Technical Report

Long Point Region Riverine Flood Hazard Mapping Update
Long Point Region Conservation Authority
Project # TPB198049

Prepared for:

Long Point Region Conservation Authority
4 Elm Street Tillsonburg, Ontario, N4G 0C4

3/31/2020

Technical Report

Long Point Region Riverine Flood Hazard Mapping Update
Project Location
Project # TPB198049

Prepared for:

Long Point Region Conservation Authority
4 Elm Street Tillsonburg, Ontario, N4G 0C4

Prepared by:

Wood Environment & Infrastructure Solutions
a Division of Wood Canada Limited
3450 Harvester Road, Suite 100
Burlington, ON L7N 3W5   Canada
T: 905-335-2353

3/31/2020

Table of Contents

List of Figures

List of Tables

List of Appendices

1.0 Introduction

1.1 Study Scope

Long Point Region Conservation Authority (LPRCA) is undertaking an update of its flood hazard mapping for portions of its watershed jurisdiction. The work is partially funded through the Federal Government of Canada's National Disaster Mitigation Program (NDMP). Two (2) separate studies are being undertaken. The current study, being completed by Wood Environment & Infrastructure Solutions (Wood), involves update of the riverine (watercourse-based) flood hazard mapping for selected, typically more vulnerable/flood susceptible watercourses.

Currently approved floodplain/flood hazard mapping for the LPRCA watershed is generally quite dated, originating between 1977 and 1987, some 35 to 45 years in age. Given the advancement in hydraulic modelling tools since that time, the current project provides an opportunity to modernize and update the hydraulic modelling and associated flood hazard mapping. Recently completed LiDAR topographic data (as collected for the Ministry of Natural Resources and Forestry) is available for the Lake Erie extent, which generally includes the Grand River watershed and areas west, which includes the entirety of the LPRCA jurisdiction. This data forms the basis of the current flood hazard mapping update, as described in subsequent sections.

Hydrologic modelling is not part of the current scope of work. Hydrologic data has been supplied by LPRCA based on the work completed as part of "LPRCA Hydrology Model Update Study" (Schroeter & Associates, April 18, 2019).

In addition to the primary effort related to the generation of updated flood hazard mapping, a flood damage and flood risk assessment are also included in the current study, in order to characterize and assess the most flood vulnerable areas. This includes identification of potential mitigation measures and projects, where feasible and effective.

The current technical report is intended to summarize the works completed for the current study, including field work and data collection, hydraulic modelling and floodplain mapping delineation, risk assessment and flood damage calculations, and other related works.

1.2 Study Area Overview

The LPRCA jurisdiction encompasses the Municipality of Bayham, the Town of Tillsonburg, most of Norfolk County and portions of Haldimand County, the County of Brant, and the Townships of Malahide, Norwich, and South-West Oxford. The area encompasses some 2,782 km^2 of area and is home to approximately 102,000 people. Primary watercourses/watersheds within LPRCA's jurisdiction are presented in Figure 1.1, and include:

- Big Otter Creek
- Big Creek
- Lynn River
- Nanticoke Creek
- Sandusk Creek

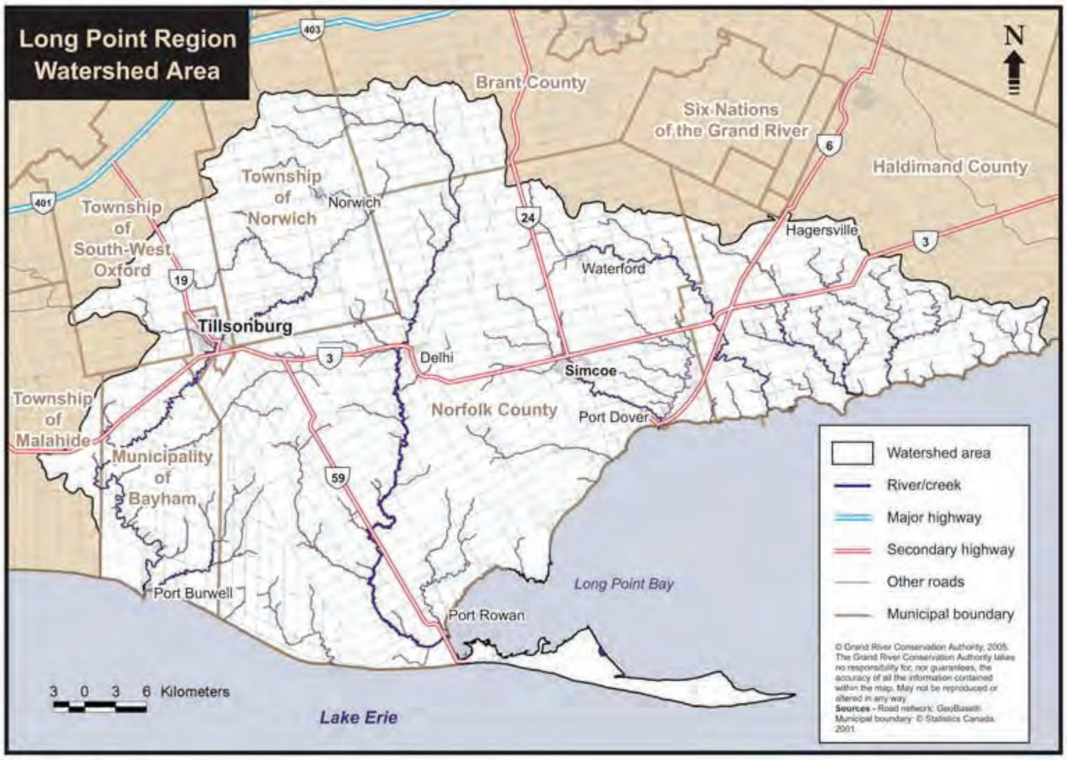

Figure 1.1. Long Point Region Jurisdiction

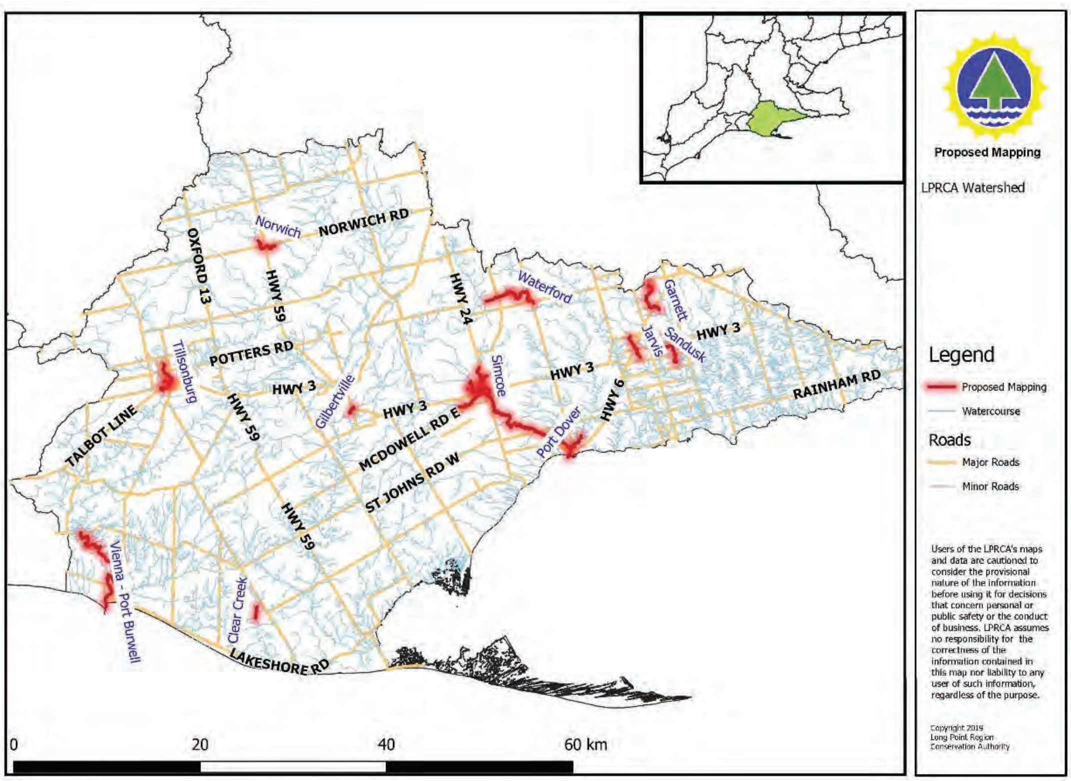

Figure 1.2. Study Area Limits

As noted in Section 1.1, the current study involves the update of flood hazard mapping for only a subset of the watercourses within the LPRCA's jurisdiction, generally those with an identified (by LPRCA) higher level of flood risk or flood susceptibility. Subject reaches are presented in Figure 1.2, and include:

- Big Otter Creek
    - Norwich
    - Tillsonburg
        - Stoney Creek
        - Big Otter Creek
    - From Calton to Port Burwell (including Vienna)
- Clear Creek (Cultus)
- Stoney Creek (Gilbertville)
- Lynn River (Simcoe to Port Dover)
    - Davis Creek
    - Patterson Creek
    - Kent Creek
    - Black Creek
    - Lynn River
- Nanticoke Creek
    - Waterford
    - Villa Nova
- Sandusk Creek
    - Garnett
    - Jarvis
    - Sandusk

The study area limits presented in Figure 1.2 include a total of approximately 89 km of watercourse where updated flood hazard mapping has been generated. As noted previously, a flood risk assessment and flood damage calculations have also been undertaken for the subject areas. The subject areas are generally located in urban areas of varying sizes, from smaller to larger towns. Flood damage calculations have considered the potential impact to different property classifications accordingly.

The subject watercourses reflect a range of different drainage system characteristics, with larger and deeper watercourses (such as Big Otter Creek and Lynn River), and shallower smaller systems (such as Sandusk Creek). Topography varies similarly, with larger watercourses generally having more defined valley systems in many cases, and other areas indicating flatter topography.

There are also several reservoirs and dams within the study limits which required further consideration. These include, but are not limited to:

- Norwich Dam (Big Otter Creek – Norwich)
- Crystal Lake and Quance Dam (Lynn River – Simcoe)
- Silver Lake and Misner Dam (Lynn River – Port Dover)
- Waterford Ponds (Nanticoke Creek - Waterford)

2.0 Background Review and Data Collection

2.1 Relevant Guidelines and Documents

The following key technical guidelines and documents have been applied for the current study:

- Conservation Authorities
  - Technical Guidelines for Flood Hazard Mapping (EWRG, March 2017)
  - LPRCA Consolidated Policies (October 2017)
- Ministry of Natural Resources and Forestry (MNRF)
  - Technical Guide – River & Stream Systems: Flood Hazard Limit (2002)
- Natural Resources Canada and Public Safety Canada
  - Canadian Floodplain Mapping Guidelines and Specifications (Version 1.0, December 2016)
  - Canadian Guidelines and Database of Flood Vulnerability Functions (March 2017)
  - National Disaster Mitigation Program Risk Assessment Information Template

2.2 Data Collection

The following information has been received and reviewed as part of the data collection process for this project; data have been sorted based on the source of the information.

Long Point Region Conservation Authority

- **Mapping and Base Data**
  - Existing floodplain mapping sheets
  - Aerial Photography (SWOOP, 2015)
  - Roads
  - Railways
  - Trails
  - Dams
  - Waterbodies
  - Watercourses
  - Wetlands
  - Parcels
  - Land Cover Mapping (4DM, 2018)
  - Flow Nodes (GAWSER Modelling Update)
  - Minor Watersheds (GAWSWER Modelling Update)

- **Modelling**
  - HEC-2 Hydraulic Models
    - Big Otter Creek – Port Burwell (1 file)
    - Black Creek (13 files)
    - Jarvis (17 files)
    - Lynn River (8 reaches A through H – total of 28 files)
    - Nanticoke Creek (13 files)
    - Sandusk Creek (24 files)
    - Vienna (2 files)

- **Reporting**
  - Fill Line and Flood Plain Mapping Study (M.M. Dillon Limited, October 1977)
  - Flood Line and Fill Line Mapping for Tillsonburg, Norwich and Vienna (James F. MacLaren Ltd, 1979)
  - Haldimand-Norfolk Floodline Mapping – Phase II (Paragon Engineering Limited, September 1985)
  - Inflow Design Flood Study – Misner Dam Assessment (CRA, February 2013)
  - Inflow Design Flood Study – Misner Dam Assessment (CRA, May 2016)
  - Waterford Dam General Assessment Report (AECOM, May 2017)
  - Land Cover Mapping Summary Report (4DM, December 2018)
  - LPRCA Hydrology Model Update Study (Technical Memorandum Schroeter & Associates, April 2019)
  - Preliminary Flood Flows for LPRCA Riverine Flood Mapping Project 2019 (Technical Memorandum, LPRCA, October 2019 and subsequent updates)

<u>Ministry of Natural Resources and Forestry (MNRF)</u>

- **Mapping and Base Data**
  - Lake Erie 1 km x 1 km LiDAR from Spring/Fall of 2017 (Airborne Imaging, January 2019 (Report)) – as prepared for the Ontario Ministry of Natural Resources and Forestry

<u>Norfolk County</u>

- **Mapping and Base Data**
  - Bridges
  - Building Footprints
  - Culverts
  - Municipal Drains
  - Parcels
  - Parks
  - Roads
  - Stormwater Management Facilities
  - Storm Sewers
  - Water and Sanitary Sewer Facilities
  - Official Plan Land Use
  - Zoning
- **Record Drawings**
  - Brook Pedestrian Bridge Repairs
  - Lynn Valley Trail Association Bridges
- **Documents and Other**
  - Official Plan
  - By-Law 2017-126 (A By-Law to Adopt the Emergency Management Program and Norfolk County Emergency Response Plan)

Haldimand County

- **Mapping and Base Data**
  - Building Footprints
  - Parcels
  - Roads
  - Municipal Drains
  - Municipal Infrastructure (Sewers and Watermains)

Elgin County

- **Mapping and Base Data**
  - Building Footprints
  - Municipal Drains
  - Fire Hydrants
  - Parcels
  - Parks
  - Roads
  - Storm Sewers
  - Stormwater Structures
  - Watermains
- **Record Drawings**
  - Edison Bridge
  - Vienna Bridge North
  - Edison Drive Bridge
  - Port Burwell Bridge

Oxford County

- **Mapping and Base Data**
  - Building Footprints
  - Facilities
  - LPRCA Buffer Area
  - Roads
  - Bridges
  - Fire Department Water Sources
  - Parks
  - Official Plan
  - Zoning
  - Points of Interest
  - Property Fabric
  - Storm Sewers, Manholes, Catchbasins, Outlets, Culverts
  - Sanitary Sewers and Manholes
  - Wastewater Treatment Plan Features
- **Record Drawings**
  - Bridge 325685 (Oxford Road 18 – Main Street, Norwich)
  - Bridge 773216 (County Road 58 – Stover Road, Norwich)
  - Norwich Dam Drawings
  - Tillsonburg Enclosure Drawings (Relocation of Bridge Street)

2.3 Previous Hydraulic Modelling and Floodplain Mapping

As noted in Section 2.2, the previous hydraulic modelling and floodplain mapping is between 35 to 45 years old. Mapping is sourced from three (3) separate studies, namely:

- Fill Line and Flood Plain Mapping Study (M.M. Dillon Limited, October 1977)
- Flood Line and Fill Line Mapping for Tillsonburg, Norwich and Vienna (James F. MacLaren Ltd, 1979)
- Haldimand-Norfolk Floodline Mapping – Phase II (Paragon Engineering Limited, September 1985)

The preceding studies all applied the HEC-2 hydraulic methodology, a pre-cursor to the current HEC-RAS software available from US Army Corps of Engineers (USACE) Hydraulic Engineering Centre (HEC). A number of these HEC-2 modelling data input files have been provided by LPRCA for the current study.

However, based on a review of the modelling files, and associated floodplain mapping, these data are considered to be of limited value to the current study. Given the vintage of the modelling data, difficulty in interpreting and extracting information (including referencing to known locations) and associated resolution of the then available topography data (including unknown map datums and projection systems), the modelling is considered applicable only as a validation/verification of the updated mapping prepared for the current study, in order to identify areas of potential changes in flooding extent.

2.4 Hydraulic Structure Review and Inventory

Hydraulic structures are a critical factor with respect to any hydraulic modelling study. The dimensions and capacities of hydraulic structures (bridges, culverts, weirs, dams, etcetera) has a direct impact on upstream flood levels and associated floodplain extents. As such, accurate representation of these features within the modelling is important.

In order to support the current study, Wood undertook a hydraulic structure inventory for the subject study areas. A long list of 133 hydraulic structures was identified, based on a co-operative review process between Wood and the LPRCA. Where possible, all of these structures were visited and inventoried by Wood's field staff between May 29 and June 11, 2019 (as well as a follow-up site visit for selected sites on November 8, 2019). A copy of the hydraulic structure inventory sheets is presented in Appendix A, along with a summary of the locations and dimensions. Of the original long list of 133 hydraulic structures, the majority (128) were field visited and inventoried, with a topographic survey of selected structure features completed separately (refer to Section 2.5). The other structures (5) were typically inaccessible due to location or private property issues, or safety concerns in some cases (overly dense vegetation or steep slopes, active railway lines, etcetera).

The field data was reviewed and assessed to determine which hydraulic structures warranted inclusion within the modelling. The criteria for model inclusion/exclusion is generally premised on whether the subject structure would be expected to have an impact upon the flood hazard limits. For this reason, pedestrian bridges are typically excluded, as they generally do not impede water flow (thin deck and open lattice side railings). Other excluded structures would include culverts and crossings with minimal covers or decks, which would similarly not be expected to impede flows or impact floodlines. Small weir type structures have been excluded in some cases for similar reasons. Ultimately, a total of 39 crossings were excluded based on the preceding considerations, resulting in a total of 95 hydraulic structures included within the hydraulic modelling.

The selected significant hydraulic structures (95) have therefore been incorporated into the hydraulic modelling based on the measured dimensions, and where completed, topographic survey data (as discussed further in subsequent sections). It should be noted that typically for hydraulic modelling (and flood hazard mapping) update studies, all available sources of hydraulic structure data are reviewed and compared. This typically includes not only the field inventory data, but also data from the previous hydraulic modelling, and record drawings (design, or as-built/as-constructed drawings). For the current study area, hydraulic structures have been incorporated based on the results of the hydraulic field inventory. As noted in Section 2.3, the data from the previous hydraulic modelling (HEC-2) is quite dated and difficult to extract. There is also a general lack of available as-built drawings for the structures. As such, the field inventory data has been applied as the primary source of hydraulic structure data for the modelling effort.

As part of the hydraulic structure inventory, low flow channel measurements have also been collected, including depth and width. These measurements have been used to implement low flow channel corrections where relevant. This is discussed in further detail in Section 3.

2.5 Topographic Survey and Data Verification

A scoped topographic survey has also been completed by Wood as part of the current study. Given the large linear scale of the watercourses to be modelled (approximately 89 km) and the availability of high-quality digital elevation data, a complete topographic survey is not considered practical, nor is it necessary. The purposes of the completed topographic survey are:

- Confirm inverts/obverts for "high priority" structures (as recommended by LPRCA staff)
- Confirm road deck elevations for all structures where possible (given that the available LiDAR data has been processed to remove road decks – "bare earth" representation)
- Validate the proposed primary topographic dataset (i.e. MNRF Lake Erie LiDAR Digital Terrain Model (DTM)
- Identify low flow correction channels for larger watercourses (as the available LiDAR data does not collect below water line information)

The completed topographic survey effort has therefore been primarily completed directly at, or immediately upstream or downstream of, identified hydraulic structures. A summary of completed topographic survey data is included as part of the hydraulic structure inventory, as detailed in Appendix A.

As an initial verification exercise, the topographic field survey completed by Wood has been compared with available topographic survey benchmarks through the MNRF's COSINE system. Note that, consistent with the MNRF Lake Erie LiDAR DTM, the Canadian Geodetic Vertical Datum 2013 (CGVD2013) has been applied in all cases. Results of this comparison are presented in Table 2.1.

Table 2.1: Summary of Survey Benchmark Verification

COSINE Control Station ID	Location Description	Elevation (m)		Difference (m)
		COSINE	Survey	COSINE
0011976U002	Port Dover – Highway No. 6 Lift Bridge over Lynn River	181.779	181.817	+0.038
0011972U500[1.]	Simcoe Decou Road Concrete Bridge over Lynn River	202.468	202.753	+0.284
0011972U405	Simcoe Victoria St. Concrete Bridge over Lynn River	208.777	208.798	+0.021
0011972U330	Simcoe Norfolk St. (Highway No. 24) Concrete Bridge over a creek	212.380	212.339	-0.041
0011965U177	Hagersville Concrete Bridge on Highway No. 6 over Sandusk Creek	213.821	213.853	+0.032

A total of five (5) control points have been compared as part of this study. One (1) location (Simcoe Decou Road) indicates a notable discrepancy of some 0.28 m. Further assessment and review would be required to confirm the accuracy of the COSINE benchmark elevation data, however given the results for the other four (4) locations, the difference in this case is considered to be an outlier. It should be noted that separately, LPRCA has undertaken its own survey of the Decou Road benchmark and further confirmed the observed discrepancy. The other four (4) benchmarks indicate close agreement, between -0.04 and +0.04 m, which suggests that the topographic survey work completed by Wood is reasonable and in good agreement with vertical datum elevations.

The topographic survey has been completed for a total of thirty-two (32) hydraulic structures. This survey includes full cross-sections on both the upstream and downstream sides of the structure (including below waterline information) as well as key elevations for the structure itself (invert/obvert) and road deck information. A more scoped topographic survey (road deck centreline, invert/obvert where obtainable) has been completed for an additional forty-six (46) structures, resulting in a total of seventy-eight (78) hydraulic structures of the ninety-seven (97) modelled with topographic survey information. The remaining nineteen (19) structures generally reflect locations on private property, or control structures which were inaccessible due to ownership or safety concerns.

For the full surveyed cross-sections, a comparison of the Lake Erie LiDAR DTM (0.5 m horizontal point spacing) and the topographic survey has been completed. A full graphical summary of cross-sections has been included in Appendix B. An example comparison from the downstream side of Structure 25 (Lynn River at Decou Road, in the vicinity of the control station 0011972U500) is presented in Figure 2.1.

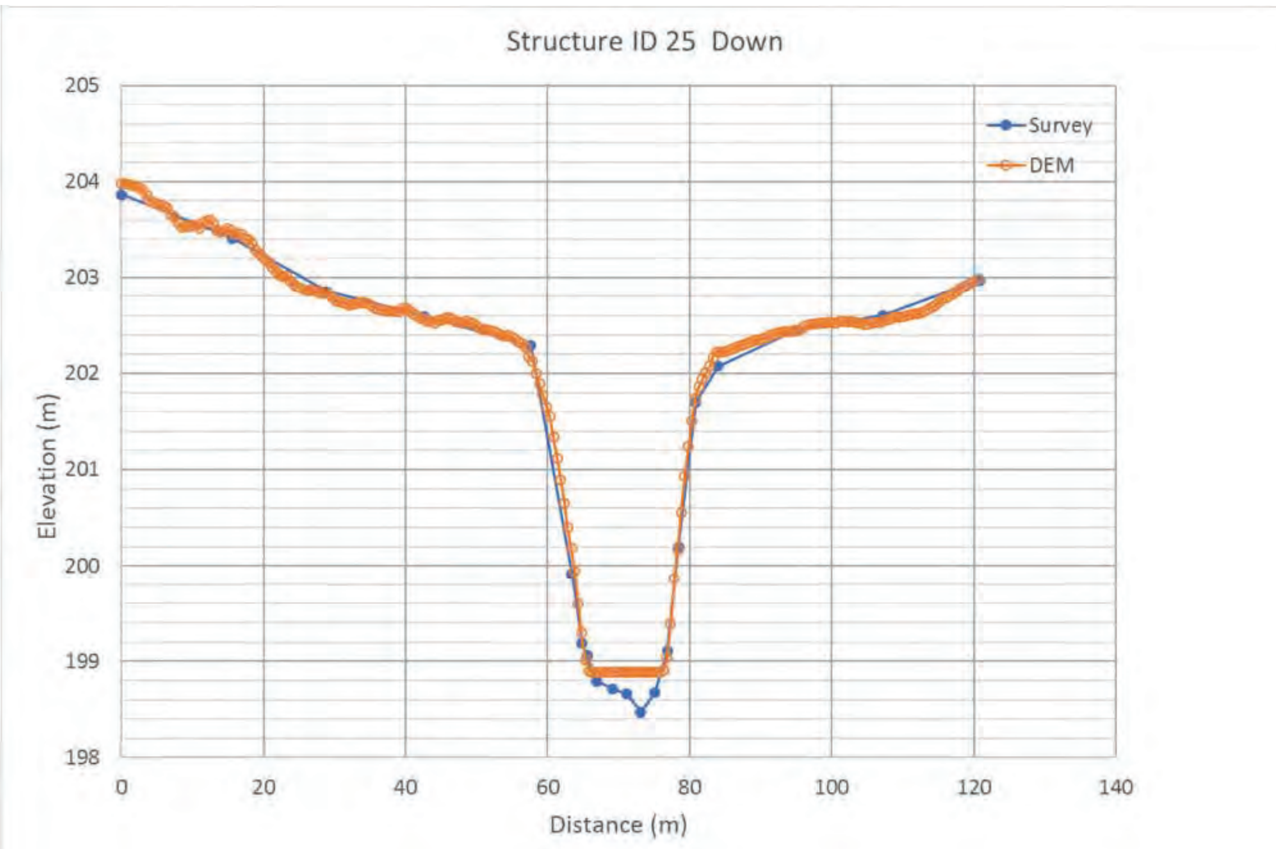

Figure 2.1. Graphical Comparison of LiDAR DTM and Topographic Survey Data

As evident from Figure 2.1 (and the other supporting figures included in Appendix B), the DTM data agrees quite well with the topographic survey data. Both overbank and primary channel areas are well represented. The point density of the DTM data (0.5 m horizontal spacing) is also evident given the large number of points shown in Figure 2.1. Based on the preceding verifications, the LiDAR DTM is considered sound and appropriate for the current flood hazard mapping study.

Notwithstanding, Figure 2.1 also indicates the limitations of the LiDAR data with respect to below water line channel bathymetry. For larger watercourses (typically where the low flow channel depth > 0.30 m), a correction is therefore required to account for this conveyance area. The applied low flow channel corrections are discussed in greater detail in Section 3; a summary is provided in Appendix B.

2.6 Base Mapping

Base floodplain mapping sheets have also been developed using AutoCAD™, in order to generate the flood inundation limits. Flood mapping sheets (and an associated tile index) have been developed on the basis of 24"x36" sheets, at a scale of 1:2,000. Base mapping sheets include the current (2015) aerial mapping, as well as roads, property lines, watercourses, waterbodies, and other key features (including dams, stream flow gauges, and survey benchmarks, where available).

3.0 Hydraulic Model and Floodplain Mapping Development

3.1 Model Software

The base hydraulic modelling for the current study has been created using the US Army Corps of Engineers software HEC-GeoRAS version 10.4.0.1 for ArcGIS 10.4. HEC-GeoRAS integrates the core HEC-RAS software with ArcGIS to facilitate the creation of a geo-referenced hydraulic model, using the available MNRF Lake Erie DTM as the core topography data. Version 5.0.6 of the conventional HEC-RAS software has then been used for further hydraulic modelling updates and model execution, which was the most current/up-to-date version of the software available at the outset of this study

3.2 Flow Data

3.2.1 Peak Flows

The current study involves hydraulic modelling only. Hydrologic modelling has been completed separately (by others) to provide the required flow rates for the hydraulic modelling. Hydrologic modelling has been completed in the GAWSER modelling platform by others (ref. LPRCA Hydrology Model Update Study - Technical Memorandum Schroeter & Associates, April 2019). In addition, LPRCA staff have completed a technical report summarizing the flows to be applied for the study ("Flood Flows for NDMP Floodplain Mapping Project in the Long Point Region, 2020"); a copy has been included in Appendix C.

It was noted that the GAWSER generated peak flows for the Lynn River watershed tended to over-estimate frequency flows as compared to the results available from a frequency analysis of available gauging data in the watershed (Water Survey of Canada monitoring stations). As such, some supplementary work was completed by Schroeter and Associates and LPRCA to refine/calibrate the peak flow estimates for this watershed.

Further, it should be noted that the supplied frequency flows for the Lynn River watershed are based on a future land use conditions scenario, to account for expected future development and growth within the watershed, particularly in the town of Simcoe. The application of Future Land Use Conditions is a requirement of the NDMP program. Overall, LPRCA determined that the use of the Future Land Use Condition scenario increased peak flows as compared to existing land use conditions by approximately 10 percent or less for the 100-Year event for the Lynn River watershed. LPRCA further determined that changes in land use and associated impacts to peak flows were negligible in other watercourses.

The effects of dams and reservoirs have also been removed from this modelling scenario, as with all other subject reaches which include dams and reservoirs (including the Norwich Dam for Big Otter Creek), consistent with Provincial Policy (MNRF, 2002).

Supplied peak flows for the 2 through 100-year return periods have been included in the hydraulic modelling, as well as the Regional Storm (Hurricane Hazel). Notwithstanding, it should be understood that for LPRCA's jurisdiction, the Regulatory Flood is the 100-year Flood event. As such, Regulatory Floodplain Mapping has been developed based on this Flood event (although all hydraulic modelling has been completed to ensure that the Regional Floodplain is also reasonably calculated; i.e. all cross-sections are extended sufficiently to contain flows).

A single station frequency analysis was performed by LPRCA on all watercourses with a flow gauge (that were considered to have a sufficient period of record) to produce the return period floods for this study. Ungauged watercourses required the use of return period storm depths applied to a synthetic rainfall distribution to produce the return period floods for this study. Any reference to return period floods in this report includes those produced using return period storms.

Steady-state flow simulation has been applied for all model scenarios.

It should be noted that, typically, additional flow nodes are added where the increase in flow between nodes exceeds 10%, in order to better represent incremental increases in flows, and avoid sudden or abrupt increases in flows and water levels. Notwithstanding, and given the scope of the current study, the supplied flow node data has been applied as received. No screening with respect to flow changes has been included.

A copy of the applied flow data (technical report completed by LPRCA) is included in Appendix C.

3.2.2 Flow Regime and Boundary Conditions

The watercourses included in the current study are all generally flat and do not involve steep grades or abrupt transitions. As such, all models have been run using a subcritical flow regime. Where modelling results indicate supercritical flow conditions (as indicated by a Froude Number approaching 1 or evidence of a hydraulic jump) a mixed flow regime (subcritical and supercritical flow) has been considered, however typically such transitions and issues have been mitigated through the implementation of additional cross-sections, and as such the application of a mixed flow regime has not been considered necessary.

Under a subcritical flow regime, only downstream boundary conditions are required. For locations which are located further upstream within the watershed (i.e. do not include the discharge point to Lake Erie), a normal depth boundary condition has been applied. The slope of the energy gradeline (EGL) has been assumed to be equal to that of the bed slope for an initial estimate; the slope value is then revised based on the results of the initial model iteration to better match the EGL slope.

For the Lynn River system (which outlets directly into Lake Erie at Port Dover, the long-term mean lake level has been applied (as per the recommendations of Section 4.7.3.1 of the Technical Guidelines for Flood Hazard Mapping, EWRG, 2017). Based on the current Monthly Water Level Bulletin from Fisheries and Oceans Canada (available at https://www.waterlevels.gc.ca/C&A/bulletin-eng.html), the all-time average summer high water surface elevation for Lake Erie is approximately 174.38 m in the IGLD85 datum. This value has been converted to the CGVD2013 datum using a conversion factor of 0.456 m (based on the Natural Resources Canada (NRCan) Benchmark Station Reports for Port Dover), which results in an associated Lake Erie boundary condition level of 173.924 m for the Lynn River hydraulic model.

It should be noted that water levels in Lake Erie have been well above this average value in recent years; approximately 175.15 m (IGLD85) in the summer of 2019. Notwithstanding, it is considered that the long-term average value is sufficient for the purposes of the current riverine floodplain mapping study; the separate shoreline flood hazard study (by others) would be expected to provide the greater shoreline hazard risk mapping in these areas. The impact of higher Lake Erie water levels has been considered as part of the sensitivity analysis, as discussed in subsequent sections.

For the Big Otter Creek system (which outlets directly into Lake Erie at Port Burwell), LPRCA staff have noted past issues with respect to ice jamming at the Port Burwell Pier. As such, it was suggested that the elevation of the Port Burwell Pier be applied as the starting boundary condition. LPRCA staff undertook a topographic survey of the pier (CGVD2013 datum), with the average resulting elevation of 175.40 m. This value has been applied as the boundary condition for the Big Otter Creek modelling (Calton Line to Lake Erie – Vienna and Port Burwell) for all flow conditions.

In certain cases, reservoirs and dams are present at either the upstream limits of, or partway along a subject watercourse. The approach to modelling these features (and associated boundary conditions) are discussed further in Section 3.4.

3.3 Geometric Data

3.3.1 Cross Sections and Flow Paths

In order to develop a base hydraulic model, cross-sections of the 1-dimensional conveyance channel (watercourse) are required. New cross-sections (independent of cross-sections applied in previous modelling efforts) have been developed for the current study. The locations of all cross-sections, including cross-section ID numbers (based on the chainage of the cross-section relative to the downstream limits of the reach section) are indicated on the flood hazard mapping sheets.

In general, hydraulic cross-sections have been located in accordance with the HEC-RAS modelling guidelines (USACE, 2010). Cross-sections for the study have been developed in consultation with LPRCA staff. In general, cross-section spacing has been maintained between 20 m (typical minimum) and 300 m (typical maximum), for a typical average spacing of 100 m or less. However, spacing may vary depending on the specifics of the location in question. A more resolute spacing may be required in steeper areas, whereas a wider spacing may be reasonable in flatter, shallower areas, particularly for larger watercourses. Generally, the distance between cross-sections should ensure that there is a maximum elevation drop of 0.5 m between cross-sections, to avoid unreasonable corresponding floodplain extents. Following the base model preparation, some cross-sections have required widening/extension to ensure that flows are adequately contained/conveyed by each section.

The typical convention for cross-sections around hydraulic structures has also been applied as per the HEC-RAS modelling guidelines (USACE, 2010), including two (2) upstream and two (2) downstream sections.

A summary of the applied cross-sections is provided in Table 3.1.

Table 3.1: Summary of Modelled Hydraulic Cross-Sections

Model	Total Length Modelled (km)	Total Number of Reaches	Total Number of Cross-Sections	Average Spacing (m)
Big Otter Creek (Norwich)	3.5	1	62	56
Big Otter Creek (Tillsonburg)	5.4	3	44	120
Big Otter Creek (Vienna)	17.1	1	97	176
Clear Creek	1.8	1	36	50
Stoney Creek	1.3	1	21	61
Lynn River	34.4	11	438	80
Nanticoke Creek	9.9	2	106	98
Sandusk Creek	15.3	3	202	75
TOTAL	**88.7**	**23**	**1,006**	**NA**

HEC-RAS requires a terrain model with three-dimensional attributes (x, y, z) for the area of interest. As discussed in Section 2.5, the 0.5 m DTM (ref. User Guide, Lidar - Digital Terrain Model, 2016-18, Land Information Ontario (LIO), 2019; a copy has been included in Appendix B) for the Lake Erie area (as available through LIO) has been used as the base topography for the HEC-RAS model. The vertical coordinate system of the LIO DTM is based on the Canadian Geodetic Vertical Datum 2013 (CGVD2013). Available documentation for the dataset indicates that the non-vegetated and vegetated vertical accuracy of the DEM are 12 cm and 18.3 cm respectively.

The HEC-GeoRAS tool developed by the Hydrologic Engineering Center, US Army Corps of Engineers (as described in Section 3.1) has been used to extract the required geometric data (cross sections, river profile etc.) for HEC-RAS model, based on the available DTM.

In addition to the cross-section lines, flow path lines have also been developed for the left and right overbanks to determine the overbank length between cross-sections. Channel length is determined directly from the watercourse centreline layer, as provided by LPRCA and refined by Wood as necessary to match the DTM data.

3.3.2 Low Flow Channel Geometry

LiDAR data generally does not include below water line data (bathymetry). The Lake Erie LiDAR DTM (as applied for the current study) is consistent with this generalization. For smaller watercourses, the below water line information is generally insignificant, and as such no correction is required in these areas. For larger watercourses (generally where the channel depth > 0.30 m), a low flow correction is necessary to reasonably represent channel conveyance and incorporate this additional area.

Potential low flow channel corrections have been reviewed based on field measured data, including both measurements at hydraulic structures as part of the field inventory program (ref. Section 2.3) and topographic survey cross-sections at selected locations (ref. Section 2.4). This information has been used to identify locations where channel depths generally exceed 0.3 m, and where low flow channel corrections are required. Depending on the measured depths, corrections may be generalized and applied to entire reaches. In other cases, a localized correction around a specific structure may be sufficient. Low flow channel corrections incorporated into the hydraulic model are presented in Table 3.2. A detailed summary of low flow channel corrections is provided in Appendix B.

Table 3.2: Summary of Low Flow Channel Corrections

Model	Reach	Cross-Section Range	Low Flow Channel Depth	Note
Big Otter Creek (Norwich)	Norwich	from 2547.96 to 1891.64	Varies from 0.14 m to 0.61 m	Locally adjusted based on surveyed invert elevations of ST 103, ST102 and ST101
Big Otter Creek (Tillsonburg)	Tillsonburg	-	-	No Adjustment
Big Otter Creek (Vienna)	Vienna	from 17037.93 to 9319.87	1.20 m	
	Vienna	from 9226.89 to 8186.62	1.2 m to 1.6m	Linearly interpolated
	Vienna	from 8186.62 to 7595.47	1.6 m to 1.8 m	Linearly interpolated
	Vienna	from 7543.01 to 276.48	1.8 m	
Clear Creek	Cultus	1547.06	0.2 m	Based on surveyed invert elevations of ST97
Stoney Creek	Gilbertville	from 1289.35 to 20.16	0.6 m	
Lynn River	Patterson Creek	1649.47 to 68.87	0.4 m	
	Black Creek	2385.53 to 203.54	0.1 m	
	Kent Creek	4638.77 to 1340.75	0.5 m	

Table 3.2: Summary of Low Flow Channel Corrections

Model	Reach	Cross-Section Range	Low Flow Channel Depth	Note
	Kent Creek	1314.13 to 475.36	0.3m	
	Lynn River (Simcoe)	1394.39 to 1243.28	0 m to 0.4 m	Linearly interpolated
	Lynn River (Simcoe)	1243.28 to 1076.09	Varies from 0 to 0.5 m	Locally adjusted to match with the Sutton Dam Invert
	Lynn River (Simcoe)	1076.09 to 664.59	0.4 m to 0.2m	Linearly interpolated
	Lynn River (Simcoe)	664.59 to 76.56	0.2 m to 0.5m	Linearly interpolated
	Lynn River (Simcoe)	16712.63 to 15946.98	1 m	
	Lynn River (Simcoe)	15925.69 to 12902.00	0.5 m	
	Lynn River (Simcoe to Lynn Valley)	12902.00 to 10628.69	0.5 m to 0 m	Linearly interpolated
	Lynn River (Lynn Valley)	10628.69 to 9273.64	0 m to 0.4m	Linearly interpolated
	Lynn River (Lynn Valley to Port Dover)	9273.64 to 6057.53	0.4 m	
	Lynn River (Lynn Valley to Port Dover)	6057.53 to 2102.49	0.4 m to 0m	Linearly interpolated
	Lynn River (Port Dover)	387.70 to 197.62	1.7 m	
Nanticoke Creek	Waterford	-	Varies from 0.14 m to 0.90 m	Locally adjusted based on surveyed invert elevations of ST128, ST127 and ST123
	Villa Nova	-	Varies from 0.11 m to 0.37 m	Locally adjusted based on surveyed invert elevations of ST 122
Sandusk Creek	Jarvis	from 3289.67 to 36.5	0.2m	Entire reach
	Jarvis East	from 7145.2 to 6841.74	Varies from 0.2 m to 1.02 m	Locally adjusted based on surveyed invert elevations of ST74
	Jarvis East	from 5663.36 to 4952.12	Varies from 0.18 m to 1.07 m	Locally adjusted based on surveyed invert elevations of ST72

Table 3.2: Summary of Low Flow Channel Corrections				
Model	**Reach**	**Cross-Section Range**	**Low Flow Channel Depth**	**Note**
	Jarvis East	From 1587.01 to 1502.38	Varies from 0.11 m to 0.55 m	Locally adjusted based on surveyed invert elevations of ST68
	Garnett	From 959.79 to 566.26	Varies from 0.13 m to 0.90 m	Locally adjusted based on surveyed invert elevations of ST89

Where a low flow channel correction has been considered warranted (as per Table 3.2), the proposed depth has been incorporated into the cross-section data directly, through a manual editing of the geometry file using a script in AutoLISP™. Based on Wood's experience, this approach is generally more efficient than editing of the source DTM data to reflect the bathymetric data. 3H:1V side slopes have been applied based on the identified water level (flat channel base) in the DTM, and the estimated depth (as per Table 3.2).

A review of the previous HEC-2 hydraulic modelling has been completed, in order to determine whether any viable channel bathymetry data could be extracted. Given uncertainty with respect to channel cross-section locations, differences in vertical datums, and the general age and accuracy of the original HEC-2 modelling, it has been determined that the previous HEC-2 models are not a viable source of channel bathymetry data.

Given their locations and extents, field measurements or survey of reservoirs was not considered feasible. As such, no data is available to validate a low flow or bathymetric correction for these features. Overall, it is considered that this should have a minimal impact on modelling results, given that this represents inundated area under dry weather conditions. The approach to modelling reservoirs is discussed further in Section 3.4.3. Notwithstanding, only two (2) reservoirs are located online mid-way within the hydraulic modelling extents, specifically Crystal Lake (Quance Dam) and Silver Lake (Misner Dam), both along the Lynn River. The proposed overall low flow channel correction for open sections of watercourse in these areas has also been applied for the reservoir sections.

3.3.3 Roughness and Energy Loss Coefficients

Channel and overbank roughness coefficients (Manning's Equation) are key inputs to the hydraulic model. The roughness coefficients represent the different roughness associated with different land uses and surfaces. Higher roughness coefficients represent less efficient conveyance, and therefore tend to result in elevated water surface elevations and wider floodplain extents.

Given the scope of the current study, and for overall traceability, a consistent land use layer for roughness is required. Wood undertook a review of potential datasets accordingly.

Norfolk County has provided an Official Planning Land Use dataset. However, the resolution of the land use is not considered sufficient for the current study purposes. In general, all areas close to watercourses are classified as "Hazard Lands", which does not allow for a sufficient distinction between land covers (i.e. urban, open space, forested, etcetera) and associated Manning's Roughness Coefficients. Further, although a large portion of the study area is located within Norfolk County, several the subject watercourses are not, which would require an alternative methodology or data source for those areas, leading to inconsistency.

As documented in Section 2.2, LPRCA commissioned a Land Cover Mapping study (as per 4DM, December 2018). This study yielded a raster dataset with a 20 m spatial resolution. It should be noted that for smaller/narrower watercourses this resolution is too coarse to accurately represent differences and changes in overbank roughness. Notwithstanding, the dataset is considered the best available source of information to determine overbank roughness values. This raster Land Cover dataset was converted into a vector dataset (polygon) using GIS tools, and edited to include the main channels. The dataset includes a total of fourteen (14) land use types. Proposed Manning's Roughness Coefficients for these land use types are presented in Table 3.3. Values are considered consistent with those proposed in the Technical Guidelines for Flood Hazard Mapping (Table 3.2.9, EWRG, 2017), as well as those of other area Conservation Authorities (specifically Standard Manning's Roughness Coefficients for TRCA Watershed Hydraulic Modelling). Copies of both have been included in Appendix D for reference.

Where land use types generate an identical Roughness Coefficient, areas have been merged, to avoid including unnecessary additional roughness change points in the cross-sections. The Roughness Coefficients presented in Table 3.3 have also be adjusted in some cases, where a review of available aerial imagery or other sources of information suggest that an alternative value would be more appropriate, particularly in urban or built up areas.

Channel roughness has been set as a uniform value of 0.035, consistent with the previously noted references.

Table 3.3: Proposed Overbank Roughness Coefficients

Classification	ID	Proposed Roughness Coefficient
Cultivated Crop Lands	1	0.08
Bare Soil Areas	2	0.05
Grasslands/Shrubs	3	0.05
Conifer Treed Forest	4	0.08
Deciduous Treed Forest	5	0.08
Mixed Treed Forest	6	0.08
Sparse Treed	7	0.08
Wetlands	8	0.08
Open Water Areas	9	0.03
Barren Areas	10	0.05
Commercial/Industrial	12	0.025
Residential	13	0.05
Settlement Open Areas	14	0.05
Roads	15	0.025

In addition to Roughness Coefficients, expansion and contraction coefficients are required to account for energy losses associated with potential changes between sections. Applied values are again consistent with the Technical Guidelines for Flood Hazard Mapping (Table 3.2.8, EWRG, 2017). Default values of 0.1 and 0.3 respectively have been applied for normal open channel cross-sections. Higher values of 0.3 and 0.5 have been applied for bridges and culverts, given the more abrupt changes associated with these features

3.3.4 Ineffective Flow Areas, Obstructions and Levees

Ineffective flow areas have been included for the upstream and downstream bounding cross-sections for all hydraulic structures. To be conservative, ineffective flow areas have generally been set at the edges of all structure openings. For the upstream side, the ineffective flow areas have been set to the road deck elevations; on the downstream side, the elevations are somewhat lower (typically mid-way between the road deck and crossing obvert/soffit) to account for potential overflow of the structure.

Building footprint mapping data provided by LPRCA has been used to identify the building obstructions. These building footprint layers have been processed in HEC-GeoRAS, such that they are included directly into the cross sections automatically. A uniform height of 5 m above ground level has been assumed for all buildings through this process.

Levees are applied within the HEC-RAS modelling for cross-sections to prevent the floodplain extents from including low lying areas within the overbanks that potentially may not be flooded until the levee elevation is reached. Given the focus of the current study on flood hazard mapping for the 100-year flood event, levees have been included sparingly with a focus upon such larger flood events. In many cases, levee locations have been revised and updated based on the preliminary hydraulic modelling results to ensure consistency (i.e. locations where the low-lying area may be accessed by one cross-section but not by others due to levees). In some cases, ineffective flow areas have been applied in place of levees, where warranted.

3.3.5 Hydraulic Structures

The completed field inventory of hydraulic structures was described previously in Section 2.4 and 2.5. A total of 95 "significant" hydraulic structures have been incorporated into the hydraulic modelling based on the measured dimensions, and where completed, topographic survey data. Road deck cross-sections have been extracted based on the Lake Erie DTM, with corrections as required based on the surveyed centreline of road (given that decks have been removed in the processed DTM). Solid parapet walls have been included accordingly as part of the definition, where present and applicable.

A complete inventory of hydraulic structures and dimensions is included in Appendix A. A break down of modelled hydraulic structures by watercourse system is presented in Table 3.4. Most of the structures have been modelled as conventional hydraulic structures (i.e. bridges and culverts), however several inline structures have been included, specifically with respect to weirs and dam/reservoir structures. Special considerations with respect to hydraulic structures (special case crossings, embankment storage, etcetera) are discussed further in Section 3.4.

Table 3.4: Summary of Modelled Hydraulic Structures

Model	Bridges	Culverts	Inline Structures	Total
Big Otter Creek (Norwich)	6	0	1	7
Big Otter Creek (Tillsonburg)	2	2	0	4
Big Otter Creek (Vienna)	3	0	0	3
Clear Creek	0	2	0	2
Stoney Creek	2	0	0	2
Lynn River	33	10	6	49
Nanticoke Creek	6	2	1	9
Sandusk Creek	7	12	0	19
TOTAL	**59**	**28**	**8**	**95**

As a default, the energy equation has been applied to the simulation of low and high flow through the Bridge Modelling Approach in HEC-RAS. Depending on the degree of overtopping and model stability, alternative high flow methods (pressure/weir) have been assessed and applied. A weir coefficient of 1.4 has been applied for high flows, which is consistent with Table 3.2.8 from the Technical Guidelines for Flood Hazard Mapping (EWRG, 2017) for a broad crested weir (typical for roadway overtopping) and Wood's professional experience.

Suitable entrance loss coefficients have been applied for culverts, based on the geometry of the crossing. Values are consistent with Table 6-3 from the HEC-RAS Reference Manual. Applied values are summarized in Table 3.5. A uniform exit loss of 1.0 has been applied for all culverts.

Table 3.5: Summary of Applied Entrance Losses

Material	Type	Entrance Loss Coefficient
Corrugated Steel Pipe	Projecting	0.9
	Mitered	0.7
	Headwall or Wingwalls	0.5
Concrete Pipe	All	0.5
Box Culverts	All	0.5

3.4 Special Considerations

3.4.1 Special Case Crossings

Special case crossings refer to those which require greater consideration than conventional bridges and culverts as discussed in Section 3.3.5. Typical special case crossings include crossings with differing geometries upstream and downstream, and longer enclosures (greater than a typical bridge or culvert). No such crossings were present in the finalized scope of work for this study.

3.4.2 Embankment and Reservoir Storage

In some cases, crossings include a large (deep) embankment, often with relatively undersized crossings (culverts in particular). In these situations, HEC-RAS may predict extremely high backwater levels on the upstream side, often in order to allow for spill flow (overtopping) of the structure. However, in many of these cases these simulated backwater levels are not realistic, based on large available storage in the upstream area (typically large valley systems). In these types of situations, an alternative modelling approach has been proposed, based on reservoir routing. As per the Technical Guidelines for Flood Hazard Mapping (EWRG, 2017), a minimum volume assessment of 10-15% can be applied as a threshold for this type of assessment.

Using this approach, a stage-storage curve is established for the area upstream of the crossing, using the available DTM data. This is then coupled with a stage-discharge curve, generally sourced from Design Charts and Nomographs, depending on the specific characteristics of the crossing. An overflow function (i.e. road overtopping) may also be necessary and can be developed using a weir type equation or equivalent. The combined storage-discharge rating curve is then used to determine the corresponding maximum storage (and therefore water surface elevation) and discharge. These results can then be implemented into HEC-RAS using one of two different methods:

- Split the reach at the crossing, and apply the calculated water surface elevations for each flood event as the flow boundary condition at the upstream limits of the crossing;

- Add the rating curve to the hydraulic cross-section immediately upstream of the structure and apply the reduced (attenuated) flow at the crossing (unattenuated flow should be applied at the downstream limits).

The latter approach has been applied for several select crossings within the study area.

In addition to the preceding, there are several reservoirs and dams located at the upstream limits of subject watercourses (rather than inline mid-way along the hydraulic modelling). Such reservoirs can also be reasonably assessed using hydrologic modelling. Two (2) such reservoirs, the Norwich Dam and the Waterford Ponds Dam, have been assessed using hydrologic modelling accordingly, based on the dimensions of their respective outlet control structures and the same general approach as applied for embankment storage crossings (i.e. development of a storage-discharge relationship).

A list of crossings that should be considered for assessment in this manner are presented in Table 3.6. Detailed calculations are included in Appendix D.

Table 3.6: Summary of Potential Crossings and Structures to be Assessed using Storage - Discharge Approach

Watercourse	Reach	Structure ID	Cross-Section ID	Name
Big Otter Creek	Big Otter Creek (Norwich)	ST105	3304.28	Norwich Dam
Clear Creek	Clear Creek (Cultus)	ST94	403.32	Cultus Road
Nanticoke Creek	Nanticoke Creek (Waterford)	ST130	NA	Waterford Ponds Dam
Sandusk Creek	Sandusk Creek (Jarvis)	ST84	2207.92	Trail (Abandoned Railway)
Stoney Creek	Stoney Creek (Gilbertville)	ST91	1069.89	Highway 3 (James Street)

It should be noted that for the four (4) roadway embankments assessed, relatively minimal reductions in flows/backwater levels resulted from the preceding approach. Notwithstanding, the resulting differences have been incorporated into the modelling accordingly.

For the Norwich Dam, reservoir levels were compared to those using an inline structure approach within the hydraulic modelling (Section 3.4.3). Ultimately, these results were found to be slightly higher, as such the more conservative values from the hydraulic modelling have been applied for floodline delineation.

For the Waterford Ponds, a rating curve has been developed based on available information with respect to the outlet control structure (ref. "Waterford Dam General Assessment Report", AECOM, May 2017) as outlined further in Appendix D. The results simulated peak reservoir levels for the Waterford Ponds have been used to delineate the floodplain limits for the subject section of the Waterford Ponds within the study limits.

3.4.3 Inline Structures

As per Table 3.4, there are a total of eight (8) inline structures modelled directly within the hydraulic modelling. A more detailed summary of these features is provided in Table 3.7.

Table 3.7: Summary of Modelled Inline Structures

Watercourse	Reach	Structure ID	Cross-Section ID	Name
Big Otter Creek	Big Otter Creek (Norwich)	ST105	3304.28	Norwich Dam
Lynn River	Lynn River (Simcoe)	ST40	1149.9	Former Sutton Pond
	Kent Creek (Simcoe)	ST63	1527.70	Colonel Stalker Park
	Lynn River (Simcoe)	ST30	15936.22	Quance Dam (Crystal Lake)
	Lynn River (Simcoe)	ST26	14365.7	Former Brook Dam
	Lynn River (Port Dover)	ST12	2204.69	Private Structure
	Lynn River (Port Dover)	ST9	421.34	Misner Dam (Silver Lake)
Nanticoke Creek	Nanticoke Creek (Waterford)	ST125	1776	Private Structure

A weir coefficient of 1.4 has been conservatively assumed for inline structures, consistent with the approach to roadway embankments.

For inline dam structures, the spillway geometry has been incorporated to the extent possible based on available record drawings, or the representation of the feature in previous hydraulic modelling. For the Quance Dam structure, a gate has been incorporated as per the previously completed hydraulic modelling. The gate has been assumed to be fully open for all storm events. Detailed calculations are included in Appendix D.

3.5 Model Sensitivity Analysis

3.5.1 Overview

Base hydraulic modelling has been developed based on a review of available data, site reconnaissance of structures, new LiDAR data, and selection of appropriate input data. However, as is the case in all numerical modelling of physical processes, there is the inherent potential for errors or uncertainty to be associated with the selection of input variables which could affect the resulting flood flows. Sensitivity analysis can be useful for a range of purposes, including:

- Testing the robustness of simulation model results in the presence of uncertainty.
- Increasing the understanding of the relationships between input and output variables in simulation models.
- Increasing confidence in simulation model results by identifying model inputs that cause significant uncertainty in the output. Increased attention to these specific model inputs can then be applied to ensure proper definition and/or parameterization.
- Ensuring the model accurately reflects watercourse conditions and responses by identifying errors in the model output as reflected by unexpected relationships between inputs and outputs.

The model sensitivity analysis has considered the assessment of the following parameters:

- Manning's Roughness Coefficients (±20%)
- Peak Discharge (±20%)
- Boundary Conditions
- Hydraulic Structure Modelling Methodology

Complete sensitivity analysis results are included in Appendix D. A discussion of general outcomes is provided in the subsequent sections.

3.5.2 Manning's Roughness Coefficients

Simulated results for all the subject watercourses with respect to Manning's Roughness Coefficient and Peak Discharge are presented in Tables D1 to D15 respectively. With respect to Manning's Roughness Coefficients, the modelling results indicate that on average, the hydraulic modelling is relatively insensitive to changes in values, with average water level changes of 0.10 m or less.

Notwithstanding, local areas may exhibit a greater sensitivity, with some of the simulated maximum differences of > 0.30 m in certain areas. The section of Big Otter Creek through Vienna and Port Burwell exhibited the greater overall average sensitivity in changes to Manning's Roughness Coefficient, with average changes of between 0.25 and 0.30 m indicated due to a 20% +\- change in Roughness. This may reflect the generally wider nature of the channel in this case, and flatter topography, which would be more sensitive to this parameter than steeper reaches.

3.5.3 Peak Discharge

Simulated results for all the subject watercourses with respect to Manning's Roughness Coefficient and Peak Discharge are presented in Tables D1 to D15 respectively. With respect to Peak Discharge, the modelling results indicate that many of the subject reaches are insensitive to changes in values, with averages water level changes of 0.10 m or less. Notwithstanding, as with Manning's Roughness Coefficients, many local areas exhibit a greater sensitivity.

The section of Big Otter Creek through Vienna and Port Burwell exhibits a relative sensitivity to changes in flow, with average changes in water level of 0.30 m due to the 20% change in peak flow. This may again reflect the larger nature of the system in this case, and the associated greater change in flows a change of 20% generates. Cultus (Clear Creek) exhibits a relative sensitivity to peak flows for the 10-year through 50-year storm events which may suggest the model is less stable for these storm events.

The Lynn River watershed and tributaries (Patterson Creek, Davis Creek, and Kent Creek as well as Black Creek) indicate a greater sensitivity to decreases in flows; these reaches are much less sensitive to increase in flows. Notwithstanding, Kent Creek and the Lynn River exhibit some notable decreases in water levels with corresponding increases in flows. This may reflect the nature of the flow regime in this case, with some areas defaulting to critical depth or experiencing transitions in flow regimes and associated hydraulic jumps, which may result in calculated decreases at local cross-sections.

3.5.4 Boundary Conditions

With respect to hydraulic modelling boundary conditions, as per Section 3.2.2, currently two (2) different boundary conditions have been applied: normal depth (for those cross-sections located upstream of Lake Erie) or a fixed water surface elevation (for those sections that outlet to Lake Erie). For Lynn River, a fixed water surface elevation based on the maximum average monthly lake level has been applied (173.924 m in the CGVD2013 datum). For Big Otter Creek, the surveyed pier elevation provided by LPRCA has been applied (175.40 m in CGVD2013).

In order to assess the sensitivity of these modelling reaches to changes in the static water level boundary condition, several different scenarios have been assessed:

- Scenario A: Mean Lake Level (IGLD 174.15 m, CGVD2013 173.694 m)
- Scenario B: Maximum Average Lake Level (IGLD 174.38 m, CGVD2013 173.924 m)
- Scenario C: 100-Year Instantaneous Flood Lake Level (CGVD2013 176.0 m)
- Scenario D: Port Dover Stillwater Levels (as per MNR, 1989)
- Scenario E: Port Dover Stillwater Levels (as per Baird, 2019) for Lynn River, and Port Stanley Joint Probability Total Water Levels (as per Baird, 2015) for Big Otter Creek (Vienna)

The applied water levels for Scenario E vary with the storm event and location being assessed. Water levels are presented in Table 3.8 (Port Dover data – applied for Lynn River) and Table 3.9 (Port Stanley data – applied for Big Otter Creek). The values are notably different from one another, with the Port Stanley results some 0.8 m +\- lower than those at Port Dover. The stillwater levels include both a static water level and associated estimated storm surge, and are therefore notably higher than the long-term average levels considered in Scenarios A and B.

Table 3.8: Summary of Lake Erie Stillwater Levels (m) for Sensitivity Analysis – Port Dover Gauge (Lynn River – Port Dover)

Source	Datum	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	200-Year (Regional)
MNR (1989)	IGLD85	175.50	175.79	175.94	176.10	176.20	176.30	176.38
	CGVD2013	175.044	175.334	175.484	175.644	175.744	175.844	175.924
Baird (2019)	IGLD85	175.56	175.85	175.99	176.15	176.25	176.34	176.42
	CGVD2013	175.104	175.394	175.534	175.694	175.794	175.884	175.964

Table 3.9: Summary of Lake Erie Stillwater Levels (m) for Sensitivity Analysis – Port Stanley Gauge (Big Otter Creek – Port Burwell/Vienna)

Source	Datum	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	200-Year (Regional)
Baird (2015)	IGLD85	174.91	175.15	175.27	175.40	175.48	175.55	175.62
	CGVD2013	174.454	174.694	174.814	174.944	175.024	175.094	175.164

Full sensitivity analysis results are included in Appendix D (refer to Table D16 for Lynn River and Table D17 for Big Otter Creek at Port Burwell). Scenarios A and B involve decreases in the boundary condition level, and therefore corresponding decreases in simulated upstream flood levels. Scenarios C, D and E all involve increases in water levels, and therefore corresponding increases in upstream flood levels. For Port Dover (Lynn River), Scenarios D and E generally differ by 0.05 m +\- on average, and therefore do not generate substantially different results as part of the sensitivity analysis. For Big Otter Creek at Port Burwell, Scenarios A, B and E involve decreases in the boundary condition water level and therefore decreases in the corresponding flood levels. In contrast, Scenarios C and D involve increases in the boundary condition water levels and therefore the upstream flood levels. The results indicate that under the highest boundary condition levels, the impact to simulated water surface elevations would extend to near the base of the Misner Dam along the Lynn River, as well as along the full length of the modelled portion of Black Creek. For Big Otter Creek, the most substantial changes in applied boundary conditions would impact water surface elevations all the way upstream to the downstream side of Plank Road in Vienna (ST107).

The preceding scenarios indicate some model sensitivity to the starting water surface elevation as would be expected. Notwithstanding, these scenarios assume the coincidental occurrence of a high lake level with storm surge and the peak flow from the subject watercourse, which is highly conservative.

With respect to the balance of the study area watercourses, a normal depth boundary condition has been applied. The slope of the energy gradeline (EGL) has been assumed to be equal to that of the bed slope for an initial estimate; the slope value is then revised based on the results of the initial model iteration to better match the EGL slope. As a further sensitivity analysis, the impact of using a critical depth boundary condition instead has been assessed. Results for subject watercourses are presented in Table D18 in Appendix D. The simulated results indicate that the maximum increase in simulated water surface elevation due this change is generally negligible (generally less than 0.10 m). Overall, the application of a critical depth boundary condition generally results in greater simulated decreases in water surface elevations. The results suggest that the application of a Normal Depth Boundary Condition is therefore generally more conservative and more appropriate.

3.5.5 Hydraulic Structure Modelling Methodology

With respect to hydraulic structure modelling methodology, two (2) different sensitivity analyses have been completed.

For the first analysis, a total of seven (7) different crossings have been selected across various watercourses to assess the relative difference in simulated water surface elevations from the application of different modelling approaches, namely the baseline Energy Equation approach as compared to Pressure/Weir. Results are presented in Table D19 in Appendix D. In general, the Pressure/Weir modelling approach is considered preferable where the structure is overtopped. Results vary depending on the structure in question; there is no consistent trend in the simulated results with both increases and decreases in water surface elevations and weir flows indicated.

For the second analysis, a sensitivity analysis of the weir coefficient (for the Pressure/Weir approach) has been undertaken, with the base value of 1.4 being varied to values of 1.5 and 1.7 respectively. Results are presented in Table D20 in Appendix D. Increases in the applied weir coefficient generate associated increases in overtopping flow, as would be expected. The changes in the weir coefficient do not result in a notable change to the simulated upstream channel water surface elevations.

3.6 Error and Warning Disposition and Model Review

As part of the development of the base hydraulic modelling, Wood has undertaken a review of model warnings, as well as potential inconsistencies or issues with modelling results. No error messages occurred in the simulation of the modelling. Typical model warnings and inconsistencies include:

- Cross-section extents being exceeded
- Model defaulting to critical depth
- Supercritical flow (Froude Number of 1 or greater) and hydraulic jumps back to subcritical flow
- Lower flow regimes resulting in higher water surface elevations (i.e. 50-year flood event generating higher water levels than 100-year flood event)
- Conveyance ratio is less than 0.7 or greater than 1.4

Many of the warning massages have been resolved by adding more cross sections into the model. In addition, several steady flow computation tolerances such as water surface calculation, critical depth calculation, maximum number of iterations, and maximum iteration in split flow computations, have been adjusted (within a reasonable range) in order to resolve the warning messages.

In some instances, issues of the model defaulting to critical depth could not be resolved, despite implementation of the preceding measures. In these cases, it is considered possible that this may in fact be a reasonable hydraulic solution (i.e. flow regime is undergoing a hydraulic jump or transition between supercritical and subcritical flow). It has not been considered appropriate to simulate a mixed flow regime, given that the subcritical flow profile will tend to always generate a higher water surface elevation than the supercritical flow profile.

3.7 Floodline Mapping

3.7.1 Floodline Delineation

Following the completion of the previous model building tasks, error and warning disposition, and model review by LPRCA staff, flood inundation and floodline mapping has been prepared.

Floodlines and flood inundation areas have been generated directly within HEC-GeoRAS, using the RAS Mapper tool. Flood inundation areas have been generated for the full range of storm events, namely the 2, 5, 10, 20, 25, 50, 100 Year (frequency analysis and hydrologic modelling based) and Regional Flood Events.

In addition, the 100-year flood and Regional floodlines have been assessed and generated in AutoCAD Civil3D™, in order to review any potential differences in floodplain limits. The results generated using the two (2) different approaches have been compared and reconciled, in order to generate the resulting final floodlines for both the 100-year and Regional Storm Events, as presented on the resulting floodplain mapping sheets (1,2:000 scale on full size 24"x36" sheets, as discussed in Section 2.6).

Based on the modelling and mapping results, no spill areas have been identified (all flows can be contained by the 1-dimensional cross-sections), except at Patterson Creak at Queensway and Hunt Street, where spill would be expected to occur for the Regional Storm event. Based on the 1-dimensional (1D) modeling results, stream flow from Patterson Creek would be expected to spill over the Queensway into Kent Creek for the Regional Storm event. A further assessment using combined 1-dimensional (1D - channel) and 2-dimensional (2D – overbank and spill zone) elements may be warranted in this area accordingly.

In addition, several other locations have been identified which may warrant further study (such as 1D-2D hydraulic modelling) to better assess the flood extents:

- Upstream of Sutton Dam (ST40) – Lynn River (Simcoe)
  - The 100-Year floodline generated by the RAS Mapper as well as the Civil3D™ extends up to Mill Pond Ct. and Elizabeth Rd. However, the water surface elevation (WSE) immediately upstream of the Sutton Dam (XS1156.41) is lower than the upstream right bank top elevation and would therefore not spill into Elizabeth Rd.
  - Also, the modeling results indicate that the back water from the downstream section (XS 1146.83) would not reach the Elizabeth Rd/Riverside Rd elevation. Therefore, the 100-Year floodline has been manually adjusted based on Wood's engineering judgement, modelling results and topography.
  - Furthermore, there is a low point on the right bank immediately downstream of the confluence of Patterson Creek and Davis Creek (approximately 50 m downstream). Current 1D modeling results indicate that the 100-Year WSE is marginally (i.e. 10 cm) below the right embankment low point elevation and prevents spilling into Elizabeth Rd.
  - Considering the flow complexities at the confluence, limitations of the 1D modeling, and the topography of the area, more detailed 1D-2D hydraulic modelling may be warranted for this area.

- Quance Dam (ST30) – Lynn River (Simcoe)
  - The current 1D hydraulic modelling results indicate that the right overbank of the dam would be overtopped, resulting in spill onto Pond Street for the 100-year storm event.
  - In addition, a simulated drop in water surface elevation of some 1.14 m is indicated across the Quance Dam. As such, the floodplain limits delineated by HEC-GeoRAS and AutoCAD Civil3D™ indicate an abrupt transition which is likely not representative of actual spill flow.
  - Based on the preceding, the 100-year floodline along the right overbank has been manually adjusted to better reflect expected spill flow direction.

  - Notwithstanding, a combined 1D-2D approach may be more appropriate in this case to better define the extents of spill flow along the right overbank.
- Upstream of Park Road (ST54) – Patterson Creek
  - This tributary of Patterson Creek has been included in the current 1D HEC-RAS modelling, however floodplain mapping for this reach has not been generated due to the substantial simulated backwater upstream of the Park Road Crossing.
  - One potential approach for this crossing would be to complete a storage assessment (as has been applied for other embankment type crossings) by generating a stage-storage-discharge relationship for the structure, routing through the inflow hydrograph, and confirming how much the resulting simulated backwater elevation differs from that generated by the base 1D HEC-RAS modelling.
  - Alternatively, a combined 1D-2D hydraulic modelling approach could be considered, however may not be warranted depending on the outcomes of the preceding storage approach.
- Thompson Road East (ST122) – Nanticoke Creek (Villa Nova)
  - The delineation of the 100-year floodline in this area is complex, given the presence of a minor ridge or high point along the left overbank in proximity to an existing residence. The bounding cross-sections in this case indicate a relatively minor change in grade across the rear and front of the house (218.33 and 218.23 m respectively). The hydraulic modelling in this area is also relatively sensitive to potential changes in the 100-year flow.
  - LPRCA staff have noted that the residence in question has previously experienced riverine flooding, as such, it is considered that the base flood inundation mapping generated by the hydraulic modelling may not be accurately representing flooding limits in this area. Based on the preceding, the relatively minor change in grade across the hydraulic modelling cross-sections in this area, and the potential sensitivity of the floodline to changes in flow, the 100-year floodline has been manually updated based on Wood's engineering judgement.
  - Given the preceding, and the complexities of the grading around the residence, more detailed site survey may be warranted, which could in turn be combined with a more resolute 1D-2D hydraulic modelling approach to better define inundation extents around the subject property.

3.7.2 Floodline Validation

As a final general model validation/verification, the simulated floodplain extents have been compared against previously generated floodplain extents (i.e. LPRCA's currently approved regulatory floodplain mapping). While the previously completed floodplain mapping shall not be considered "correct", any areas where notable discrepancies (either greater or lesser) have been reviewed and assessed to confirm reasons for the identified differences.

In general, the floodlines generated as part of the current study are reasonably consistent with LPRCA's currently approved floodplain mapping. This is considered attributable to the fact that the applied peak flows for the current study are generally consistent with those previously applied, and that there have been minimal changes with respect to channel alignment, topography, or floodplain development as compared to the previously completed mapping. Some localized changes are indicated in the updated mapping, which may reflect more resolute topographic data in those cases or differences in hydraulic modelling simulation results due to updated software, or in some cases changes in the simulated backwater from hydraulic structures.

A comparison of identified inundated structures is presented in Table 3.10 between the previously completed mapping and information (as supplied by LPRCA) and the updated work completed by Wood for the current study.

Table 3.10: Comparison of Number of Inundated Structures

Watercourse	Community	100-Year Flood			Regional Flood		
		Previous (LPRCA)	Updated (Wood)	Change	Previous (LPRCA)	Updated (Wood)	Change
Big Otter Creek	Norwich	6	3	-3	46	27	-19
	Tillsonburg[1]	27	11	-16	99	38	-61
	Vienna and Port Burwell	115	109	-6	203	171	-32
Clear Creek	Cultus	12	11	-1	13	15	+2
Davis Creek (Lynn River)	Simcoe	0	1	+1	33	27	-6
Kent Creek (Lynn River)	Simcoe	98	135	+37	394	289	-105
Patterson Creek (Lynn River)[2]	Simcoe	18	7	-11	28	16	-12
Lynn River	Simcoe to Port Dover	80	174	+94	556	467	-89
Black Creek (Lynn River)	Port Dover	23	27	+4	37	37	0
Stoney Creek	Gilbertville	13	4	-9	13	10	-3
Nanticoke Creek	Waterford	5	13	+8	85	61	-24
	Villa Nova	6	1	-5	14	9	-5
Sandusk Creek	Garnett	5	3	-2	16	5	-11
	Jarvis	39	11	-28	64	66	+2
	Jarvis East	3	2	-1	9	11	+2
TOTAL	**ALL**	**450**	**512**	**+62**	**1,610**	**1,249**	**-361**

1. Updated (Wood) results do not include Cranberry Creek, as this was removed from the project scope based on discussions with LPRCA.
2. Updated (Wood) results do not include the tributary of Patterson Creek upstream of Park Road. This tributary requires further assessment due to simulated backwater upstream of the noted structure.

For the 100-year flood event (currently the Regulatory Event for LPRCA's jurisdiction), most of the changes by area presented in Table 3.10 are nominal, and generally involve slight decreases in the number of inundated properties. Notwithstanding, there is an overall increase in the total number of affected properties, which is generally attributable to two (2) specific sections. The most notable changes occur in:

- Kent Creek (Lynn River) in Simcoe – increase of 37 affected properties
- Lynn River (between Simcoe and Port Dover) – increase of 94 affected properties
- Jarvis – decrease of 28 affected properties

For the Regional Storm Event, there is contrarily an overall decrease in the number of affected properties. Most of the study areas consistently indicate a decrease in affected properties except for nominal increases in Cultus, Jarvis, and Jarvis East. The most notable changes again occur in:

- Big Otter Creek (Vienna to Port Burwell) – decrease of 32 affected properties
- Kent Creek (Lynn River) in Simcoe – decrease of 105 affected properties
- Lynn River (between Simcoe and Port Dover) – decrease of 89 affected properties
- Nanticoke Creek (Waterford) – decrease of 24 affected properties

The specific reasons for the identified differences cannot be clearly confirmed without undertaking a more fulsome review of the originally completed hydraulic modelling (HEC2) and associated input data and assumptions.

3.8 Hydraulic Structure Capacity Assessment

The results of the updated hydraulic modelling analysis have been used primarily to generate updated floodplain mapping and assess the number of structures expected to be at risk of flooding during both the 100-Year and Regional Storm Events. In addition, the modelling results have been reviewed to assess the simulated hydraulic structure capacity (i.e. bridges and culverts). Both the flood event which causes surcharging (i.e. water surface profile above the obvert or soffit elevation) and which causes overtopping (spill over the top of the road or railway embankment) have been identified; results are presented in Table 3.11. It should be noted that in certain cases a deficiency may be identified due to backwater conditions from a downstream constraint; the current results do not distinguish between such potential causes.

Table 3.11: Summary of Simulated Hydraulic Structure Capacity

Watercourse	Structure ID	Description	Class	Flood Event Causing Surcharging	Flood Event Causing Overtopping
Big Otter Creek (Norwich)	98	Trail	Local	-	-
	100	Stover Street South	Urban Arterial	-	Regional
	101	Pitcher Street	Collector	-	Regional
	102	Averys Lane	Collector	-	Regional
	103	Main Street West	Urban Arterial	-	Regional
	104	North Court Street	Collector	-	Regional
Big Otter Creek (Tillsonburg)	111	Highway 3	Rural Arterial	-	-
	114	John Pound Road	Collector	100 Year	Regional
	115	Baldwin Street	Collector	-	-
	117	Simcoe Street	Urban Arterial	-	-
Big Otter Creek (Vienna and Port Burwell)	106	Bridge Street	Rural Arterial	-	-
	107	Plank Road	Rural Arterial	100 Year	Regional
	108	Plank Road	Rural Arterial	100 Year	20 year
Clear Creek (Cultus)	94	Cultus Road	Collector	2 Year	100 Year
	97	Access Road	Local	-	2 Year
Davis Creek (Lynn River)	1	Second Avenue W	Collector	Regional	-
	41	First Avenue W	Collector	100 Year	Regional

Table 3.11: Summary of Simulated Hydraulic Structure Capacity					
Watercourse	**Structure ID**	**Description**	**Class**	**Flood Event Causing Surcharging**	**Flood Event Causing Overtopping**
	42	Former Railway	Local	-	-
	43	Davis Street W	Collector	-	Regional
	44	Fourteenth St W	Collector	2 Year	10 Year
	5	Norfolk St N	Urban Arterial	5 Year	Regional
	45	Fourteenth St E	Collector	5 Year	Regional
	46	Trail	Local	5 Year	Regional
	2	Fourteenth Street	Collector	-	Regional
	51	Thirteenth St W	Collector	100 Year	Regional
Kent Creek (Lynn River)	56	Colborne Street N	Collector	25 Year	100 Year
	57	Talbot Street N	Collector	-	10 Year
	58	Head Street N	Collector	100 Year	10 Year
	59	Windham Street	Collector	10 Year	10 Year
	60	Queen Street N	Collector	50 Year	100 Year
	61	Cedar Street	Collector	50 Year	100 Year
	62	Private	Local	-	5 Year
	64	Private	Local	-	2 Year
	65	Private	Local	-	2 Year
	6	Hillcrest Road	Rural Arterial	5 Year	50 Year
Patterson Creek (Lynn River)	52	Hunt Street North	Collector	-	Regional
	55	Former Railway	Local	Regional	
	3	Fourteenth Street	Collector	-	Regional
Lynn River	7	Walker St	Urban Arterial	-	-
	8	Chapman St E	Urban Arterial	Regional	-
	11	Prospect Street	Collector	-	Regional
	14	St John's Road East	Rural Arterial	-	-
	15	Blueline Road	Rural Arterial	-	Regional
	16	Pedestrian Bridge	Local	100 Year	Regional
	19	Ireland Road	Collector	-	Regional
	20	Lynn Valley Road	Collector	-	Regional
	21	Trail	Local	-	-
	22	Trail	Local	-	Regional
	25	Decou Road	Collector	-	Regional
	27	Pedestrian Bridge	Local	-	Regional
	29	Victoria Street	Collector	-	50 Year
	31	Argyle Street	Collector	-	Regional

Table 3.11: Summary of Simulated Hydraulic Structure Capacity

Watercourse	Structure ID	Description	Class	Flood Event Causing Surcharging	Flood Event Causing Overtopping
	32	Norfolk Street N	Urban Arterial	100 Year	Regional
	34	Norfolk Street N	Urban Arterial	-	50 Year
	38	Queensway East	Urban Arterial	-	Regional
	39	Norfolk St N	Urban Arterial	-	Regional
Black Creek (Lynn River)	10	Concession 2 Woodhouse	Collector	-	Regional
Stoney Creek	4	Pine Grove Road	Rural Arterial	10 Year	Regional
	91	Highway 3	Rural Arterial	5 Year	Regional
Nanticoke Creek (Waterford)	123	Thompson Road E	Rural Arterial	5 Year	20 Year
	124	Cockshutt Road	Rural Arterial	-	5 Year
	127	Conc 8 Townsend	Rural Arterial	-	50 Year
	128	Conc 8 Townsend	Rural Arterial		10 Year
	129	Main Street N	Urban Arterial	-	-
	133	Former Railway	Local	-	-
Nanticoke Creek (Villa Nova)	121	Former Railway	Local	-	-
	122	Thompson Road E	Rural Arterial	-	Regional
Sandusk Creek (Garnett)	86	Railroad	Rural Arterial	-	-
	88	Conc 10-W-1	Collector	100 Year	Regional
	89	Highway 6	Rural Arterial	-	-
	90	Conc 11-W-1	Collector	-	Regional
Sandusk Creek (Jarvis)	75	Private	Local	-	Regional
	76	Talbot Street East	Rural Arterial	Regional	-
	77	Walpole Street	Collector	Regional	-
	78	Peel Street W	Collector	-	Regional
	79	Main Street N	Urban Arterial	100 Year	Regional
	80	Lydia Street	Collector	-	Regional

Table 3.11: Summary of Simulated Hydraulic Structure Capacity

Watercourse	Structure ID	Description	Class	Flood Event Causing Surcharging	Flood Event Causing Overtopping
	82	Church Street	Collector	100 Year	Regional
	83	Mary Street	Collector	100 Year	Regional
	84	Trail	Local	-	-
	85	Nanticoke Creek Pkwy	Rural Arterial	-	Regional
Sandusk Creek (Jarvis East)	68	Conc 6-W-1	Collector		Regional
	71	Railroad	Rural Arterial	-	-
	72	Highway 3	Rural Arterial	10 Year	25 Year
	73	Railroad	Rural Arterial	-	100 Year
	74	Conc 8-W-1	Collector	5 Year	25 Year

The expected performance of a hydraulic structure varies depending on the class of roadway, with a higher standard required for more critical and heavily travelled roadways (i.e. highways, arterials) than local or private roadways. Overall, of the 87 structures included in Table 3.11, the majority (69) indicate no overtopping for storms less than the 100-year storm event (approximately 80%). The remainder (18) indicate varying degrees of performance, with overtopping indicated for storm events less than the 100-year storm event. Most of the structures with the greatest simulated frequency of overtopping (i.e. for a 2 or 5-year event) are private structures, which would not be a municipal responsibility to maintain or upgrade. Potentially undersized municipal hydraulic structures have been considered further as part of a mitigation analysis in Section 4.3.

4.0 Risk Assessment and Flood Damages

4.1 Flood Damage Calculations

The number of expected buildings inundated by the 100-Year flood and Regional Storm Event have been presented previously in Section 3.8. As per that assessment, a total of 512 buildings are located within the 100-Year floodplain while 1,249 buildings are within the Regional Storm floodplain.

In order to further quantify the potential implications of the estimated flood inundation, and in order to support the required Risk Assessment (discussed in further detail in Section 4.2), a flood damage calculation has been undertaken. The proposed approach relies on the methodology and data sources outlined in "Canadian Guidelines and Database of Flood Vulnerability Functions" (Natural Resources Canada and Public Safety Canada, March 2017). This document provides the most current depth-damage curves for Canada and are based on data collected from the 2013 flooding in Alberta (Calgary).

A GIS layer of building extents from member municipalities was provided by LPRCA to Wood for use in the calculation of flood damages. Small buildings (generally less than $20m^2$) have been removed, as it has been assumed that these would generally reflect minor features such as sheds and storage areas. Other buildings have been removed based on their attribute classification (such as WASHROOM, SILO, SHED, PORCH, GARAGE, BOATHOUSE, BARN, QUONSET, or GREENHOUSE).

Notwithstanding the preceding, the limited amount of building attribute data necessary for flood damage calculations was available in the information provided. In order to supplement the available data, LPRCA staff undertook a focused site reconnaissance effort for the most vulnerable areas, identified as the Community of Vienna, and the Town of Simcoe. A total of 472 residences were surveyed through this process (59 in Vienna, and the remaining 413 in Simcoe). Information collected by LPRCA staff for the selected residences included:

- Estimated class of residential building consistent with the "Canadian Guidelines and Database of Flood Vulnerability Functions"
    - Class A
    - Class B
    - Class C
    - Class MW (Multi-family, 4 stories or less)
    - Class MA (Multi-family, 5 stories or more)
- Whether or not a basement was evident for the structure
- Location of the front door (side of the house)
- Estimated height above ground elevation of the front door

With respect to building class, classifications for other areas (where field reconnaissance was not completed) based on best available information such as building "TYPE" attribute in the GIS building layer. Aerial Photography and Google Streetview™ have been used to differentiate building classifications generally (i.e. residential or non-residential) and more specifically (i.e. sub-class). For residential areas, some classification has been completed based on commonalities with areas where the field reconnaissance was completed (i.e. for the balance of Vienna and Simcoe). Additional information, such as building footprint area, has been used to assist the residential building classification, with larger footprints assumed to correlate with higher value residences (i.e. Class A - area greater than 220 m^2 ; Class B – area greater than 110 m^2; Class C – area smaller than $110m^2$). Assessed property value was not applied in the assignment of building classification. Non-residential buildings have been classified into the following four sub-classes:

- Class S1 (Shop or Commercial)
- Class S2 (Industrial)
- Class S3 (Resort Dwelling – i.e. Hotel/Motel)
- Class S5 (Institutional or Recreational)

In order to calculate the flood depth of each affected property, the building polygon layer was used to sample the source DTM, with the lowest resulting elevation applied. The first-floor elevation has been determined using this elevation plus the field measured front door offset height (where available) or an assumed 0.7 m height for residential buildings (4 steps ±) or 0.2 m for non-residential buildings (i.e. commercial and institutional buildings – closer to grade).

For residential buildings, data on whether or not a basement is present has been applied based on the field reconnaissance, where available. Similar to the approach to the building classification, commonalities with areas where the field reconnaissance was completed (i.e. Vienna and Simcoe) have been used to determine the typical presence of basements for other adjacent areas, along with available information from Google Streetview™ for typical areas. Where no such information is available, it has generally been assumed that a basement is present.

A raster of the simulated floodplain elevations has been developed using GIS tools, and used to determine the corresponding maximum flood elevation at the intersect of each inundated building polygon. The preceding data regarding estimated first floor elevation has then been used to determine the corresponding maximum flood depth relative to this elevation. Basement elevations have been assumed to be 2.7 m below the first-floor elevation.

In addition to directly inundated properties, the guidelines include a 75 m buffer from the floodline for groundwater flooding impacts (i.e. basement flooding). This buffer has been applied accordingly, however a verification calculation has been undertaken to check whether the flood level would in fact be greater than the estimated basement floor elevation (calculated using the same methodology as noted previously). If not, then these properties have been removed from the damage calculation, despite their inclusion in the 75 m buffer.

Flood damage calculations have been completed based on the curves available in the previously noted reference (NRCan/PSC, March 2017). The residential building damage curves are based on a combination of both structure and content repair/replacement costs. For non-residential buildings, a great deal of information on damage costs are available for specific consideration regarding contents depending on the specific type of business under consideration (i.e. an electronics store, medical building, hardware store, etcetera). For the purposes of the current study, non-residential contents have been more broadly categorized into the following categories:

- Class C6 (Shop or Commercial – Retail)
- Class L1 (Industrial)
- Class H1 (Resort Dwelling – Hotels)
- Class N1 (Institutional and Recreational)

It should be noted that the preceding focuses only on structure and content damages only. As per the guidelines (NRCan/PSC, March 2017), damages should also be considered for residential displacement impacts (i.e. cost associated with temporary accommodation outside of the home in a hotel room, apartment or otherwise), as well as business disruption impacts (lost productivity associated with temporary closure of business or other limitations). These additional damages have not been included in the current calculations.

Detailed flood damage calculations have been included in Appendix E. A summary of flood damage calculations is presented in Table 4.1 for the 100-year flood event, and Table 4.2 for the Regional Storm Event. Damages have been rounded up to the nearest $1,000 increment.

Table 4.1: Flood Damage Calculations (Building Structure and Contents) – 100-Year Storm Event

Watercourse	Community	Affected Buildings			Flood Damages (Structure and Contents)		
		Residential	Non-Resid	Total	Residential	Non-Resid	Total
Big Otter Creek	Norwich	34	1	35	$3,530,000	$22,000	$3,552,000
	Tillsonburg	28	4	32	$3,678,000	$4,120,000	$7,797,000
	Vienna and Port Burwell	116	11	127	$15,905,000	$1,624,000	$17,529,000
Clear Creek	Cultus	10	1	11	$1,336,000	$73,000	$1,409,000
Davis Creek (Lynn River)	Simcoe	21	-	21	$2,808,000	-	$2,808,000
Kent Creek (Lynn River)	Simcoe	197	4	201	$19,386,000	$566,000	$19,951,000
Patterson Creek (Lynn River)	Simcoe	9	2	11	$1,682,000	$1,190,000	$2,872,000
Lynn River	Simcoe to Port Dover	217	36	253	$21,457,000	$8,583,000	$30,040,000
Black Creek (Lynn River)	Port Dover	21	2	23	$4,439,000	$519,000	$4,957,000
Stoney Creek	Gilbertville	15	1	16	$2,008,000	$53,000	$2,060,000
Nanticoke Creek	Waterford	21	-	21	$2,419,000	-	$2,419,000
	Villa Nova	6	-	6	$621,000	-	$621,000
Sandusk Creek	Garnett	13	-	13	$1,526,000	-	$1,526,000
	Jarvis	52	-	52	$5,178,000	-	$5,178,000
	Jarvis East	13	-	13	$2,150,000	-	$2,150,000
TOTAL	**ALL**	**773**	**62**	**835**	**$88,123,000**	**$16,750,000**	**$104,869,000**

As evident from Table 4.1, the number of affected properties is greater than that previously presented (512 as per Table 3.8); this is attributable to the inclusion of properties expected to be affected by basement flooding due to saturated ground conditions (i.e. within 75 m buffer of the floodline). The results indicate total estimated flood damages of $88M for residential properties, and $17M for non-residential properties, for a total of $105M. As noted, this does not include any additional damages due to displacement (residential) or loss of productivity (non-residential). The greatest overall damages are indicated for the Community of Vienna ($17M), the Town of Simcoe ($26M) and the section of the Lynn River between Simcoe and Port Dover ($30M). These areas account for 70% of the total estimated flood damages.

Table 4.2: Flood Damage Calculations (Building Structure and Contents) – Regional Storm Event							
Watercourse	Community	Affected Buildings			Flood Damages (Structure and Contents)		
		Residential	Non-Resid	Total	Residential	Non-Resid	Total
Big Otter Creek	Norwich	67	3	70	$7,452,000	$845,000	$8,296,000
	Tillsonburg	39	15	54	$6,054,000	$7,018,000	$13,072,000
	Vienna and Port Burwell	123	14	137	$24,307,000	$3,888,000	$28,194,000
Clear Creek	Cultus	11	1	12	$1,468,000	$78,000	$1,468,000
Davis Creek (Lynn River)	Simcoe	61	5	66	$9,087,000	$786,000	$9,873,000
Kent Creek (Lynn River)	Simcoe	234	9	243	$33,515,000	$2,119,000	$35,633,000
Patterson Creek (Lynn River)	Simcoe	13	3	16	$1,940,000	$2,237,000	$4,176,000
Lynn River	Simcoe to Port Dover	338	74	412	$59,786,000	$42,131,000	$101,916,000
Black Creek (Lynn River)	Port Dover	28	2	30	$11,605,000	$831,000	$12,435,000
Stoney Creek	Gilbertville	28	3	31	$3,810,000	$338,000	$4,148,000
Nanticoke Creek	Waterford	70	-	70	$11,431,000	-	$11,431,000
	Villa Nova	7	-	7	$1,319,000	-	$1,319,000
Sandusk Creek	Garnett	23	-	23	$2,768,000	-	$2,768,000
	Jarvis	131	1	132	$15,529,000	$60,000	$15,588,000
	Jarvis East	20	1	21	$3,342,000	$1,004,000	$4,345,000
TOTAL	**ALL**	**1,193**	**131**	**1,324**	**$193,407,000**	**$61,329,000**	**$254,735,000**

Similar to Table 4.1, the number of identified impacted buildings in Table 4.2 is greater than previously identified (in Table 3.8 – 1,249) due to the inclusion of a 75 m groundwater impact buffer. Estimated flood damages for the Regional Storm are approximately 2.5 times that for the 100-year storm, with total damages of $255M ($193M for residential and $61M for non-residential). As with the 100-year storm event, the majority of these damages occur for Vienna and Port Burwell ($28M) and the Simcoe area ($152M). With the inclusion of Black Creek for Port Dover ($11M), the total for these areas again represents the majority of the total damages (75%). Notable damages are also indicated for Jarvis ($16M) and Waterford ($11M) and Tillsonburg ($13M).

4.2 Risk Assessment

4.2.1 Overview

The completion of the National Disaster Mitigation Program (NDMP) Risk Assessment Information Template (RAIT) is a key requirement of the NDMP program. An initial version of the RAIT was completed by LPRCA staff in support of the application to the NDMP program; the RAIT is proposed to be updated based on the information and data generated as part of the current study, including information related to inundated buildings and associated flood damage potential, as per Section 4.1. The RAIT generally considers various potential impacts to People and Society, Environment, Local Economy, Local Infrastructure, and Public Sensitivity. The RAIT considers the potential magnitude of these impacts, as well as, the expected likelihood of occurrence, and estimated confidence level in the estimated results given the difficulty in estimating certain parameters.

In support of this task, LPRCA and Wood facilitated RAIT workshop sessions for those areas with the greatest identified flood risk and impact, namely the Community of Vienna (within the Municipality of Bayham, Elgin County) and Norfolk County. The potential to hold additional RAIT workshops was discussed with other communities within the study area (Haldimand County and Oxford County in particular), however it was agreed that a formal workshop was not warranted or required in both cases. Ultimately the input received from member municipalities has been applied to update the RAIT to reflect the best available information.

4.2.2 Municipality of Bayham (Vienna)

The RAIT workshop with the Municipality of Bayham was held on February 6, 2020 at the Town's offices in Straffordville. Attendees from the Municipality included:

- Paul Shipway, CAO
- Randy White, Fire Chief
- Ed Roloson, Manager of Water/Wastewater
- Steve Adams, Public Works Operations Supervisor

There was notable discussion regarding the recent (February 2018) riverine flooding event in Vienna. The event resulted in 100-year water levels, though not 100-year flows, due to the impacts of heavy pack ice (approximately 1 foot thick) and ice jamming. Municipal staff commented that the event was the most notable in the community since 2008. Municipal staff confirmed that the 100-year flooding extents indicated in Wood's updated mapping approximately matched the flooding extents witnessed during that event. Staff noted that homes on the east side of Plank Road (Chute Line to Oak Street) and along Edison Drive (including to the north of the creek) experienced flooding and were evacuated. All three (3) bridges in this area are considered critical infrastructure, in particular the "bailey bridge" along Edison Drive, as this is the only access for residents in that area. Overall, flooding recovery was 1 day or less

With respect to at risk infrastructure, staff noted there is a sanitary pumping station in Vienna near the intersection of Front Street and Plank Road, which was affected by the flooding event. Once floodwaters overtop the roadway, there is an excessive amount of inflow to the pumping station, which results in the pumping station becoming overwhelmed, which can in turn result in basement flooding for area residents. There is a wastewater treatment plant (WWTP) in Port Burwell along Chatham Street, however this facility has no history of bypasses or flooding, including recent Lake Erie flooding events. There are no expected impacts to drinking water systems, given that water is municipally supplied via an off-site treatment plan which is not considered to be at risk of flooding impacts.

Municipal staff provided the following input to the RAIT:

- Fatalities
    - Generally, it was suggested that fatalities from flooding were of low probability, particularly if residents follow the advice and direction of municipal staff.
    - There are no specific vulnerable populations in the Regulatory flood zone (i.e. hospitals, retirement or nursing homes, etcetera).
- Displacement
    - Municipal staff noted that following the 2018 flood, residents returned to their residences relatively quickly. Hydro meters that were removed during the flood were generally restored the following day. As a result of the 2018 event, the municipality declared an emergency, requested Provincial assistance, and applied for Provincial disaster relief funding.

- Environment
  - Overall sanitary back-up (basement flooding) impacts were generally limited.
  - More serious environmental impacts have occurred as a result of residents storing waste barrels, propane cylinders and other materials in close proximity to the creek; a notable amount of waste was noted along the creek banks in Vienna.
  - No flooding of the area gas station or other fuel spills were noted.
- Economy
  - Impacts to local economy or businesses due to the flooding were considered minimal.
- Transportation
  - Roadways were closed for approximately 30 hours during the flood period, however alternative routes were available for area transport.
  - Minimal damage was noted to area roadways (gravel and asphalt).
- Energy and Utilities
  - Both electricity and gas services were restored by the morning after the flooding.

Other flood-prone areas within the Municipality of Bayham were noted, including Culloden Road, a culvert in the vicinity of Sandytown and Eden Line, Bayham Drive at Highway 3, and Richmond Road.

Municipal staff indicated that, in their opinion, there were no "low hanging fruit" with respect to potential flood mitigation in the Vienna area or elsewhere along Big Otter Creek. It was generally acknowledged that properties along Big Otter Creek are at risk of riverine flooding. It was noted that Plank Road bridges in Vienna and the Port Burwell Pier are susceptible to ice jamming.

4.2.3 Norfolk County

The RAIT workshop with Norfolk County was held on February 13, 2020 at the County's offices in Simcoe. Attendees from Norfolk County included:

- Jeff Demeulemeester, Project Manager - Public Works
- Shawn Vanacker, Director Roads
- James Robertson, Captain, Community Safety Officer (Emergency Management)
- Gord Stilwell, Acting Fire Chief
- Richard Roberts, Supervisor - GIS

It was noted that Norfolk County has previously completed its own Hazard Identification and Risk Assessment (HIRA) process in 2019, which considered a broad suite of hazards, along with the associated frequency of occurrence and associated consequence (damage). Flood was ranked as #8, reflecting a frequency of "likely" and an associated level of risk of "high".

County staff noted that there are no issues with major flooding issues on roadways, and any flooding is typically nuisance flooding for owners located directly adjacent to watercourses. Staff noted that although the updated (and previous) riverine floodplain mapping indicates flooding for multiple watercourses in Simcoe, this has not been observed by staff. Staff noted that some flooding has occurred historically near the Queensway (by the Tim Hortons) and along Riverside Drive (near the Sobeys), however both are considered related to urban drainage issues (catchbasins).

Within Port Dover, staff noted that the bridge on Concession 2 was re-constructed approximately 10 years ago and included raising of the road profile. The water level has however been observed to be close to the roadway previously during storm events.

Within Waterford, elevated water levels close to the road have been noted along Concession 8 Townsend. Similarly, elevated water levels have been noted in the vicinity of Cockshutt Road and Thompson Road, but there has never been flooding on to the road.

With respect to other areas, no flooding has been observed in Cultus, which is consistent with LPRCA staff observations. County staff did note that flooding has been observed along Pinegrove Road in Gilbertville.

4.3 Potential Mitigation Measures

Based on the results of the preceding sections, a high-level review of potential mitigation measures to address flood-prone areas (those with an identified elevated flood risk and associated flood damages) has been undertaken.

Policy measures have also not been considered as part of the current review. Notwithstanding, such measures may warrant further consideration by the LPRCA and its Municipal partners. Currently, the 100-year flood is the Regulatory Event for the LPRCA. It should be noted that for the majority of the other Conservation Authorities in Southern Ontario, the Regulatory Event is the greater of the 100-year flood or the Regional Storm Flood (in this case, Hurricane Hazel). Adoption of the Regional Storm as the Regulatory Event would result in a greater control over the number of potentially flood vulnerable properties, however consideration of such a change is beyond the scope of the current study. Likewise, policies which consider the acquisition of flood-prone properties (and associated conversion to recreational or more passive land uses) can be effective in mitigating future flood damages, however such policies are beyond the scope of the current study.

The flood mitigation analysis has been restricted to hydraulic improvements only; no consideration of potential hydrologic changes (i.e. additional upstream storage through new dams or reservoirs, retroactive stormwater management controls for urban areas, flow diversions or bypasses, etcetera) has been made as this is beyond the scope of the current study. It should be noted that further hydrologic studies may be completed in the future, including additional flow monitoring and model calibration studies, which may potentially result in reduced estimates of flood flows, which would also reduce the associated estimated flood risk. Given the magnitude of the identified flood risk, and associated minimal observed historic flooding, the Lynn River watershed may be a candidate for such a further study. This is again however beyond the scope of the current study.

Further, hydraulic mitigation measures have not considered channel works (berming and cut/fill analyses) given the complexities of these types of works including grading and property constraints. Related infrastructure works (such as inflow/infiltration reduction, sanitary sewer system sealing, etcetera) have also not been considered, as this is beyond the scope of the current study.

Potential mitigation measures have therefore generally been restricted to two (2) types: dam removals (i.e. of previously decommissioned dams where structures/features have been left in place) and hydraulic structure improvements (i.e. structure upgrades/upsizing). Further hydraulic structure upgrades have been limited to public structures; private structures would be the responsibility of those affected landowners.

With respect to dam structure removal, dams and associated inline structures considered as part of the current study have been presented in Tables 3.6 and 3.7. Of these, only two (2) have been decommissioned but remain in place; the former Sutton Dam (Patterson Creek) and the former Brooks Dam (Lynn River). Full mitigation through the removal of these remnant structures has been considered and simulated results are presented in Table 4.3, both with respect to the simulated reduction in water surface elevations but also the estimated reduction in number of inundated properties.

With respect to hydraulic structure improvements, the simulated performance results presented in Table 3.11 have been reviewed to assess those public crossings which are indicated as having deficient conveyance capacity, either with respect to simulated surcharging or overtopping. Based upon an initial feasibility review, it was noted that many of the identified deficient structures are already generally maximized based on the existing channel width or roadway height, and that a further upgrade would likely not be feasible. As such, a limited number of potential public hydraulic structure improvements have been identified. Results are again presented in Table 4.3, both with respect to the simulated reduction in water surface elevations but also the estimated reduction in number of inundated properties.

Table 4.3: Summary of Potential Mitigation Measures and Estimated Benefit

Works Type	Location and Description	100-Year Flood		Regional Flood	
		Reduction in Inundated Properties[1]	Maximum Reduction in Flood Level (m)	Reduction in Inundated Properties[1]	Maximum Reduction in Flood Level (m)
Dam Removal	Former Sutton Dam (ST40) - Lynn River	0 (5+/-)	0.30	0 (5+/-)	0.20
	Former Brooks Dam (ST26) - Lynn River	0 (10+/-)	1.09	0 (10 +/-)	0.24
Structure Replacement	Fourteenth Street West (ST44) – Davis Creek (1.2 m x 0.6 m CSPA to 2.4 m x 1.5 m box culvert)	1 (9+/-)	3.37	0 (5+/-)	0.30
	Cultus Road (ST94) – Clear Creek (1.2 m x 1.1 m CSPA to 1.8 m x 1.2 m box culvert)	1 (7+/-)	0.88	0 (6+/-)	0.02
	Highway 3 (ST91) – Stoney Creek (5.5 m x 1.6 m Bridge to 8.5 m x 1.6 m Bridge)	0 (2+/-)	0.24	0 (2+/-)	0.03

1. First value is direct affected/inundated properties, second number refers to additional properties removed from the 75 m groundwater inundation buffer (as per flood damage calculations described in Section 4.1)

The simulated results for the former Sutton Dam indicate that complete removal of the structure would have a relatively modest benefit, with a reduction of 0.30 m and 0.20 m for the 100-Year and Regional Floods respectively; only those properties on the flood fringe (i.e. expected to be impacted by groundwater flooding impacts) would be removed. A greater overall benefit is indicated for the removal of the former Brooks Dam structure with respect to both water levels (maximum reduction of 1.09 and 0.24 m) and inundated properties (again, only within the 75 m groundwater flooding impacts).

With respect to hydraulic structures, a notable deficiency was identified for the Fourteenth Street West crossing of Davis Creek (ST44) within Simcoe. Upgrading the existing 1.2 m x 0.6 m CSP arch culvert to a concrete box culvert, more consistent with adjacent crossings, would result in a notable backwater reduction, with the 100-year flood level reduced by a maximum of 3.37 m (which would also remove 1 property from the direct flood inundation area, and a further 9 from the associated 75 m groundwater flooding buffer). Although not directly presented in Table 4.3, the potential upgrade would have similar benefits for more frequent storm events, such as the 5-year storm event (maximum flood level reduction of approximately 3 m).

The Cultus Road crossing (Clear Creek) has also been identified as deficient based on simulated hydraulic modelling results. As noted in previous sections, a storage-discharge modelling approach was undertaken to consider the large valley storage available, however this approach resulted in a relatively modest reduction in simulated water levels. The existing CSP arch culvert was surveyed by LPRCA staff for the current study and appears to be partially sedimented based on overall creek profiles. A potential upgrade to an appropriately sized concrete box culvert (including associated channel profile modifications to ensure a consistently positive grade) has been assessed. The potential upgrade would reduce 100-year flood levels by an estimated maximum of 0.88 m and remove one (1) property from the flood inundation limit (a further 7 properties would be removed from the associated 75 m groundwater buffer zone). More modest reductions are indicated for the Regional Storm Event.

Lastly the Highway 3 crossing in Gilbertville (Stoney Creek) has been assessed for potential mitigation measures. Similar to Cultus Road, this crossing was assessed using a storage-discharge approach (as per Table 3.6) to account for potential upstream storage. Overall, this approach yielded a negligible change in simulated water levels as compared to the base modelling approach. Based on existing channel geometry and roadway elevations, there is no potential to increase the height of the subject structure, however a potential 3 m widening of the crossing has been assessed. As evident from Table 4.3, the overall benefits are limited, with a maximum water level reduction of 0.24 and 0.03 m for the 100-Year and Regional Floods, and a removal of only 2 properties from the estimated 75 m groundwater flooding buffer.

5.0 Consultation

5.1 Public Consultation

A series of Public Information Centres (PICs) were held as part of this technical study to present the results to the public and collect feedback and information. PICs were held at two stages of the study, PIC No. 1 and PIC No. 2, each taking place at three (3) locations, resulting in a total of six (6) open houses.

5.1.1 Public Information Centre #1

Event Description and Background Information

PIC No. 1 was held at three locations within the study area in different communities in order to increase accessibility and attendance. Each PIC was held from 6:00 pm to 8:00 pm at the following locations:

1. LPRCA Head Office, located at 4 Elm Street, Tillsonburg on Tuesday, November 26, 2019
2. Simcoe Recreation Centre, located at 182 South Drive, Simcoe on Wednesday, November 27, 2019
3. Vienna Community Centre, located at 26 Fulton Street, Vienna on Thursday, November 28, 2019

Notification for the PIC was sent by LPRCA to stakeholders, local residents and agencies by e-mail, and information regarding the PIC was also advertised on the LPRCA and local municipality websites and media accounts. PIC No. 1 provided an opportunity for the public and stakeholders to review background information related to the Riverine Flood Hazard Assessment. The information was presented on display boards for participants to review at their own pace. In addition to display boards, participants were given the opportunity to view the past and draft updated floodplain mapping in areas of interest to them on a laptop computer. Participants at the PIC were encouraged to provide input on area issues and opportunities through conversation with consultant team representatives and LPRCA staff, and by completion of provided comment sheets.

Information Presented

The following background information, project scope and next steps were presented on display boards:

- Flood Risk
    - Types of Flooding
    - Watercourse Flooding Throughout the Season
    - Flood Information
- What is Flood Hazard Mapping?
- Project Scope
    - Purpose
    - Schedule
    - Key Tasks
- Project Study Areas
- Background Review and Field Work
- Draft Base Mapping
- Next Steps and Schedule

Summary of Feedback and Attendance

PIC No. 1 in Tillsonburg - November 26, 2019

The attendance record was signed by two (2) individuals, and no comment forms were received.

PIC No. 1 in Simcoe – November 27, 2019

The attendance record was signed by 18 individuals, and two comment forms were received. Feedback included positive review of location, format and project team members present. Additional comments included a request for the Shoreline Flooding Hazard Assessment document and information regarding a specific stream reach that was levelled in the past.

PIC No. 1 in Vienna – November 28, 2019

The attendance record was signed by 15 individuals, and no comment forms were received.

A copy of all materials from PIC No. 1, including notices, PIC boards and received comments forms have been included in Appendix F1.

5.1.2 Pubic Information Centre #2

Event Description and Background Information

PIC No. 2 was held at three locations within the study area in different communities in order to increase accessibility and attendance. Each PIC was held from 6:00 pm to 8:00 pm at the following locations:

1. Vienna Community Centre, located at 26 Fulton Street, Vienna on Wednesday, February 19, 2020
2. LPRCA Head Offce, located at 4 Elm Street, Tillsonburg on Wednesday, February 26, 2020
3. Simcoe Recreation Centre, located at 182 South Drive, Simcoe on Thursday, February 27, 2020

Notification for the PIC was sent by LPRCA to stakeholders, local residents and agencies by email, and information regarding the PIC was also advertised on the LPRCA and local municipality websites and media accounts. PIC No. 2 provided an opportunity for the public and stakeholders to review background information related to the Riverine Flood Hazard Assessment, project updates, and provide input regarding areas of flooding. The information was presented on display boards for participants to review at their own pace. In addition to display boards, participants were given the opportunity to view the past and draft updated floodplain mapping in areas of interest to them on a laptop. Participants at the PIC were encouraged to provide input on area issues and opportunities through conversation with consultant team representatives and LPRCA staff, and by completion of provided comment sheets.

Information Presented

The following background information, project scope and updates, and next steps were presented on display boards:

- Flood Risk
    - Types of Flooding
    - Watercourse Flooding Throughout the Season
    - Flood Information
- What is Flood Hazard Mapping?
- Project Scope
    - Purpose
    - Schedule
    - Key Tasks

- Project Study Areas
- Background Review and Field Work
- Riverine Floodplain Mapping
- Why Does Floodplain Mapping Change?
- Next Steps and Schedule

Summary of Feedback and Attendance

Vienna – February 19, 2019

The attendance record was signed by 9 individuals, and no comment forms were received. Oral feedback during the PIC was generally positive and mostly consisted of interested citizens inquiring about their specific property and the purpose of the study.

Tillsonburg - November 26, 2019

There was zero attendance at the Tillsonburg PIC No. 2.

Simcoe – November 27, 2019

The attendance record was signed by 12 individuals, and no comment forms were received. Oral feedback during the PIC was generally positive and mostly consisted of interested citizens inquiring about their specific property and the purpose of the study.

A copy of all materials from PIC No. 2, including notices, PIC boards and received comments forms have been included in Appendix F1.

5.1.3 Miscellaneous Consultation

In addition to the consultation that occurred as part of PIC No. 1 and PIC No. 2, the following consultation with members of the public took place:

- A Port Dover resident called regarding whether their property was located within the riverine floodplain limits; Wood forwarded on the information to LPRCA staff to respond.
- The Port Dover Waterfront Preservation Association contacted the Project Team regarding the Silver Lake Revitalization Project and the potential involvement of Wood as the consultants. Members from this organization attended both PIC No. 1 and 2 at the Simcoe location and
- McNally Brown Group contacted the Project Team regarding the dates of the upcoming PIC and requested to be added to the Project Contact List.

5.2 Indigenous Consultation

Indigenous consultation is a key component of public works, and as part of the study the following actions were undertaken to engage Indigenous Communities.

Mississaugas of the New Credit First Nation (MNCFN)

On November 12, 2019, LPRCA shared an introductory letter and information package with MNCFN. The purpose of this letter was to introduce the project and determine if MNCFN had an interest in the study. Included with the letter was a copy of the Notice of Commencement and PIC No. 1, and figures depicting the project study areas. No response was received.

On January 2, 2020, LPRCA shared a letter with MNCFN which provided an overview of the study, including the purpose and scope, the upcoming dates and locations of PIC No. 2, and inquiry whether MNCFN had an interest in the study. Included with the letter was a copy of the Notice for PIC No. 2, and figures depicting the project study areas. No response was received.

Six Nations of the Grand River (SNGR)

On November 12, 2019, LPRCA shared an introductory letter and information package with SNGR. The purpose of this letter was to introduce the project and determine if SNGR had an interest in the study. Included with the letter was a copy of the Notice of Commencement and PIC No. 1, and figures depicting the project study areas. No response was received.

On January 2, 2020, LPRCA shared a letter with SNGR which provided an overview of the study, including the purpose and scope, the upcoming dates and locations of PIC No. 2, and an inquiry whether SNGR had an interest in the study. Included with the letter was a copy of the Notice for PIC No. 2, and figures depicting the project study areas. No response was received.

A copy of all materials regarding MNCFN and SNGR consultation can be found in Appendix F2.

5.3 Stakeholder Consultation

Key stakeholder groups, identified through past experience of the LPRCA and its municipal partners, were consulted as part of the study. LPRCA shared a letter on January 2, 2020, which provided an overview of the study, including the purpose and scope, the upcoming dates and locations for PIC No. 2, and an invitation to share any questions or comments regarding the study with LPRCA.

This letter was shared with the following key stakeholder groups:

- Christian Farmers Federation of Ontario
- National Farmers Union – Local 306 (Elgin)
- National Farmers Union – Local 301 (Haldimand & Norfolk)
- Elgin Federation of Agriculture
- Haldimand Federation of Agriculture
- Norfolk Federation of Agriculture
- Oxford County Federation of Agriculture

No responses were received.

A copy of all materials regarding stakeholder consultation can be found in Appendix F3.

5.4 Municipal Consultation

The LPRCA and its local municipal partners work collaboratively together, and the following municipalities within Long Point Region were consulted throughout the duration of the study:

- Oxford County
- Norfolk County
- Town of Tillsonburg
- Municipality of Bayham
- Elgin County

Local municipalities were consulted at the following key decision-making points:

- Project Kick-off Meeting, April 25, 2019
- Project Team Meeting, October 25, 2019
- PIC No. 1 and PIC No. 2
    - o Consultation occurred with each municipality leading up to the PIC, as they assisted in selecting a location for the PIC, advertising the PIC on their platforms (websites, newspapers, social media), and municipal staff attended each respective PIC.

- Risk Assessment Workshops:
    - A Risk Assessment Workshop was held with the Municipality of Bayham and Norfolk County, as identified in Section 4.2.
- Project Team Meeting, January 29, 2020

Local municipalities will be circulated on the final study report. LPRCA will work collaboratively with its municipal partners to integrate the updated flood hazard mapping into their respective municipal hazard mapping.

6.0 Summary and Conclusions

The current Technical Report has been prepared to document the work completed in support of the Long Point Region Conservation Authority's Riverine Flood Hazard Mapping Update Study. This study has involved the generation of updated hydraulic modelling and associated floodplain mapping for some 89 km of watercourse in the identified most flood-prone areas within the watershed, including the completion of an updated hydraulic structure inventory for the subject reaches. As demonstrated by the current technical report, the hydraulic modelling work has been completed in accordance with relevant guidelines and standards, as well as best professional practices.

In addition to the core hydraulic modelling and floodplain mapping generation effort, updated flood damages have been calculated for both the 100-Year Flood and Regional Storm event. These updates calculations have supported the completion of the Risk Assessment Information Template (RAIT) which is a fundamental component of the current overall study.

Municipal staff and stakeholders from The Town of Tillsonburg, Oxford County, Township of Norwich, Municipality of Bayham, Elgin County, Norfolk County, and Haldimand County participated on the Project Team. Municipal team member were primarily from planning, geographic information systems, and public works divisions within the respective municipalities. The team met at key times throughout the project to provide consultation and input, coordinate public consultation, and review deliverables.

Consultation with affected municipal stakeholders has been completed as part of the current study, to inform this process.

A scoped review of potential mitigation measures has also been undertaken as part of the current study. Overall, it is considered that there are limited measures related to potential hydraulic structure improvements and former dam structure removals; notwithstanding some potential measures have been noted. Further flood mitigation measures may warrant further consideration as part of a separate study.

Public consultation has been undertaken in conjunction with the current study, with two (2) separate Public Information Centres (PICs) being held over the course of the study to provide an opportunity for the public to review and comment on study progress and results. The outcomes of these sessions have been incorporated into the current study reporting accordingly.

Yours truly,

Wood Environment & Infrastructure Solutions
a Division of Wood Canada Limited

Per: Matt Senior, M.A.Sc., P.Eng.
Associate Water Resources Engineer

LICENSED PROFESSIONAL ENGINEER
M. J. SENIOR
100118537
3/31/2020
PROVINCE OF ONTARIO

Per: Priyantha Hunukumbura, Ph.D., P.Eng.
Water Resources Engineer

LICENSED PROFESSIONAL ENGINEER
P.B.HUNUKUMBURA
100230595
03/31/2020
PROVINCE OF ONTARIO

MJS\PH\PN