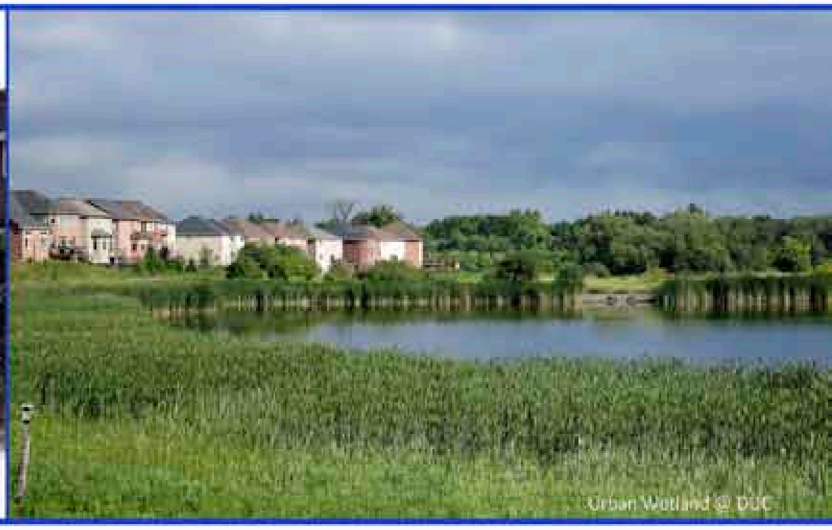
INTACT CENTRE
ON CLIMATE ADAPTATION

UNIVERSITY OF
WATERLOO

When the Big Storms Hit

The Role of Wetlands to Limit Urban and Rural Flood Damage



Prepared for the Ontario Ministry of Natural Resources and Forestry

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Intact Centre on Climate Adaptation

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About the Intact Centre on Climate Adaptation

The Intact Centre on Climate Adaptation (Intact Centre) is an applied research centre at the University of Waterloo. The Intact Centre was founded in 2015 with a gift from Intact Financial Corporation, Canada's largest property and casualty insurer. The Intact Centre helps homeowners, communities and businesses to reduce risks associated with climate change and extreme weather events. For more about the Intact Centre, please visit: www.intactcentreclimateadaptation.ca

About the University of Waterloo

University of Waterloo is Canada's top innovation university. With more than 36,000 students, the university is home to the world's largest co-operative education system of its kind. The university's unmatched entrepreneurial culture, combined with an intensive focus on research, powers one of the top innovation hubs in the world. For more about the University of Waterloo, please visit: www.uwaterloo.ca

The Intact Centre would like to acknowledge the following groups for their contributions:

Credit Valley Conservation (CVC) is a community-based environmental organization, dedicated to protecting, restoring and managing the natural resources of the Credit River Watershed Established by the provincial government in 1954, CVC is one of 36 conservation authorities in Ontario. CVC provided hydrologic and hydraulic modelling support for this project.

The Grand River Conservation Authority (GRCA) manages water and other natural resources on behalf of 39 municipalities and close to one million residents of the Grand River watershed. The watershed is the largest in Southern Ontario. GRCA provided hydrologic and hydraulic modelling support for this project.

IBI Group is a globally integrated architecture, planning, engineering and technology firm. IBI Group's team in Calgary, Alberta (Stephen Shawcross and David Sol) supported this project by leveraging their Rapid Flood Damage Assessment Model (RFDAM) to automate flood damage calculations and analysis.

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Executive Summary

This report assesses the potential for wetlands to affect the financial impacts associated with rural and urban flooding. Working with the Grand River Conservation Authority (Ontario), Credit Valley Conservation (Ontario) and Ducks Unlimited Canada, the Intact Centre on Climate Adaptation (Intact Centre) determined that wetlands, if maintained in their natural state, can substantially reduce flood damage costs to buildings (ranging from residential homes and apartment buildings, to industrial, commercial and institutional structures).

These findings have national applicability, albeit the research focused on two Southern Ontario pilot sites, one rural and one urban. For both sites, computer models simulated a major Fall flood, to compare flood damages under conditions where wetlands were maintained in their natural state and where they were replaced with agricultural land use. The researchers found that flood damages were lower if wetlands were maintained in their natural state, with financial cost savings of 29 and 38 per cent in rural and urban areas, respectively.

The rural pilot site was located near the City of Mississauga (Ontario) and the urban pilot site was located within the City of Waterloo (Ontario). The magnitude of the modelled flood was based on a severe, yet realistic, flood event (i.e., Hurricane Hazel, 1954, approximately equivalent to a 1-in-500 year flood), that had historically caused substantial property damage and loss of life in the Greater Toronto Area (Ontario).

At the rural pilot site, if wetlands were maintained in their natural state, flood damages would have been \$8.9 million. This was \$3.5 million, or 29 per cent, lower than the \$12.4 million cost that would have been realized if wetlands had been replaced with agricultural development.

For the urban pilot site, if wetlands were maintained in their natural state, the cost of flood damages would be \$84.5 million, which was \$51.1 million, or 38 per cent, lower than \$135.6 million cost that would have occurred had wetlands been replaced with agricultural development.

If the modeling assumed that wetlands were replaced by urban, largely impervious surfaces (such as buildings, roads and parking lots), rather than agricultural development, the value of flood damages avoided would have exceeded 29 - 38 per cent. Accordingly, the additive value of wetlands to reduce flood damage, as profiled in this report, is conservative.

This report demonstrates quantitatively that wetlands conservation is a cost-effective means to reduce flood risk in Canada. As such, the findings are consistent with, and reinforcing of, directives outlined in the *Wetland Conservation Strategy for Ontario*, the Province of Ontario's *Climate Change Action Plan*, and the Government of Canada's *Pan-Canadian Framework on Clean Growth and Climate Change.*

In summary, maintaining wetlands in their natural state offers a broadly-applicable and cost-effective means to reduce the financially and socially pervasive impacts of flooding that are increasingly affecting all Canadians.

Residential Wetlands @DUC

Chapter 1. Introduction

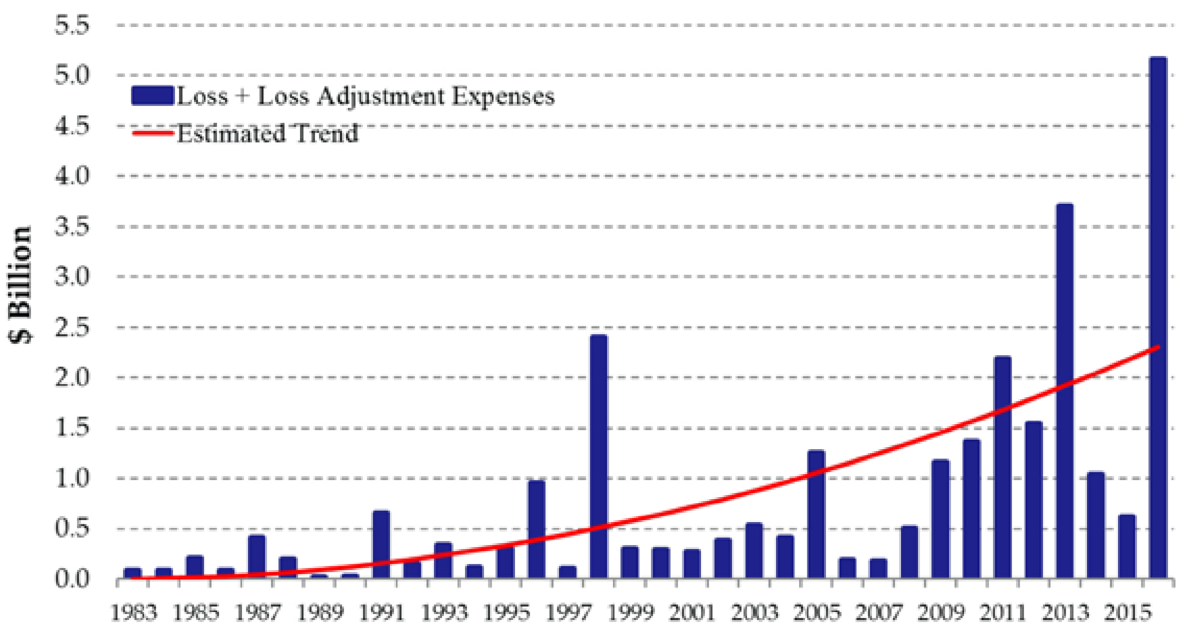
This report assesses the value of wetlands conservation to reduce flood damages associated with riverine flooding, based on modelling of two watersheds in Southern Ontario. The value is outlined in terms of flood damages avoided and average insurable claims foregone for properties located in the rural communities of Glen Williams, Cheltenham-Inglewood and Norval (north of the City of Mississauga) and within the urban setting of the City of Waterloo.

Before turning to the utility of wetlands to mitigate costs, it is first necessary to quantify the growing impacts of flooding realized across Canada following extreme precipitation events.[i]

As documented by the Insurance Bureau of Canada, "property and casualty insurance payouts from extreme weather have more than doubled every five to 10 years since the 1980s."[ii] As shown in Figure 1, for seven out of eight years (2009 – 2016), extreme weather-related insurance payouts have exceeded $1 billion in Canada, which is atypical relative to pre-2009 insurable losses. The primary cause of claims during the seven-year period up to 2016 was flooding.

Reflecting insurable losses, disaster recovery payments through Canada's federal Disaster Financial Assistance Arrangements (DFAA) have also greatly increased during this program's 45-year history. As noted by the Office of the Auditor General of Canada, "over the past

Figure 1: Catastrophic Insured Losses* from Natural Disasters in Canada (1983 to 2016), Values in 2016 CAN$



***Insured losses for a given disaster are deemed catastrophic when they total $25 million or more. Catastrophic losses for a year are the sum total of insured losses from these natural disasters.**
Source: Insurance Bureau of Canada (April 2017), PCS, CatIQ, Swiss Re, Munich Re & Deloitte

Chapter 1. Introduction

six fiscal years, the federal government spent more on recovering from large-scale natural disasters than in the previous 39 fiscal years combined."[iii] DFAA spending on floods was foremost, representing 75 per cent of all weather-related expenditures.[iv]

To improve resilience against future disasters, including floods, all levels of government in Canada have begun to prepare for severe weather. This effort is consistent with the *Paris Agreement*, signed in December 2016, which committed Canada to addressing current and future climate change impacts through enhancing adaptive capacity, strengthening resilience and reducing vulnerability.[v]

In 2017, the Government of Canada released the *Pan Canadian Framework on Clean Growth and Climate Change*, which further emphasized the need to adapt to a changing climate and build resilience. One of the climate adaptation focus areas noted, under the *Pan Canadian Framework*, was to consider climate change in long-lived infrastructure investments, which include both "traditional and natural adaptation solutions to build resilience, reduce disaster risks, and save costs over the long term."[vi]

In addition to the increased frequency and severity of rainfall events, growth in urban development has also altered drainage characteristics of natural catchments by increasing the volume and rate of surface runoff.[vii] This can produce higher peak-flows in drainage channels due to an overall growth in the extent of impervious surface coverage. Moreover, "the effects of development in urban basins are most pronounced for moderate storms following dry periods."[viii] Therefore, even in the absence of severe storms, growth in urbanization can cause rivers and streams to exceed their carrying capacity and lead to overland and sewer flooding. This is a prevalent issue for Canada, where urbanization is a continuing trend, with peripheral municipalities showing the highest population growth across the country.[ix]

Accordingly, land use planning policies that promote natural infrastructure preservation (and limit increased imperviousness in urban watersheds) are advocated by multiple groups in Canada to reduce flood risk.[x,xi] This has also been, and remains, a central component of natural hazard management promoted in Ontario through the *Provincial Policy Statement*,[xii] as supported by the province's Ministry of Natural Resources and Forestry.[xiii]

In addition to limiting flood risk, studies describe a range of ecosystem services that wetlands provide, including groundwater recharge and discharge; flood and drought attenuation; erosion control and sediment stabilization; water quality improvements and nutrient cycling; habitat provision; recreational and cultural uses; as well as carbon sequestration.[xiv]

Specific to flood mitigation, there is growing awareness that wetlands can play an instrumental role.[xv,xvi,xvii] Researchers note that wetlands do reduce the rate of overland water transport, while enhancing groundwater infiltration and desynchronizing water delivery to streams during storms. This function helps to reduce the frequency and magnitude of flooding, particularly when soils in the watershed are not saturated.[xviii] Similarly, floodplain wetlands (i.e., wetlands that adjoin rivers) are effective in flood attenuation, as they slow the speed of flood waves and they can store large quantities of surface water.[xix]

Notwithstanding their pervasive utility, over 70 per cent of Southern Ontario's pre-settlement wetlands have been lost through agricultural drainage, development, encroachment, land clearance, filling and road construction.[xx] Similar losses have been noted in other provinces. To help curtail this trend, this report quantifies the utility of wetlands to limit flood costs borne by all Canadians – simply put, "leaving natural wetlands natural" is a prudent choice for Canada.

Chapter 2. Method

This Chapter provides an outline of the process that municipalities, conservation authorities and watershed management practitioners can follow to assess the financial value of wetlands conservation for flood damage reduction (Section 2.1). It also contains an in-depth discussion on how this process was executed at the two sites for the purposes of this study (Section 2.2).

Two sites that were analyzed included rural areas of Glen Williams, Cheltenham-Inglewood and Norval, located in the Credit River Watershed (north of the City of Mississauga, Ontario) and an urban area of Uptown Waterloo, located in the Laurel Creek Watershed, upstream of the City of Waterloo, Ontario.

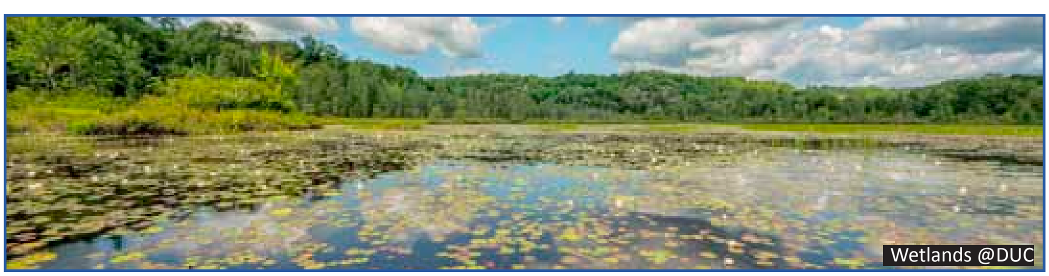
The two sites were selected based on four criteria: 1) representation of both a rural and an urban community, 2) wetland area and hydrologic diversity, 3) proximity to populated centers, and 4) availability of high quality hydrologic and hydraulic modelling:

1. **Representation of rural and urban communities:** Both rural and urban communities were selected to ensure the findings had a broad range of geographic applicability. While the majority of Ontario's population resides in urban centres, according to the *State of Rural Canada* report, Ontario has more rural residents than other provinces in Canada.[xxi] Furthermore, while both rural and urban communities are facing increased climate hazards (such as floods), the opportunity for natural infrastructure use and wetlands conservation is higher for rural communities.

2. **Wetland area and hydrologic diversity:** The total wetlands area included in the Credit River Watershed pilot study analysis was 72.9 hectares. The total wetlands area included in the pilot study analysis for the Laurel Creek Watershed was 540 hectares. Whereas the majority of wetlands analyzed for the Credit River Watershed pilot site were headwater wetlands, the majority of wetlands in the Laurel Creek Watershed were floodplain wetlands. For additional detail in reference to these watersheds, see Appendix A.

3. **Proximity to populated centres:** The benefit of wetlands for flood attenuation is likely to be greater if wetlands are in close proximity to developed areas. For both pilot sites, wetlands were in close proximity to populated areas, thus helping to ensure that the benefits, if any, of flood attenuation afforded by wetlands, could be quantified.

4. **Availability of high quality hydrologic and hydraulic modelling:** Both Credit Valley Conservation (CVC) and Grand River Conservation Authority (GRCA) have undertaken significant work to model wetlands in their respective watersheds as part of floodplain modelling. Therefore, both CVC and GRCA were able to share the outputs of their hydrologic and hydraulic modelling to support the project.

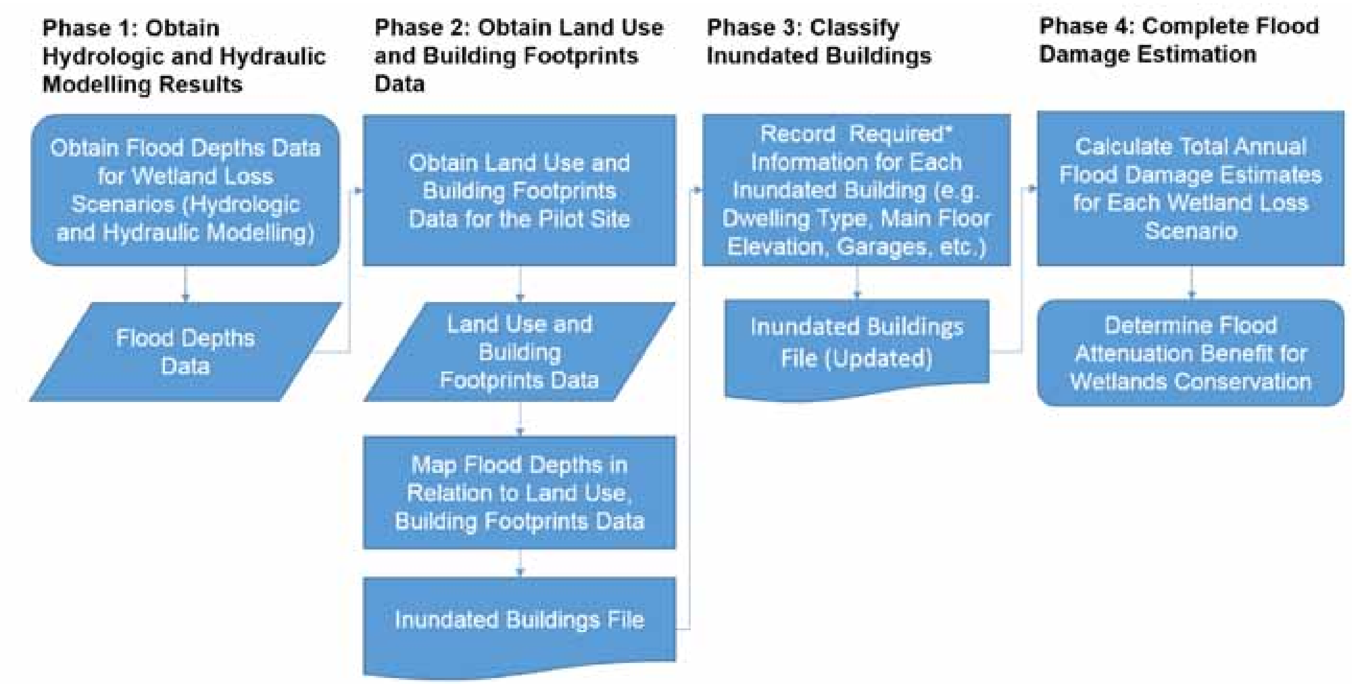

Wetlands @DUC

Chapter 2. Method

2.1 Assessing Financial Value of Wetlands Conservation for Flood Damage Reduction: A Generally Applicable Overview

Key steps pertaining to the process of assessing financial value of wetlands conservation for flood damage reduction are profiled in Figure 2.

Figure 2: Assessing Financial Value of Wetlands Conservation for Flood Damage Reduction (Process Flow)



*Information requirements differ based on the method of flood damage estimation chosen. For example, the inputs required for flood damage estimation using Ontario's *Flood Damage Estimation Guide* (2007) differ from the inputs required for flood damage estimation using Alberta's *Provincial Flood Damage Assessment Study* (2014).

Phase 1: Obtain Hydrologic and Hydraulic Modelling Results

During this phase, hydrologic and hydraulic modelling of wetland loss is carried out by third party experts to obtain flood extents and depths data "with and without" wetlands. In Ontario, floodplain modelling carried out by conservation authorities (under the direction of the Ontario Ministry of Natural Resources and Forestry[xxii]) can be used for this analysis. The hydrologic and hydraulic modelling should at least include the return periods for a 2-year, 5-year, 10-year, 25-year, 50-year, 100-year and Regulatory Storm (e.g., Timmins or Hurricane Hazel). Key output of Phase 1 is raster data[xxiii] (or shapefiles[xxiv]) showing flood extents and flood depths for a range of precipitation events and wetland loss scenarios.

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Phase 2: Obtain Land Use and Building Footprints Data
During this phase, land use data and building footprints data is collected for the study area. This data is typically available through local government websites and open data portals. Geographic Information System (GIS) software (i.e., ArcMap GIS) is then used to combine information from Phase 1 with land use and building footprints data to identify inundated buildings "with and without" wetlands.

Phase 3: Classify Inundated Buildings
Inundated buildings are then classified according to their use (e.g., residential, office, institutional, industrial, retail), structural type (e.g., single-family home, apartment building, etc.) main floor elevation relative to grade, as well as presence of underground parking and basements. Building information can be recorded manually or through specialized software (e.g., IBI Group's Google Earth Pro). This information is used for flood damage estimation (Phase 4).

Phase 4: Complete Flood Damage Estimation
To estimate flood damages for buildings, the recommended approach is to use the most recent flood depth-damage functions from the Government of Alberta, *Provincial Flood Damage Assessment Study* adjusted for inflation and regional context (Appendices B and C). If the scope of analysis includes an estimation of flood damages for municipal infrastructure, the process outlined in Appendix D can be followed. Once the total value of annual flood damages for each wetland loss scenario is estimated, one can compare the estimated flood damage costs "with and without" wetlands conserved. The value of flood damages avoided because of wetlands conservation is the economic benefit of wetlands for flood attenuation.


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Chapter 2. Method

2.2 Assessing Financial Value of Wetlands Conservation for Flood Damage Reduction: Detailed Discussion

This section describes how the process outlined above was followed to assess the value of wetlands conservation for the two pilot sites.

Phase 1: Obtain Hydrologic and Hydraulic Modelling Results

Credit Valley Conservation (CVC) and Grand River Conservation Authority (GRCA) oversaw all aspects of hydrologic and hydraulic modelling for the Glen Williams, Cheltenham-Inglewood and Norval area and Uptown Waterloo, respectively. Table 1 outlines wetland loss and rainfall event scenarios modelled by CVC and GRCA for the two pilot sites.

For Glen Williams, Cheltenham-Inglewood and Norval area, only the loss of headwater wetlands in the Credit River Watershed was modelled, whereas for Uptown Waterloo, loss of all wetlands in the Laurel Creek Watershed was modelled. The difference in modeling parameters was due to the fact that for the Credit River Watershed analysis, the hamlets of Glen Williams, Cheltenham-Inglewood and Norval were selected to estimate flood damages. As these hamlets are located upstream in the watershed, the impacts of modelling wetlands loss for the entire watershed (i.e., downstream of the hamlets) would bear no relevance to the upstream reaches. Within the Laurel Creek Watershed, the Uptown Waterloo area was located downstream of the wetlands area of the watershed.

Table 1: Wetland Loss and Rainfall Events: Modelled Scenarios

Wetland Loss Scenarios	Rainfall Events (Fall Season)
1. Baseline scenario (wetlands maintained in their current state) 2. Loss of all wetlands (through conversion to agricultural land use) 3. Loss of all wetlands and hummocky terrain (through conversion to agricultural land use)	1-in-2 year 1-in-5 year 1-in-10 year 1-in-25 year 1-in-50 year 1-in-100 year Hurricane Hazel

For Glen Williams, Cheltenham-Inglewood and Norval area, CVC used GAWSER hydrologic model and HEC-RAS 1D hydraulic model to derive flood flow depths and extents. For Uptown Waterloo, GRCA used GAWSER and PC-SWMM hydrologic models, and HEC-RAS 2D hydraulic model. As noted by CVC and GRCA, these models were used for floodplain mapping and were previously calibrated and verified against observed gauge and reservoir flow data. For more detail on hydrologic and hydraulic modelling, see Appendix A, *Notes: Hydrologic and Hydraulic Modelling*.

The wetland-loss scenarios selected for the study reflect the “best case” and the “worst case” scenarios for wetlands conservation. The “best case” scenario is the baseline, where all existing wetlands are maintained in their current state. The “worst case” scenario reflects total replacement of wetlands with agricultural land use. An additional scenario (hummocky terrain loss) was included, to illustrate the broader benefits of natural infrastructure preservation for flood attenuation. Hummocky terrain has depression features, which may result in wetland development and offer substantial water storage, especially if connected to a river network.[xxv]

Chapter 2. Method

For both watersheds, flooding was modelled for the Fall season, which is typically characterized by high precipitation events. The Spring, which is also flood prone, was not addressed due to challenges associated with modelling snowmelt.

Hydrologic and hydraulic modeling for Uptown Waterloo showed that only a Hurricane Hazel level event would result in riverine flooding that would damage buildings. Modelling for all other rainfall events (i.e., 1-in-2 year; 1-in-5 year; 1-in- 10 year; 1-in-25 year; 1-in-50 year and 1-in-100 year) predicted no flood damage to buildings.

Similarly, for Glen Williams, Cheltenham-Inglewood and Norval, modelling indicated that only a Hurricane Hazel level event would result in flood damages to buildings. Under other rainfall events modelled (i.e., 1-in-2 year; 1-in-5 year; 1-in-10 year; 1-in-25 year; 1-in-50 year and 1-in-100 year), there were no property flood damages in the Glen Williams and Norval areas. However, in the Cheltenham-Inglewood portion of the Credit River Watershed, flooding for three out of 316 buildings was predicted. This was deemed inconsequential, as the three properties represent less than one percent of the total building count and real estate value for Cheltenham-Inglewood.

A major rainfall, *sensu* Hurricane Hazel, was therefore the only level event for which the economic cost of flood damages was calculated for this study. Under conditions of a changing climate, whereby extreme weather will be more intense, Hurricane Hazel level events will be increasingly common. For example, in June 2004, northwest of the Laurel Creek Watershed, a severe localized storm generated 160 mm of rainfall in four hours and 202 mm of rainfall in 24 hours. This storm, modeled over the Laurel Creek Watershed, would have resulted in Hurricane Hazel level flows in Laurel Creek through the Uptown Waterloo area. Therefore, examining the role of wetlands in flood attenuation for a Hurricane Hazel level storm is a well-founded model parameter.

Phase 2: Obtain Land Use and Building Footprints Data
The Intact Centre obtained Digital Elevation Models (DEM) from CVC and GRCA. The CVC elevation data was provided with 0.5-meter resolution from the Greater Toronto Area DEM (2002), updated on July 7, 2015. The GRCA elevation data was provided with 10 cm resolution from LiDAR acquired by Stantec.

For Glen Williams, Cheltenham-Inglewood and Norval area, the Intact Centre obtained land use data (2014) and building footprints data (2016) from the Region of Peel and DTMI Spatial, respectively. For Uptown Waterloo, the Intact Centre obtained land use data (2015) and building footprints (2016) from DMTI Spatial and the City of Waterloo, respectively.

Overlaying this information in GIS with hydrologic and hydraulic model outputs from CVC and GRCA enabled the Intact Centre to understand the depths and extent of flooding for each inundated building within the two pilot sites. Based on the modelling of Hurricane Hazel, the projected count of flooded buildings was 47 for Glen Williams, Cheltenham-Inglewood and Norval area and 371 buildings for Uptown Waterloo.

Phase 3: Classify Inundated Buildings
The IBI Group's Google Earth Pro View tool was used to virtually examine all buildings projected to be inundated. The tool allowed for the buildings to be classified and for the information to be recorded (see Appendix B for details regarding the Earth Pro View tool).

Chapter 2. Method

Fifty properties were also visited by Intact Centre staff in the Uptown Waterloo area to ensure accuracy of building classification completed using IBI Group's Google Earth Pro View tool. No corrections were required. IBI Group's Google Earth Pro View tool was then used to classify all buildings located in Glen Williams, Cheltenham-Inglewood and Norval area.

Phase 4: Complete Flood Damage Estimation
Three methods were used to estimate the cost of flood damages, and to determine if one method might prove to be more rigorous to use in flood valuation relative to the other two going forward:

Method 1: Flood damage estimates with/without wetlands, determined utilizing average insurable claims data from a July 8, 2013, Greater Toronto Area flood event
Average insurance claims estimates associated with the July 8, 2013 storm in the Greater Toronto Area (GTA) were obtained. The Insurance Bureau of Canada confirmed the average insurance claim value for a low-rise residential basement flood for this event was $40,000.[1] Using the Bank of Canada inflation calculator, this value is equivalent to $41,813 in 2016 dollars. This number was applied to low-density residential properties affected by riverine flooding for the two pilot sites. Average insurance claims for all other property types, including medium- and high-density residential properties, commercial, industrial and institutional buildings, were based on estimates from the July 8, 2013 GTA flood, provided by Intact Financial Corporation.

Method 2: Flood damage estimates with/without wetlands, determined utilizing Ontario's *Flood Damage Estimation Guide* (2007)
The flood depth-damage curves used in Ontario were originally developed for Ontario's Ministry of Natural Resources by Paragon Engineering Limited and Ecologistics Limited in 1984 and 1985. In 2007, these flood depth-damage curves were updated by Water's Edge Environmental Solutions Team LTD., W.F. Baird & Associates Coastal Engineers Limited and Planning Solutions Inc. who used Consumer Price Index (CPI) adjustments to account for inflation. With assistance from Statistics Canada, the Intact Centre used CPI data to further adjust the flood depth-damage curves to 2016 dollars (Appendix E). This approach, therefore, considered key guidance offered by the province's *Flood Damage Estimation Guide.*

In the course of preparing these estimates, an error was noted in the Ontario flood depth-damage curves that may exaggerate flood damages by at least one order of magnitude. The extent to which this error has been carried forward into modelling programs and the resultant impact on planning decisions is not known at this time. The error remains present in the text of the Ontario *Flood Damage Estimation Guide* (2007) at the time of publishing.[2]

[1]This figure applies to owner-occupied claims; it is rounded; includes ex gratia payments; excludes claims denied or closed without payment; and pertains to building, contents, and allocated loss adjustment expenses.

[2]The Intact Centre uncovered that the flood damages values reported in Ontario's *Flood Damage Estimation Guide* (2007) are expressed in $/sq.ft. and in $/m^2, whereas they should be expressed in $/structure. This was confirmed through examination of the original *Flood Damage Estimation Guide* (1989) and subsequent e-mail communication with one of the authors of the *Flood Damage Estimation Guide* (1989). The Intact Centre reported this finding to Ontario's Ministry of Natural Resources and Forestry and maintained flood-damage values as $/structure in this report.

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Method 3: Flood damage estimates with/without wetlands, determined utilizing the depth-damage functions from Alberta's *Provincial Flood Damage Assessment Study* (2014)
In 2014, IBI Group (i.e., a global architecture, planning, engineering and technology firm) developed flood-depth-damage functions for the Government of Alberta, *Provincial Flood Damage Assessment Study.* To do so, IBI Group surveyed residential, industrial, commercial and institutional (IC&I) properties to quantify structural and contents damages.[xxvi,xxvii] IBI Group also developed a Rapid Flood Damage Assessment Model (RFDAM) to automate flood damage calculations, based on building elevation, flood elevation and depth-damage functions. See Appendix B for a description of the RFDAM and for adjustment factors applied by IBI Group to support flood estimation for this study.

See Appendix C for the original flood depth-damage functions developed for Alberta's *Provincial Flood Damage Assessment Study* (2014).

Note: the economic value of riverine flood damages avoided through keeping wetlands intact could also be quantified in terms of municipal stormwater management infrastructure upgrades required to achieve the minimum level of service for a municipality (Appendix D). Since the municipal infrastructure for both pilot sites had sufficient capacity to attenuate flooding for all rainfall events, as per the minimum municipal and provincial design standards (i.e., no property flooding was projected to occur for frequent rain events), no management infrastructure upgrades were deemed necessary – and the economic evaluation was not performed.

Chapter 3. Results

In this Chapter, Sections 3.1 and 3.2 profile estimated financial benefits of wetlands conservation for rural areas of Glen Williams, Cheltenham-Inglewood and Norval, as well as the urban area of Uptown Waterloo, respectively. The Chapter concludes with a discussion of the three-flood damage estimation methods, highlighting the advantages of using Alberta's *Provincial Flood Damage Assessment Study* (2014) for similar future analyses.

3.1 Glen Williams, Cheltenham-Inglewood and Norval

As shown in Table 2, the agricultural conversion of all headwater wetlands in the Credit River Watershed would result in a 55 percent increase in the number of flooded buildings in Glen Williams, Cheltenham-Inglewood and Norval area for a Hurricane Hazel level event occurring in the Fall. Table 3 summarizes the estimated value of resulting flood damages.

As shown, the cost of flood damages to building structures in Glen Williams, Cheltenham-Inglewood and Norval is expected to be lower if wetlands are maintained in their current state.

The absolute value and the scale of this cost avoidance differs based on the methods chosen, ranging from a 46 percent reduction in average insurable claims, to 17 and 29 per cent reduction

Table 2: Number of Building Structures Flooded in Glen Williams, Cheltenham-Inglewood and Norval for a Modelled Hurricane Hazel (Fall Season)

Wetland Scenarios	Number of Residential Building Structures Flooded	Number of Industrial, Commercial and Institutional Building Structures Flooded	Total Number of Building Structures Flooded
Baseline scenario (wetlands maintained in their current state)	24	5	29
Loss of all headwater wetlands in the Credit River Watershed	36	9	45
Loss of all headwater wetlands and hummocky terrain in the Credit River Watershed	38	9	47

Chapter 3. Results

Table 3: Estimated Value of Flood Damages for Glen Williams, Cheltenham-Inglewood and Norval, Modelled Hurricane Hazel (Fall Season) 2016 CAN$

Wetland Scenarios	Method 1: Estimated insurance claims for property flood damages		Method 2: Property flood damages as per Ontario's *Flood Damage Estimation Guide*		Method 3: Property flood damages as per Alberta's *Provincial Flood Damage Assessment Study* Functions	
Baseline scenario (wetlands maintained in their current state)	$994,847		$4,317,619		$8,861,614	
Loss of all headwater wetlands in the Credit River Watershed	$1,841,353		$5,171,833		$12,432,234	
Estimated reduction in flood damage costs	**$846,506**	**46%**	**$854,214**	**17%**	**$3,570,620**	**29%**
Loss of all headwater wetlands and hummocky terrain in the Credit River Watershed	$2,141,923		$5,375,126		$13,461,328	
Estimated reduction in flood damage costs	**$1,147,076**	**54%**	**$1,057,507**	**20%**	**$4,599,714**	**34%**

on flood damages to building structures, using Ontario's *Flood Damage Estimation Guide* and Alberta's *Provincial Flood Damage Assessment Study*, respectively.

Lastly, if the impact of hummocky terrain was included in the evaluation of flood damages, it would lead to a further reduction in flood damages.

Chapter 3. Results

3.2 Uptown Waterloo

The Uptown Waterloo area is more densely populated than Glen Williams, Cheltenham-Inglewood and Norval.[3] Accordingly, the total number of buildings structures flooded would be significantly higher for Uptown Waterloo, should a flood event occur (see Table 4). Table 5 summarizes the associated value of flood damages for this pilot site.

Table 4: Number of Building Structures Flooded in Uptown Waterloo for a Modelled Hurricane Hazel (Fall Season)

Wetland Scenarios	Number of Residential Building Structures Flooded	Number of Industrial, Commercial and Institutional Building Structures Flooded	Total Number of Building Structures Flooded
Baseline scenario (wetlands maintained in their current state)	255	78	333
Loss of all wetlands in the Laurel Creek Watershed	286	84	370
Loss of all wetlands and depression areas in the Laurel Creek Watershed	287	84	371

[3]Glen Williams, Cheltenham-Inglewood and Norval are low-density rural communities, with the total population under 3,000 and the total building count under 1,000. In contrast, the Uptown Waterloo area is densely populated, with a population of 14,938 and a total building count of 2,145.

Chapter 3. Results

Table 5: Estimated Value of Flood Damages for Uptown Waterloo for a Modelled Hurricane Hazel (Fall Season) 2016 CAN$

Wetland Scenarios	Method 1: Estimated insurance claims for property flood damages		Method 2: Property flood damages, as per Ontario's *Flood Damage Estimation Guide*		Method 3: Property flood damages, as per Alberta's *Provincial Flood Damage Assessment Study*	
Baseline scenario (wetlands maintained in their current state)	$12,494,736		$51,394,130		$84,486,719	
Loss of all wetlands in the Laurel Creek Watershed	$15,186,791		$104,735,987		$135,581,997	
Estimated reduction in flood damage costs	**$2,692,055**	**18%**	**$53,341,857**	**51%**	**$51,095,278**	**38%**
Loss of all wetlands and depression areas in the Laurel Creek Watershed	$16,574,796		$105,005,254		$138,084,723	
Estimated reduction in flood damage costs	**$4,080,060**	**25%**	**$53,611,124**	**51%**	**$53,598,004**	**39%**

As illustrated, the cost of flood damages to building structures in Uptown Waterloo is expected to be lower if wetlands are maintained in their current state. The absolute value and the scale of this cost avoidance, again, differs based on the methods chosen - ranging from 18 per cent reduction in average insurable claims, to 51 and 38 per cent reduction on flood damages to building structures, using Ontario's *Flood Damage Estimation Guide* and Alberta's *Provincial Flood Damage Assessment Study*, respectively.

Preserving hummocky terrain leads to a further reduction in flood damages in the study area.

3.3 Discussion of Flood Damage Estimation Methods

As illustrated in sections 3.1 and 3.2 above, method three, or flood damages estimates using inputs from Alberta's *Provincial Flood Damage Assessment Study* (2014), predict the highest absolute benefit of wetlands conservation. The discussion below outlines why this method is arguably the most accurate of the three valuation techniques, or by corollary, why the other two methods may underestimate the value of flood damage.

Chapter 3. Results

Method 1: Flood damage estimates with/without wetlands, determined utilizing average insurable claims data from a July 8, 2013, Greater Toronto Area flood event

This method may underestimate the value of flood damages for the following three reasons:

1. For every dollar of insured losses in Canada, there are $3 to $4 of uninsured losses that are borne by governments and individuals.
2. Flood damage estimates determined using average insurable claims data from the July 8, 2013 GTA flood likely underestimate flood damage from the more severe, Hurricane Hazel level event, analysed in this study.
3. Overland flood damages were not historically covered through personal property insurance. Personal property overland flood insurance became more widely available in Canada following the 2013 floods in Alberta and Ontario. Therefore, the cost of overland flood damages may not be fully accounted for when using this method of analysis.

Method 2: Flood damage estimates with/without wetlands, determined utilizing Ontario's *Flood Damage Estimation Guide* (2007)

This method may underestimate the value of flood damages for the following three reasons:

1. Ontario's *Flood Damage Estimation Guide* is based on a survey of residential buildings in Ontario dating back to the 1980s. Since the 1980s, both building use and construction approaches have changed. For example, compared to the 1980s, residential basements are now more frequently used as living spaces, with more electronics and equipment (e.g., furnace and heating, ventilation and air conditioning systems) stored below grade. Such changes, along with the changes in construction approaches since the 1980s, are not fully captured through CPI adjustments. Therefore, the 2007 *Flood Damage Estimation Guide* for Ontario likely understates the values of flood damages that can be expected for residential buildings in the province.
2. Ontario's *Flood Damage Estimation Guide* does not provide values for estimating flood damage for apartment buildings.
3. For residential buildings, Ontario's *Flood Damage Estimation Guide* provides flood damage values per property, implying that the larger the inundated structure, the lower flood damage is per unit area. The opposite tends to occur during flood events (the larger the structure, the more significant damages that are typically incurred).

In conclusion, out of the three methods employed, Alberta's *Provincial Flood Damage Assessment Study* (2014) provides the most recent, and by extension, most applicable, data set for estimating structural and contents damage for residential, industrial and commercial buildings in Canada. This allows for a more accurate estimation of flood damage than the other two methods – accordingly, it is the recommended method for flood damage estimations going forward.


Wetlands @DUC

Chapter 4. Discussion & Conclusion

This study confirms that wetlands conservation can be a powerful means to reduce flood damages related to riverine flooding. As illustrated, simply maintaining wetlands in their natural state can result in financial cost saving of 29 and 38 per cent in rural and urban settings, respectively, under conditions of severe precipitation.

These finding are conservative - if the report considered wetlands conversion to urban, largely impervious surfaces (such as buildings, roads and parking lots), rather than agricultural land development - the financial value of cost savings would have exceeded 29 and 38 per cent.

Moreover, further quantification of benefits associated with wetlands conservation, including habitat protection, biodiversity improvements, water quality enhancement, drought attenuation and carbon sequestration, amplifies the message that maintaining wetlands in their natural state is a financially prudent and a socially desired outcome for Canadian communities.

This report underscores the role that natural infrastructure, such as wetlands, plays in flood mitigation and provides impetus for communities to view natural infrastructure as a climate adaptation solution.

The report provides the financial argument for wetlands conservation, supporting the directives outlined in the *Wetland Conservation Strategy for Ontario*, the proposed *Naturally Resilient: Ministry of Natural Resources and Forestry's Natural Resource Climate Adaptation Strategy* and in the Government of Canada's *Pan-Canadian Framework on Clean Growth and Climate Change.*

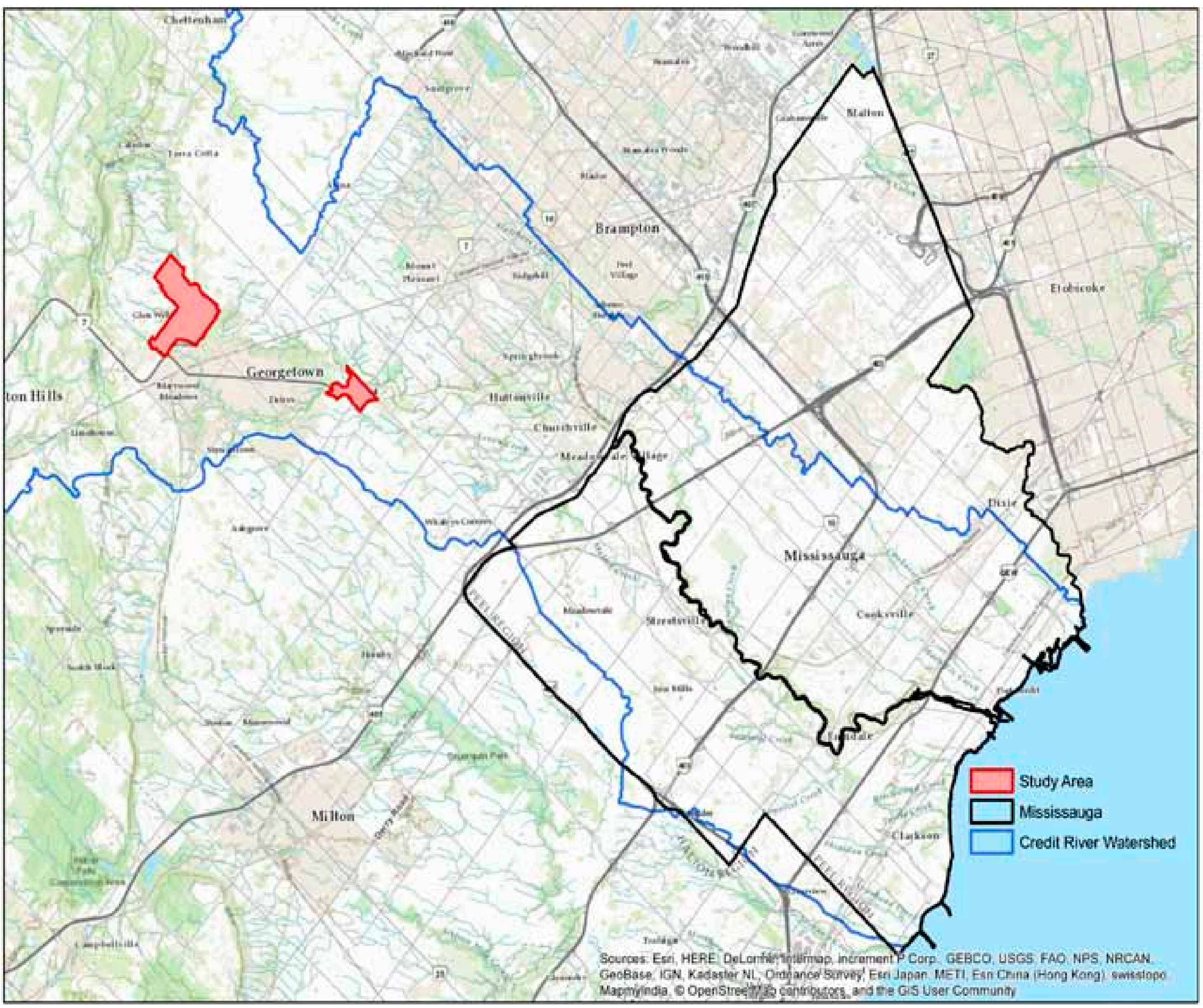
Thames River Wetland @DUC

Appendix A: Background Information on the Credit Valley and Laurel Creek Watersheds

Credit Valley Watershed

Depicted in Figure 3 below, are the locations of the populated areas where flood damages were analyzed for the Credit River Watershed.

Figure 3: Glen Williams, Cheltenham-Inglewood and Norval, Credit River Watershed, Ontario



Appendix A: Background Information on the Credit Valley and Laurel Creek Watersheds

The following tables provide population, building count and wetlands modelling assumptions for the Credit River Watershed.

Table 6: Population and Building Count within the Credit River Watershed

Pilot Site 1: Population and Building Count		
Location	Population*	Total Building Count**
Glen Williams, ON	1,700	529
Norval, ON	310	135
Cheltenham-Inglewood, ON	900	316

*Population count sources: Town of Caledon[xxviii] and Town of Halton Hills.[xxix]

**Buildings count sources: DTMI Spatial[xxx] and, Region of Peel.[xxxi]

Table 7: Wetland and Hummocky Terrain Modelling Assumptions within the Credit River Watershed

Pilot Site 1: Wetland and Hummocky Terrain Modelling Assumptions						
	Total Area of wetlands*	**Total area of provincially significant wetlands**	**Total area of locally significant wetlands**	**Total area of hummocky terrain**	**Average storage capacity of wetlands****	**Average storage capacity of hummocky terrain*****
Description	Total wetlands area - evaluated and unevaluated - located in Credit River Watershed upstream of Norval	Provincially significant wetlands area located in Credit River Watershed upstream of Norval	Locally significant wetlands area located upstream of Norval	Hummocky terrain area included in the model run	Average storage capacity of wetlands assumed in the model	Average storage capacity of hummocky terrain assumed in the model
Total	729, 000 m^2 (72.9 ha)	546,638 m^2 (54.6 ha)	182,212 m^2 (18.2 ha)	400,000 m^2 (40 ha)	43,731 m^3	39,990 m^3

* Includes Silver Creek which outlets to the Credit River in Norval.

**The GAWSER model does not model each individual wetland, so the approach to estimating storage capacity represents an average condition in the fall for the entire modelled area of wetlands.

*** The hummocky terrain component is not defined within the range of the storms but would exceed 100 mm of depth.

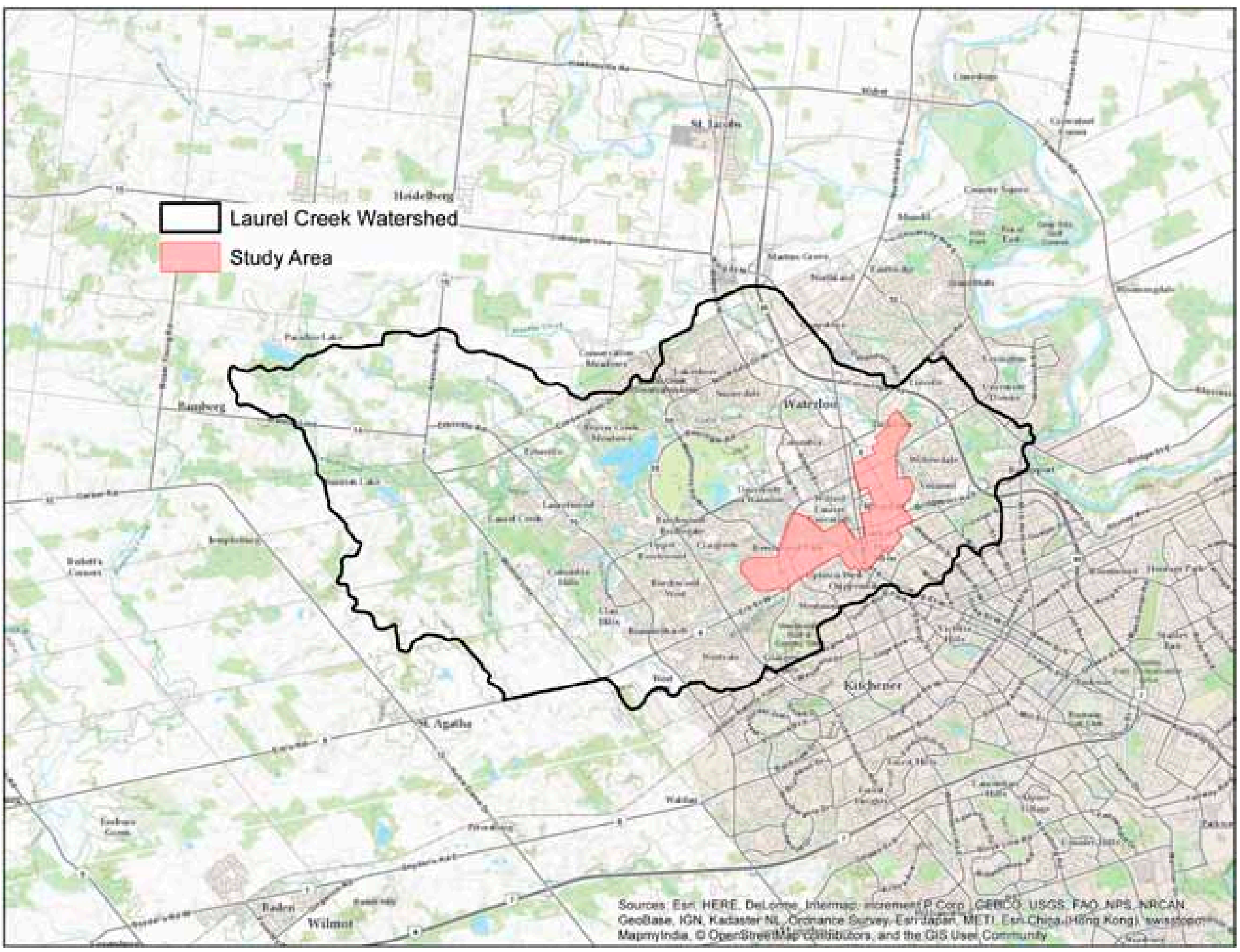
See notes on Hydrologic and Hydraulic Modelling for more details

Appendix A: Background Information on the Credit Valley and Laurel Creek Watersheds

Laurel Creek Watershed

Depicted below (Figure 4) are the populated areas where flood damages were analyzed for the Laurel Creek Watershed.

Figure 4: Uptown Waterloo, Laurel Creek Watershed Ontario



Appendix A: Background Information on the Credit Valley and Laurel Creek Watersheds

The following tables provide population, building count and wetlands modelling assumptions for the Laurel Creek Watershed pilot site.

Table 8: Population and Building Count within Laurel Creek Watershed

Pilot Site 2: Population and Building Count information		
Location	Population[xxxii]	Total Building Count[xxxiii]
Uptown Waterloo, ON	14,938	2,145

Table 9: Wetland and Hummocky Terrain Modelling Assumptions with Laurel Creek Watershed

Pilot Site 2: Wetland and Hummocky Terrain Modelling Assumptions						
Description	**Total area of wetlands***	**Total area of provincially significant wetlands**	**Total area of locally significant wetlands**	**Total area of hummocky terrain**	**Average storage capacity of wetlands**	**Average storage capacity of hummocky terrain**
	Total wetlands area - evaluated and unevaluated - located in the Laurel Creek Watershed	Provincially significant wetlands area located in the Laurel Creek Watershed	Locally significant wetlands area located in the Laurel Creek Watershed	Hummocky terrain area included in the model run	Average storage capacity of wetlands assumed in the model	Average storage capacity of hummocky terrain assumed in the model
Total	5,400,000 m^2 (540 ha)	4,890,000 m^2 (489 ha)	510,000 m^2 (51 ha)	250,000 m^2 (25 ha)	560,000 m^3	285,000 m^3

* The wetland areas are attributed to the Laurel Creek Watershed upstream of the Laurel Creek Reservoir; the wetlands are part of the watershed that drains into the reservoir. Since most of the wetlands within the watershed are located in this area, it is similar to the wetlands area for the entire Laurel Creek Watershed.

See notes on Hydrologic and Hydraulic Modelling for more details.

Appendix A: Background Information on the Credit Valley and Laurel Creek Watersheds

Notes: Hydrologic and Hydraulic Modelling

Credit Valley Conservation (CVC) and Grand River Conservation Authority (GRCA) oversaw all aspects of hydrologic and hydraulic modelling for the purposes of this study. The Intact Centre obtained the flood depths and extents from CVC and GRCA, based on the outputs of their respective modelling. The conservation authorities provided the following explanations about the hydrologic and hydraulic modeling, respectively.

Credit River Watershed

For Credit River Watershed, CVC used the GAWSER* hydrologic and HEC-RAS 1D hydraulic models to derive flood flow depths and extents. These models were calibrated and verified against observed gauge and reservoir flow data.

Stormwater management facilities, such as ponds, were included in the GAWSER model used for the economic analysis. Culverts, bridges and dams were included in the HEC-RAS model only, to estimate flood elevations. The flows were routed through the Island Lake Dam located in Orangeville. The dam is a passive structure used for low flow augmentation and recreation. It has some minor attenuation capacity that may reduce flow rates immediately downstream of the structure. However, it has little or no impact on flood risk in the flood vulnerable areas along the Credit River.

To account for wetlands storage capacity, Hydrologic Response Unit (HRU) was the main input variable in the GAWSER model that governed the potential for downstream flood attenuation.[4] Since the maximum storage depth could vary according to plant growth and surface covers (depending on the time of year), the HRU was specified as a maximum depression depth, varying between 75 and 115 percent. In an event mode, the wetlands would start with zero water depth, such that the entire maximum depression storage depth was available to reduce downstream flooding. In a continuous mode, the depression depth would fill up quickly, and then it would fluctuate throughout the year due to precipitation, evaporation and some infiltration.

In addition to modelling the storage directly associated with the surface areas of the wetlands, the GAWSER model also accounted for storage associated with hummocky terrain. The extent of the hummocky terrain was calculated and then modelled at the sub-catchment level. For the area draining to the hummocky terrain, there is sufficient storage area within the existing topography to contain the runoff generated by a Hurricane Hazel type event.

To simulate the removal of wetlands, the depression storage values were modelled as a typical agricultural HRU with the soil types set the same as the soil that is dominant in that sub-catchment.


Matchdash @DUC

[4] Wetlands are one type of HRU in the model. Other HRUs include urban lands, crop lands on sandy soils, forest, etc. Although all wetlands are, by definition, the same HRU, there are some parameters such as depression storage that can vary from wetland to wetland. For this study, all wetlands were modelled assuming the same HRU, as the data did not exist to treat them individually.

Appendix A: Background Information on the Credit Valley and Laurel Creek Watersheds

Laurel Creek Watershed
For the Laurel Creek Watershed, GRCA hired Stantec to execute GAWSER* and PC-SWMM hydrologic modelling and HEC-RAS 2D hydraulic modelling.

Storm water management facilities, dams, bridges and culverts were left in both the hydrologic and the hydraulic models. These models were calibrated and verified against observed gauge and reservoir flow data.

To model wetland storage capacity, elevation-storage area curves were estimated from a high resolution 1 metre by 1 metre Digital Elevation Model. The outflows from the large depressions were estimated using the HEC-RAS model. If the HEC-RAS model did not exist for a particular area, a crude HEC-RAS model was created to estimate the discharge curve from a large depression. Large depressions were physically modelled/represented as reservoirs. The reservoirs were modelled to spill, once the elevation in the depression or wetland reached the spillage point.

Where there were many small wetlands, their volume in any given catchment was estimated from the Digital Elevation Model. The volume of the wetland storage was divided by the catchment area, to convert the volume of storage to a depth of storage over the entire catchment. The depth of storage associated with wetlands or dry depressions increased the depression storage for the catchment.

To simulate the removal of wetlands, the depression storage values were reduced to lower storage values for agricultural areas.

This modelling approach could be improved in the future, with consideration given to modelling of overland flow and peak flows timing. The reduction in peak flow is expected to further increase the economic value of wetlands from a flood reduction perspective.

**The GAWSER model is not an integrated ground and surface model and, therefore, may significantly underestimate the influence of wetlands on flood attenuation.*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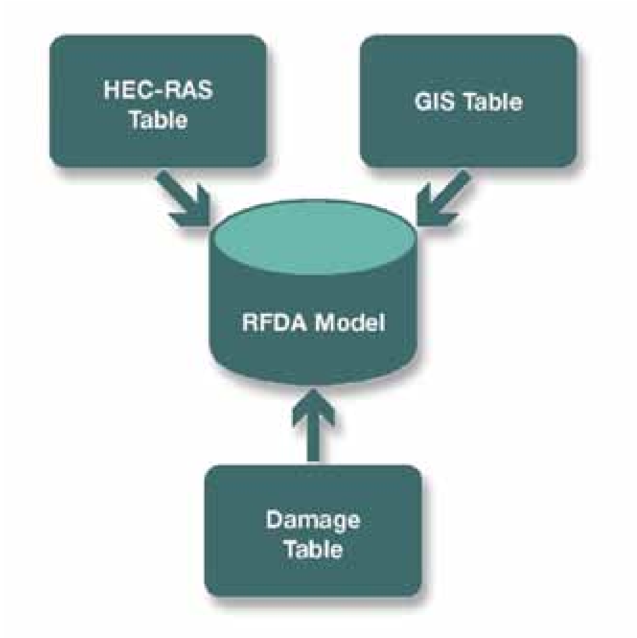
Appendix B: IBI Group Rapid Flood Damage Assessment Model (RFDAM)

IBI Group's Rapid Flood Damage Assessment Model (RFDAM) works with three input tables: (1) the GIS inventory table of residential and commercial/retail buildings in the study area; (2) the specific depth-damage curves for contents and structures indexed to that community; and (3) the hydraulic flood-frequency-elevation table derived from the HEC-RAS model.

Figure 5: IBI Group Rapid Flood Damage Assessment Model



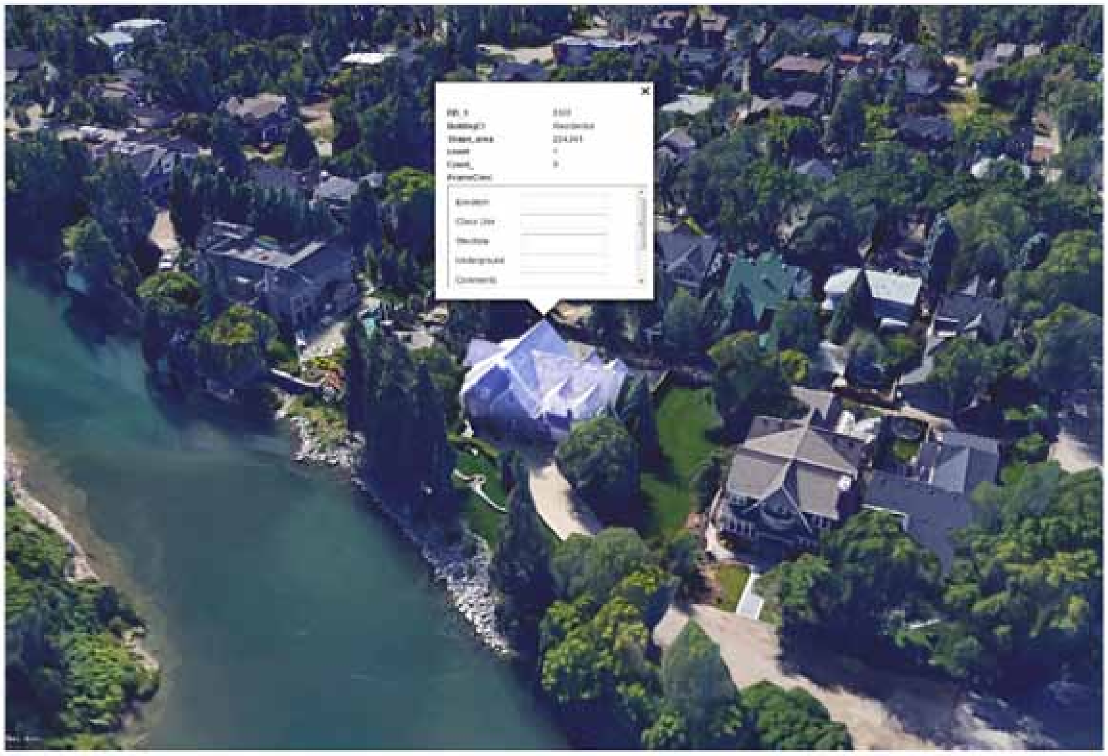
Building Inventory

IBI Group's flood damage assessment model inputs details about each building in the flood hazard area into flood-damage calculations (details are outlined below). Where field verification of building details is not feasible, Internet-based resources can be employed to construct the building inventory. Google Earth Pro's Street View is the primary method of remotely determining main floor use and elevation. If incorporating data from tax assessment records, municipal map viewers can be used to reconcile parcel and address information to match records with polygons. Finally, Internet searches can help identify uses that are not clear from the street view or other data sources.

To facilitate the entry of building classification and estimated main floor elevation, IBI Group developed an application for use within Google Earth Pro. A shapefile of all properties is created with one of the attribute fields containing HTML code. When imported into Google Earth Pro, this code creates a dynamic window that allows the user to enter a building's characteristics right from the Google Earth application. This drastically increases the speed at which the inventory can be completed. Figure 6 illustrates a screenshot of this tool in use.

Appendix B: IBI Group Rapid Flood Damage Assessment Model (RFDAM)

Figure 6: IBI Group Google Earth Pro View



The following is a list of required building attributes for the RFDAM model, as well as a brief description of desktop collection methods.

- *Location (x,y coordinates)*
  A centroid point is created from each of the building polygons within the study area (detached garages and other small accessory buildings are omitted).
- *Size (main floor area)*
  The main floor area is based on the GIS building polygon. For houses (single family, duplex, townhouse, etc.), the area is adjusted to account for eave overhangs when the polygon is generated by aerial imagery. Additionally, the area of any attached garages and carports is deducted from the shape area. Such deduction can either be recorded as a percentage in the Google Earth input tool, or noted as being a standard single- or double-car garage for calculation purposes.
- *Structure class and type*
  The class and type are determined visually, generally through Google Street View. Where multiple uses are present, the predominant use is selected, or in the case of retail, the general merchandise class may be the most appropriate.
- *Elevation at grade*
  The ground elevation is obtained by sampling the LiDAR layer at the building centroid.
- *Main floor elevation (from grade)*
  Main floor elevation is generally not recorded in the available municipal data sets. The elevation can be estimated using Google Street View imagery. The number of risers at the entrance of a building is a good guide for estimating elevation from grade. For buildings with primary use or suite below grade, a negative main floor elevation is used rather than a basement.

Appendix B: IBI Group Rapid Flood Damage Assessment Model (RFDAM)

- *Below-grade development*
  The presence of a below-grade development is recorded as a yes or no. For houses, the assumption that all basements have finished spaces is made. For apartments and non-residential buildings, this refers to underground parking.

HEC-RAS Table
The HEC-RAS or flood elevation table contains the water surface elevation at each building location for all return periods studied. This information is obtained by sampling each flood raster for every building centroid. For the purposes of this project, flood elevations for each building were provided to IBI Group based on the modelling provided by Credit Valley Conservation and Grand River Conservation Authority.

Damage Table
The damage tables contain all the stage-damage functions for the various classifications and building types in the inventory. These curves were developed by IBI Group in 2014 based on detailed surveys of Alberta households and first-principle repair estimates. Specifically, IBI Group completed 83 residential dwelling unit surveys in Calgary and Edmonton, Alberta. The updated flood damage functions for the non-residential buildings were based on previous studies and verified through sampling (12 industrial, commercial and institutional buildings were sampled to validate previous study results).

The following adjustment factors were applied by IBI Group to support flood estimation for this project.

Adjustment Factors - Contents Damages
The Survey of Household Spending (SHS) was used to measure the change in household content value between the provinces. Average household expenditures are measured annually in categories similar to the CPI and are available at the provincial level. If average household spending on televisions, for example, is the same between provinces, it is assumed that there will be the same dollar value of television equipment in the household, even if the CPI of an unchanging television set falls. This index can therefore be used to adjust values between years and provinces. Accordingly, weighted categories of spending can be derived from the residential contents survey to represent goods damaged by floodwaters. Adjusting the Alberta household content values to Ontario values can be performed using the following formula:

*ON damages = AB damages * (Weighted ON spending/Weighted AB spending)*

Table 10: Residential Content Damages Adjustment: Alberta to Ontario, 2014 CAN$

Category	2014 Survey of Household Spending		Weight	Weighted Survey of Household Spending		ON/AB Index
	ON	AB		ON	AB	
Furnishings and equipment	$2,226	$2,359	0.59	$1,313	$1,392	
Clothing and accessories	$3,884	$4,378	0.21	$816	$919	
Recreation	$3,739	$5,147	0.2	$748	$1,029	
Total				$2,877	$3,341	0.86

Appendix B: IBI Group Rapid Flood Damage Assessment Model (RFDAM)

The 2014 SHS was the latest available release at the time of reporting; thus, no adjustments from 2014 to 2016 values were made.

Adjustment Factors - Structures Damages
The cost of labour and materials for construction and restoration varies across the country and over time. Two sources of data were employed to adjust the Alberta structural damages amounts for use in Ontario: the 2014 Altus Construction Cost Guide and Statistics Canada's Construction Price Indexes. The construction cost guide accounts for geographic differences, and the price indexes allow for adjustments from 2014 to 2016 dollars.

Type	ON/AB Index
Office	0.980
Retail	0.891
Institutional	0.972
Hotels	0.976
Parking Structures	1.047
Apartments	0.937
Houses	1.093
Industrial	0.836

Specifically, 2014 GTA construction costs per square foot for each class of building were divided by the 2014 Calgary costs to provide a 2014 ratio. A second ratio was obtained by dividing the 2016 GTA construction price index for each class of building by the 2014 GTA construction price index. The product of these two ratios provides an index to adjust structurals.

Notably, Ontario flood damage values for residential properties were reported in Ontario's *Flood Damage Estimation Guide* in terms of dollars per depth of flooding, per building structure. Accordingly, IBI Group set up a special run of the RFDAM (the RFDAM was designed to calculate flood damages per square metre) so that the Ontario flood damages values could be easily processed. This was done by setting the value of the residential building area to one for each single-family structure and to the number of units for each attached structure (townhouses and duplexes). The flood damages for non-residential buildings were calculated on a square metre basis, as Ontario's *Flood Damage Estimation Guide* provides flood damage values for non-residential buildings on a square metre basis.

Appendix C: Flood Damage Values from Alberta's *Provincial Flood Damage Assessment Study* (2014)

The flood damage values noted below were used as an input into IBI Group's Rapid Flood Damage Assessment Model (RFDAM).

All values reported in this Appendix are expressed in $/m^2 (2014).

Adjustment indices to translate content and structural damage values for use in Ontario (2016 dollars) are provided in Appendix B

Class A - Residential One-Storey					
Depth relative to main floor[1]	Main Floor Contents	Main Floor Structure	Basement Contents[2]	Basement Structure[2]	Total
-2.7	$0	$0	$0	$0	$0
-2.6	$0	$0	$400	$231	$632
-2.4	$0	$0	$554	$271	$825
-2.1	$0	$0	$715	$299	$1,015
-1.8	$0	$0	$778	$299	$1,077
-1.5	$0	$0	$784	$305	$1,090
-1.2	$0	$0	$786	$335	$1,122
-0.9	$0	$0	$788	$335	$1,123
-0.6	$0	$0	$810	$356	$1,167
-0.3	$0	$0	$836	$357	$1,193
0	$0	$0	$836	$365	$1,201
0.1	$373	$588	$836	$365	$2,162
0.3	$624	$594	$836	$365	$2,420
0.6	$758	$674	$836	$365	$2,633
0.9	$809	$848	$836	$365	$2,858
1.2	$816	$848	$836	$365	$2,865
1.5	$816	$848	$836	$365	$2,865
1.8	$839	$848	$836	$365	$2,888
2.1	$839	$848	$836	$365	$2,888
2.4	$839	$848	$836	$365	$2,888
2.7	$839	$848	$836	$365	$2,888

1 - Distance between floors is variable in model; 2.7 metres is illustrated.

2 - Not all structures have basements, and it is a separate calculation in the model.

Appendix C: Flood Damage Values from Alberta's *Provincial Flood Damage Assessment Study (2014)*

Class A -Residential Two-Storey					
Depth relative to main floor[1]	Main Floor Contents	Main Floor Structure	Basement Contents[2]	Basement Structure[2]	Total
-2.7	$0	$0	$0	$0	$0
-2.6	$0	$0	$226	$241	$467
-2.4	$0	$0	$354	$354	$708
-2.1	$0	$0	$395	$406	$802
-1.8	$0	$0	$437	$406	$843
-1.5	$0	$0	$440	$429	$869
-1.2	$0	$0	$442	$466	$908
-0.9	$0	$0	$444	$466	$910
-0.6	$0	$0	$475	$506	$980
-0.3	$0	$0	$523	$507	$1,030
0	$0	$0	$523	$522	$1,045
0.1	$343	$665	$523	$522	$2,053
0.3	$545	$676	$523	$522	$2,266
0.6	$663	$826	$523	$522	$2,534
0.9	$748	$1,051	$523	$522	$2,845
1.2	$766	$1,051	$523	$522	$2,862
1.5	$767	$1,051	$523	$522	$2,863
1.8	$767	$1,051	$523	$522	$2,863
2.1	$767	$1,051	$523	$522	$2,863
2.4	$767	$1,051	$523	$522	$2,863
2.7	$767	$1,051	$523	$522	$2,863

1 - Distance between floors is variable in model; 2.7 metres is illustrated.

2 - Not all structures have basements, and it is a separate calculation in the model.

Appendix C: Flood Damage Values from Alberta's *Provincial Flood Damage Assessment Study* (2014)

Class B - Residential One-Storey					
Depth relative to main floor[1]	Main Floor Contents	Main Floor Structure	Basement Contents[2]	Basement Structure[2]	Total
-2.7	$0	$0	$0	$0	$0
-2.6	$0	$0	$226	$232	$458
-2.4	$0	$0	$339	$282	$621
-2.1	$0	$0	$375	$312	$687
-1.8	$0	$0	$401	$312	$713
-1.5	$0	$0	$410	$322	$732
-1.2	$0	$0	$411	$334	$745
-0.9	$0	$0	$412	$334	$746
-0.6	$0	$0	$426	$362	$788
-0.3	$0	$0	$504	$363	$867
0	$0	$0	$504	$374	$877
0.1	$221	$400	$504	$374	$1,498
0.3	$384	$407	$504	$374	$1,668
0.6	$431	$457	$504	$374	$1,765
0.9	$492	$578	$504	$374	$1,947
1.2	$494	$578	$504	$374	$1,949
1.5	$494	$578	$504	$374	$1,949
1.8	$495	$578	$504	$374	$1,950
2.1	$495	$578	$504	$374	$1,950
2.4	$495	$578	$504	$374	$1,950
2.7	$495	$578	$504	$374	$1,950

1 - Distance between floors is variable in model; 2.7 metres is illustrated.

2 - Not all structures have basements, and it is a separate calculation in the model.

Appendix C: Flood Damage Values from Alberta's *Provincial Flood Damage Assessment Study* (2014)

Class B - Residential Split Level					
Depth relative to main floor[1]	Main Floor Contents	Main Floor Structure	Basement Contents[2]	Basement Structure[2]	Total
-2.7	$0	$0	$0	$0	$0
-2.6	$0	$0	$0	$0	$0
-2.4	$0	$0	$0	$0	$0
-2.1	$0	$0	$0	$0	$0
-1.8	$0	$0	$0	$0	$0
-1.5	$0	$0	$0	$0	$0
-1.4	$0	$0	$0	$0	$0
-1.2	$0	$0	$113	$116	$229
-0.9	$0	$0	$169	$141	$310
-0.6	$0	$0	$188	$156	$344
-0.3	$0	$0	$200	$156	$356
0.1	$108	$210	$219	$161	$698
0.3	$194	$217	$296	$185	$892
0.6	$217	$242	$296	$185	$940
0.9	$252	$302	$297	$190	$1,040
1.2	$253	$302	$297	$191	$1,043
1.3	$360	$502	$297	$191	$1,350
1.5	$441	$502	$297	$191	$1,431
1.8	$463	$527	$297	$191	$1,478
2.1	$494	$588	$297	$191	$1,569
2.4	$495	$588	$297	$191	$1,570

1 - Distance between floors is variable in model; 2.7 metres is illustrated.

2 - Not all structures have basements, and it is a separate calculation in the model.

Appendix C: Flood Damage Values from Alberta's *Provincial Flood Damage Assessment Study* (2014)

Class B - Residential Two-Storey					
Depth relative to main floor[1]	Main Floor Contents	Main Floor Structure	Basement Contents[2]	Basement Structure[2]	Total
-2.7	$0	$0	$0	$0	$0
-2.6	$0	$0	$163	$242	$405
-2.4	$0	$0	$255	$331	$586
-2.1	$0	$0	$294	$385	$678
-1.8	$0	$0	$324	$385	$709
-1.5	$0	$0	$332	$402	$735
-1.2	$0	$0	$336	$420	$756
-0.9	$0	$0	$336	$420	$756
-0.6	$0	$0	$364	$470	$833
-0.3	$0	$0	$427	$473	$900
0	$0	$0	$427	$490	$917
0.1	$235	$524	$427	$490	$1,676
0.3	$342	$536	$427	$490	$1,795
0.6	$422	$625	$427	$490	$1,964
0.9	$481	$792	$427	$490	$2,190
1.2	$507	$792	$427	$490	$2,216
1.5	$508	$792	$427	$490	$2,217
1.8	$511	$792	$427	$490	$2,220
2.1	$511	$792	$427	$490	$2,220
2.4	$512	$792	$427	$490	$2,221
2.7	$512	$792	$427	$490	$2,221

1 - Distance between floors is variable in model; 2.7 metres is illustrated.

2 - Not all structures have basements, and it is a separate calculation in the model.

Appendix C: Flood Damage Values from Alberta's *Provincial Flood Damage Assessment Study* (2014)

Class C - Residential One-Storey					
Depth relative to main floor[1]	Main Floor Contents	Main Floor Structure	Basement Contents[2]	Basement Structure[2]	Total
-2.7	$0	$0	$0	$0	$0
-2.6	$0	$0	$294	$237	$530
-2.4	$0	$0	$350	$309	$659
-2.1	$0	$0	$385	$356	$741
-1.8	$0	$0	$418	$356	$774
-1.5	$0	$0	$422	$374	$796
-1.2	$0	$0	$422	$383	$806
-0.9	$0	$0	$423	$383	$806
-0.6	$0	$0	$439	$424	$863
-0.3	$0	$0	$511	$427	$938
0	$0	$0	$511	$439	$950
0.1	$240	$467	$511	$439	$1,657
0.3	$360	$479	$511	$439	$1,789
0.6	$420	$557	$511	$439	$1,927
0.9	$468	$672	$511	$439	$2,090
1.2	$479	$672	$511	$439	$2,100
1.5	$479	$672	$511	$439	$2,101
1.8	$479	$672	$511	$439	$2,101
2.1	$479	$672	$511	$439	$2,101
2.4	$479	$672	$511	$439	$2,101
2.7	$479	$672	$511	$439	$2,101

1 - Distance between floors is variable in model; 2.7 metres is illustrated.

2 - Not all structures have basements, and it is a separate calculation in the model.

Appendix C: Flood Damage Values from Alberta's *Provincial Flood Damage Assessment Study* (2014)

Class C - Residential Split Level					
Depth relative to main floor[1]	Main Floor Contents	Main Floor Structure	Basement Contents[2]	Basement Structure[2]	Total
-2.7	$0	$0	$0	$0	$0
-2.6	$0	$0	$0	$0	$0
-2.4	$0	$0	$0	$0	$0
-2.1	$0	$0	$0	$0	$0
-1.8	$0	$0	$0	$0	$0
-1.5	$0	$0	$0	$0	$0
-1.4	$0	$0	$0	$0	$0
-1.2	$0	$0	$147	$118	$265
-0.9	$0	$0	$175	$154	$329
-0.6	$0	$0	$192	$178	$371
-0.3	$0	$0	$209	$178	$387
0.1	$117	$245	$225	$187	$774
0.3	$183	$257	$302	$218	$960
0.6	$212	$296	$302	$218	$1,028
0.9	$240	$354	$302	$225	$1,121
1.2	$245	$354	$302	$227	$1,128
1.3	$363	$587	$302	$227	$1,478
1.5	$423	$587	$302	$227	$1,539
1.8	$451	$626	$302	$227	$1,606
2.1	$475	$684	$302	$227	$1,687
2.4	$480	$684	$302	$227	$1,692

1 - Distance between floors is variable in model; 2.7 metres is illustrated.
2 - Not all structures have basements, and it is a separate calculation in the model.

Appendix C: Flood Damage Values from Alberta's *Provincial Flood Damage Assessment Study* (2014)

Class C - Residential Two-Storey					
Depth relative to main floor[1]	Main Floor Contents	Main Floor Structure	Basement Contents[2]	Basement Structure[2]	Total
-2.7	$0	$0	$0	$0	$0
-2.6	$0	$0	$191	$207	$398
-2.4	$0	$0	$232	$322	$554
-2.1	$0	$0	$257	$399	$656
-1.8	$0	$0	$264	$399	$663
-1.5	$0	$0	$264	$428	$692
-1.2	$0	$0	$264	$442	$706
-0.9	$0	$0	$264	$442	$706
-0.6	$0	$0	$287	$508	$794
-0.3	$0	$0	$346	$512	$858
0	$0	$0	$346	$532	$878
0.1	$204	$599	$346	$532	$1,681
0.3	$271	$619	$346	$532	$1,767
0.6	$301	$744	$346	$532	$1,923
0.9	$376	$897	$346	$532	$2,152
1.2	$383	$897	$346	$532	$2,158
1.5	$384	$897	$346	$532	$2,159
1.8	$386	$897	$346	$532	$2,161
2.1	$386	$897	$346	$532	$2,161
2.4	$386	$897	$346	$532	$2,161
2.7	$386	$897	$346	$532	$2,161

1 - Distance between floors is variable in model; 2.7 metres is illustrated.
2 - Not all structures have basements, and it is a separate calculation in the model.

Appendix C: Flood Damage Values from Alberta's *Provincial Flood Damage Assessment Study* (2014)

One Storey Mobile Home (No Basement)					
Depth relative to main floor	Main Floor Contents	Main Floor Structure	Basement Contents	Basement Structure	Total
-2.7	$0	$0	$0	$0	$0
-2.6	$0	$0	$0	$0	$0
-2.4	$0	$0	$0	$0	$0
-2.1	$0	$0	$0	$0	$0
-1.8	$0	$0	$0	$0	$0
-1.5	$0	$0	$0	$0	$0
-1.2	$0	$0	$0	$0	$0
-0.9	$0	$0	$0	$0	$0
-0.6	$0	$0	$0	$0	$0
-0.3	$0	$0	$0	$0	$0
0	$0	$0	$0	$0	$0
0.1	$243	$362	$0	$0	$605
0.3	$379	$405	$0	$0	$785
0.6	$426	$405	$0	$0	$831
0.9	$481	$470	$0	$0	$951
1.2	$483	$470	$0	$0	$953
1.5	$483	$470	$0	$0	$953
1.8	$483	$470	$0	$0	$953
2.1	$483	$470	$0	$0	$953
2.4	$483	$470	$0	$0	$953
2.7	$483	$470	$0	$0	$953

Appendix C: Flood Damage Values from Alberta's *Provincial Flood Damage Assessment Study* (2014)

Apartment Building with Four Floors or Less			
Depth relative to main floor	Main Floor Contents	Main Floor Structure	Total
0	$0	$0	$0
0.1	$260	$822	$1,082
0.3	$394	$914	$1,307
0.6	$494	$1,105	$1,599
0.9	$565	$1,203	$1,768
1.2	$571	$1,203	$1,774
1.5	$571	$1,203	$1,774
1.8	$571	$1,203	$1,774
2.1	$571	$1,203	$1,774
2.4	$571	$1,203	$1,774
2.7	$571	$1,203	$1,774

Apartment Building with Five Floors or More			
Depth relative to main floor	Main Floor Contents	Main Floor Structure	Total
0	$0	$0	$0
0.1	$221	$449	$670
0.3	$384	$449	$833
0.6	$435	$680	$1,115
0.9	$514	$792	$1,306
1.2	$527	$937	$1,464
1.5	$528	$937	$1,466
1.8	$528	$937	$1,466
2.1	$528	$937	$1,466
2.4	$538	$937	$1,475
2.7	$538	$937	$1,475

For underground parking, damages are assumed at $215/m^2.

Appendix C: Flood Damage Values from Alberta's *Provincial Flood Damage Assessment Study* (2014)

Non-Residential Structure - Structural Damages $\$/m^2$

Relative Depth (m)	Office/ Retail	Industrial/ Warehouse	Hotel/ Motel	High Rise	Institution
0	$0	$0	$0	$0	$0
0.1	$105	$16	$113	$79	$68
0.3	$127	$21	$212	$79	$107
0.6	$132	$23	$230	$105	$108
0.9	$135	$23	$242	$116	$109
1.2	$138	$24	$254	$134	$110
1.5	$155	$30	$284	$134	$115
1.8	$164	$31	$320	$134	$117
2.7	$185	$38	$391	$134	$130
3	$185	$42	$391	$134	$130
5	$185	$42	$391	$134	$130
6	$185	$42	$391	$134	$130

For underground parking, damages are assumed at $\$215/m^2$.

Appendix C: Flood Damage Values from Alberta's *Provincial Flood Damage Assessment Study* (2014)

Non-Residential Structure - Content Damages

Relative Depth (m)	General Office	Medical	Shoes	Clothing	Stereos/TV	Paper Products	Hardware/ Carpet	Retail	Misc Retail	Furniture / Appliances	Groceries
0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
0.15	$121	$150	$200	$187	$352	$96	$142	$209	$182	$138	$148
0.3	$127	$450	$600	$385	$504	$183	$265	$408	$349	$198	$270
0.6	$219	$900	$729	$572	$689	$366	$427	$636	$512	$306	$410
0.9	$380	$1,350	$984	$1,314	$852	$557	$880	$844	$782	$345	$531
1.2	$380	$1,380	$1,100	$1,425	$1,139	$740	$943	$1,072	$919	$376	$616
1.5	$380	$1,425	$1,121	$1,705	$1,352	$810	$1,005	$1,252	$1,026	$408	$616
1.8	$380	$1,500	$1,159	$1,862	$1,467	$906	$1,068	$1,366	$1,103	$439	$616
2.1	$380	$1,500	$1,189	$1,862	$1,467	$906	$1,130	$1,366	$1,115	$439	$616
2.4	$380	$1,500	$1,219	$1,862	$1,467	$906	$1,257	$1,366	$1,134	$439	$616
2.7	$381	$1,500	$1,219	$1,862	$1,467	$906	$1,257	$1,366	$1,134	$439	$616
3	$381	$1,500	$1,219	$1,862	$1,467	$906	$1,257	$1,366	$1,134	$439	$616

Appendix C: Flood Damage Values from Alberta's *Provincial Flood Damage Assessment Study* (2014)

Non-Residential Structure - Content Damages (Continued)

Relative Depth (m)		Drugs	Auto	Hotels	Restaurant	Personal Services	Financial	Warehouse/ industrial	Theatres	Institution	Hospital
0		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
0.15		$50	$46	$20	$72	$37	$121	$173	$0	$59	$72
0.3		$350	$254	$39	$257	$74	$127	$433	$0	$119	$92
0.6		$505	$462	$52	$434	$167	$219	$635	$68	$312	$182
0.9		$610	$878	$65	$442	$260	$380	$1,011	$68	$446	$311
1.2		$715	$982	$104	$452	$278	$380	$1,155	$68	$475	$341
1.5		$820	$1,005	$131	$452	$408	$380	$1,184	$68	$475	$363
1.8		$897	$1,005	$144	$452	$687	$380	$1,242	$68	$475	$363
2.1		$897	$1,005	$144	$452	$696	$380	$1,285	$68	$475	$363
2.4		$897	$1,005	$144	$452	$705	$380	$1,328	$68	$475	$363
2.7		$897	$1,005	$144	$452	$705	$380	$1,357	$344	$475	$363
3		$897	$1,005	$144	$452	$705	$380	$1,386	$621	$475	$363

Appendix D: Greenland Consulting Engineers' Estimation Method for Municipal Infrastructure Upgrades Avoided

The Intact Centre engaged Greenland Consulting Engineers to develop a five-step approach to assess the value of municipal stormwater management infrastructure upgrades avoided as a result of preserving wetlands. This methodology, documented below, is expected to be used in instances where the loss of wetlands results in a significant reduction in the level of service below municipal stormwater management design requirements.

Step 1: Drainage Watercourse Hydrology
Step 1 involves obtaining the existing hydrology model for the relevant watercourses (e.g. PCSWMM, Visual OTTHYMO, GAWSER or any model accepted by the province/conservation authority for floodplain delineation). The hydrology model should be updated with the most recent information including, but not limited to, Digital Elevation Model (DEM), watershed attributes and land use classifications. The hydrology model used to assess municipal damages should be the same hydrology model used to assess private sector damages.

Step 2: Hydraulic Model
Using the watercourse flow data, watercourse crossing data, updated DEM, and channel/floodplain conditions from Step 1, a watercourse hydraulic model should be executed for the existing conditions for the various return period storm events (e.g., HEC-RAS or any model accepted by the province/conservation authority for floodplain delineation). In Ontario, the standard design storm return periods are 2-year, 5-year, 25-year, 50-year, 100-year and Regulatory Storm (e.g., Timmins, or Hurricane Hazel).

Step 3: Determine Design Return Period for Watercourse Crossing
Using the hydraulic model in Step 2, starting at the furthest downstream end of the watercourse and working upstream, determine whether the first downstream municipally owned infrastructure asset (e.g., culvert, bridge, swale) meets the minimum standards for the design storm. Since some municipalities have storm design standards and some do not, relevant municipal standards (if available), or Ontario's Ministry of Natural Resources (MNR) flood hazard criteria[xxxiv] (in absence of such standards) would govern this analysis. For example, if the first watercourse crossing starting at the downstream end was a culvert under a rural arterial road spanning greater than 6.0 metres, is that culvert able to convey the 50-year storm event (as per Table B-3 of the MNR *Technical Guide, River & Stream Systems: Flooding Hazard Limit*)? If yes, then the culvert is sized appropriately, a desired level of protection is achieved and the municipality accepts the damages for repair under larger magnitude storm events. If no, then a determination of what steps need to be taken to enable the culvert to convey the 50-year storm is carried out (Step 4).

Step 4: What Improvements Are Required to Ensure an Appropriate Level of Protection?
Based on the appropriate design return period information obtained in Step 3, Step 4 addresses improvements to infrastructure required to meet the applicable standards for the design storm return period. If, in the previous example, a culvert under a rural arterial road could not convey the 50-year

Appendix D: Greenland Consulting Engineers Estimation Method for Municipal Infrastructure Upgrades Avoided

storm, then the following questions need to be asked. First, does the culvert meet the minimum size, as outlined in the relevant municipal standards? If the culvert is less than the minimum size, it needs to be replaced with at least the minimum size per municipal standard. If the culvert is greater than the minimum size and cannot convey the design storm, the culvert will need to be increased in size so that it can convey the storm. Engineering calculations (or modelling) are required to determine the appropriate culvert size. The costs to upgrade the culvert to the appropriate size represent the cost of damage avoidance. Hydrology and associated peak flows should be determined for all relevant return events.

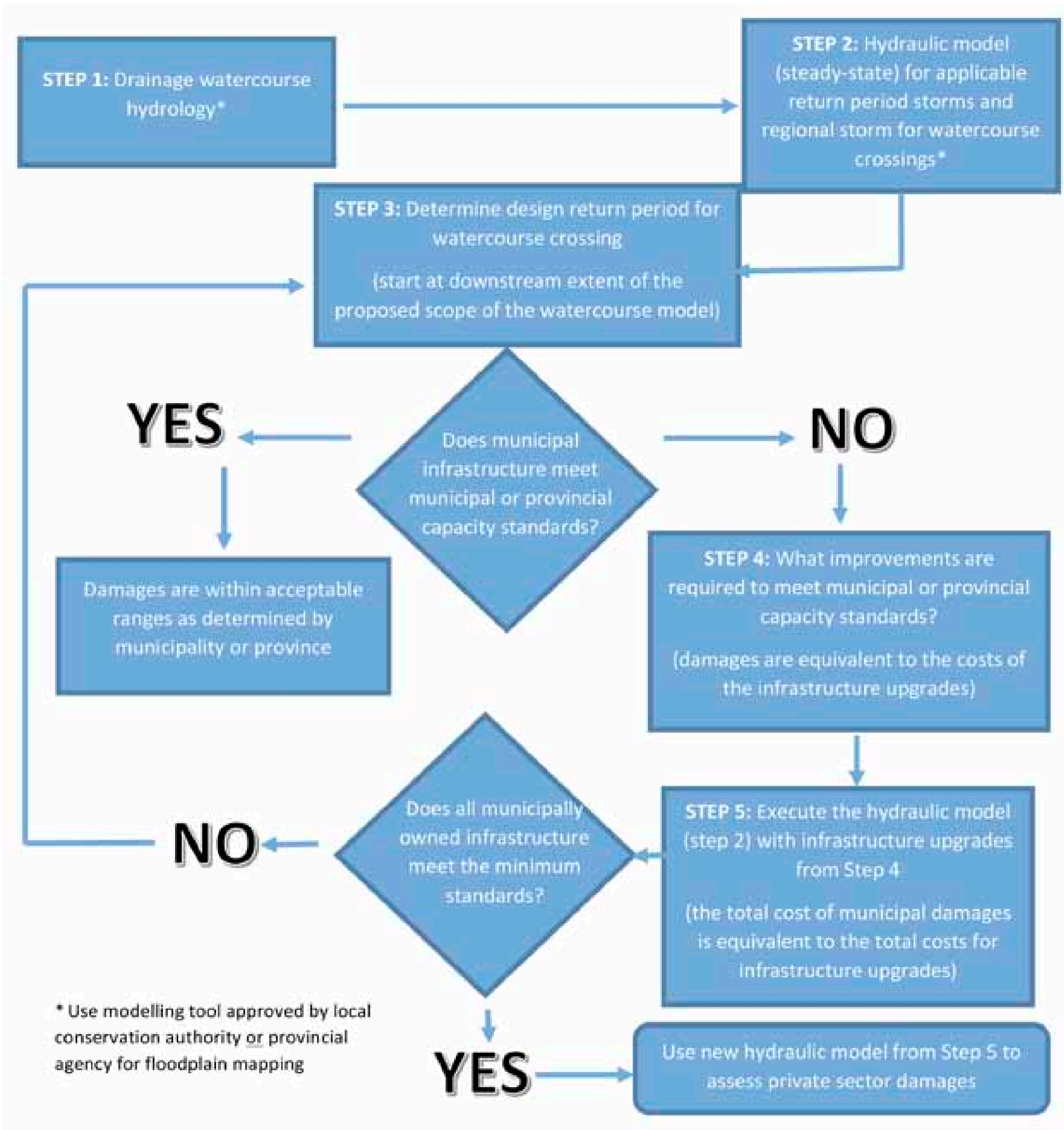
Step 5: Update Hydraulic Model with New Infrastructure

Using the newly upgraded municipal infrastructure from Step 4, the newly-sized culvert should be used to re-run the model from Step 2 to determine the extent of flooding, if any, following the upgrade. The following questions would be asked: while still moving upstream, does all the municipally owned infrastructure meet the standards? If yes, then the process is complete and the new hydraulic model can be used to assess private sector damages. If not, then Steps 3 to 5 need to be repeated until all municipally owned infrastructure meets the minimum design storm criteria, as set by the municipality or by the MNR flood hazard criteria. This may take several iterations with multiple design storms, depending on the watercourse crossing. The total municipal damages due to flooding for the subject watercourse would be the sum of all the required costs to improve the crossings to the municipal and/or provincial standards with respect to the storm flow conveyance capacity.

As detailed in key findings (Chapter 4), flooding for both pilot sites did not exceed the levels of service guaranteed by the municipality. Accordingly, for the two pilot sites, the analysis of municipal infrastructure upgrades was not carried out, as existing municipal stormwater management infrastructure had sufficient capacity to handle stormwater for their respective levels of service.

Please refer to the flow chart diagram below for a summary of these steps.

Appendix D: Greenland Consulting Engineers Estimation Method for Municipal Infrastructure Upgrades Avoided



Appendix E: Consumer Price Index Adjustments for Ontario's *Flood Damage Estimation Guide* (2007)

To calculate required Consumer Price Index (CPI) adjustments for Ontario's *Flood Damage Estimation Guide* (2007), relevant index groups were selected. For the *Flood Damage Estimation Guide* Groups 1 through 7, "Household Operations, Furnishings and Equipment," Ontario values of CPI Table 326-0021 were used. The calculation entailed taking the price index from the year of interest (2015) and subtracting the price index of the base year from it (2005). The result is then divided by the base year. Please refer to the tables below for final 2016 values.

GROUP 1: ONE STOREY WITHOUT BASEMENT

2005 Flood Damage Values – $ per structure

Depth (m)	LOW	MEAN	HIGH
-2.44	-	-	-
-2.13	-	-	-
-1.83	-	-	-
-1.52	-	-	-
-1.22	-	-	-
-0.91	-	-	-
-0.61	-	77	85
-0.3	-	233	466
0	1,787	3,115	10,257
0.3	7,959	15,200	33,700
0.61	8,779	16,657	36,253
0.91	9,498	19,303	40,585
1.22	10,750	22,199	49,774
1.52	11,835	24,257	58,540
1.83	12,441	25,409	60,726
2.13	12,682	25,971	62,070
2.44	12,924	26,508	63,328

2016 Flood Damage Values – $ per structure

Depth (m)	LOW	MEAN	HIGH
-2.44	-	-	-
-2.13	-	-	-
-1.83	-	-	-
-1.52	-	-	-
-1.22	-	-	-
-0.91	-	-	-
-0.61	-	90	100
-0.3	-	274	548
0	2,100	3,661	12,054
0.3	9,353	17,863	39,604
0.61	10,317	19,575	42,604
0.91	11,162	22,685	47,695
1.22	12,633	26,088	58,494
1.52	13,908	28,506	68,795
1.83	14,620	29,860	71,364
2.13	14,904	30,521	72,944
2.44	15,188	31,152	74,422

Appendix E: Consumer Price Index Adjustments for *Ontario's Flood Damage Estimation Guide* (2007)

GROUP 2: ONE STOREY WITH BASEMENT

2005 Flood Damage Values – $ per structure

Depth (m)	LOW	MEAN	HIGH
-2.44	174	916	1,564
-2.13	565	4,475	9,127
-1.83	696	4,907	9,838
-1.52	763	5,605	11,065
-1.22	783	6,042	13,758
-0.91	955	6,538	15,356
-0.61	1,040	6,810	15,891
-0.3	1,169	7,047	16,282
0	3,060	10,517	22,131
0.3	12,197	24,364	42,738
0.61	13,554	25,914	45,177
0.91	15,111	28,049	48,578
1.22	17,004	30,910	53,400
1.52	18,652	33,257	57,436
1.83	19,669	34,461	59,682
2.13	20,224	35,225	60,893
2.44	20,772	35,960	62,041

2016 Flood Damage Values – $ per structure

Depth (m)	LOW	MEAN	HIGH
-2.44	204	1,076	1,838
-2.13	664	5,259	10,726
-1.83	818	5,767	11,561
-1.52	897	6,587	13,003
-1.22	920	7,100	16,168
-0.91	1,122	7,683	18,046
-0.61	1,222	8,003	18,675
-0.3	1,374	8,282	19,134
0	3,596	12,359	26,008
0.3	14,334	28,632	50,225
0.61	15,928	30,454	53,091
0.91	17,758	32,963	57,088
1.22	19,983	36,325	62,755
1.52	21,920	39,083	67,498
1.83	23,115	40,498	70,137
2.13	23,767	41,396	71,560
2.44	24,411	42,260	72,909

Appendix E: Consumer Price Index Adjustments for *Ontario's Flood Damage Estimation Guide* (2007)

GROUP 3: TWO STOREYS WITHOUT BASEMENT

2005 Flood Damage Values – $ per structure

Depth (m)	LOW	MEAN	HIGH
-2.44	-	-	-
-2.13	-	-	-
-1.83	-	-	-
-1.52	-	-	-
-1.22	-	-	-
-0.91	-	-	-
-0.61	27	27	31
-0.3	145	155	357
0	1,991	2,443	7,183
0.3	7,293	12,732	24,699
0.61	8,041	14,001	26,515
0.91	9,047	15,938	29,179
1.22	10,357	18,393	33,887
1.52	11,472	20,139	37,555
1.83	11,998	21,092	38,564
2.13	12,335	21,591	39,000
2.44	12,630	22,069	39,364

2016 Flood Damage Values – $ per structure

Depth (m)	LOW	MEAN	HIGH
-2.44	0	0	0
-2.13	0	0	0
-1.83	0	0	0
-1.52	0	0	0
-1.22	0	0	0
-0.91	0	0	0
-0.61	32	32	36
-0.3	170	182	420
0	2,340	2,871	8,441
0.3	8,571	14,962	29,026
0.61	9,450	16,454	31,160
0.91	10,632	18,730	34,291
1.22	12,171	21,615	39,823
1.52	13,482	23,667	44,134
1.83	14,100	24,787	45,320
2.13	14,496	25,373	45,832
2.44	14,843	25,935	46,260

Appendix E: Consumer Price Index Adjustments for *Ontario's Flood Damage Estimation Guide* (2007)

GROUP 4: TWO STOREYS WITH BASEMENT

2005 Flood Damage Curves – $ per structure

Depth (m)	LOW	MEAN	HIGH
-2.44	192	497	1,542
-2.13	1,062	2,715	5,416
-1.83	1,278	3,016	5,843
-1.52	1,408	3,510	6,471
-1.22	1,511	3,802	7,111
-0.91	1,826	4,254	7,988
-0.61	1,928	4,487	8,209
-0.3	2,060	4,723	8,813
0	4,031	7,811	16,841
0.3	11,389	18,539	38,953
0.61	12,276	20,124	42,154
0.91	13,751	22,277	45,892
1.22	15,278	25,057	50,471
1.52	16,347	27,327	54,998
1.83	16,958	28,417	56,710
2.13	17,220	29,140	58,002
2.44	17,455	29,794	59,184

2016 Flood Damage Curves – $ per structure

Depth (m)	LOW	MEAN	HIGH
-2.44	226	584	1,812
-2.13	1,248	3,191	6,365
-1.83	1,502	3,544	6,867
-1.52	1,655	4,125	7,605
-1.22	1,776	4,468	8,357
-0.91	2,146	4,999	9,387
-0.61	2,266	5,273	9,647
-0.3	2,421	5,550	10,357
0	4,737	9,179	19,791
0.3	13,384	21,787	45,777
0.61	14,427	23,649	49,539
0.91	16,160	26,180	53,931
1.22	17,954	29,447	59,313
1.52	19,211	32,114	64,633
1.83	19,929	33,395	66,645
2.13	20,237	34,245	68,163
2.44	20,513	35,013	69,552

Appendix E: Consumer Price Index Adjustments for *Ontario's Flood Damage Estimation Guide* (2007)

GROUP 5: SPLIT LEVEL

2005 Flood Damage Curves – $ per structure

Depth (m)	LOW	MEAN	HIGH
-2.44	630	681	2,468
-2.13	2,832	3,140	9,923
-1.83	3,054	3,489	10,236
-1.52	3,593	4,107	10,939
-1.22	4,572	5,225	13,021
-0.91	7,651	10,206	17,455
-0.61	8,313	11,135	18,177
-0.3	8,928	12,119	18,960
0	11,474	14,541	23,142
0.3	17,714	22,510	33,431
0.61	18,686	23,979	35,385
0.91	20,289	25,314	37,565
1.22	22,573	28,595	41,509
1.52	25,491	35,143	50,699
1.83	26,260	36,175	51,659
2.13	26,869	37,096	52,547
2.44	27,584	38,282	53,359

2016 Flood Damage Curves – $ per structure

Depth (m)	LOW	MEAN	HIGH
-2.44	740	800	2,900
-2.13	3,328	3,690	11,661
-1.83	3,589	4,100	12,029
-1.52	4,222	4,826	12,855
-1.22	5,373	6,140	15,302
-0.91	8,991	11,994	20,513
-0.61	9,769	13,086	21,361
-0.3	10,492	14,242	22,281
0	13,484	17,088	27,196
0.3	20,817	26,453	39,288
0.61	21,959	28,180	41,584
0.91	23,843	29,749	44,146
1.22	26,527	33,604	48,781
1.52	29,957	41,299	59,581
1.83	30,860	42,512	60,709
2.13	31,576	43,595	61,752
2.44	32,416	44,988	62,707

Appendix E: Consumer Price Index Adjustments for *Ontario's Flood Damage Estimation Guide* (2007)

GROUP 6: TOWNHOUSES

2005 Flood Damage Curves – $ per structure

Depth (m)	LOW	MEAN	HIGH
-2.44	-	517	943
-2.13	-	3,038	5,542
-1.83	-	3,283	5,988
-1.52	-	4,145	7,559
-1.22	-	4,471	7,659
-0.91	-	5,071	8,546
-0.61	-	5,186	8,628
-0.3	80	5,263	8,711
0	1,306	6,808	10,282
0.3	5,329	14,080	18,389
0.61	6,071	14,832	19,189
0.91	7,036	16,572	21,593
1.22	8,793	18,085	22,970
1.52	9,979	19,077	25,155
1.83	10,424	19,557	25,705
2.13	10,737	19,782	25,950
2.44	11,031	19,995	26,163

2016 Flood Damage Curves – $ per structure

Depth (m)	LOW	MEAN	HIGH
-2.44	-	608	1,108
-2.13	-	3,570	6,513
-1.83	-	3,858	7,037
-1.52	-	4,871	8,883
-1.22	-	5,254	9,001
-0.91	-	5,959	10,043
-0.61	-	6,094	10,139
-0.3	94	6,185	10,237
0	1,535	8,001	12,083
0.3	6,263	16,547	21,610
0.61	7,135	17,430	22,551
0.91	8,269	19,475	25,376
1.22	10,333	21,253	26,994
1.52	11,727	22,419	29,562
1.83	12,250	22,983	30,208
2.13	12,618	23,247	30,496
2.44	12,963	23,498	30,746

Appendix E: Consumer Price Index Adjustments for *Ontario's Flood Damage Estimation Guide* (2007)

GROUP 7: MOBILE HOMES

2005 Flood Damage Curves – $ per structure

Depth (m)	LOW	MEAN	HIGH
0	-	2,843	-
0.3	-	13,431	-
0.61	-	14,325	-
0.91	-	16,401	-
1.22	-	18,231	-
1.52	-	20,058	-
1.83	-	20,735	-
2.13	-	20,808	-
2.44	-	20,995	-

2016 Flood Damage Curves – $ per structure

Depth (m)	LOW	MEAN	HIGH
0	-	3,341	-
0.3	-	15,784	-
0.61	-	16,834	-
0.91	-	19,274	-
1.22	-	21,425	-
1.52	-	23,572	-
1.83	-	24,367	-
2.13	-	24,453	-
2.44	-	24,673	-

Appendix E: Consumer Price Index Adjustments for *Ontario's Flood Damage Estimation Guide* (2007)

Commercial, Industrial and Institutional for Fort McMurray, Alberta

2005 Flood Damages Values – $ per structure

	Depth (m)						
Category	**0.15**	**0.3**	**0.61**	**0.91**	**1.22**	**1.52**	**1.83**
A	69.62	119.09	188.71	258.33	287.64	337.11	379.25
B	0.00	234.51	491.01	729.18	815.29	925.22	1,049.81
C1	124.58	327.95	622.92	1,013.16	1,364.93	1,755.17	1,863.27
C2	278.48	593.61	850.11	1,921.90	2,119.77	2,473.37	2,748.18
C3	183.21	269.32	379.25	635.75	780.48	1,000.34	1,295.31
C4	106.26	214.36	414.06	635.75	798.81	905.07	1,011.33
C5	69.62	119.09	188.71	258.33	287.64	357.26	406.73
C6	199.70	403.07	622.92	824.46	1,024.16	1,205.54	1,333.79
D	89.77	139.24	208.86	294.97	326.12	375.59	426.88
E	69.62	119.09	208.86	333.45	456.20	600.94	729.18
F	69.62	159.39	263.83	448.87	626.59	829.95	936.21
G	69.62	251.00	414.06	729.18	798.81	850.11	888.58
H/I	31.15	64.12	95.27	124.58	135.58	166.72	199.70
J	69.62	119.09	229.02	333.45	551.47	696.21	785.98
K	49.47	100.77	150.23	240.01	287.64	357.26	445.21
L	89.77	175.88	263.83	408.56	456.20	509.33	547.80
M	0.00	0.00	133.74	164.89	175.88	205.20	236.34
N	89.77	234.51	320.62	353.60	0.00	0.00	0.00

Appendix E: Consumer Price Index Adjustments for *Ontario's Flood Damage Estimation Guide* (2007)

Code	Name	Associated CPI Group and Table for Adjustment to 2015 $
A	General Office	Office [327-0051]
B	Medical	Health and personal care [326-0020]
C1	Shoes	Footwear [326-0020]
C2	Clothing	Clothing [326-0020]
C3	Stereo/TV	Home entertainment equipment, parts and services [326-0020]
C4	Paper Products	Paper, plastic and aluminum foil supplies [326-0020]
C5	Hardware/Carpet	Hardware manufacturing [329-0077]
C6	Miscellaneous Retail	Clothing accessories, watches and jewelry [326-0020]
		Clothing material, notions and services [326-0020]
D	Furniture/Appliances	Household furnishings and equipment [326-0020]
E	Groceries	Food [326-0020]
F	Drugs	Medicinal and pharmaceutical products [326-0020]
G	Auto	Passenger vehicle parts, maintenance and repairs [326-0020]
H	Hotels	Traveler accommodation [326-0020]
I	Restaurants	Food purchased from restaurants [326-0020]
J	Personal Service	Personal care services [326-0020]
K	Financial	Financial services [326-0020]
L	Warehouse/Industrial	Total, industrial structures [327-0043]
M	Theatres	Other cultural and recreational services [326-0020]
N	Institutional/Other	Total, institutional structures [327-0043]

Appendix E: Consumer Price Index Adjustments for *Ontario's Flood Damage Estimation Guide* (2007)

2016 Flood Damage Values

	Depth (m)						
Category	**0.15**	**0.3**	**0.61**	**0.91**	**1.22**	**1.52**	**1.83**
A	52.16	89.23	141.39	193.55	215.51	252.57	284.15
B	-	270.81	567.01	842.04	941.48	1,068.43	1,212.30
C1	112.89	297.17	564.45	918.07	1,236.82	1,590.43	1,688.39
C2	241.86	515.56	738.33	1,669.20	1,841.05	2,148.16	2,386.84
C3	54.28	79.80	112.37	188.37	231.25	296.40	383.80
C4	124.70	251.55	485.90	746.06	937.41	1,062.11	1,186.81
C5	75.55	129.23	204.77	280.32	312.13	387.67	441.35
C6	245.71	495.94	766.44	1,014.42	1,260.13	1,483.30	1,641.10
D	105.50	163.63	245.45	346.64	383.25	441.39	501.66
E	87.47	139.95	262.42	418.96	573.19	755.05	916.18
F	87.47	160.34	265.40	451.54	630.32	834.89	941.78
G	69.48	250.49	413.22	727.71	797.20	848.39	886.78
H/I	36.56	75.25	111.81	146.21	159.12	195.67	234.38
J	88.40	151.21	290.79	423.39	700.21	883.99	997.97
K	62.37	127.05	189.42	302.61	362.67	450.45	561.34
L	117.49	230.20	345.31	534.74	597.09	666.63	716.98
M	-	-	174.18	214.75	229.06	267.24	307.80
N	115.52	301.79	412.60	455.04	-	-	-

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