur outside of this window, a qualified biologist will be required to complete a survey to determine the presence of any nesting activity prior to any removals.

6.3 Surface Water Protection

The recommended works have the potential to impact fish habitat, and therefore a Self-Assessment will be undertaken during detailed design to determine if a review by Fisheries and Oceans Canada (DFO) is required. Any in-water works could be subject to the warm water fisheries timing window, which generally prohibits construction activity in or near the water between March 1st and July 1st.

To prevent accidental introduction of debris into the water, the establishment and use of specific construction access routes is recommended, as well as the use of mitigation techniques that contain sediment and debris within the work site. In addition, a spills response plan should be developed and implemented in the event of a fuel spill or sediment release.

Best Management Practices (BMPs) for the protection of aquatic habitat, including the use of standard erosion and sediment control devices, will be reviewed at the detailed design stage and incorporated into the detailed design package and should adhere to the principles limiting soil mobilization and trapping sediment as close to the source as possible. The Greater Golden Horseshoe Area Conservation Authorities, Erosion and Sediment Control Guidelines for Urban Construction (GGHA, 2006) will be followed for the development and implementation of the comprehensive Erosion and Sediment Control (ESC) plan.

6.4 Groundwater Management

It is possible that some local dewatering may be required for the construction of the centralized municipal flood storage facility and/or culvert replacements. The need for any dewatering during construction will be determined through the geotechnical and hydrogeological studies recommended in **Section 5.3**.

It is expected that any groundwater impacts during construction will be localized and temporary as the depth of excavation and anticipated zone of influence will be minimal. During detailed design, it will be necessary to develop appropriate strategies to minimize, treat and dispose of any dewatering discharge water. Should construction site dewatering requirements be greater than 50,000 L/day, permitting with the MECP will be required. Construction site dewatering of more than 50,000 L/day but less than 400,000 L/day (under normal site conditions) will require registration on the MECP Environmental Activity and Sector Registry (EASR) and fulfillment of EASR regulation monitoring and mitigation requirements. A Permit to Take Water (PTTW) will be required if any of the construction requires dewatering of over 400,000 L/day.

6.5 Soils Management

The recommended works will involve removal of existing buildings, foundations and parking areas, limited topsoil stripping, excavation and backfilling. All excess and unsuitable materials generated during construction will be managed appropriately. The materials may be reused as a construction material or transported from the site. Materials may also be temporarily stockpiled in preparation for these uses or temporarily removed from the site if required. Any soil stockpiles will be stabilized in accordance with the Greater Golden Horseshoe Area Conservation Authorities, Erosion and Sediment Control Guidelines for Urban Construction (GGHA, 2006), and any excess fill should be managed in accordance with the 'Management of Excess Soil – A Guide for Best Management Practices' (MECP, 2014). In addition, a comprehensive ESC plan will be prepared in the detailed design stage.

An Environmental Site Assessment (ESA) is recommended to determine the potential for contaminated soils on the properties to be acquired for the centralized municipal flood storage facility, as noted in **Section 5.3**. If contaminated wastes are encountered either naturally or through the Contractor's efforts (e.g., diesel spill) they must be taken to an approved waste disposal site by an appropriately licensed waste disposal carrier as per the operational constraint for the management of contaminated materials, and the MECP's York Durham District Office be contacted for further guidance. In addition, a spills response plan is to be developed and implemented in the event of a fuel spill. The Contractor will be required to manage all waste materials generated by construction activities in accordance with all provincial and federal regulations/approval requirements.

6.6 Property Impacts

Construction of the centralized municipal flood storage facility requires excavation in proximity to the existing developments to the north and south, and the recommended culvert replacements will require works within or beyond easements where the roadway culverts have been extended through private property.

Modifications to existing agreements or new easement agreements may be needed for implementation and future maintenance of the replacement culvert sections on private property. Temporary working easements may also be needed for construction of the culvert replacements on private property.

The Contractor will minimize impacts on adjacent private properties by confining all construction activities to the working area and not entering upon or occupying any private property outside of the working area for any purpose unless written permission from the landowner has been obtained in advance (by the Contractor or the City) and proof of which is provided to the City before entering the property. Should access to private property be granted, the property will be restored to its original condition or better following the completion of construction operations.

Pre-construction condition surveys, including photographs, are recommended for properties containing the culvert extensions that are to be replaced and for the properties adjacent the proposed flood storage facility. These surveys are intended to document the physical condition of the buildings, pavement structures and other infrastructure on private property prior to construction and may assist the City, property owners and the contractor in the event of a claim for damage.

Other than minor, temporary restrictions, access to businesses will be maintained during and following construction.

6.7 Air Quality, Noise and Vibration

The Contractor's activities, specifically the operation of construction equipment, will result in a temporary increase in noise, vibration and dust in the project area during the construction period. It is anticipated that these effects will be short in duration and limited to periods of construction machinery operation, and can be effectively mitigated by providing advance notice of construction to the adjacent businesses, by limiting construction activities to normal working hours, and applying best management practices. If warranted, only non-chloride dust suppressants are to be applied during construction. A comprehensive list of dust prevention and control measures can be found in Environment Canada's "Best Practices for the Reduction of Air Emissions from Construction and Demolition Activities" (Cheminfo, 2005).

6.8 Traffic and Transportation

Traffic on Torbay Road may be temporarily impacted during construction of the centralized municipal flood storage facility, and partial to full road closures will be required for culvert replacements at Steelcase Road East, Woodbine Avenue, Denison Street and Steelcase Road West. A traffic management plan will be developed in accordance with Ontario Health and Safety Book 7 to ensure the least possible impact, and standard traffic control measures will be implemented to safely co-ordinate traffic flow. Signage and Flagmen will be posted if necessary during these events.

6.9 Permits and Approvals

The complete list of required permits and approvals will be established during detailed design. However, it is expected that the following permits and approvals will be required for construction of the recommended option.

- **Toronto and Region Conservation Authority**: A permit will be required for Development, Interference with Wetlands and Alterations to Shorelines and Watercourses (Ontario Regulation 166/06).
- **Ontario Ministry of the Environment, Conservation, and Parks**: Depending on construction requirements, registration on the Environmental Activity and Sector Registry or a Permit to Take Water (PTTW) will be required for construction site dewatering.
- **Ontario Ministry of the Environment, Conservation, and Parks**: The centralized municipal flood control facility will require an Environmental Compliance Approval (ECA)
- **Ministry of Natural Resources and Forestry**: An Information Gathering Form will be submitted at the completion of the Environmental Assessment. While no further approvals are anticipated under the Endangered Species Act, it is recommended that this be confirmed through additional consultation with MNRF staff during detailed design.
- **Ministry of Transportation**: The Steelcase Road West culvert and extension through 361 and 351 Steelcase Road West are within the area controlled by the Ministry of Transportation (MT), and a permit may be required from MTO's Highway Corridor Management Offices under the Public Transportation and Highway Improvement Act.
- **Fisheries and Oceans Canada**: A Self-Assessment will be undertaken during detailed design to determine if a review by Fisheries and Oceans Canada is warranted. If the review by Fisheries and Oceans Canada determines that the project will cause serious harm to fish that are part of or that support

a commercial, recreational or Aboriginal fishery, it may be necessary to apply for an Authorization (*Paragraph 35(2)(b)*) Fisheries Act Authorization from the Minister of Fisheries and Oceans). Given the current condition of the channel, the resulting improvements in water quality and the mitigation of channel erosion, it is unlikely that the project will be forwarded to Fisheries and Oceans Canada for a formal review.

- **York Region**: As noted in **Section 5.1.2**, Woodbine Avenue is a Regional Road and replacement of the Woodbine Avenue culvert and extensions through private property upstream and downstream will need to be completed by or co-ordinated with York Region. A Road Occupancy Permit will be required if the works are not led by the Region. fs
- **Utilities**: Approvals will be required from utility owners for protection and/or relocation of any existing above and below ground utilities potentially impacted by the recommended works.

6.10 Post-Construction Impacts and Mitigation

Few impacts are anticipated following construction of the central municipal flood storage facility and culvert replacements and implementation of the flood proofing and education program. The proposed replacement culverts will improve conveyance and also reduce the risk for debris obstructions at culvert inlets and maintenance effort associated with its removal. No negative impacts are anticipated.

The central municipal flood storage facility will temporarily detain runoff to reduce peak flow rates in the Don Mills Channel downstream of Steelcase Road East. If not designed properly, there is a small risk that the facility could negatively impact flood levels upstream of Steelcase Road East. As noted in **Section 5.5**, water levels in the completed facility will be monitored to verify its performance and inform the design of any modifications to the control structure warranted to mitigate any impacts on upstream flood levels.

Finally, while details of the flood proofing and education program will be determined through future study (see **Section 5.1.3**), no negative impacts are anticipated following its implementation.

7 PUBLIC CONSULTATION

7.1 Consultation Approach

The Municipal Class Environmental Assessment (EA) requires contact with the public at certain points during the EA study. The study involves '*works undertaken in a watercourse for the purposes of flood and erosion control*,' and therefore the study was completed as a Schedule 'B' project under the Municipal Class EA. The points of public contact for this project are summarized in **Table 7-1**.

Table 7-1 Public Consultation Summary

Point of Contact	Date
Notice of Commencement	January 21, 2016
Public Open House #1	November 9, 2016
Public Open House #2	April 4, 2018
Notice of Completion	July 26, 2018

7.2 Notice of Commencement

A Notice of Commencement was prepared and circulated on January 21, 2016, on behalf of the City of Markham. A copy of the Notice is provided in **Appendix F** for reference. The Notice was mailed directly to relevant agencies, First Nations organizations, utilities, and surrounding property owners. The Notice of Commencement was also advertised in the Markham Sun & Economist and the City of Markham's website. The Notice summarized the purpose and scope of the study and invited interested parties to provide comments. All comment forms received are included in **Appendix F**.

7.3 Public Information Centre # 1

The first Public Information Centre (PIC) was held on November 9, 2016, from 3:00 pm to 7:00 pm. The PIC was hosted at the Courtyard Marriott hotel, located within the study area at 7095 Woodbine Avenue in the City of Markham. The Notice for PIC # 1 was advertised in the Markham Sun & Economist on October 27 and November 3, posted on the City of Markham's website, and was mailed to surrounding property owners and all stakeholders who indicated in interest in the study in their response to the Notice of Commencement. A copy of the Notice of PIC # 1 is included in **Appendix F**.

The purpose of the first Public Information Centre was to inform the public of the ongoing flooding issues associated with the Don Mills Channel, describe the existing social and natural environments present in the study area, and present some potential alternative concept solutions to mitigate the flooding problems. The PIC followed an informal open house format with display boards presenting the project information. The PIC provided participants with an opportunity to review and comment on the project information and correspond directly with the project team. A copy of the display boards is included in **Appendix F**. Attendees were encouraged to provide contact information on the sign-in sheet and complete a comment form.

Eight individuals attended the PIC, and two comment forms were received. A copy of the comment forms are included in **Appendix F**. Comment forms submitted indicated that the commenters had not experienced extreme flooding, but rather they had occasional standing water on their property. One comment form received suggested that detention ponds, increased channel maintenance and onsite retention should be considered to reduce flooding. All of these suggestions were captured in the alternative solutions that were developed and evaluated in **Sections 3** and **4** of this report.

7.4 Public Information Centre #2

The second PIC was held on April 4, 2018, from 3:00 pm to 7:00 pm. The PIC was hosted at the Markham Civic Centre (Canada Room) located at 101 Town Centre Boulevard in the City of Markham. The Notice for PIC # 2 was advertised in the Markham Sun & Economist on March 22 and March 29, posted on the City of Markham's website, and was mailed to surrounding property owners and all stakeholders who indicated in interest in the study in their response to the Notice of Commencement. A mobile roadside sign with information on PIC # 2 was also placed at several different locations in the study area during the two weeks leading up to the PIC. A copy of the Notice of PIC # 2 is included in **Appendix F**.

The purpose of PIC # 2 was to present and seek feedback regarding the alternative solutions considered to reduce flooding and flood damages from the Don Mills Channel, the evaluation of alternatives and preliminary preferred solution. Information regarding the timing and phasing for implementation of the preliminary preferred solution was also presented at the PIC. Similar to PIC # 1, PIC # 2 followed an informal open house format with display boards presenting the project information, and representatives from the City of Markham and TMIG were in attendance to interact with attendees, guide them through the display boards and answer any questions.

Nine individuals attended the PIC, and three comment forms were received. A copy of the comment forms are included in **Appendix F**. Two of the comment forms indicated support for the preliminary preferred solution. The third commenter noted that their property on Torbay Road experiences flooding almost every summer, with water entering the building and vehicles parked on site damaged by flooding several times in the past. This commenter suggested that the Don Mills Channel behind their Torbay Road property be cleaned and maintained, and requested a separate meeting with City of Markham staff for further discussion.

7.5 Notice of Completion

The Notice of Completion was advertised in the Markham Sun & Economist on July 26 and August 2, 2018 and posted on the City of Markham's website. Copies of the Notice were also mailed directly to relevant agencies, First Nations organizations, utilities, surrounding property owners, and all other stakeholders who indicated an interest in the study through previous project consultations. A copy of the Notice of Completion is included in **Appendix F**, and includes the locations where the Project File Report could be viewed and instructions on how to provide comments and request a Part II Order.

Note that as of July 1, 2018, a Part II Order Request Form must be used to request a Part II Order. The Part II Order Request Form is available online on the Forms Repository website (http://www.forms.ssb.gov.on.ca/) by searching "Part II Order" or "012-2206E" (the form ID number).

Copies of the Draft Final Project File Report were sent to the MECP, TRCA, MTO and York Region on June 18, 2018. Comments were received from MECP on July 5, 2018. The letter from MECP and a response letter indicating how their concerns have been addressed in this Final Project File Report are included in **Appendix F**.

York Region provided comments on July 19, 2018 clarifying that the Region only owns the central section of the Woodbine Avenue culvert within their right-of-way, and providing insight into the process to be followed for the City of Markham to undertake the replacement of the Woodbine Avenue culvert. A copy of York Region's comments is included in **Appendix F**.

7.6 Project Liaison Committee Meetings

7.6.1 Liaison Committee Meeting # 1

The first project liaison committee meeting was held on September 19, 2016. The meeting involved stakeholders who have historically been affected by flooding in the Don Mills Channel area, as well as City of Markham staff and councillors and TRCA staff. In total, 13 people attended the meeting at the City of Markham Civic Centre.

Liaison Committee members expressed concerns regarding a perceived lack of maintenance of the Don Mills Channel. In addition to increased maintenance, committee members suggested that alternative solutions for the Don Mills Channel study should include incentives for existing property owners to retrofit their sites to better control runoff volumes and peak flow rates delivered to the Don Mill Channel, providing additional flood storage in the channel either underneath adjacent parking lots or through regrading the parking lots to store water at lower elevations, expanding the storage available in the Highway 404 right-of-way, and combinations of different types of solutions. Committee members also suggested that solutions that can be entirely or partially implemented in a short period of time be given priority in the evaluation of alternatives.

7.6.2 Liaison Committee Meeting # 2

The project liaison committee met again on March 28, 2018, and were provided a summary of the alternatives considered to reduce flooding from the Don Mills Channel, the evaluation of alternatives and the anticipated timing and phasing for implementation of the preliminary preferred solution.

Committee members again requested that the City increase the frequency for inspection and maintenance of the channel. City staff agreed to review the current maintenance program for the Don Mills Channel, but informed the committee that the primary source of debris appears to be from illegal dumping, which complicates the City's maintenance program. Different variations of the alternative solutions were suggested by committee members, but TMIG and City of Markham staff explained that these variations had been considered and provided justification for why they were not included in the preferred solution to reduce flood damages from the Don Mills Channel.

Minutes from both Liaison Committee Meetings are included in **Appendix F.**

7.7 First Nations and Metis Community Consultation

The Municipal Class EA process requires the proponent to consult with all First Nations and Métis communities that could have a potential interest in an undertaking. First Nations communities were initially identified through the Aboriginal and Treaty Rights Information System (ATRIS) system (http://sidait-atris.aadnc-aandc.gc.ca/atris_online/home-accueil.aspx), and the identified communities were circulated the Notice of Commencement (Refer to **Appendix F5**).

Many of the First Nations and Métis communities responded to the initial study notice. Additional efforts were undertaken to ensure that the remaining communities were informed of the project and provided an opportunity to comment on the proposed works. The following table summarizes the date and form of contact with the First Nations and Métis communities and the responses received to date. All correspondence with First Nations and Métis communities can be found in **Appendix F**.

Table 7-2 Summary of First Nations and Métis Community Consultation

Community	Date and Form of Initial Contact	Date(s) and Form of Follow-up Contact	Date Response Received	Comments
Alderville First Nation	2016-02-05 (L)	2016-10-27 (L) 2018-03-23 (L) 2018-04-06 (E)		After no response was given from all mail out notices, an e-mail was sent to summarize the process to date as well as to provide the website for additional information regarding the study to solicit comments.
Curve Lake First Nation	2016-02-05 (L)	-	2016-02-23 (L)	Expressed interest and concern for archaeological resources
Hiawatha First Nation (Mississaugas of Rice Lake)	2016-02-05 (L)	-	2016-02-09 (L)	No interests, but expressed concern for archaeological resources and request to keep on Study Mailing List
Mississaugas of Scugog Island First Nation	2016-02-05 (L)	-	2016-02-16 (F)	No interests, but expressed concern for archaeological resources and request to keep on Study Mailing List
Peterbrough and District Wapiti Métis Council	2016-02-05 (L)	2016-10-27 (L) 2018-03-23 (L) 2018-04-06 (E)		After no response was given from all mail out notices, an e-mail was sent to summarize the process to date as well as to provide the website for additional information regarding the study to solicit comments.
Métis Nation of Ontario (MNO)	2016-02-05 (L)	2016-10-27 (L) 2018-03-23 (L) 2018-04-06 (E)		After no response was given from all mail out notices, an e-mail was sent to summarize the process to date as well as to provide the website for additional information regarding the study to solicit comments.
Chippawas of Rama	2016-02-05 (L)		2016-11-02 (E) 2018-04-03 (E)	Acknowledged receipt of notice and forwarded the information to Karry Sandy McKenzie.
Mississaugas of New Credit First Nation	2016-02-05 (L)		2016-03-10 (E) 2017-08-30 (L)	Expressed low concern for the proposed project and requested to keep apprised of further developments.
BeauSoliel First Nations	2016-02-05 (L)	2016-10-27 (L) 2018-03-23 (L) 2018-04-06 (E)		After no response was given from all mail out notices, an e-mail was sent to summarize the process to date as well as to provide the website for additional information regarding the study to solicit comments.

Community	Date and Form of Initial Contact	Date(s) and Form of Follow-up Contact	Date Response Received	Comments
Chippawas of Georgina Island First Nation	2016-02-05 (L)	2016-10-27 (L) 2018-03-23 (L) 2018-04-06 (E)		After no response was given from all mail out notices, an e-mail was sent to summarize the process to date as well as to provide the website for additional information regarding the study to solicit comments.
Kawartha Nishnawbe First Nation	2016-02-05 (L)	2016-10-27 (L) 2018-03-23 (L) 2018-04-06 (E)		After no response was given from all mail out notices, an e-mail was sent to summarize the process to date as well as to provide the website for additional information regarding the study to solicit comments.

(L) – Letter (T) – Telephone (E) – E-mail (F) – Fax

7.8 Other Agency and Stakeholder Consultation

7.8.1 Ontario Ministry of Transportation

Staff from the City of Markham met with representatives of the Ontario Ministry of Transportation (MTO) on March 22, 2016 to discuss the project. MTO staff stated that any works must not increase the risk of flooding on the Highway 404 right-of-way and the Don Mills Channel downstream of Highway 404. MTO staff declined an invitation to attend future Liaison Committee meetings, but committed to reviewing and providing comments on the Draft and Final Project File Report. Minutes of the meeting are included in **Appendix F.**

7.8.2 Toronto and Region Conservation Authority

A meeting was held with staff from the TRCA on April 26, 2017. The project team presented a summary of the existing conditions through the study area, the alternatives under consideration, and the selection of the centralized municipal flood storage facility combined with culvert replacements as the preliminary preferred solution. TRCA staff did not raise any significant concerns with the preliminary preferred alternative, but did request an Environmental Impact Assessment of the Don Mills Channel to verify the existing limited ecological function and minimal environmental impacts associated with preferred solution. Minutes of the meeting are included in **Appendix F.**

7.8.3 York Region

A meeting was held with staff from York Region on February 27, 2018. York Region staff were provided an update on the Don Mills Channel Flood Reduction Study and preliminary preferred solution, which includes the replacement of the Region's culvert on Woodbine Avenue. York Region was also made aware of the predicted frequency of flooding of Woodbine Avenue and the apparent settlement of the Region's culvert. Notes from the meeting are provided in **Appendix F**.

7.8.4 Individual Landowner Consultation

A number of landowners in the study area were not able to attend the second PIC in April 2018 and requested individual meetings with the City's project manager. No specific issues were raised and these landowners were generally supportive of the recommended solution. Minutes from the individual landowner meetings are included in **Appendix F**.

8 SUMMARY

Background

The Don Mills Channel study area was developed in the 1960's, prior to the adoption of modern stormwater management practices to control the quantity and quality of storm runoff. As part of the development of the area, the Don Mills Channel was transformed from a natural watercourse through agricultural lands to the realigned and confined system of channels and culverts that exist today. Consistent with practices at the time of development, the realigned Don Mills Channel was designed to convey the runoff from a 5 year storm event, with no provision for flows from larger, less frequent events. A number of sections of the channel were subsequently enclosed in culverts to facilitate industrial development. These enclosures, combined with the lack of planning for conveyance of storm runoff for storms greater than the 5 year event, have resulted in frequent flooding in the study area.

The first well documented occurrence of flooding from the Don Mills Channel occurred in August 1985 from a storm estimated to be between a 10 year and 25 year return period event. The study area was impacted by another severe storm on August 19, 2005 that dropped roughly 100 mm of rainfall over a study area in a little over 2 hours (Clarifica, 2005). That storm, estimated to be in excess of a 100 year event, resulted in severe flooding of many properties near the Don Mills Channel. The Don Mills Channel again experienced flooding from moderate return period storm events on July 27th and August 1st, 2014.

Previous studies to mitigate flooding from the Don Mills Channel concluded that any feasible flood reduction solutions would be extremely expensive and challenging, and no adequate funding sources available for their construction. In response, the City of Markham completed its Stormwater Funding Study to identify annual funding requirements to remediate areas in the City at risk of flooding, including the Don Mills Channel, and began charging a new City-wide Stormwater Fee in 2015 to fund flood remediation works.

The Don Mills Channel Flood Reduction Municipal Class EA study has built on previous assessments to determine the preferred solution to reduce flooding and flood damages from the Don Mills Channel.

Existing Conditions

The study area is fully developed for commercial and industrial development, and is designated as Commercial and Employment (several categories) in the City of Markham Official Plan. The past development of the area, prior to emergence of modern environmental protections and stormwater management practices, has resulted in very limited and degraded terrestrial and aquatic habitat through the study area. Numerous portions of the channel have been impacted by erosion, and several of the culverts along the Don Mills Channel are nearing the end of their serviceable life.

A detailed PCSWMM 2D model of the Don Mills Channel and catchment area was developed as part of this study to better understand flooding conditions through the study area. The PCSWMM 2D simulates hydrologic conditions and routes the generated runoff through representations of the existing on-site peak flow controls, storm sewers and overland flow routes leading to the Don Mills Channel, and the hydraulics of the Don Mills Channel itself. The 2D component of the model simulates flow paths and flooding through the study area when water overtops the banks of the Don Mills Channel during severe storm events. The model was validated against observed high water levels from the severe storms of 2005 and 2014, and was used to predict flooding conditions for the 2 year through 100 year return period storm events. The PCSWMM model confirmed that the channel cannot contain runoff from the 2 year storm event, and predicts that 8 buildings will be flooded in a 5 year storm (flood levels above finished floor elevations) and 18 buildings flooded in a 100 year storm. Average annualized damages, representing the product of risk x damages, is estimated at approximately $1.7 per year.

Alternative Solutions

A number of different solutions were developed to reducing flooding and/or flood damages from the Don Mills Channel and are briefly summarized below.

- Status Quo: The City would continue to regularly inspect and maintain the Don Mills Channel, and continue to require redevelopment in areas draining to the Don Mills Channel to significantly over-control storm runoff.
- Enhanced Channel Maintenance: All woody vegetation would be cleared and the Don Mills Channel would be maintained with regularly mown side slopes
- Channel Widening with Culvert Replacements: Up to 24 properties abutting the existing Don Mills Channel would be acquired, and the channel would be reconstructed as an approximately 60 m wide natural watercourse and valley corridor. The existing culverts at Steelcase Road East, Woodbine Avenue, Denison Street and Steelcase Road West would be replaced with much larger structures, and all other piped sections would be replaced by the natural channel corridor
- Acquisition of Flood Prone Properties: Up to 16 properties at risk of flooding in a 5 year storm event would be secured in public ownership, the existing structures would be demolished and the properties would be restored as parks or open space.
- Underground Flood Control Storage: Approximately 40,000 m^3 of storage would be created through construction of storage tanks under parking lots or other portions of existing developed sites at appropriate locations in the study area. The underground storage tanks could integrate low impact development and green infrastructure best management practices, which would reduce runoff volumes and improve water quality and baseflow in the Don Mills Channel in addition to reducing peak flow rates.
- Central Municipal Flood Control Storage: Several properties upstream (south) of Steelcase Road East would be acquired to allow construction of a large flood storage facility immediately adjacent the Don Mills Channel. A flow control structure would be constructed across the channel to restrict flow rates and back stormwater up into the facility during severe storm events.
- Flow Diversion: A large storm sewer would be constructed on Steelcase Road East and West to capture high flows and divert them away from the most flood prone areas, returning the flow to the Don Mills Channel just upstream of Highway 404.
- Flood Proofing and Education: Instead of reducing flooding from the Don Mills Channel, flood damages would be reduced by retrofitting buildings to prevent water from entering during flood events, and by encouraging implementation of best management practices to reduce damages to both indoor and outdoor areas on private property.
- Combined Alternative: This alternative would include the central municipal flood storage facility, replacement of the culverts at Steelcase Road East, Woodbine Avenue, Denison Street and Steelcase Road West, and a flood proofing and education program.

The alternative solutions were evaluated against a number of criteria considering the natural environment, social and cultural impacts, technical effectiveness and challenges and cost. The preferred solution to reduce flooding and flood damages from the Don Mills Channel is the Combined Alternative. This solution involves the construction of a central municipal flood storage facility upstream (south) of Steelcase Road East with a storage volume of approximately 37,000 m^3, replacement of the existing corrugated steel pipe culverts at Steelcase Road East, Woodbine Avenue, Denison Street and Steelcase Road West with 12 m to 15 m open span concrete structures, and implementation of a flood proofing and education program that can be expanded to other flood vulnerable areas in the City of Markham. The works are expected to cost approximately $69 Million to implement and will reduce average annualized flood damages from $1.7 Million to $0.2 Million.

Table 8-1 Evaluation Summary

Alternative	Capital Cost	Operation and Maintenance Costs	Resulting Average Annualized Flood Damages	Selection Notes
Status Quo	None	Low	$1.7 Million (no reduction)	Not selected. There is no reduction in flood damages in the short and medium terms
Enhanced Channel Maintenance	Very Low	Low-Medium	$1.7 Million (no reduction)	Not selected. The existing culverts govern the overall system capacity, and removal of channel vegetation will have no impact on flooding
Channel Widening with Culvert Replacements	Very High	Low	$0	Not selected. The cost and challenges to acquire up to 24 properties are prohibitive
Acquisition of Flood Prone Properties	Very High	Low	$0.5 Million	Not selected. The cost and challenges to acquire up to 16 properties are prohibitive, and it will not reducing flooding on roadways and the non-acquired properties
Underground Flood Control Storage	Medium	High	$0.6 Million	Not selected. There are significant challenges to construct and maintain storage facilities on existing developed private properties
Central Municipal Flood Control Facility	Low-Medium	Low-Medium	$0.9 Million	Not selected. The facility does not reduce flooding sufficient to prevent damages in a 5 year storm event
Flow Diversion	Low	Medium	n/a[1]	Not selected. The diversion would result in unacceptable increases in the depth and frequency of flooding on Highway 404
Flood Proofing and Education	Low	Medium	$0.9 Million	Not selected. There are significant challenges to implement flood proofing measures at all flood vulnerable properties, and it will not reduce flooding on roads and parking lots
Combined Alternative	Medium	Low-Medium	$0.2 Million	**Selected**. The combined works will prevent damages in a 5 year storm event and can be reasonably implemented in a relatively short period of time

[1] Flood damages were not calculated as the alternative in not reasonable/feasible

Additional Considerations and Recommendations

It is recommended that the central municipal flood storage facility be constructed first, as it can be implemented relatively quickly and achieves over half of the total reduction in flood damages associated with the combined alternative. The culvert replacements should proceed from downstream (Steelcase Road West) to upstream (Steelcase Road East) if feasible, but additional analyses have confirmed that, if warranted due to condition on timing for other roadway improvements, any culvert can be replaced in isolation with no concerns for upstream or downstream flood impacts.

A number of additional studies are required to facilitate implementation of the preferred solution, including detailed topographic surveys, geotechnical and hydrogeological investigations, utility investigations, Environmental Site Assessments for any acquired properties and an Environmental Impact Statement to ensure that the central municipal flood storage will achieve a net overall benefit to the natural environment.

A permanent flow and/or water level monitoring station is recommended in the vicinity of Steelcase Road East to refine the calibration of the PCSWMM model, and to allow comparisons to flood levels following construction of the central municipal flood storage facility.

Anticipated Project Timeline

The anticipated project timeline is as follows:

- 2018 - 2021: Property acquisition
- 2019 - 2029: Development and implementation of a flood proofing / education program
- 2021 - 2022: Detailed design and construction of central municipal flood storage facility
- 2026 - 2030: Detailed design and construction of roadway culverts

Note that the anticipated project timeline is dependent on the amount of time it takes for the City to complete the property acquisitions and to complete additional required studies. Based on the findings of the additional studies and property acquisitions, there is a potential that the project may need to be revised. Should any significant modification to the project be required, the modifications are subject to a review and shall be documented in revision or addendum to the Project File Report. In addition, a Revised Notice of Completion shall be issued for a 30-day review period

Public Consultation

Considerable consultation with the public, agencies and other stakeholders has taken place throughout the Don Mills Channel Flood Reduction Study. A Liaison Committee, comprised of City of Markham councillors and staff, TRCA staff and landowners, provided oversight of the project. Two Public Information Centres provided opportunities for the landowners and the public to provide feedback regarding existing conditions through the study area, input to the development of alternative solutions and feedback on the preliminary preferred solution. Numerous additional meetings took place with individual affected landowners and staff from the TRCA, York Region and MTO. All concerns raised by the public, landowners and agency staff have been considered in the evaluation of alternative solutions and have been addressed in this final Project File Report.

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