Lake Ontario Shoreline Management Plan

Prepared for:

Central Lake Ontario Conservation Authority

Ganaraska Region Conservation Authority

Lower Trent Region Conservation Authority

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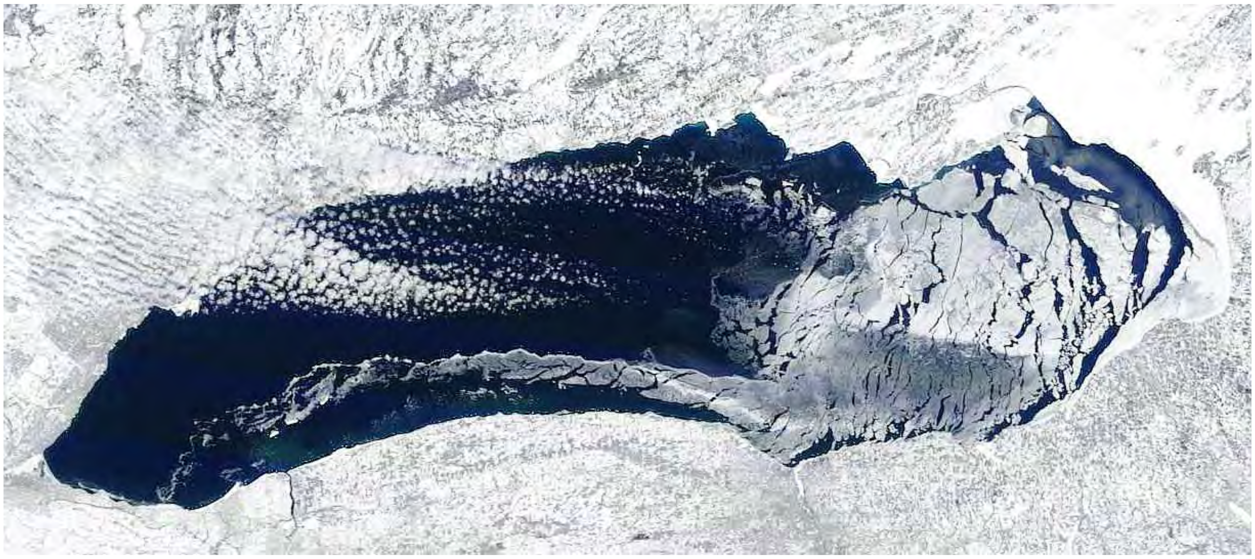
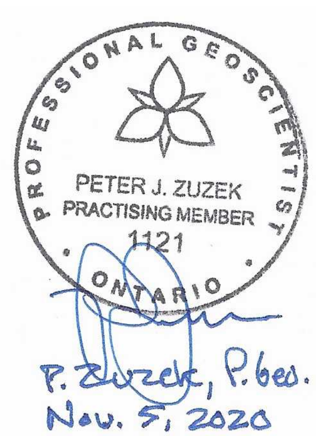
Zuzek inc.
ONE WORLD

March 6, 2014 MODIS Satellite Image of Lake Ontario





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EXECUTIVE SUMMARY

Zuzek Inc. and SJL Engineering Inc. were retained by the Central Lake Ontario (CLOCA), Ganaraska (GRCA) and Lower Trent Region (LTRCA) Conservation Authorities to develop an updated Shoreline Management Plan (SMP) for their respective Lake Ontario shorelines. The SMP replaces the original SMP for the region, which was prepared in 1990 by Sandwell Swan Wooster (SSW, 1990). The total shoreline length covered by the SMP is approximately 135 km and stretches from Lakeside Neighbourhood Park in Ajax (CLOCA west boundary) to Carrying Place, Quinte West (LTRCA east boundary).

The development of the updated SMP was guided by several principles and objectives, as discussed in Section 1.0 of this document. The overarching principle guiding the study is to promote sustainable coastal development in the future through integrated coastal zone management. To accomplish this, a sustainable balance must be achieved between environmental, social, economical, cultural and recreational objectives when making management decisions and planning for new development along the shoreline. The key objectives of the SMP are to increase the resilience of coastal communities, protect new development from coastal hazards, update existing hazard mapping using the best available information, incorporate nature-based solutions, protect and enhance existing private and public amenities along the shoreline, and to integrate climate change impacts when considering the coastal hazards of the future.

This SMP is also guided by several pieces of legislation including Ontario Regulation 97/04 as developed under the Conservation Authorities Act (1990), pertaining to the regulation of development on hazardous lands. Each conservation authority has their own regulation under the Act addressing development, interference with wetlands and alterations to shorelines and watercourses. The specific documents are Ontario Regulations 42/06 (CLOCA), 168/06 (GRCA) and 163/06 (LTRCA).

Guidance is also provided in the Provincial Policy Statement (PPS), issued by the Ministry of Municipal Affairs and Housing (2020). The PPS recognizes that Ontario's long-term prosperity requires resilient communities supported by long-term strategic development plans, protection of natural resources, and sustainable economic growth. Additional details on the legislation guiding the development of this SMP is provided in Section 2.0.

Extensive field investigations and technical work was completed as a component of this study, and is discussed in detail in Section 3.0 and 4.0. This includes the collection of an oblique aerial photo library (captured from a drone) and shore protection database for all developed areas within the project. Technical aspects of the previous SMP were updated, including the measurement of shoreline change rates (erosion and accretion), sediment transport trends, and 100-year wave and water level conditions. Using the results of this technical work, the project shoreline was divided into 12 project reaches and updated hazard mapping was produced for each reach including delineation of the erosion hazard, flood hazard, and dynamic beach hazard, where appropriate as per provincial guidelines. The procedure for delineating shoreline hazards is discussed in Section 5.0 of the SMP.

Shoreline management recommendations are presented for each project reach based on the delineated shoreline hazards and identified threats to human safety, private and public assets, and the natural environment. Shoreline management recommendations are grouped into the following four broad categories; *Avoid*, *Retreat*, *Accommodate* and *Protect*. Shoreline management including guidance in the design and implementation of shoreline protection structures is presented in Section 7.0.

Summaries of existing shoreline conditions, all technical aspects of the study, shoreline hazards and recommended shoreline management approaches are provided by project reach in a series of Reach Summary Templates which can be found in Appendix A. Shoreline hazard mapping for each of the three Conservation Authorities is found in Appendix B, C and D.

Finally, Section 8.0 presents a summary of key conclusions arising from the SMP including broad recommendations for the region. Commentary is also provided on the suggested implementation strategy and next steps. This includes exploring linkages between this SMP and Municipal Official Plans, integrating the information presented herein with other aspects of shoreline management including species protection and habitat creation, and seeking continued partnerships with senior levels of government to pursue common principles and objectives. Ultimately, the success of this SMP meeting the objectives will be influenced by ability of all parties to collaborate and implement the plan.

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1.0 INTRODUCTION

Zuzek Inc. and SJL Engineering Inc. were retained by the Central Lake Ontario Conservation Authority, Ganaraska Region Conservation Authority and Lower Trent Region Conservation Authority to update the Shoreline Management Plan (SMP) for the north-central shoreline of Lake Ontario. The sections that follow provide a brief overview of the old SMP, the study area, site conditions within each Conservation Authority (CA), and the Principles and Objectives for the updated SMP.

1.1 Previous Shoreline Management Plan

The original Lake Ontario Shoreline Management Plan (SMP) was prepared by Sandwell Swan Wooster Inc. (SSW) in 1990. The original SMP summarized the local conditions, including geology, soils, shoreline types, and land use patterns. Historical wave and water level information was reviewed, along with information on alongshore sediment transport. Damage Centres were identified, and erosion and flooding hazard limits were summarized. The SMP concluded with recommendations for shoreline protection concepts based on shoreline type, including low to medium bluffs, medium to high bluffs, beaches, and marshes.

The report also included recommendations for land use planning to protect the aesthetic and recreational benefits of the shoreline. The 1990 SMP identified appropriate flooding and erosion hazard setbacks to protect future development within 66 individual shoreline reaches. The SMP is partly responsible for some of the most successful large-scale development setbacks on Lake Ontario. Refer to Figure 1.1 for an example of a large natural setback that buffers the development in Newcastle, Ontario.

Figure 1.1 Erosion Buffer and Natural Area, Newcastle, Ontario

Two additional studies were completed by the LTRCA to study shoreline hazards and shoreline management recommendations on a smaller regional scale, namely the Cramahe Shorelands

Report (LTRCA, 1997) and the Alnwick/Haldimand Shoreline Report (LTRCA, 2003). Together these studies cover the Lake Ontario shoreline from the west LTRCA boundary to Popham Bay (just west of Presqu'ile Beach). These documents superseded the 1990 SMP for this region and provide a more integrated approach to shoreline management that includes considerations for broader issues beyond shoreline hazards such as aquatic habitat, terrestrial habitat, public shoreline access and cumulative impacts of shoreline activities. Updated hazard setbacks and recommendations for shoreline protection were also provided.

The 2020 SMP builds off the work and findings from the original 1990 report and, where applicable, the 1997 and 2003 LTRCA reports with updated technical analysis, new information on lake levels and waves, a wider range of shoreline hazard adaptation and mitigation recommendations, and detailed hazard mapping for the region.

1.2 Study Area

The Lake Ontario Shoreline Management Plan covers the north-central shoreline of Lake Ontario within the jurisdiction of the Central Lake Ontario Conservation Authority (CLOCA), the Ganaraska Region Conservation Authority (GRCA), and the Lower Trent Region Conservation Authority (LTRCA). Refer to Figure 1.2 for a map of the study area.

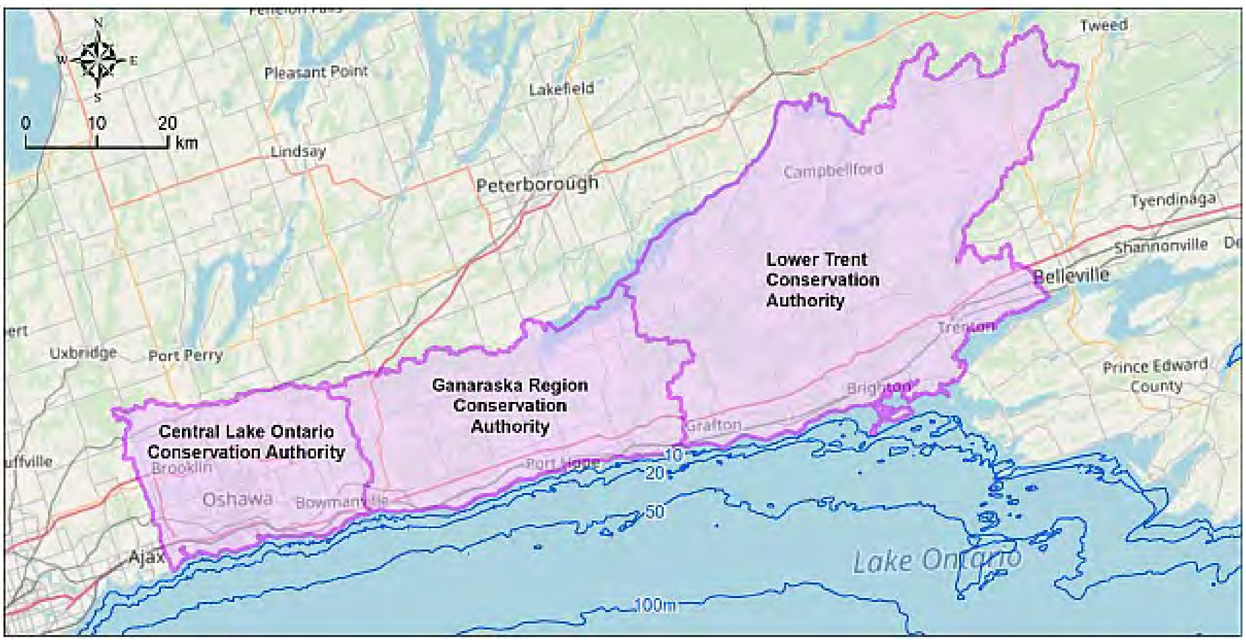


Figure 1.2 Study Area

1.2.1 Conservation Authorities

The CLOCA jurisdiction is approximately 30 km in length and features a wide variety of exposed Lake Ontario shoreline, including eroding bluffs, drowned river valleys, barrier beaches and wetland complexes, rivermouth harbours, and beaches adjacent to jettied navigation channels (referred to as fillet beaches).

Located in the central portion of the study area, the GRCA shoreline is approximately 45 km in length and is largely rural except for the coastal communities of Port Hope and Cobourg. The

Lake Ontario jurisdiction for GRCA is a mixture of eroding bluffs, low plain shorelines, harbours and fillet beaches, and barrier beaches protecting riverine wetlands.

The LTRCA shoreline is over 60 km in length and includes the most diverse shoreline conditions within the study area. The bluffs in the west transition into beaches and exposed bedrock around Presqu'ile Provincial Park, which shelters Brighten Bay from Lake Ontario storms. Brighton Bay features extensive coastal wetlands, as does the eastern limit of the study area in Wellers Bay.

1.3 Principles and Objectives

The development of the updated SMP was guided by a series of principles and objectives, along with the legislative requirements outlined in Section 2.0.

Principles:

- Sustainable Coastal Development: strives for a sustainable balance between the environment, society, and the economy when making management decisions along the shoreline and planning for new development.

- Integrated Coastal Zone Management (ICZM): ICZM is a dynamic, multi-disciplinary, and iterative process of promoting the sustainable management of our coastal zones. ICZM seeks, over the long-term, to balance environmental, economic, social, cultural, and recreational objectives, all within the limits of a dynamic coastal ecosystem. ICZM and by extension this SMP, provides policy direction and a process for protecting coastal development and maintaining healthy coastal ecosystems. Management decisions within the coastal zone should be framed within littoral cells or sub-cells that define the movement and deposition of sediment along the shoreline.

Objectives of the Shoreline Management Plan:

- Increase the resilience of coastal communities.
- Protect new development from coastal hazards.
- Update coastal hazard delineations using the best available data and technical analyses.
- Integrate climate change impacts when estimating future coastal hazards.
- Maintain the sediment supply to local beaches and barrier beach ecosystems.
- Incorporate nature-based solutions to reduce coastal hazards where possible.
- Protect and enhance existing public amenities along the coast.

1.4 Report Format and Organization

The report is organized into eight principal sections and covers the legislation, policy and technical direction guiding the SMP, field investigations and coastal data, technical analysis, shoreline hazards, public engagement, shoreline management recommendations, conclusions, and a series of technical appendices. Summaries of key project items including existing shoreline conditions, shoreline hazards and shoreline management recommendations are provided for each project reach in Appendix A. Hazard maps for the three CAs are presented in Appendix B to D.

2.0 LEGISLATION, POLICY AND TECHNICAL DIRECTION

The relevant legislation and policy that guided the development of this SMP is summarized in the sections that follow along with relevant technical references.

2.1 Conservation Authorities Act

The responsibility and mandate for coastal management by CAs is outlined in the Conservation Authorities Act, which is currently under review. Ontario Regulation 97/04 was developed under the Conservation Authorities Act (1990) and pertains to the regulation of development on hazardous lands. For the coastlines of the Great Lakes, the limit of hazardous lands is defined as the furthest landward extent of the following:

- Coastal Flooding: the 100-year combined flood level plus an allowance determined by the CA for wave uprush and other water related hazards.
- Erosion: the future shoreline position accounting for shoreline erosion over the 100-year planning horizon plus a stable slope allowance.
- Dynamic Beach: an allowance to accommodate dynamic beach movements over time.

The Regulated Area is determined by the greatest landward extent of the hazardous lands described above, plus an additional allowance determined by the Authority, not to exceed 15 m. The Authority may grant permission for development in the Regulated Area if, in its opinion, the control of flooding, erosion, dynamic beaches, pollution or the conservation of land will not be affected by the development.

2.1.1 Ontario Regulations for the CAs

As outlined in the Conservation Authorities Act, each individual CA can develop their own regulation for development, interference with wetlands, and alterations to shorelines and watercourses. The regulations for shorelines pertain to flooding, erosion, and dynamic beach hazards, which are the focus of this SMP update.

Table 2-1 Ontario Regulations for the CAs

CA	Ontario Regulation	Date (yyyy-mm-dd)
CLOCA	42/06	2006-02-17
GRCA	168/06	2006-05-04
LTRCA	163/06	2013-02-08

2.2 Provincial Policy Statement (MMAH, 2020)

The Provincial Policy Statement (PPS) recognizes that Ontario's long-term prosperity requires resilient communities supported by long-term strategic development plans, protection of natural resources, and sustainable economic growth. The PPS is a key part of Ontario's policy-led land use planning system and sets out the policy framework for regulating the development and use of land. To ensure healthy and resilient communities, the policy statement recommends: 1) avoid development patterns that cause negative environmental impacts or safety concerns (such as developing on hazardous lands), 2) promote development in existing settlement areas to avoid unnecessary land conversions (e.g. avoid conversion of agricultural land to urban land), and 3) promote development that conserves native biodiversity.

To promote healthy and active communities, the PPS recommends maintaining existing and providing new public access to our shorelines. Existing Provincial Parks, Conservation Areas and other natural areas must be protected from negative impacts associated with new development. The linkages between the protection of Ontario's natural heritage system and long-term environmental health and social well-being are also highlighted, including the following recommendations:

- Natural features and areas (e.g. Presqu'ile and Wellers Bay) shall be protected for the long term.
- The long-term ecological function and biodiversity of natural heritage systems should be maintained, restored, and improved where possible.
- Development and site alterations shall not be permitted on wetlands, fish habitat or habitat of endangered and threatened species.

The shoreline of Lake Ontario represents an area, as identified in the PPS, where the diversity and connectivity of natural features and their long-term ecological function should be maintained, restored or improved in recognition of the linkages between natural heritage features and areas, surface water features and ground water features. To implement this PPS requirement, development and site alteration is not permitted in significant wetlands (coastal or otherwise) and may only be permitted in certain other features if it has been demonstrated that there will be no negative impacts on the features or their ecological functions.

The Conservation Authorities have a delegated responsibility with respect to Section 3.1 of the PPS to ensure that development is directed away from areas of natural or non-manmade hazards where there is unacceptable risk to public safety, property, or assets, such as buildings. Development shall be directed in accordance with guidance developed by the Province (as amended from time to time), to areas outside of hazardous lands adjacent to the shorelines of the Great Lakes which are impacted by flooding hazards, erosion hazards or dynamic beach hazards. More explicitly, development and site alteration shall not be permitted within the dynamic beach hazard and areas that would be rendered inaccessible to people and vehicles during times of flooding hazards, erosion hazards, or dynamic beach hazards. Furthermore, planning authorities shall prepare for the impacts of a changing climate that may increase the risks associated with natural hazards. Finally, development and site alterations must not create new hazards, aggravate existing hazards, or result in adverse environmental impacts.

The PPS was revised effective May 2020 following recommendations of the Provincial Special Advisor on Flooding "to recognize that mitigating risk to public health or safety or of property damage from natural hazards, including the risks that may be associated with the impacts of a changing climate, will require the Province, municipalities and Conservation Authorities to work together". It should also be noted that Section 3.1.3 was revised to state "Planning authorities shall prepare for the impacts of a changing climate that may increase the risk associated with natural hazards". In other words, if climate change projections suggest higher lake levels may be possible or the erosion rates will be higher in the future than historical measured rates, this information should be integrated into updated hazard maps.

2.3 Technical Direction

The technical methods used in the updated SMP to assess coastal hazards and map the hazardous lands are briefly reviewed.

2.3.1 Technical Guide for Great Lakes – St Lawrence River System (MNR, 2001a)

In 2001, the Ministry of Natural Resources and Forestry (MNRF) released the Technical Guide for the Great Lakes – St. Lawrence River System and Large Inland Lakes (MNR, 2001a). These guidelines provide the technical basis and procedures for establishing the hazard limits for flooding, erosion, and dynamic beaches in Ontario as well as scientific and engineering options for addressing the hazards.

2.3.2 Understanding Natural Hazards (MNR, 2001b)

MNRF prepared Understanding Natural Hazards (MNR, 2001b) to assist the public and planning authorities with an explanation of the Natural Hazard Policies (3.1) of the Provincial Policy Statement of the Planning Act. This publication updates and replaces the older Natural Hazards Training Manual (from 1997).

2.3.3 Guidelines for Developing Schedules of Regulated Areas

Additional technical information for establishing the boundaries of hazardous lands adjacent to the coastline of the Great Lakes are provided by Conservation Ontario and MNRF (2005) in a document entitled Guidelines for Developing Schedules of Regulated Areas. Additional technical information used to define hazardous lands and supplement the information in Ontario Regulation 97/04 is provided, including the following details relevant to this SMP:

- Coastal Flooding: in the absence of detailed technical information, the wave uprush limit is 15 m measured horizontally from the 100-year combined flood level.

- Erosion: the 100-year erosion allowance must be determined with a minimum of 35 years of shoreline recession data and the stable slope angle should be taken as 3:1 (H:V) in the absence of detailed, site-specific data.

- Dynamic Beach: in the absence of detailed technical information, a dynamic beach is the sum of the 100-year combined flood level, the 15 m wave uprush limit and an additional 30 m allowance for the dynamic nature of beach movements.

3.0 FIELD INVESTIGATIONS AND COASTAL DATA

Section 3.0 reviews the field investigations and data collected for the development of the SMP.

3.1 Oblique Aerial Photography

Oblique aerial photography covering nearly 70 km of shoreline (approximately 50% of the project region) was captured in November 2018 using an unmanned aerial vehicle (UAV). The purpose of capturing the aerial photography was to develop a current, georeferenced photographic database of the shoreline, particularly in developed areas, ecologically sensitive areas, or areas otherwise identified as high-risk. This library of photographs was the primary source of information for the development of a high-resolution shoreline protection database (refer to Section 3.3). It also provided the project team with the ability to view and assess portions of the shoreline that would otherwise be unreachable by land.

The UAV featured a built-in camera with a 12.7-megapixel sensor, three-axis image stabilization and geotagging capabilities. Photographs were typically taken from an elevation of approximately 35 m, a horizontal distance of approximately 60 m offshore, and with shore-parallel spacing of individual images on the order of 30 to 50 m. This allowed for complete shoreline coverage with overlap in adjacent photos while producing images with high enough resolution to assess the condition of shoreline structures at the individual private property scale. Where appropriate, images were captured from a higher elevation to provide an increased range of view. This included areas such as large barrier beach and wetland complexes, high bluff shorelines and harbours.

Beginning at the west end of the project shoreline on November 7, 2019, a total of 13 flights were carried out across the CLOCA shoreline covering a cumulative distance of approximately 18 km. Covered areas and associated flight identification numbers are provided in Table 3-1. Sample photographs of the CLOCA shoreline from the photo database are provided in Figure 3.1.

Table 3-1 List of UAV flights within CLOCA to capture oblique aerial photos of the shoreline

Description	Shoreline Length (km)	Flight ID(s)	Flight Date
Lakeside Park to Halls Road (Ajax)	2.0	1a	Nov. 7, 2018
Ontario Shores Hospital to Whitby Harbour	2.4	1b, 1c	Nov. 8, 2018
Crystal Beach Blvd. to Lakefront Park West	2.5	2a, 2aa	Nov. 8, 2018
Stone Street to Oshawa Harbour	3.8	2b, 2c, 2d	Nov. 9, 2018
Darlington Nuclear Station	2.0	3a	Nov. 8, 2018
St. Mary's Cement Plant	2.2	3b	Nov. 8, 2018
Cedar Crest Beach Rd. to Port Darlington East Beach	2.7	3c, 3d	Nov. 8, 2018

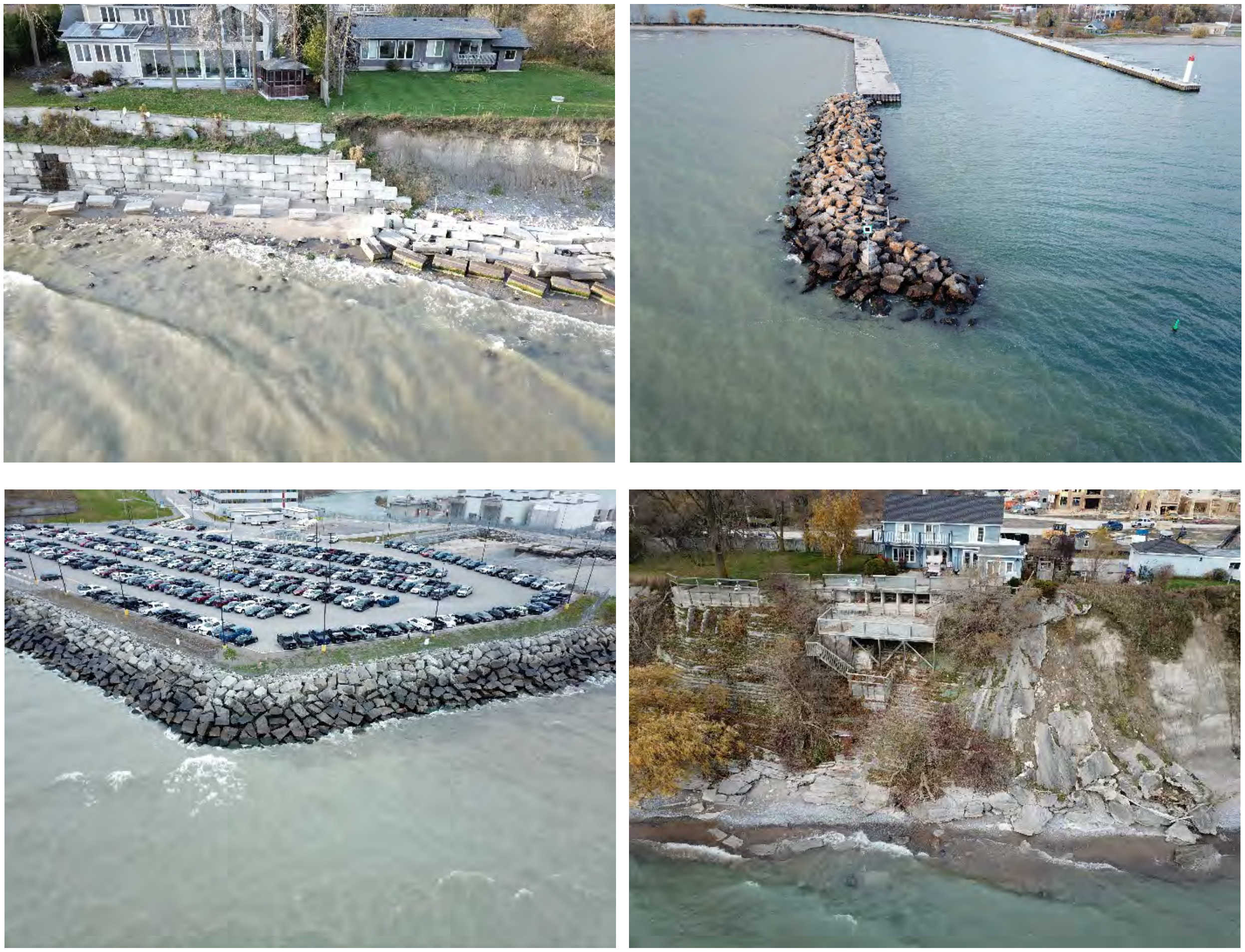


Figure 3.1 Sample photos of CLOCA shoreline captured with the UAV. From top left to bottom right; Ontoro Blvd., Whitby Harbour, Darlington Nuclear Power Plant, Port Darlington East

Oblique aerial photos of the GRCA shoreline were captured between November 11 and November 22, 2018. Over 18 km of shoreline was photographed with a selection of photos from the database provided in Figure 3.2. Covered areas and associated flight identification numbers are provided in Table 3-2.

Table 3-2 List of UAV flights within GRCA to capture oblique aerial photos

Description	Shoreline Length (km)	Flight ID(s)	Flight Date
Wilmot Creek	0.8	4a	Nov. 12, 2018
Newcastle to Bond Head	3.2	4b	Nov. 12, 2018
Port Granby	2.0	DC1, DC2	Nov. 12, 2018
Port Britain	0.5	4c	Nov. 12, 2018
Port Hope West Beach to Lake Street	3.1	4d, 4e	Nov. 11, 2018
Glen Watford Road to Lucas Point Park (Cobourg)	7.2	5a, 5b, 5c, 5d	Nov. 22, 2018
Spicer	1.6	6a	Nov. 22, 2018

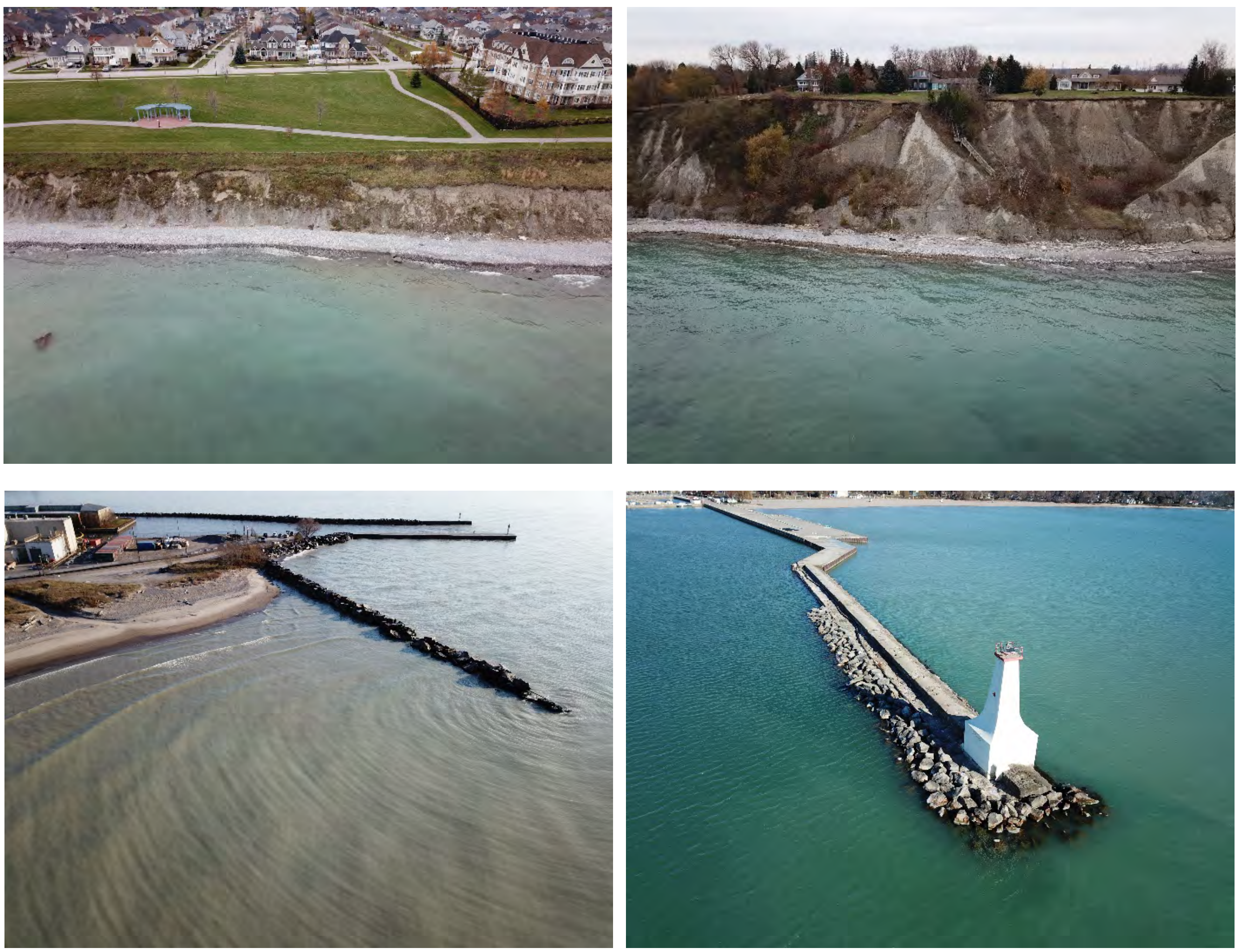


Figure 3.2 Sample photos of GRCA shoreline captured with the UAV. From top left to bottom right; Newcastle, Bond Head Bluffs, Port Hope West Beach and Jetty, Cobourg East Breakwater

The LTRCA shoreline was photographed using the UAV between November 13 and November 24, 2018. A total of 33 km of shoreline was photographed and geotagged. A selection of photos from the LTRCA shoreline are presented in Figure 3.3, while all covered areas and associated UAV flight details are provided in Table 3-3.

Table 3-3 List of UAV flights within LTRCA to capture oblique aerial photos of the shoreline

Description	Shoreline Length (km)	Flight ID(s)	Flight Date
Archer's Road to Chubb Point Road	5.2	6b, 6c	Nov. 22, 2018
Wicklow Beach	0.5	7a	Nov. 13, 2018
Lakeport	0.3	7b	Nov. 13, 2018
Ogden Point to Victoria Beach	4.0	7c	Nov. 13, 2018
Beach Drive	0.5	8a	Nov. 22, 2018
Kelly Lane to Presqu'ile Beach (Brighton)	4.5	8b	Nov. 23, 2018
Presqu'ile Southwest Shoal	1.0	8c	Nov. 23, 2018
Presqu'ile Lighthouse to Bayshore Road	4.2	9a, 9b, 9c	Nov. 23, 2018
Ontario Street to Gosport (Brighton)	4.4	9d, 10a, 10b	Nov. 23, 2018
Stewart Road to Murray Canal (Brighton)	1.9	10c	Nov. 23, 2018
Stoney Point Road (Brighton)	1.0	11a	Nov. 24, 2018
Evergreen Lane to Wellers Bay	5.4	11b, 11c, 11d	Nov. 24, 2018

Figure 3.3 Sample photos of LTRCA shoreline captured with the UAV. From top left to bottom right; Victoria Beach, Presqu'ile Beach, Brighton, Barcovan Beach Road

3.2 Sediment Samples

A total of 17 sediment samples were collected across the project shoreline and analyzed in a laboratory. Samples were generally collected near the waterline by digging a 50 cm deep hole and collecting undisturbed sediment from the side of the hole at least 20 cm below grade. The soil samples were subsequently dried and subjected to a gradation analysis using a column of progressively smaller sieves and a mechanical shake table. The mass retained in each sieve was determined and the cumulative weight passing was calculated and plotted against sediment grain size.

Grain sizes were found to be highly variable throughout the project reach, with the narrowest gradations occurring in embayments and fillet beaches and the widest gradations appearing on the open coast. Open coast shorelines were generally found to feature grain sizes ranging from medium sand (D_{50} = 0.25 – 0.5 mm) all the way to cobble and boulders. Larger grain sizes were typically more prevalent on headlands while smaller grain sizes were more prevalent in embayments.

Fillet beaches on either side of harbours at Oshawa, Port Darlington, Port Hope and Cobourg were generally found to be comprised of medium sand with narrow gradations (D_{50} = 0.25 – 0.5 mm). The fillet beaches at Whitby, Newcastle and Ogden Point tended to have larger gradations comprised of coarse to very coarse sand (D_{50} = 0.5 – 2.0 mm). Presqu'ile Beach, the primary depositional beach for the region featured the smallest grain sizes of any sampled beaches with grain sizes ranging from fine to medium sand (D_{50} = 0.125 – 0.5 mm).

The results of the sediment sampling and gradation analyses were used to assist in determining sediment transport pathways and littoral sub-cells. The information was also used in the calculation of longshore sediment transport potential which is discussed further in Section 4.4.

3.3 Shoreline Protection Database

A comprehensive shoreline protection database was developed as a component of the study in order to document the state of the hardened shoreline as of November 2018. The database was developed primarily from the oblique aerial photography inventory discussed in Section 3.1 and supplemented with ground observations and measurements where necessary, including for all significant public infrastructure. All major built-up areas and most private property shore protection were included in the database, with only a small number of rural private properties not being covered. In total, nearly 40 km of shoreline was confirmed to be armoured and logged in the shoreline protection database, representing approximately 25% of the project shoreline. The percent of natural versus armoured shoreline by conservation authority as of late 2018 is reported as follows:

- CLOCA: 29% armoured / 71% natural.
- GRCA: 20% armoured / 80% natural.
- LTRCA: 27% armoured / 73% natural.

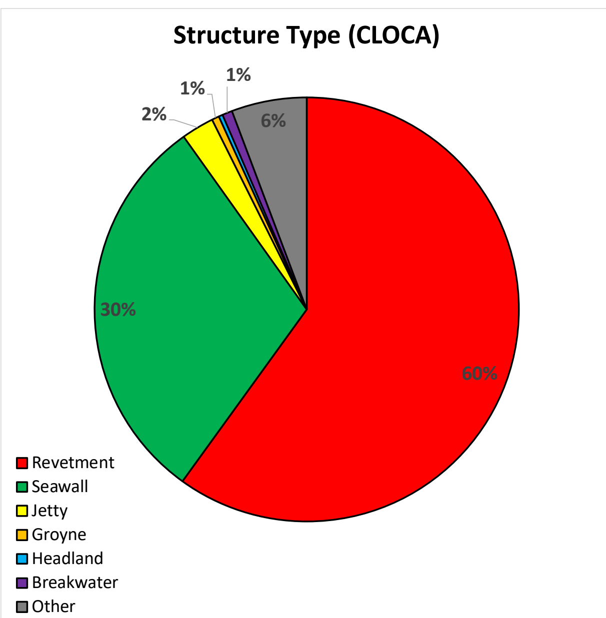
Each shore protection structure added to the database was delineated with start and end coordinates. Each structure was labelled as public, private or mixed ownership, and assigned information including the following key variables:

1. **Primary Structure Type:** includes both the type of structure (i.e. seawall, revetment, jetty, etc.) and the primary structure material (i.e. rubble, armour stone, concrete blocks, sheet pile, composite, etc.).
2. **Secondary Structure Type:** secondary information for composite shoreline protection (i.e. groyne backed by a beach curb, concrete block revetment with armour stone crest, etc.).
3. **Level of Design:** well-engineered, moderately engineered, ad-hoc and unknown.
4. **Structure Condition:** excellent, good, moderate, poor, failed, unknown.
5. **Structure Importance:** critical (i.e. protects nuclear power plant), high (protects important public infrastructure), moderate (most private property protection), low (protects undeveloped lands or low energy environments), unknown.

Statistics pertaining to the state of shoreline infrastructure were assessed from the completed shore protection database both by conservation authority, and by project reach (project reaches are discussed in Section 4.7). Tabulated statistics included (but were not limited to) the following:

- % armoured by structure type.
- % armoured by level of design.
- % armoured by structure condition.
- % armoured by structure importance.
- Level of design by structure type.
- Structure condition by structure type.
- Structure importance by structure type.

Sample statistics from the shoreline protection database are provided in Figure 3.4, Figure 3.5 and Figure 3.6 for CLOCA, GRCA and LTRCA respectively. Additional statistics and summary observations by project reach (refer to Section 4.7) are presented in the accompanying reach summary documents (Appendix A). The entire shoreline database including tabulated statistics has been provided to the Conservation Authorities in digital form. The provided shore protection database and all presented statistics are reflective of the state of the shoreline in late 2018.



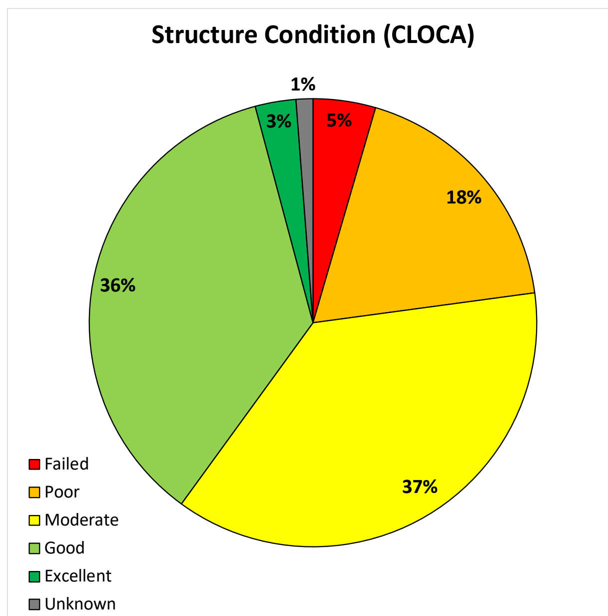
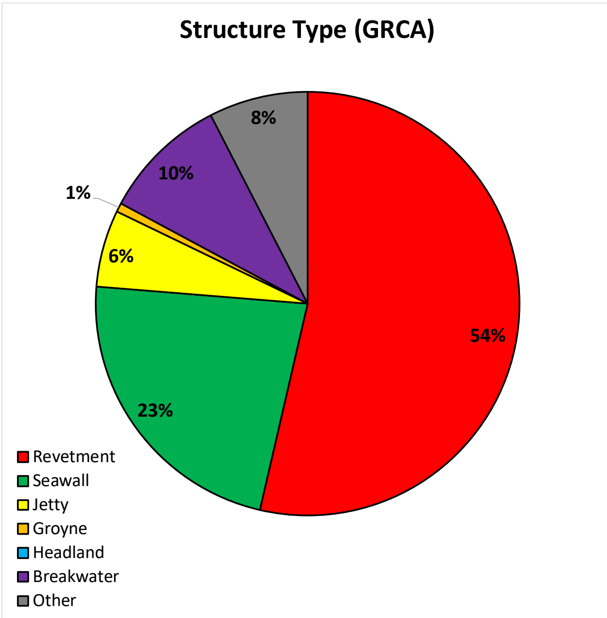


Figure 3.4 Summary shore protection statistics for CLOCA shoreline



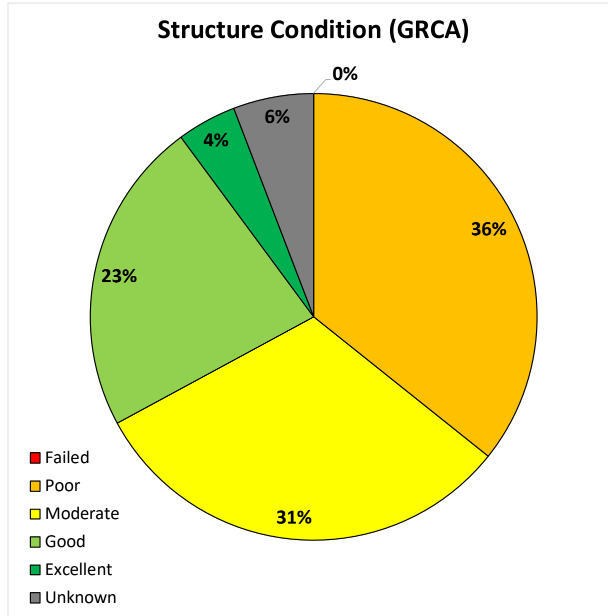
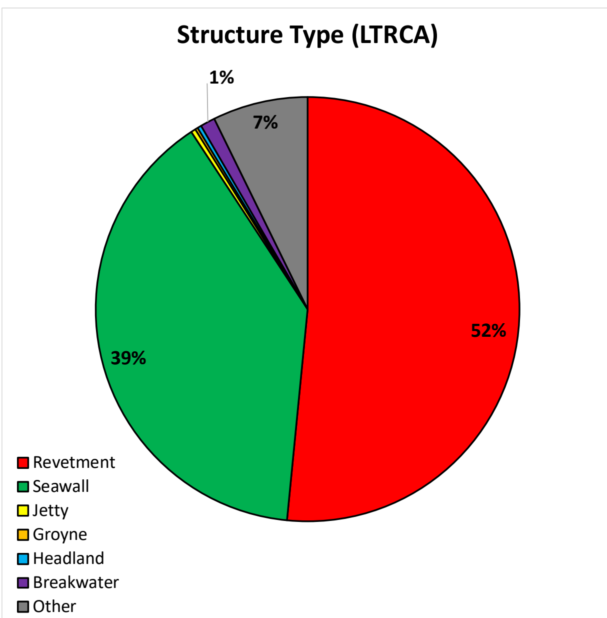


Figure 3.5 Summary shore protection statistics for GRCA shoreline



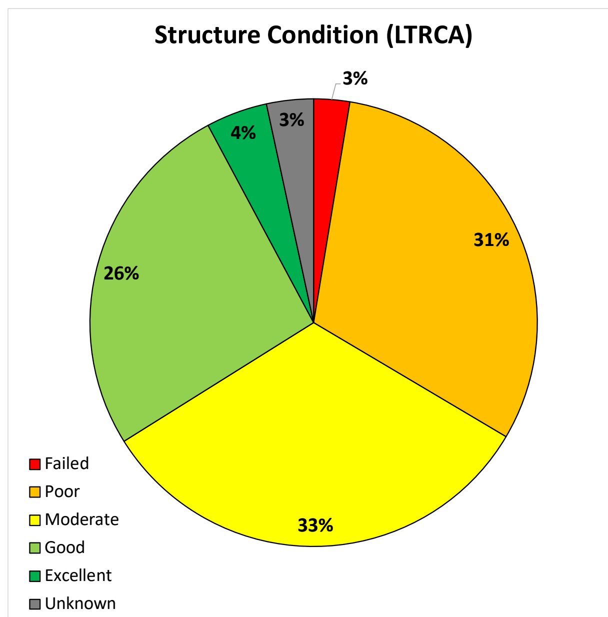


Figure 3.6 Summary shore protection statistics for LTRCA shoreline

3.4 Significant Natural Features

The original SMP (SSW, 1990) identified significant ecological areas including coastal wetlands, forests, wildlife habitat and the rare animals they support, and significant spawning areas and habitat for fisheries. Table 3-4 identifies these areas within the three CAs.

Table 3-4 Significant Natural Features from 1990 SMP (SSW)

CA	Sensitive Areas
CLOCA	Cranberry Marsh, Lynde Shores, Whitby Harbour, Thickson's Woods, Pumphouse Marsh, Oshawa Harbour, Oshawa Second Marsh, Darlington Provincial Park, Robinson Creek, Tooley Creek, Darlington Creek, Westside Marsh, Bowmanville Creek
GRCA	Wilmot Creek, Bond Head Bluffs, Crysler Point Bluff, Wesleyville Marsh, Willowbeach Marsh, Ganaraska River, Carr Marsh
LTRCA	Barnum House Creek, Lot 25 Haldimand Township, Shelter Valley Creek, Wicklow Station, Colborne Creek, Loughbreeze Creek, Salem Creek, Spencer Point Creek, Hunt and Beach Woodlands, Butler Creek, Presqu'ile Park, Presqu'ile Bay, Stony Point, Shoal Point, Young Cover

The Canadian Wildlife Service (CWS) provided two regional-scale datasets for the study area including high value wetland and biodiversity areas. The information for CLOCA is presented in Figure 3.7. As expected, there is overlap with the regions identified in the 1990 SMP, such as Cranberry Marsh/Lynde Shores and Oshawa Second Marsh. The information for GRCA and LTRCA is provided in Figure 3.8 and Figure 3.9.

Since the 1990 SMP, natural heritage planning has evolved from a features-based "islands of green" approach to an integrated "systems approach" that includes natural heritage features and areas, and their interactions with hydrological and geological systems to form "cores" and "linkages", making one cohesive "Natural Heritage System" that may be expressed at various scales. Within the study area, examples of these systems include the Natural Heritage System for the Greenbelt Plan, the Natural Heritage System for the Growth Plan, the Natural Heritage System mapped in the Municipality of Clarington Official Plan, and the Northumberland County draft Natural Heritage System. Each of these systems has recognized the Lake Ontario Shoreline as part of the respective Natural Heritage System, in recognition of the shoreline as an area where the diversity and connectivity of natural features and their long-term ecological function should be maintained, restored or improved.

Through the Greenbelt Plan (2017), the province has placed significant segments of the Lake Ontario Shoreline within the study area in a "Protected Countryside" that also includes a regional-scale Greenbelt Natural Heritage System along the Lake Ontario shoreline. This includes the Lynde Shores Conservation Area in the Town of Whitby, and the shoreline from Newcastle Village to the boundary between the Region of Durham and Northumberland County. The province has also placed large segments of the Lake Ontario Shoreline east of the Greenbelt Boundary within the regional-scale Natural Heritage System for the Growth Plan, part of the provincial Growth Plan for the Greater Golden Horseshoe.

Local watershed planning efforts have resulted in the establishment of a Natural Heritage System for the CLOCA watershed that spans the undeveloped reaches of the Lake Ontario shoreline. In addition, CLOCA's Wildlife Corridor Protection and Enhancement Plan (2015) recognized the

Lake Ontario Shoreline as part of the Regional Wildlife Movement Corridor with supporting core and secondary habitats.

In November 2019 Northumberland County issued a draft report on their Natural Heritage System Plan (North-South Environmental Inc., 2019), which covers more than half of the study coastline, including the majority of GRCA's and LTRCA's jurisdiction along Lake Ontario. The plan components include wetlands, endangered and threatened species, areas of natural and scientific interest, wildlife habitat areas, significant valley lands, fish habitat, watercourses, and woodlands. Three options were identified to map the extent of the Natural Heritage System within the county. Once the report is finalized, the recommendations should be included in future management approaches and land-use/development decisions along the Lake Ontario shoreline.

Prior to permitting shoreline development, it is recommended that the project be reviewed to determine whether or not it will impact any of the significant ecological areas identified in the 1990 SMP (Table 3-4) or those identified by the Canadian Wildlife Service and presented in Figure 3.7 thru Figure 3.9. Finally, if the project is identified to be within one or more Natural Heritage Systems, the recommendations of those studies should be adhered to and additional ecological and biological studies may be required.

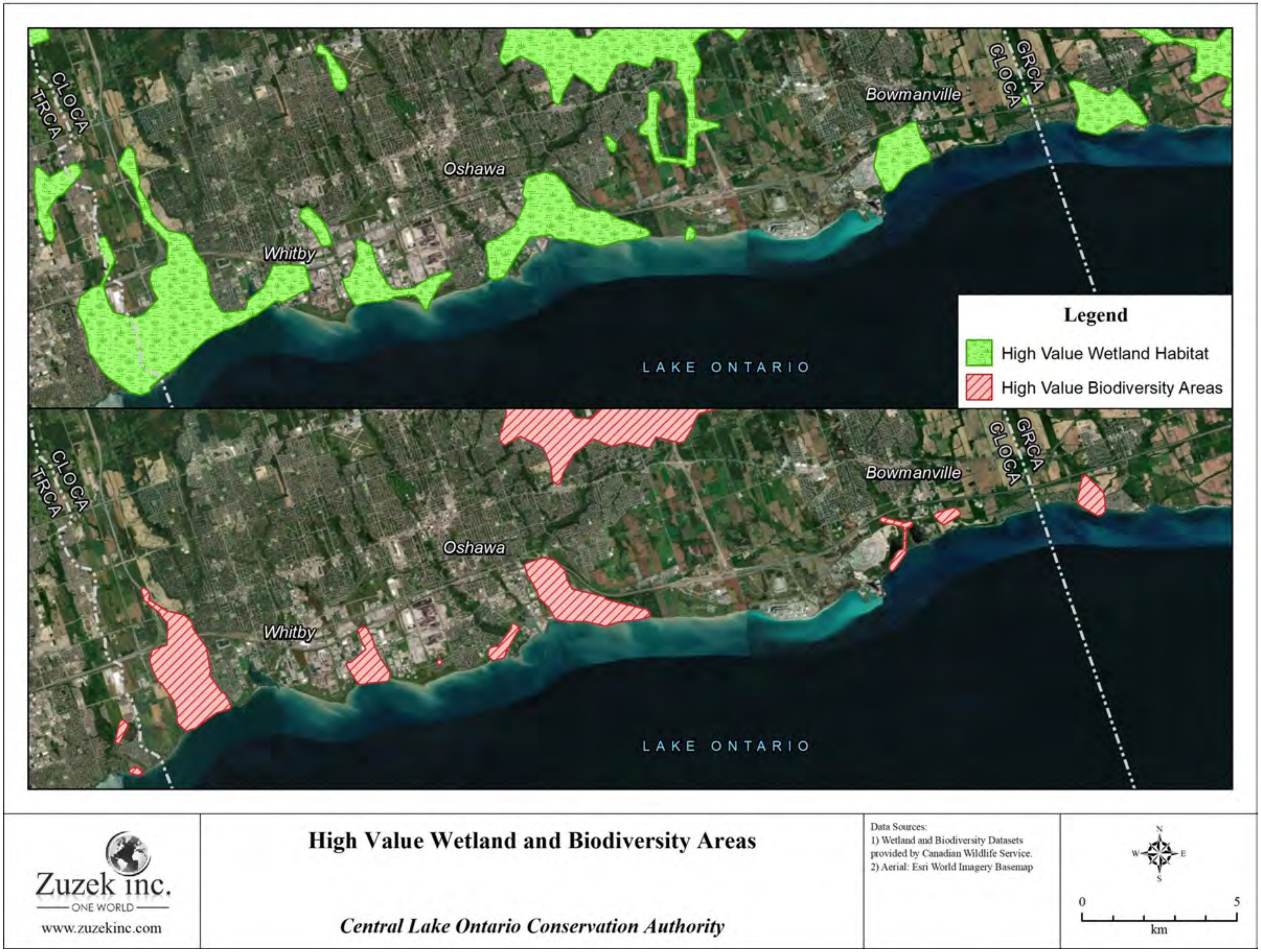


Figure 3.7 CWS High Value Wetland and Biodiversity Areas in CLOCA

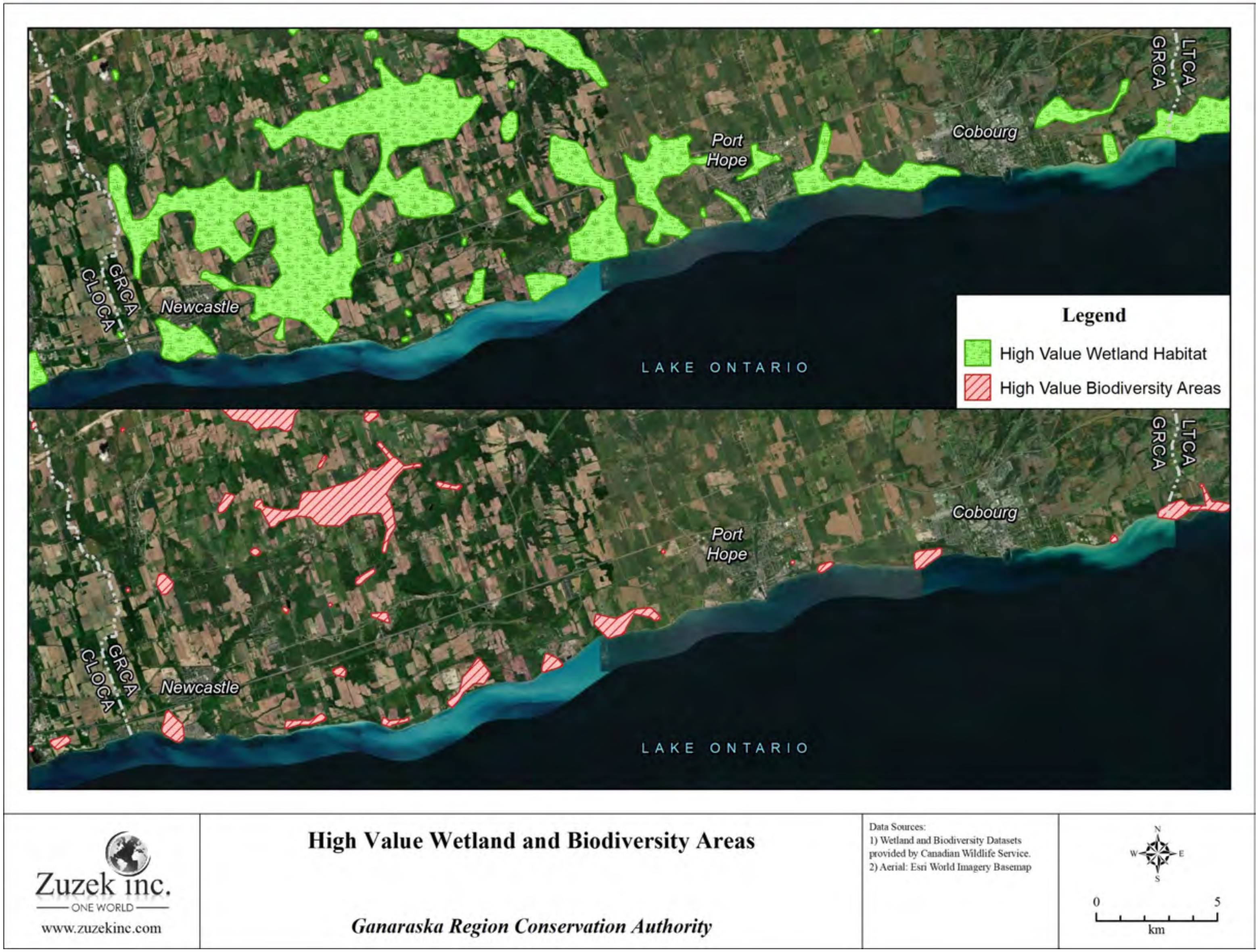


Figure 3.8 CWS High Value Wetland and Biodiversity Areas in GRCA

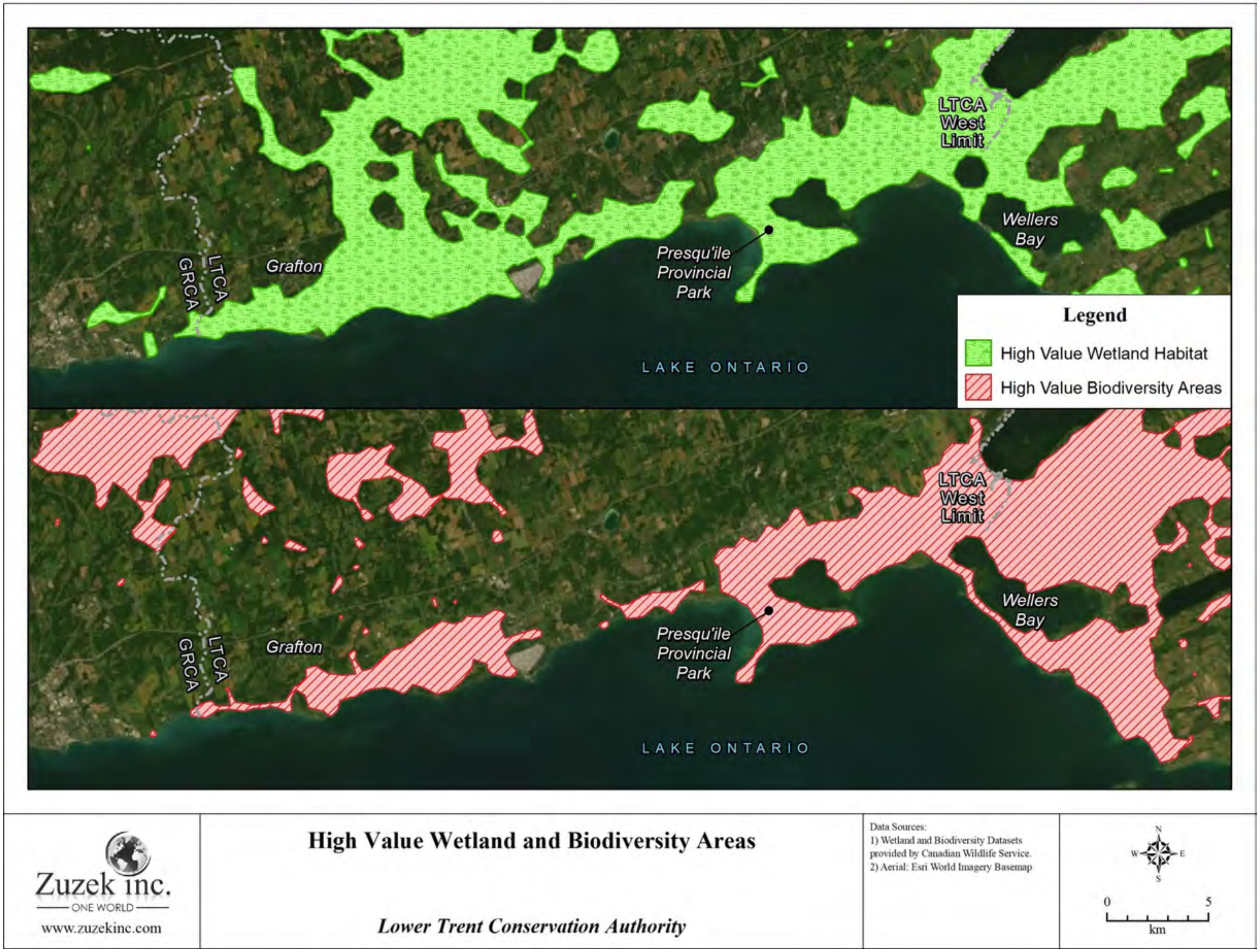


Figure 3.9 CWS High Value Wetland and Biodiversity Areas in TLCA

3.5 Emergency Field Visits in the Spring of 2019

Lake Ontario reached record high water levels in the spring and summer of 2019, surpassing historical records set just two years prior in 2017. A peak hourly lake level of approximately +75.96 m IGLD'85 was measured at the Cobourg water level gauge on May 29, 2019. The duration of extreme water levels was also unusually long with static lake levels exceeding +75.80 m IGILD85' for a period of 50 days from May 22nd to July 11th.

In response to the record high water levels, an emergency site visit was conducted by members of the study team to capture aerial imagery and observe flood and erosion-prone communities during the peak of the high-water season. Several high-risk areas on the CLOCA shoreline were visited on May 28, while the GRCA and LTRCA shorelines were traversed on the following day, May 29. Flooding of developed areas was observed to be most significant at Crystal Beach Boulevard and Cedar Crest Beach Road within the CLOCA jurisdiction. In these communities upwards of 50 private properties were partially or fully flooded at the time of the site visit. Within the GRCA minor flooding was identified in developed areas at Bond Head Parkette and around Cobourg, including Cobourg East Beach which was largely under water. Within the LTRCA the most severe flooding of developed areas was in Popham Bay (west of Presqu'ile Beach), in Brighton Bay along Harbour Street, throughout the community of Gosport and at Evergreen Lane, where well over 100 private properties were partially or fully under water.

Significant and rapid shoreline erosion of developed areas was also experienced in conjunction with the high water levels in 2019. Several of these erosion-prone areas were visited and photographed during the emergency site visits, including Crystal Beach Boulevard, Cedar Crest Beach Road, Port Darlington East Beach (CLOCA), Bond Head, Port Britain, Lucas Point Park (GRCA), and Grafton Shores (LTRCA).

In addition to flooding and erosion impacts in developed areas, significant environmental and ecological impacts were realized during the 2019 high water season across the project region. Barrier beaches were severely impacted by elevated water levels and increased exposure to waves, with barrier beaches at Cranberry Marsh, Lynde Creek (CLOCA) and Carr's Marsh (GRCA) suffering significant breaches. This has resulted in the exposure of the protected wetlands and dramatic changes in the overall energy regime experienced in these ecologically sensitive areas. The resilience of these barrier beaches and their ability to repair themselves will become evident in time, however it is possible these systems will not fully recover on their own.

Several aerial photographs collected during the emergency site visits in May of 2019 are shown in Figure 3.10. The observations made and photographs collected were critical in assisting the study team to understand the severity of shoreline hazards in the region and the locations of highest risk. These locations are discussed in greater detail in the reach summaries presented in Appendix A. The information collected during the emergency site visits was also important in the development of shoreline management recommendations for the region, which are discussed in detail in Section 7.0.

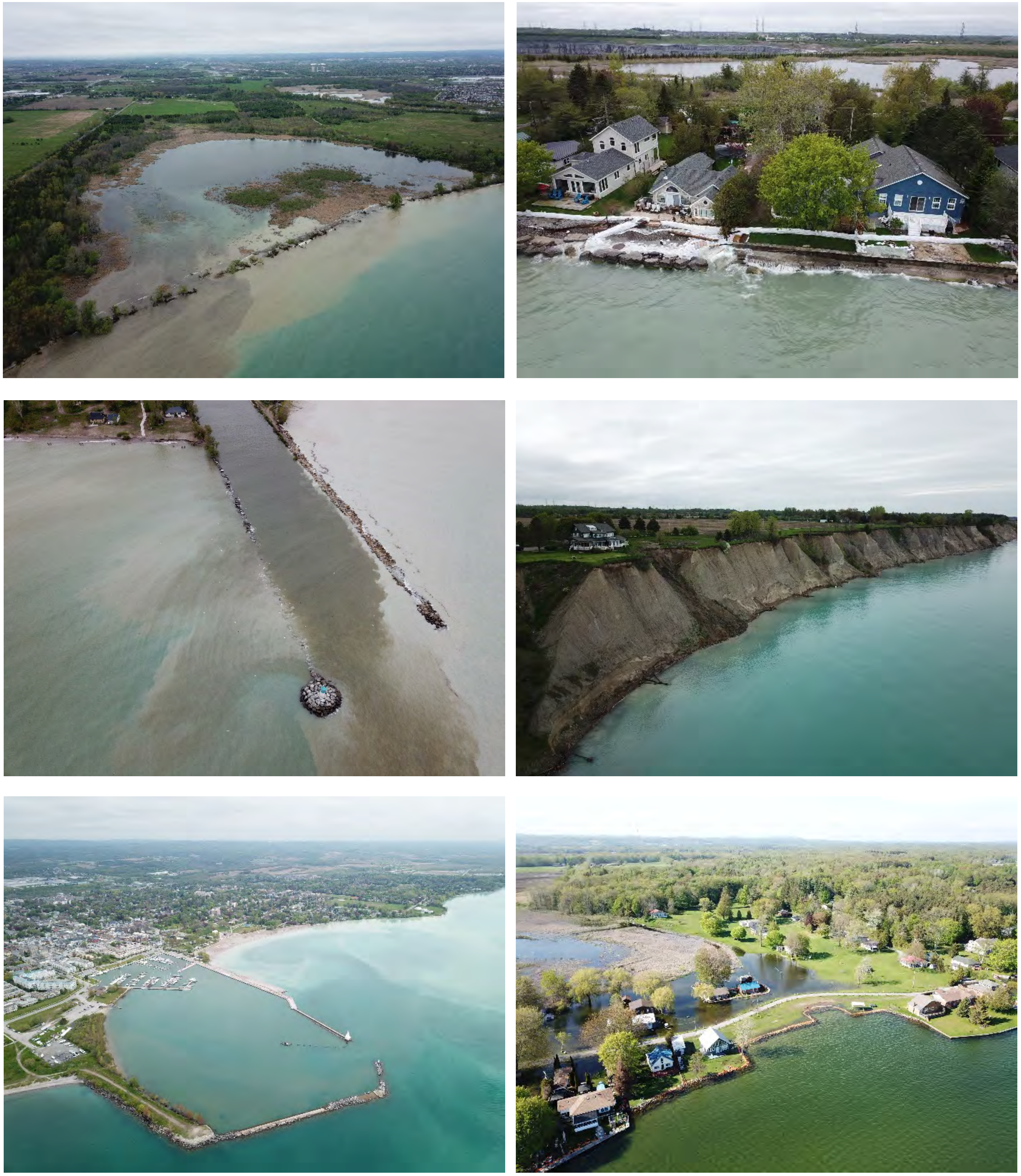


Figure 3.10 Impacts of record high water levels in the Spring of 2019. Top left to bottom right: Cranberry Marsh barrier beach, Cedar Crest Beach Rd, Port Darlington jetties (CLOCA), Bond Head bluffs, Cobourg Harbour and East Beach (GRCA), and Evergreen Lane (LTRCA)

4.0 TECHNICAL ANALYSIS

The technical analysis completed to update the 1990 SMP is presented in Section 4.0.

4.1 Geology and Surficial Sediment

The surficial bedrock in the study area consists of limestones and shales from the Middle Ordovician period, when the Great Lakes region was part of a warm tropical sea (OGS, 1991; SSW, 1990). In the western portion of the study area, the bedrock is covered by more recent glacial deposits. However, east of Cobourg, the limestone bedrock is often found at the waters edge and in the nearshore. Refer to Figure 4.1 for an aerial view of the exposed bedrock east of Cobourg Harbour.

Figure 4.1 Exposed Limestone Bedrock East of Cobourg Harbour

The bedrock is capped with a complex sequence of glacial sediment formed during the advance and retreat of multiple glaciers, the final known as the Wisconsin Glacier, which covered all of southern Ontario (Chapman and Putnam, 1984). The melting began approximately 12,000 years ago resulting in the ice sheet advancing north and into the modern lake basins.

Within the study area, the retreating glacier left behind consolidated glacial deposits (till) and unconsolidated outwash (sand plains) from Whitby to Port Hope. The bluffs are low to moderate in the west and reach their maximum east of Newcastle at Bond Head. The bluffs are separated by river valleys and shallow embayments. East of Port Hope to Presqu'ile Provincial Park, the banks are generally low and feature sandy soils and glacial outwash (Chapman and Putnam, 1984; SSW, 1990).

Presqu'ile Provincial Park is anchored along the south shore by a large limestone exposure which shelters Brighton Bay and was ultimately responsible for the large depositional sand spits that accumulated to the north. Sand and gravel transported west to east along the study shoreline accumulated against the bedrock exposure and ultimately closed off the bay and formed the current beach ridge. Brighton Bay is a low coastal plain fringed by coastal wetlands, as is Wellers Bay at the eastern limit of the study area (Chapman and Putnam, 1984).

4.2 Water Levels

Shoreline hazards on the shores of the Great Lakes are defined in part based on the 100-year combined flood level. The 100-year combined flood level is defined as the combination of static water level and wind setup (storm surge) having a combined probability of occurrence of 1 in 100-years (1% in any given year). Combined flood levels used in the regulation of shoreline hazards throughout Ontario and appearing in past Shoreline Management Plans are based on work completed by the Ministry of Natural Resources and Forestry published in a report titled "Great Lakes System Flood Levels and Water Related Hazards" (MNR, 1989). Published flood levels were based primarily on the statistical analysis of historical water level data from a coordinated network of gauging stations around the lakes, from early century up to and including 1988.

Since the MNR publication more than 30 years of high-resolution static water level and storm surge data has been logged at numerous water level gauges around Lake Ontario. The monthly mean lake levels from 1918 to 2019 are presented in Figure 4.2. Moreover, numerical modelling, data processing and statistical analyses capabilities have improved significantly over those available more than three decades ago. Finally, water level regulation practices have been adjusted and adapted since the introduction of water level regulation on Lake Ontario in 1960, most recently with the implementation of Plan 2014 which came into effect in 2017.

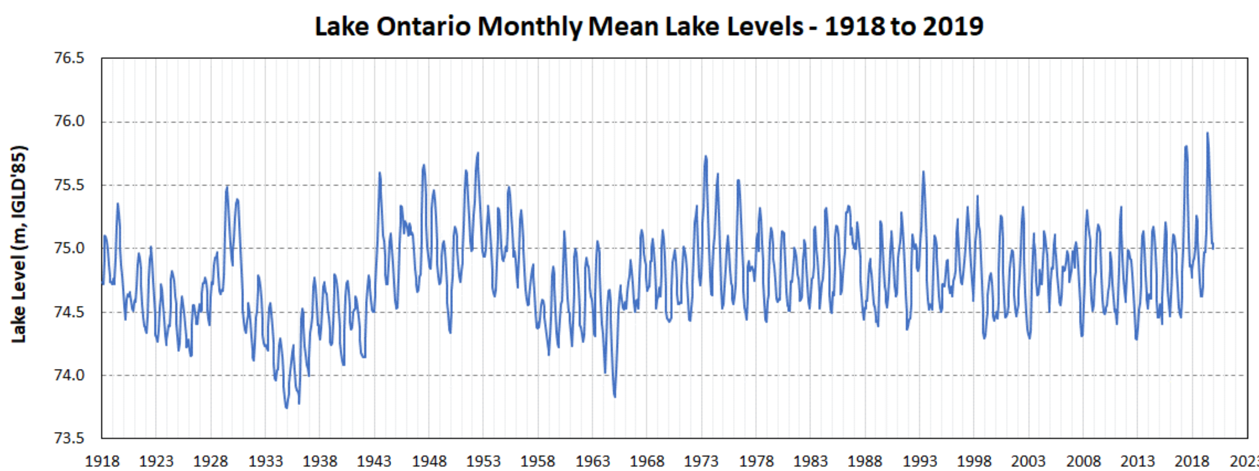


Figure 4.2 Monthly Mean Lake Levels from 1918 to 2019

Updated 100-year combined flood levels based on the best available data were analysed as a component of the updated SMP and are presented in the sections that follow for all three Conservation Authorities.

4.2.1 Water Level Regulation

The Great Lakes are a chain of five lakes with shared jurisdiction between Canada and the United States. Together they form the largest surface freshwater system on earth with a total drainage basin of more than 500,000 square kilometres. Lake Ontario is the furthest downstream of the five lakes. Water levels within Lake Ontario are influenced by the operation of the Moses-Saunders Power Dam in Cornwall, Ontario, however this dam has no influence on lake levels in the other four Great Lakes. Of the water draining out of Lake Ontario, approximately 85% by volume arrives from Lake Erie via the Niagara River. The remaining 15% comes directly from the Lake Ontario drainage basin and local tributaries. Water leaves Lake Ontario primarily through evaporation and via the St. Lawrence River outlet.

Up until the mid twentieth century Lake Ontario was unregulated with outflow flowing freely via the St. Lawrence River. In the mid 1950's the St. Lawrence Seaway and Power Project was introduced including the construction of navigation channels to facilitate the movement of goods and the Moses-Saunders Power Dam at Cornwall for the generation of hydro-electricity. These changes increased the outflow capacity of the St. Lawrence River and provided the ability to moderate water levels both upstream and downstream through the control of the Moses Saunders Dam. As a result, a water level regulation plan was developed in the late 1950's and further adapted in the early 1960's with the intention of keeping water levels within an acceptable range to mitigate both upstream and downstream flooding while encouraging recreational boating, the safe transport of goods and the production of hydro-electricity. This plan was referred to as Plan 1958-D and was the official water level regulation plan adopted by the International Joint Commission (IJC) from 1960 to 2016.

Between 2000 and 2014 the IJC examined alternative regulation plans to better balance the various upstream and downstream interests and to update water level regulation practices in light of decades of shoreline development and fluctuations in water supply. Recognizing that Plan 1958-D had not considered the health of ecosystems, the new plan considered the effects of water level variations on coastal wetland environments and the protection of natural processes within the shoreline environment. Plan 2014 included guidance on releases at the dam that would occasionally allow for slightly higher highs during periods of above average water supply and lower lows during periods of drought. The new water level regulation plan was implemented in 2017. Inflow to Lake Ontario has historically been unregulated and remains unregulated with no water level control structures in place between Lake Erie and Lake Ontario.

IJC modelling shows that water level regulation on Lake Ontario results in maximum water levels being approximately 0.3 m lower than would otherwise be realized under pre-project conditions during extreme high-water periods such as those experienced in 2017 and 2019. The IJC has operated with deviations from Plan 2014 to best protect the interests of riparian landowners, while balancing the requirement to provide acceptable conditions for safe navigation through the St. Lawrence Seaway, among other interests. In 2020 the IJC announced increased investment in reviewing Plan 2014 through the Great Lakes Adaptive Management Committee (GLAM).

4.2.2 Static Lake Levels

Modelled and measured historical static water level data were provided by Environment and Climate Change Canada (ECCC) for use in this study. The datasets included:

- Measured mean lake level (1900 – 2019).
- Modelled mean lake level assuming historical supplies with pre-1950's channel configuration and no water level regulation plan (from 1900 – 2008).
- Modelled mean lake level assuming historical supplies and water level regulation as per Plan 1958-DD (from 1900 – 2008).
- Modelled mean lake level assuming historical supplies and water level regulation as per Plan 2014 (from 1900 – 2008).

The modelled datasets were produced by ECCC's Great Lakes routing model and are based on historical water supplies throughout the Great Lakes – St. Lawrence River system. The routing model has been calibrated to historical data and is the most accurate prediction tool available for assessing water levels resulting from various water supply scenarios and outflow decisions at the dam in Cornwall.

Given that the two highest water level seasons on record for Lake Ontario occurred since the conclusion of the model datasets (2008), measured mean lake level data from 2008 to October 2019 was added to all three modelled datasets.

Each dataset was separated by month. Each monthly dataset containing 119 years of water level data was subsequently ranked from highest to lowest and fitted to several statistical distributions. The distribution providing the highest overall correlation coefficient for each dataset was selected. Table 4-1 provides a summary of 100-year static water levels for each month of the year and for each of the four datasets described above.

Table 4-1 Seasonal 100-year static water levels (m IGLD'85)

	100-year ARI Static Water Level (m IGLD85') (1900 - 2019)			
Month	Measured	Modelled (Pre-Regulation)	Modelled (Plan 1958-DD)	Modelled (Plan 2014)
January	75.21	75.76	75.23	75.31
February	75.28	75.77	75.27	75.36
March	75.42	75.92	75.30	75.40
April	75.69	76.12	75.59	75.70
May	75.85	76.21	75.75	75.83
June	75.88	76.18	75.77	75.84
July	75.82	76.12	75.74	75.76
August	75.69	75.98	75.58	75.54
September	75.45	75.82	75.26	75.28
October	75.29	75.68	75.13	75.10
November	75.18	75.63	75.06	75.04
December	75.13	75.69	75.08	75.08

As is illustrated in Table 4-1, based on an extreme value analysis that considers current water level regulation policies (Plan 2014) and historical water supplies, the maximum 100-year static lake level for Lake Ontario is +75.84 m IGLD'85 occurring in the month of June (last column of Table 4-1). For comparison, the calculated 100-year static lake level achieved by analysing the Plan 1958-DD dataset based on the same historical water supplies is +75.77 m IGLD'85, a difference of only 7 cm. This compares well to the 6 cm difference suggested by the IJC in the development of Plan 2014. The cumulative probability distribution for the Plan 2014 dataset and the month of June is shown in Figure 4.3.

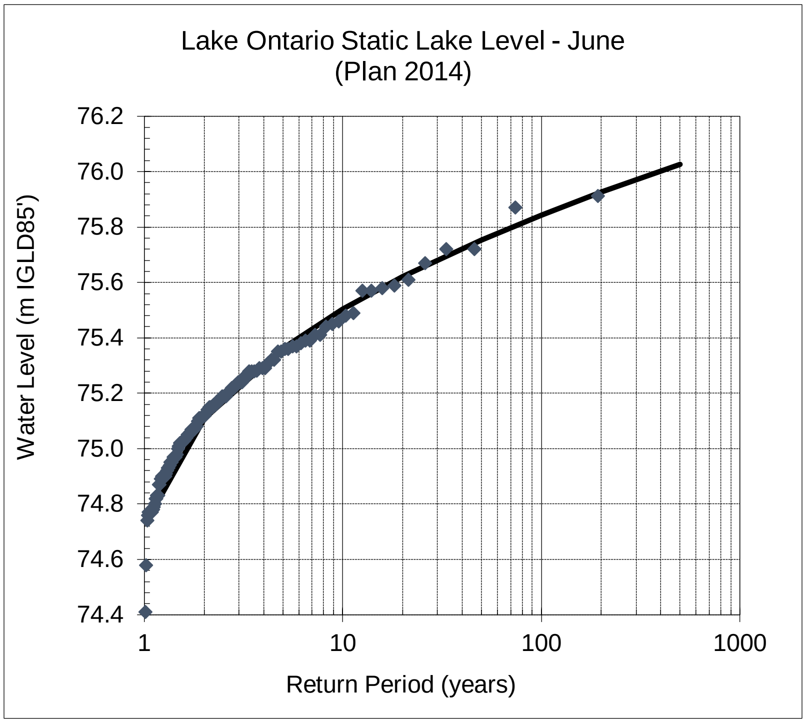


Figure 4.3 Cumulative probability distribution plot of modelled static lake levels assuming Plan 2014 water level regulation (Weibull Distribution)

Interestingly, the "Pre-Regulation" dataset results in a 100-year static water level that is 37 cm higher than the calculated value for Plan 2014. This is because the construction of the St. Lawrence Seaway and the Moses Saunders Dam and the introduction of water level regulation in 1960 increased the maximum conveyance of the system, allowing water to leave Lake Ontario via the St. Lawrence River at a higher rate than was previously possible prior to the Seaway. These findings are consistent with those published by the IJC and discussed in Section 4.2.1 above.

Based on the updated analysis presented herein, the recommended 100-year static water level for Lake Ontario accounting for the present water level regulation plan is +75.84 m IGLD'85. This represents an increase of 18 cm over the 100-year static lake level published in MNR (1989). Should the present water level regulation plan (Plan 2014) be replaced or updated with new rules, the 100-year static lake level should be re-evaluated.

4.2.3 Storm Surge

Storm surge is the temporary rise in water levels during a storm resulting from a combination of barometric pressure gradients and wind setup. On large inland lakes the effects of pressure variations are generally smaller than wind setup, which can be substantial. Setup occurs when wind-induced shear stress at the water-air interface pushes water in the same direction as the wind. When winds are in an onshore direction this will cause water levels to increase along the shoreline. For the case of inland lakes, this temporary increase in water level at one side of the lake will be offset by a temporary decrease at the opposite end of the lake. The amplitude of a storm surge event at a given location is dependent on the wind speed, wind direction, fetch (open water distance over which the wind is blowing), the geometry of the lake, and lake bathymetry (depth and slope of the lakebed).

There are several water level gauges around Lake Ontario that log data at sufficient temporal resolution to capture storm surge events, which typically last on the order of 12 to 24 hours. Data from the following three water level gauges and covering the period from 1962 to 2019 (57 years) were obtained from the Department of Fisheries and Oceans (DFO) for further analysis:

- Toronto (Station ID 13320).
- Cobourg (Station ID 13590).
- Kingston (Station ID 13988).

Storm surge events were isolated from static lake levels in each dataset by calculating the difference between the instantaneous water level and a moving average from before and after the storm. The residual between the two values represents the temporary water level increase at the gauge location above (or below) static lake level due to a storm surge event.

The surge events were separated into monthly datasets to capture seasonality. In general, storm surge events are more frequent and severe during the fall and winter months than they are during the summer. Since storms are random, as an event that occurred on March 31st could also happen in April in the future. Therefore, the 12 monthly datasets were compiled to include storm surge events measured during the specified month and surges from one month before and after were also included (e.g., the April surge dataset also include March and May events). Each dataset was subsequently fitted to several cumulative probability distributions. The distribution resulting in the best overall correlation coefficient for each month was selected. The 100-year storm surge magnitudes at each gauge location and for each month of the year are presented in Table 4-2. Figure 4.4 presents the cumulative distribution plot for the month of January at the Cobourg water level gauge.

Table 4-2 Seasonal 100-year storm surge magnitude at DFO water level gauges

	100-year Storm Surge Magnitude (m) (1962 - 2019)		
Month	**Toronto**	**Cobourg**	**Kingston**
January	0.27	0.28	0.57
February	0.28	0.29	0.58
March	0.25	0.30	0.61
April	0.25	0.31	0.53
May	0.25	0.30	0.50
June	0.24	0.28	0.38
July	0.23	0.20	0.23
August	0.19	0.20	0.34
September	0.20	0.24	0.34
October	0.21	0.33	0.58
November	0.25	0.35	0.58
December	0.27	0.34	0.61

The highest monthly surge for each gauge location were:

- Toronto: 100-year surge = 0.28 m (February).
- Cobourg: 100-year surge = 0.35 m (November).
- Kingston: 100-year surge = 0.61 m (March / December).

The above values are 6 cm, 9 cm and 5 cm lower than those published in MNR (1989) for Toronto, Cobourg and Kingston respectively. This is due in part to the fact that the MNR analysis was completed using a much shorter temporal period of only 26 years. It is also in part due to the limited number of statistical distributions that were evaluated in the 1989 study.

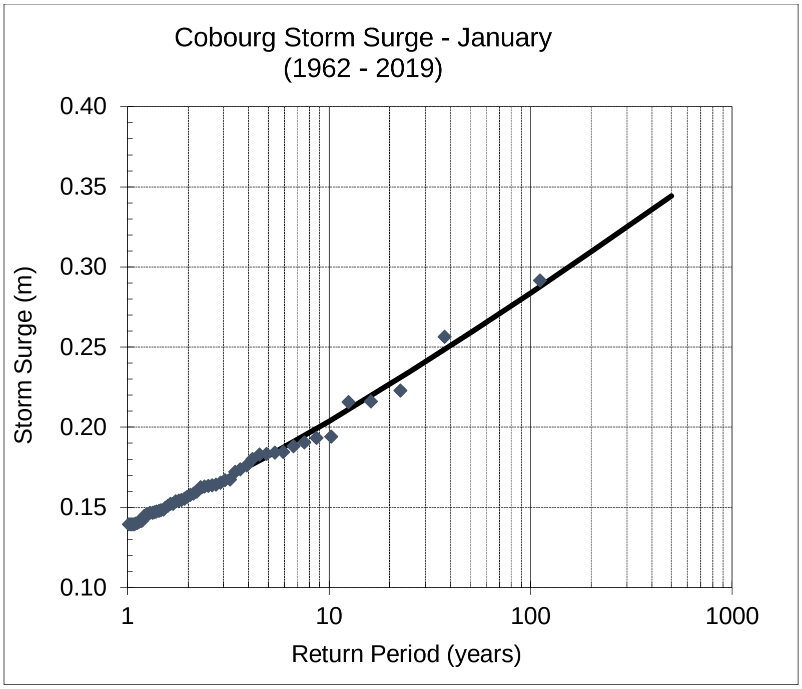


Figure 4.4 Cumulative probability distribution plot of measured storm surge at Cobourg for the month of January (Weibull Distribution)

4.2.4 Joint Probability

The 100-year combined flood level is defined as the combination of static lake level and storm surge with a combined probability of occurrence of 1 in 100-years. In order to assess the 100-year combined flood level, a seasonal joint probability analysis must be performed on the static lake level and storm surge datasets.

In the seasonal joint probability analysis, static lake level and storm surge are treated as independent variables X and Y. An extreme value analysis is first completed for each independent variable and for each month of the year, as was discussed in Section 4.2.2 and 4.2.3. The convolution formula is then used to determine the joint probability of combined water levels "Z" (where Z = X + Y). The resulting joint probability equation can be expressed as:

$$P(Z) = \sum_{Rx} P(X) \cdot P(Z - X)$$

Assessing the above formulation for a range of possible combined flood elevations (Z) at each water level gauge location and for each month of the year results in series of monthly cumulative joint probability distributions of static water levels and storm surge. Figure 4.5 shows one such joint probability distribution for the month of June at the Cobourg water level gauge. The 100-year combined flood level is the value that corresponds to a cumulative probability of occurrence of 1% (0.01).

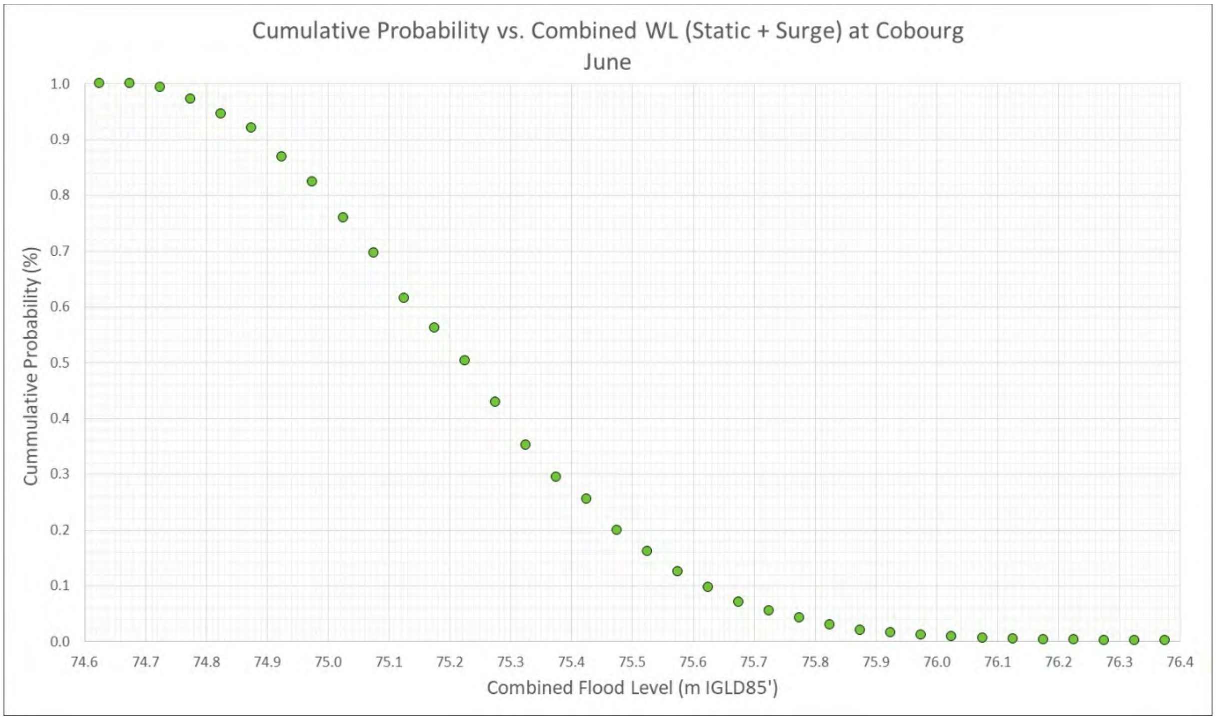


Figure 4.5 Cumulative joint probability distribution plot of combined flood level (static water level and storm surge) at Cobourg for the month of June

Table 4-3 presents the results of the joint probability analysis for the 100-year average recurrence interval at each of the three water level gauge locations.

Table 4-3 Seasonal 100-year combined flood levels at Toronto, Cobourg and Kingston resulting from joint probability analysis of static water levels and storm surge

	100-year Combined Flood Level (m IGLD85')		
Month	Toronto	Cobourg	Kingston
January	75.51	75.51	75.68
February	75.55	75.54	75.72
March	75.58	75.58	75.73
April	75.89	75.89	75.99
May	76.01	76.01	76.08
June	76.01	76.01	76.03
July	75.91	75.91	75.91
August	75.67	75.68	75.74
September	75.42	75.44	75.52
October	75.26	75.32	75.48
November	75.20	75.24	75.42
December	75.28	75.29	75.49

Finally, 100-year combined flood levels appropriate for use within each of the three conservation authority jurisdictions were assessed by interpolating between the gauge locations presented in Table 4-3. The results were checked against the findings presented in MNR (1989) with good agreement. The resulting 100-year combined flood levels recommended for each of the three Conservation Authorities are summarized as follows:

- CLOCA = +76.01 m IGLD'85
- GRCA = +76.01 m IGLD'85
- LTRCA = +76.03 m IGLD'85

4.3 Wave Climate

Section 4.3 reviews the offshore wave climate, nearshore wave transformation modelling, and wave uprush calculations.

4.3.1 Offshore Waves

The offshore wave climate affecting the north shore of Lake Ontario was assessed from the Wave Information Study (WIS) database. The WIS is a United States Army Corps of Engineers (USACE) sponsored project led by the Coastal and Hydraulics Laboratory Engineering Research and Development Center providing hourly wave climatologies for all major shorelines throughout the United States. Included in this study was a 45-year wave hindcast for Lake Ontario covering the period from 1970 to 2014. In a wave hindcast, historical wind fields are used to drive a wave generation and propagation model in order to produce a timeseries of historical waves. The model is then calibrated to measured wave buoy data where available. The WIS database is the most accurate and complete wind-wave dataset available for Lake Ontario.

The WIS database includes wave data at 39 output locations within the project area, each containing 45 years of hourly wave data. The output points are generally located a distance of at least 3 km offshore due to the limited spatial resolution of the wave model. Five wave output points were selected for use in this project, spaced evenly across the project shoreline. The selected output points are summarized as follows:

Table 4-4 WIS offshore wave data output locations

Description	WIS ID	Lat	Long	Dist. Offshore (km)	Water Depth (m)
CLOCA (West)	91173	43.82	-78.84	4.0	30 m
CLOCA (East)	91178	43.84	-78.66	4.5	36 m
GRCA (West)	91184	43.86	-78.44	5.0	44 m
GRCA (East)	91194	43.91	-78.12	5.2	33 m
LTRCA	91201	43.94	-77.86	4.7	35 m

The 45-year timeseries of wave data at each of the five output locations was subjected to an extreme value analysis in order to determine storm conditions corresponding to various average recurrence intervals (5-year, 10-year, 100-year, etc.). Assessed wave parameters included significant wave height (defined as the highest 1/3 of wave heights during a storm event), peak wave period and mean wave direction. Storm lists were generated at each output location and the top 45 events (one per year) were fitted to several extreme value statistical distributions. The distribution resulting in the highest overall correlation coefficient for each dataset was selected. The results of this analysis at station ID 91184, located approximately 5 km offshore of Port Granby (GRCA), are presented in Table 4-5.

Table 4-5 Offshore wave conditions associated with a variety of average recurrence intervals at WIS station 91184, approximately 5 km offshore of the GRCA shoreline

Return Period (years)	Significant Wave Height (m)	Peak Wave Period (s)	Mean Wave Direction (deg)
1	4.65	9.0	225
2	5.07	9.0	225
5	5.58	9.5	230
10	5.92	9.5	230
20	6.23	10.0	230
25	6.32	10.0	230
50	6.61	10.0	230
100	6.89	10.0	230

4.3.2 Nearshore Waves

The numerical wave module Delft3D-WAVE was used to transform the offshore WIS storm waves to the project shoreline. Delft3D-WAVE utilizes the third-generation, phase-averaged spectral wave model SWAN developed at Delft University of Technology. SWAN has been widely used throughout the Great Lakes and accounts for all significant nearshore wave transformations including shoaling, refraction, bottom friction and depth-induced breaking.

Six separate wave model grids were setup to cover the project shoreline, two for each conservation authority. Each model grid extended offshore enough distance to include the nearest WIS offshore wave output location within the model domain. The spatial resolution of all six models was approximately 50 x 50 m at the shoreline. Figure 4.6 presents the 6 model domains including the location of all five WIS output locations.

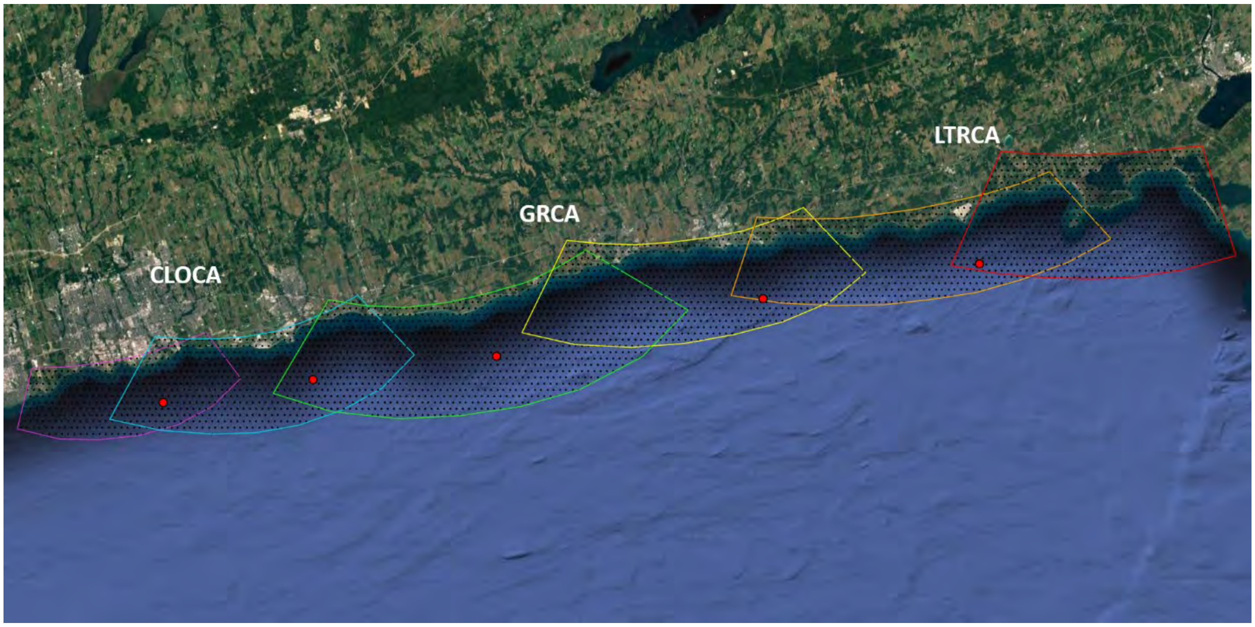


Figure 4.6 Delft3D WAVE model domains (6) and WIS offshore points (red dots)

Model bathymetry was blended using two bathymetric sources. From the shoreline to a depth of approximately 10 m below chart datum, high resolution LiDAR bathymetric data collected in 2017 and provided by Canadian Hydrographic Services was used (courtesy of ECCC). Further offshore and in areas of poor LiDAR coverage, 1 metre bathymetric contours were used courtesy of the National Oceanic and Atmospheric Administration (NOAA). This blended dataset resulted in high spatial resolution in shallow water where wave transformations are most significant, while providing smoother, lower resolution bathymetry further offshore where wave conditions are less sensitive to the lake bottom. The land boundary was created by delineating the shoreline position from 2018 satellite imagery. The model grid for the CLOCA West shoreline (Ajax to Darlington Provincial Park) is presented as Figure 4.7 with model depths shown as colour contours.

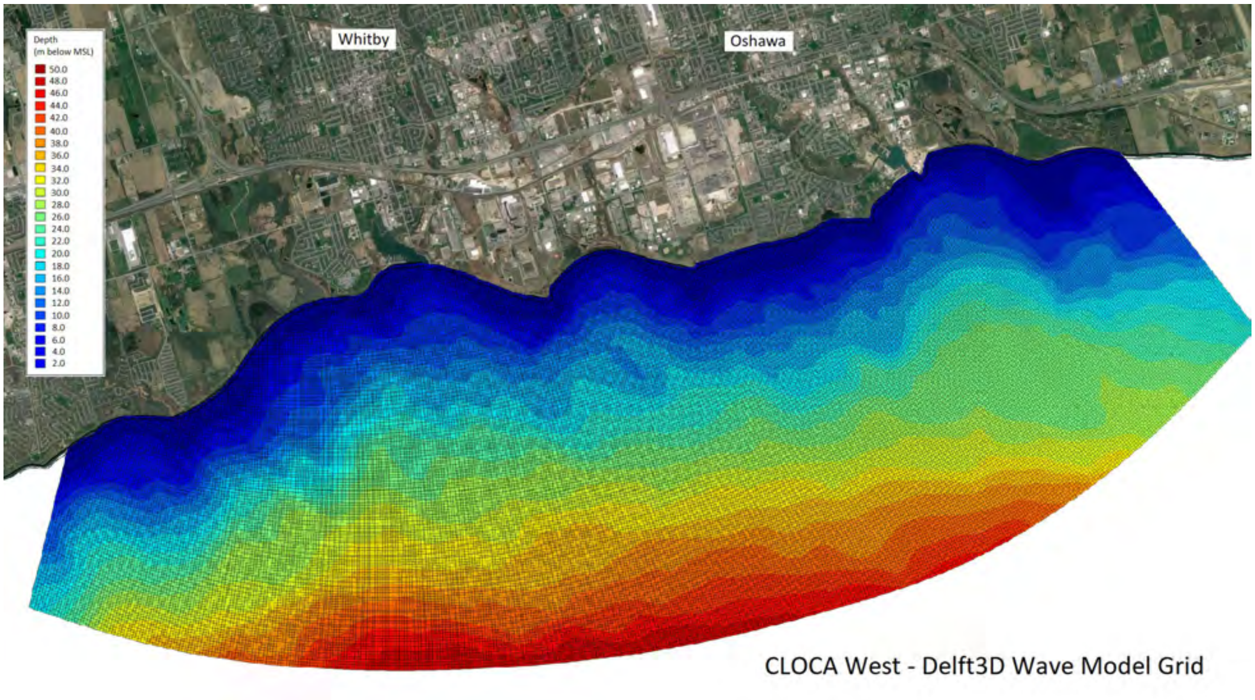


Figure 4.7 CLOCA West model domain showing grid and bathymetry (colour contours)

Offshore storm waves were input at the model boundaries and calibrated to reproduce the WIS conditions at each of the WIS output locations. The following WIS output points were used for the calibration of each model:

- Model 1 (CLOCA West): WIS ID91173.
- Model 2 (CLOCA East): WIS ID91178.
- Model 3 (GRCA West): WIS ID91184.
- Model 4 (GRCA East): WIS ID91194.
- Model 5 (LTRCA West): WIS ID91201.
- Model 6 (LTRCA East): WIS ID 91201.

Once calibrated, the models were run for a variety of return period storm events (1-year, 10-year, 100-year, etc.) to assess storm wave conditions along the project shoreline. A water level of +76.0 m IGLD'85 was used for all simulations. Nearshore wave conditions were output at 100 metre offshore intervals to a maximum offshore distance of 1 km, and along transects spaced approximately every kilometre along the project shoreline. The resulting 100-year nearshore wave conditions were subsequently used in the determination of wave uprush (refer to Section 4.3.3) and in the development of recommendations for shoreline protection structures (Section 7.3). Nearshore wave conditions are also summarized by project reach in Appendix A.

4.3.3 Wave Uprush

Wave uprush is a critical component in the determination of shoreline hazards and is defined as the maximum vertical elevation above the still water level that a wave will reach on a sloping surface (beach or structure). The MNR Technical Guide (2001) provides a list of classical wave uprush formulations suitable for use on the Great Lakes. Most formulations rely on offshore wave height, wave period, beach slope and beach material (i.e. grain size) as input and were empirically developed based on laboratory scale model tests. Reported runup values were taken as the average result from the following four formulations:

- Hunt (1959)
- Holman (1986)
- Upper Bound Method (MNR, 2001)
- Modified Mase (1989, 2012)

100-year wave uprush values were calculated at 55 representative locations along the project shoreline, with locations selected to capture significant changes in shoreline orientation, shoreline type (i.e. low plain, high bluff, etc.), surf zone slope and substrate (beach and lakebed material). Wave uprush was calculated at the 2% exceedance level as is standard practice, meaning the reported elevation is reached by the highest 2% of waves during a storm. The elevation of the wave uprush predictions varied from approximately 1.1 metres to 2.1 metres on the natural beach and bluff shorelines throughout the project region, measured above the 100-year water level. Lower uprush values were generally determined for shallow sloping shorelines comprised of finer sediments such as those occurring in large embayments and on fillet beaches. Larger uprush values were determined for exposed shorelines featuring steeper nearshore slopes.

Wave uprush at all 55 representative locations along the shoreline are included in the 100-year flood hazard elevations provided in Appendix A, and in the flood hazard mapping provided in Appendix B, C and D. Start and end coordinates for the calculated 100-year flood hazards are provided in Appendix A, within each project reach. The component attributed to wave uprush is the difference between the 100-year flood hazard elevation and the 100-year combined flood level. A full definition of the 100-year flood hazard and how it is determined is provided in Section 5.3. It is recommended that buildings within the flood hazard be floodproofed to the 100-year flood hazard elevation, at minimum.

Lower flood hazard elevations than those shown in this SMP may be realized in sheltered embayments and areas with significant riparian vegetation, due to a localized reduction in the wave uprush potential. A lower wave uprush value would have to be established based on a local engineering study that considers shoreline topography and nearshore wave transformations at a much higher spatial resolution (i.e. lot by lot) than is provided in this SMP.

4.4 Sediment Transport

4.4.1 Longshore Sediment Transport Potential

Longshore sediment transport potential is the rate at which sand and gravel are transported along a shoreline due to wave action if unlimited supply of material is available to be transported. Longshore sediment transport potential provides an important indication of which dominant direction sediment moves along a shoreline ("net" longshore potential), and is an important factor in determining where sediment may be originating from (sources) and where it is being deposited (sinks).

To calculate longshore sediment transport potential the nearshore wave climate must first be understood, particularly the amount of wave energy arriving from various directions along the shoreline. Understanding nearshore storm wave extremes as discussed in Section 4.3 is not sufficient, as longshore sediment transport can occur to some degree during virtually all non-calm conditions on the shoreline. As such, a full time series of wave conditions must be analysed to compute longshore sediment transport potential.

Each of the 45-year offshore hourly wave datasets discussed in Section 4.3.1 were summarized in scatter tables of wave direction vs. wave period. Wave direction was discretized into 22.5 degree directional bins while wave periods were grouped into four bins as follows:

- T_p = 3 – 5 seconds.
- T_p = 5 – 7 seconds.
- T_p = 7 – 9 seconds.
- T_p = > 9 seconds.

The Delft3D-WAVE model discussed in Section 4.3.2 was run for each wave direction and wave period combination in the scatter tables, a total of 32 wave conditions for each of the 6 models (two for each conservation authority).

Nearshore wave conditions were output from the models at 100 m offshore intervals along 46 sediment transport transects. Transect locations were selected to capture all major changes in shoreline orientation. Wave shoaling and depth limited breaking formulae were applied to the 2D transformed waves and transformation tables were generated for each output location. The tables included wave height and wave direction transformation coefficients from the offshore WIS location to the nearshore output point for each of the wave direction and period combinations in the offshore wave scatter tables.

Using the wave transformation tables, the full 45-year hourly time series of offshore wave conditions at the five WIS data locations was transformed to the nearshore transects.

To calculate longshore sediment transport potential the CERC formula was used (CERC, 1984). The CERC formulation is a classical equation for the determination of bulk sediment transport rates. The CERC formula was applied at each timestep in the nearshore wave timeseries to assess the potential rate and direction of sediment transport during that hour in response to the nearshore wave conditions. The easterly and westerly transport rates were then summed over the entire 45-year period to determine the gross annual sediment transport potential in each direction at each transect. Results were tabulated for each 100 m cross-shore bin along the transect. Figure 4.8 presents an example plot of the resulting gross sediment transport potential for transect 16 located east of Bond Head (GRCA). The red bars represent westward longshore transport potential, while the green bars present eastward longshore transport potential. The y-axis is the distance offshore, measured from the water line.

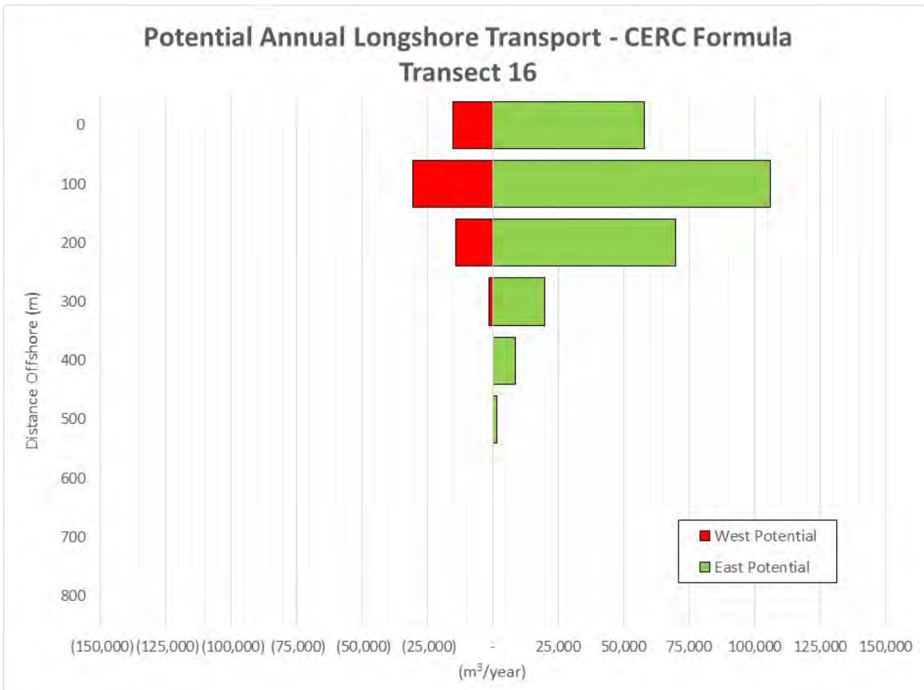


Figure 4.8 Longshore sediment transport potential calculated at transect 16 (east of Bond Head) using the CERC formula

Potential annual longshore transport rates are summarized for each project reach in Appendix A.

4.4.2 Actual Longshore Sediment Transport

Calculated longshore sediment transport *potential* is the rate at which sand and gravel could be transported along the shoreline if an infinite supply of sediment were available on the lake bottom and beach. When sediment sources are limited, the *actual* sediment transport rates will be lower than the *potential* transport rates.

Actual longshore sediment transport can be estimated by performing a sediment budget analysis for the shoreline. For example, in a sediment budget analysis sources of sediment from shore erosion and rivers are quantified along with the sand and gravel in sinks, such as fillet beaches adjacent to harbours. The primary source of sand and gravel for the north shore of Lake Ontario is the eroding bluffs and nearshore lake bottom. The eroded bluff material is comprised of a wide range of sediment sizes. Fine grained sediment such as clay and silt are transported offshore and deposited on the lakebed in deep water, thereby not contributing to the shoreline. Large material such as cobbles and boulders are only transported short distances in the most energetic storm events, and therefore are typically found close to shore where they originated from the eroding banks and bluffs. Medium grained sediments such as sand, gravel and pebbles can be transported along the shoreline and have a meaningful impact on the formation and resilience of beaches.

A high-level sediment budget was created whereby the local rates of bluff erosion and lakebed downcutting were assessed in the vicinity of each sediment transport transect to determine the overall existence and volume of sediment that may be available for transport. Based on the results of this assessment and visual observations of the nearshore conditions, estimates of the *actual* sediment transport are generally only a small fraction of the calculated *potential* sediment transport. This is indicative of a littoral system limited sources of new sand and gravel for the shoreline and nearshore, which is the case of the study shoreline. Estimated *actual* sediment transport rates for each project reach are summarized in Appendix A.

4.5 Updated Shoreline Change Rates

Shoreline change rates can be measured at different temporal and spatial scales. For this study, the focus was long-term rates that are representative of the trend over many decades (e.g., greater than 50-years) to support the hazard assessment. Short-term rates or trend reversals are not relevant for regulatory erosion hazard mapping. The methods and results from the shoreline change analysis within the study area are described in the sections that follow.

4.5.1 Geo-reference Historical Images and Digitizing

Historical aerial photographs from 1953 and 1954 were obtained from the Conservation Authorities. These images were geo-referenced with ArcGIS software using recent orthophotographs. Root Mean Square (RMS) errors were used to quantify a maximum potential horizontal positional error in the geo-referenced photos, which is reported during the geo-referencing of aerial photos with GIS software. The maximum RMS errors are reported in Table 4-6. It is important to note that technical studies (Crowell et al, 1991) have shown the actual horizontal error in geo-referenced aerial images and maps is generally much lower than the RMS error (in other words, RMS error is a conservative estimate). If the RMS error for a specific photograph was greater than the rate of change measured from photo (e.g., bluff erosion rate), the photograph was not used in the shoreline change analysis.

Table 4-6 Maximum Potential RMS Error for Aerial Photo Registration

CA	Photo Year	No. of Photos	Maximum RMS Error (m)
CLOCA	1954	11	5.4
GRCA	1954	17	5.3
LTRCA	1953/1954	17	4.5

Methods used to minimize errors in georeferenced imagery include well distributed tie points, selecting appropriate transformation methods, and routine visual checks against base imagery. The top of bluff and waterline for beaches were selected as the erosion reference feature. Water lines were adjusted to account for water level on the date the photograph was taken, where necessary. These locations were digitized in ArcGIS from the historical aerial photographs and the recent orthophotography (2018). When interpreting such features from registered aerial photographs, there is some level of uncertainty due to factors such as photo resolution and scale, photo quality, and vegetation. If the erosion reference feature could not be identified in either the historical or recent imagery, no delineation was made resulting in a gap in the line segment.

Digitizing the erosion reference feature can also introduce positional error when working in GIS. This may be due to poor photo resolution, shadows, and sun glint. Uncertainty during delineation was minimized by using large map scales (e.g., 1:2,500 or better) to view photos, including a high density of vertices, and frequent comparisons with other photo years to help identify feature position and extent.

4.5.2 1953/54 to 2018 Change Rates

The results for Reach 5, which extends from the east side of Port Darlington to the Port of Newcastle, are reviewed herein to further highlight the methods for the shoreline change analysis, which were first documented in Zuzek et al. (2003). Refer to Figure 4.9 for a map with the spatial extent of Reach 5. The orange shoreline highlights locations where the top of bluff was digitized, while the red shoreline identifies areas with eroding shorelines. Locations with no trend, such as the centre of the Wilmot Creek development, were not included in the analysis due to the presence of shoreline protection structures, which would bias the results.

A sample of the 1954 and 2018 top of bluff lines for the western limit of the Wilmot Creek development are presented in Figure 4.10. The black lines are the recession transects drawn between the historical and recent top of bluff lines. The erosion transects for Reach 5 are plotted from west to east in Figure 4.11. There is significant variability in the recession measured at each transect with values ranging from 5 m to over 20 m during the 64-year period.

The individual transects are further analyzed in Figure 4.12, where they are sorted in ascending order from lowest to highest (black diamonds), and annualized. In other words, the erosion at each transect is converted to a rate, in metres per year. When a group of erosion transects is analyzed together, such as the population of transects for Reach 5, the Average Annual Recession Rate (AARR) is a simple statistical measure to characterize these data. The AARR for the entire population of recession transects is 0.17 m/yr and plotted as the green line in Figure 4.12. While the AARR is a simple statistical calculation, it is clearly not a good characterization of the historical recession rate, which are highly variable. Further, if only the AARR was used for establishing a 100-year erosion hazard setback for Reach 5, it would under-estimate erosion across roughly half the reach. Put another way, the erosion setback would fail to characterize the erosion risk for roughly 50% of the bluff coastline.

To address the deficiencies in using the AARR, the standard deviation (SD) of the transect population is also calculated, annualized, and added to the AARR plotted on Figure 4.12. The orange horizonal line is the AARR plus 1 SD and the red line is the AARR plus 2 SD. With a normal population distribution, the AARR plus and minus 2 SD should encompass roughly 95% of the data. The SD is clearly a good measure of the variance in these data given that only a small portion of the individual transects fall above the red line on Figure 4.12.

For the erosion hazard mapping included in this SMP, the AARR and the annualized SD were calculated for each Reach or sub-reach in the analysis. The erosion rate used to estimate the future 100-year top of bank was the AARR plus 1SD (annualized). For a normal distribution, the AARR plus 1 SD (annualized) should encompass 84% of the future recession. Therefore, the approach will conservatively estimate the future top of bank for 84% of the shoreline in Reach 5.

A similar methodology was followed for the beach shorelines in the study area. A sample of the 1954 and 2018 waterlines digitized from the aerial photographs in Reach 7 and 9 are presented in Figure 4.13 and Figure 4.14. These methods are consistent with other recent Shoreline Management Plans and coastal hazard studies, including the Elgin County SMP (Baird, 2015) and the Chatham-Kent Lake Erie Shoreline Study (Zuzek Inc., 2020).

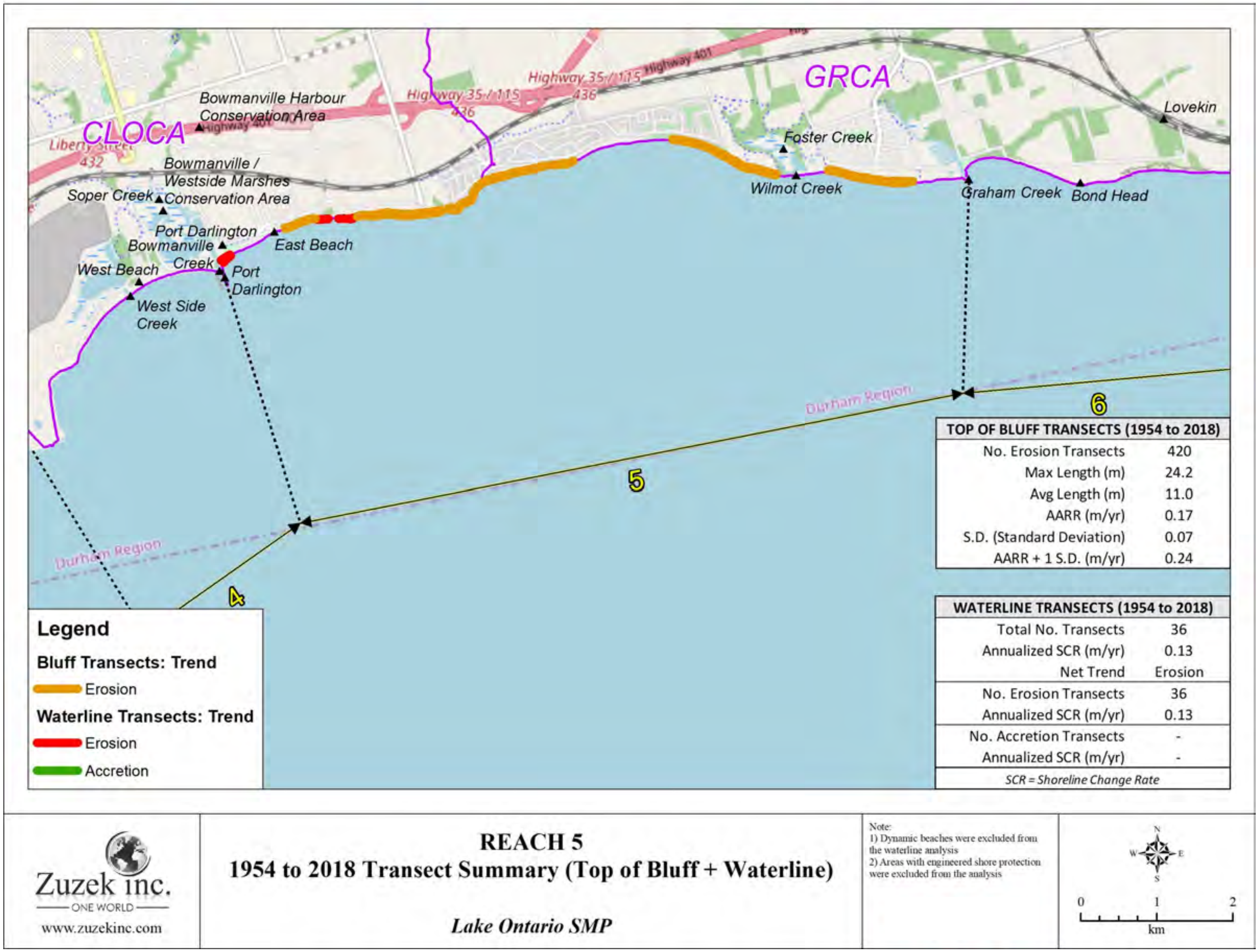


Figure 4.9 Digitized Bluff Lines in Reach 5 (areas with no line obscured by vegetation or shore protection)

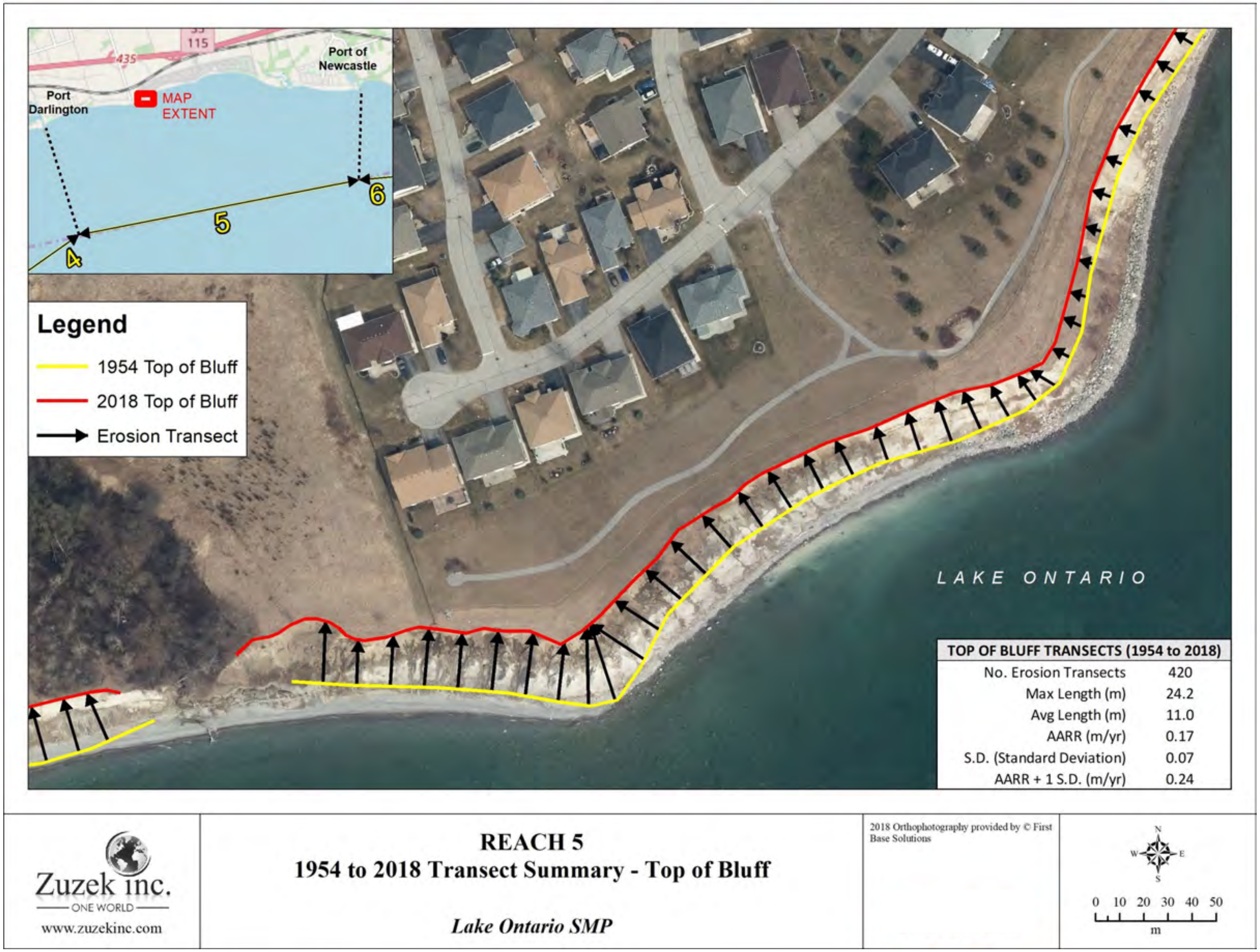


Figure 4.10 Recession Transects between 1954 and 2018 Top of Bank Lines, Wilmot Creek Development

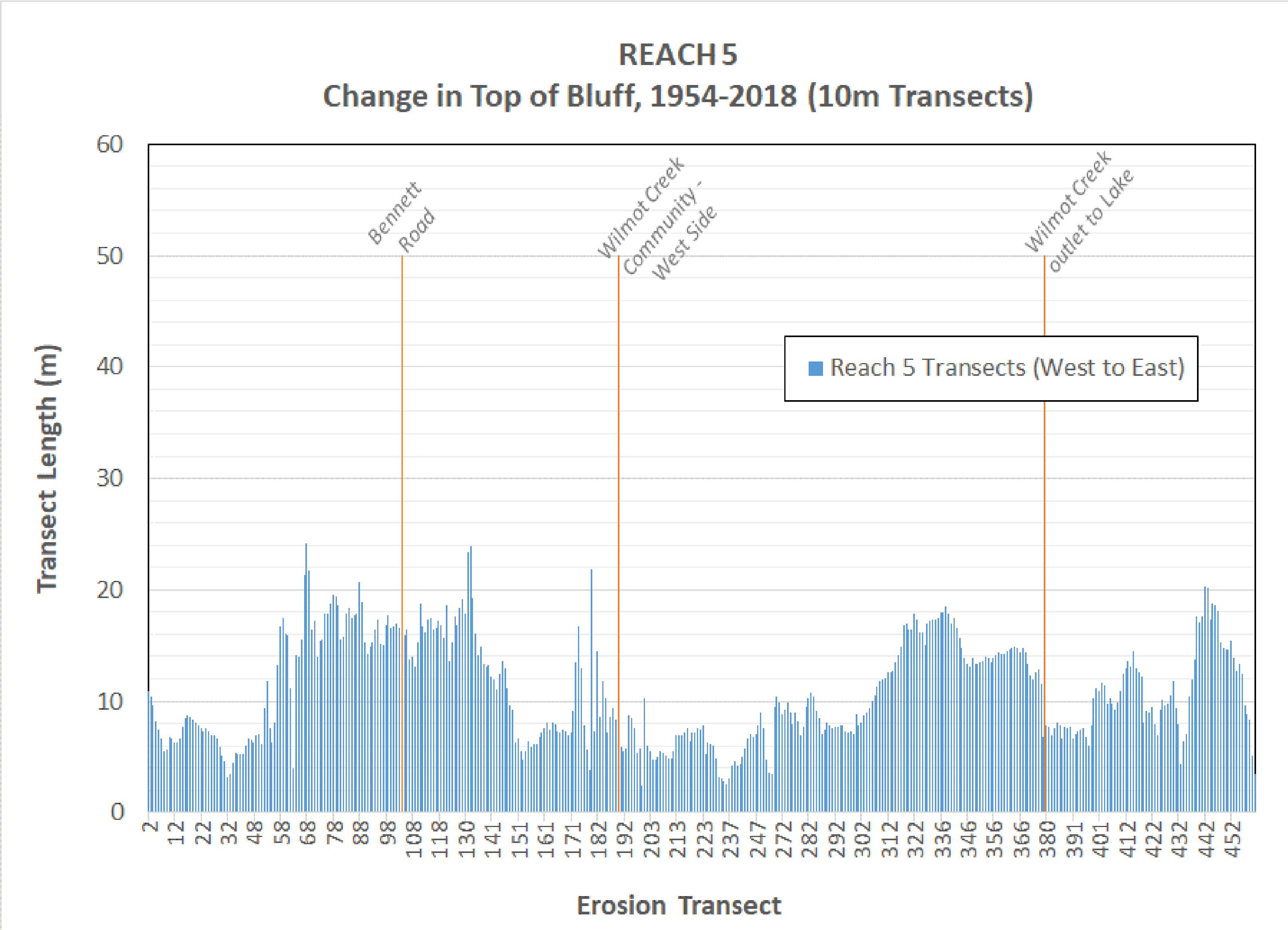


Figure 4.11 Reach 5 Erosion Transects Plotted from West to East (transect measurement from 1954 to 2018)

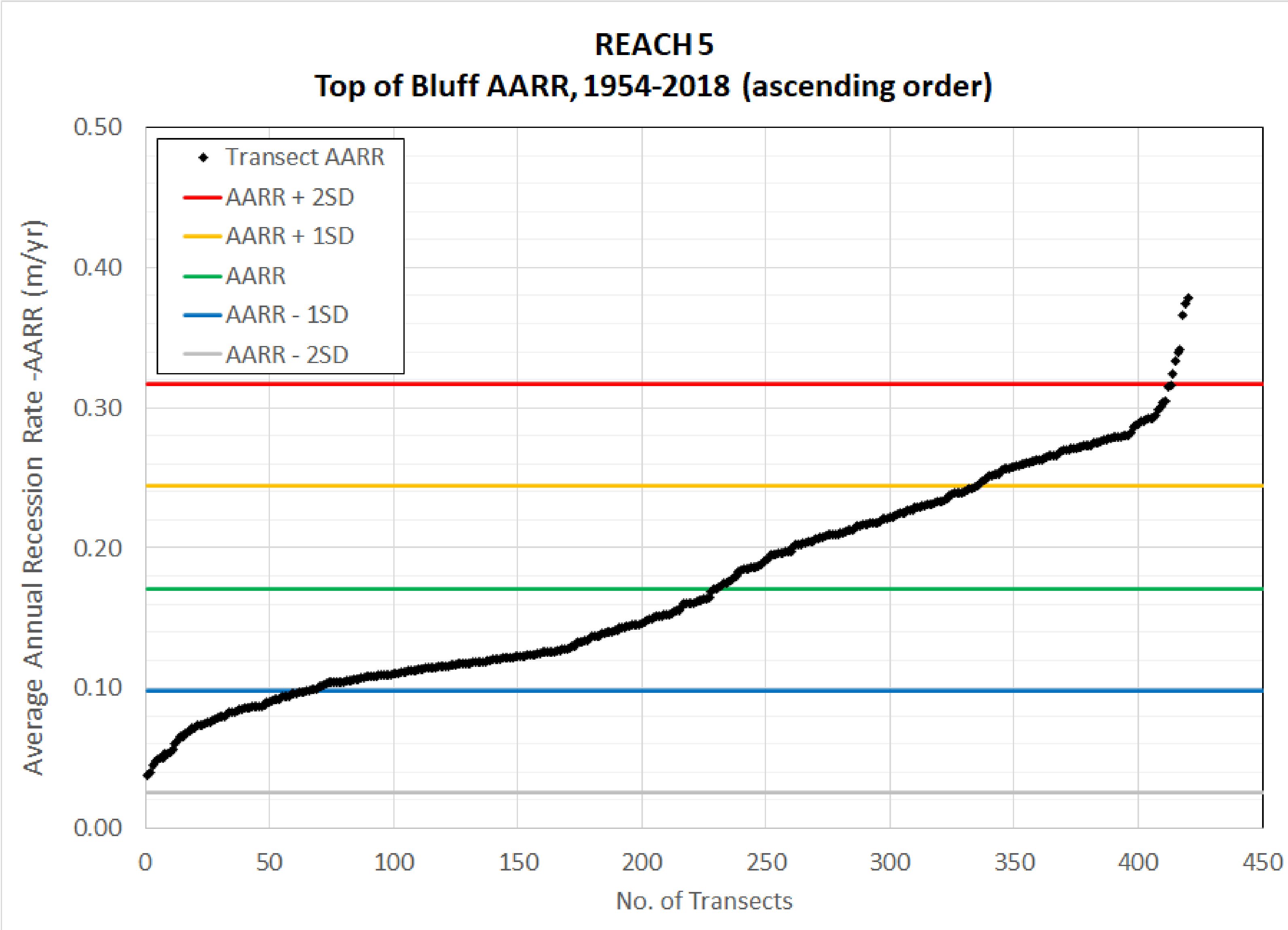


Figure 4.12 Erosion Transects Sorted in Ascending Order, Reach 5

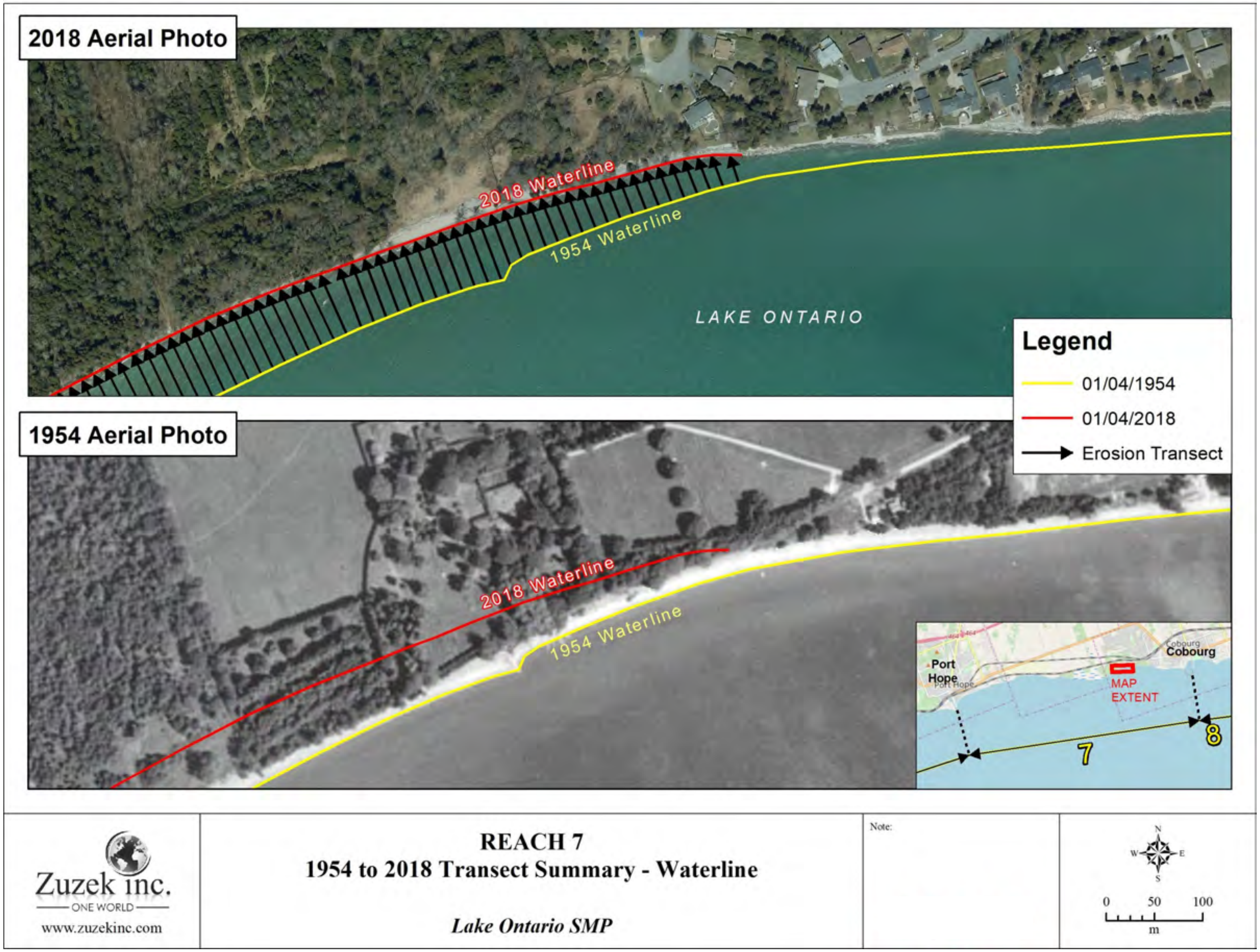


Figure 4.13 Reach 7 Waterline Erosion Measurements

REACH 9
1954 to 2018 Transect Summary - Eroding Waterline

Lake Ontario SMP

Zuzek inc.
ONE WORLD
www.zuzekinc.com

Note:

N W E S
0 50
m

Figure 4.14 Reach 9 Waterline Erosion Measurements

4.6 Influence of Climate Change

A recent technical study supported by Natural Resources Canada (Zuzek Inc., 2019) investigated the impacts climate change on future storms and ice cover in the Great Lakes Basin. This investigation was the first of its kind to focus solely on storm impacts to wave heights and surges in the basin with future ice conditions. The key findings are summarized in the following report sections.

4.6.1 Warming Due to Climate Change

The projected winter warming in Canada for RCP2.6 and RCP8.5 future emission scenarios were recently summarized by Bush and Lemmen (2019). Refer to information for 2031-2050 and 2081-2100 in Figure 4.15. Significant winter warming is projected, especially for RCP8.5. By late century, winter temperatures for this scenario are projected to be 5 to 7 degrees Celsius warmer in Southern Ontario.

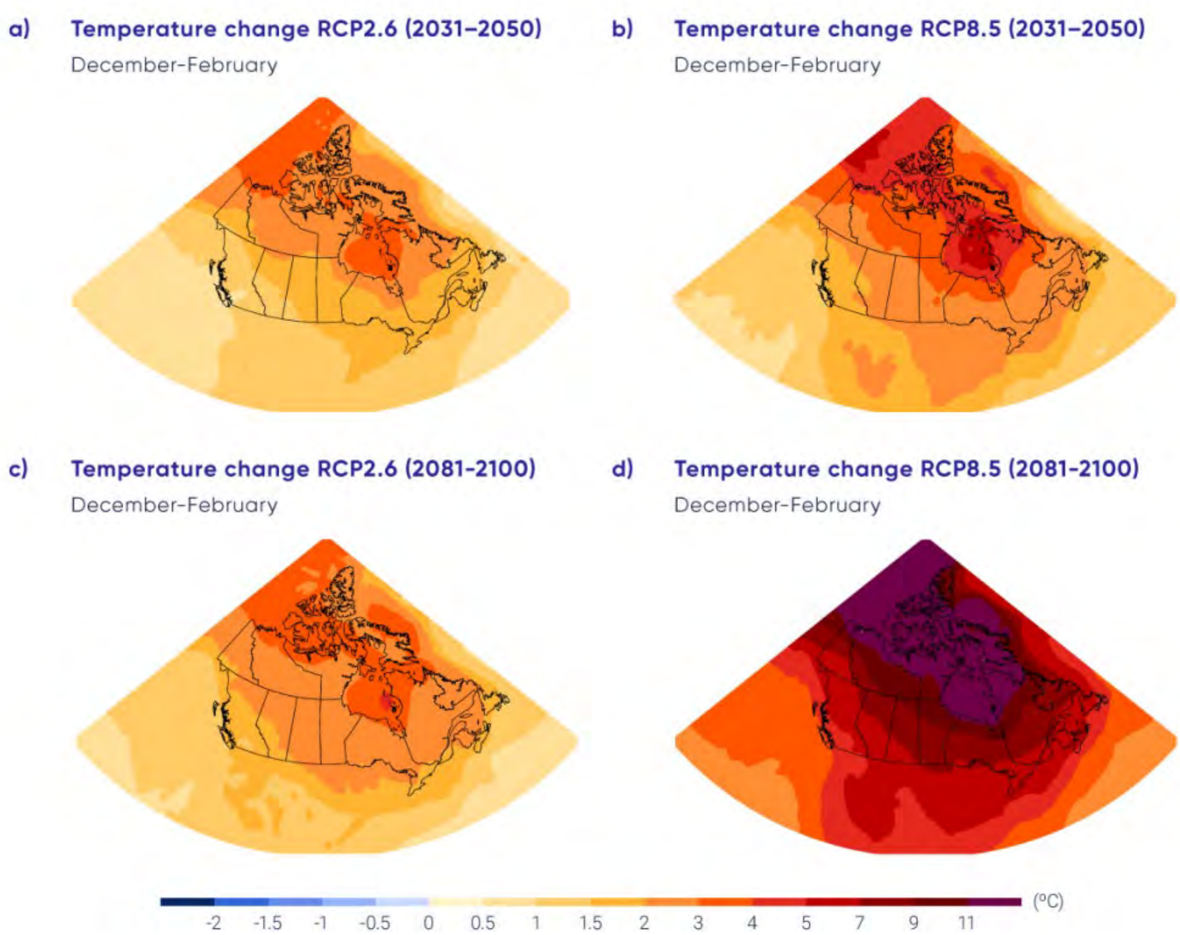


Figure 4.15 Winter Warming for Mid- and Late-Century (from Bush and Lemmen, 2019)

4.6.2 Ice Cover Projections Due to Warming

Ice cover in the Great Lakes has been decreasing since 1973 (Wang et al, 2012) with similar trends documented across the northern hemisphere (Sharma et al, 2019). The projected winter warming will continue to increase land and lake temperature, resulting in further reductions in ice cover in the future. Figure 4.16 provides a conceptual diagram of these potential changes with extensive ice cover in the eastern basin (left-hand panel), coverage limited to the Kingston Basin in the middle image, and no ice coverage in the open lake for the winter image in the right-hand panel. As the winter temperatures continue to warm in Southern Ontario, the duration of lake ice coverage will continue to decrease and could approach zero by late century (e.g., 2080).

Figure 4.16 Schematic Diagram of Reduced Lake Ontario Ice Coverage

Based on future land and lake temperatures extracted from Weather Research and Forecasting (WRF) model for a late century RCP8.5 scenario, RWDI (2020) reached similar conclusions. Lake Erie and Ontario could be ice free in the future. This conclusion was recently validated by an ongoing ECCC study for the Great Lakes (ECCC, Internal File 2020).

4.6.3 Changes in Wave Climate and Storm Surge

The impacts of climate change on future wave heights, and storm surges was recently evaluated for Lakes Erie and Ontario (Baird, 2019) as part of the NRCan supported study (Zuzek Inc., 2019). The wave height analysis was completed by selecting the top 15 wave height storms on Lake Ontario from 2000 to 2013, then comparing the predicted wave heights for the same storms for a late-century RCP8.5 emission scenario. The results did not produce any consistent trends on the potential impacts of climate change on future wave heights (e.g., larger or smaller wave heights in the future). The analysis did, however, highlight the importance of lake ice cover on the generation of deep-water waves and propagation of those waves into the shoreline in the winter.

In the second part of the analysis, an hourly wind-wave hindcast was completed using spatially varying winds across Lake Ontario for the historical baseline period (2000 to 2013) with actual ice-cover. The same weather was then simulated for late-century with the RCP8.5 emission scenario and zero ice-cover (assuming no lake ice in the future).

For each grid cell in the wave model, hourly wave energy density was calculated for the 13-year wave hindcast. The results from the historical hindcast were subtracted from the future (late century) simulation to estimate the potential increase in wave energy due to climate change. The results are summarized in Figure 4.17. In the Kingston basin at the northeastern end of the lake, the loss of winter ice cover resulted in a 100% increase in the amount of winter wave energy reaching the coast. For the coast around Presqu'ile Provincial Park, the increase in winter wave energy is estimated to be 60% to 70%. Further east, in the jurisdiction of CLOCA, the method projected a 20% increase in winter wave energy. However, it is important to note that the satellite methods used to capture winter ice cover will not capture narrow bands of shore-fast ice, which are common in the western basin of Lake Ontario. Therefore, the projected increase of only 20% is likely an under-estimate of the future climate change impacts.

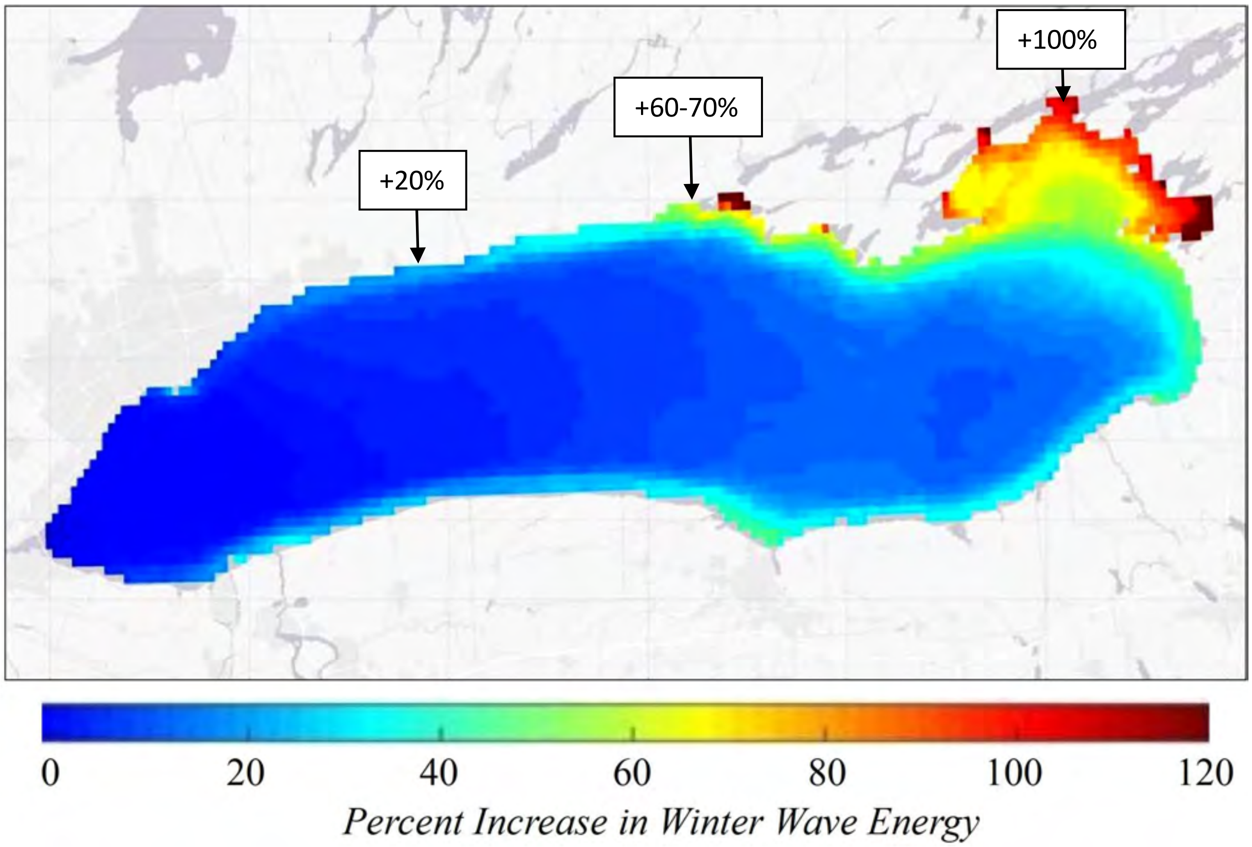


Figure 4.17 Projected Increase in Winter Wave Energy for RCP8.5 (late century)

4.6.4 Future Hazard Mapping Updates to Integrate Climate Change Impacts

As outlined in Section 2.2, the 2020 PPS directs planning authorities to prepare for the impacts of climate change that may increase the risk associated with natural hazards. For example, if the projected decrease in ice cover and shore-fast ice occur, the amount of wave energy reaching the shoreline will increase in the future. Since wave energy has been shown to be surrogate for erosion if the geologic properties of the shore materials do not change (Baird, 2004), then a 25% increase in winter wave energy could result in a 25% increase in future erosion rates at a site.

At present, the technical guidance (MNR, 2001a; MNR, 2001b; CO & MNR, 2005) available to Conservation Authorities or practitioners does not provide direction on how to defensibly integrate the projected impacts of climate change on future coastal hazards. If the guidance is updated in the future, it may be necessary to update the hazard mapping generated for this SMP.

4.7 Littoral Cells and Shoreline Reaches

The only lake-scale study on littoral cell boundaries in Lake Ontario was completed by the Conservation Authorities and Water Management Branch of the Ministry of Natural Resources and Forestry in 1988 (Reinders). A littoral cell is defined as a self-contained coastal system that encompasses areas of erosion, longshore sediment transport, and deposition.

Based on the sediment boundaries identified in the report, the study area is part of a large littoral cell that extends more than 100 km from East Point Park in Scarborough to Presqu'ile Provincial Park (Reinders, 1988). Historically, prior to modification of the Lake Ontario shoreline by ports and harbours, a grain of sand at the west end of the littoral cell could be transported by waves and currents to the east and ultimately be deposited in the main beach of Presqu'ile Provincial Park.

Today, much of the historical littoral cell from East Point to Presqu'ile has been sub-divided into small sub-cells by harbour jetties and port facilities on headlands, which are partial barriers to longshore sediment transport. For example, the coast from Port Hope to Cobourg is a sub-cell of the larger littoral cell from East Point to Presqu'ile. In this region there is only limited exchange of sediment with the adjacent sub-cells due to the harbour and rivermouth jetties at Port Hope and Cobourg (refer to Figure 4.18).

Figure 4.18 Reach 7 Boundaries from Port Hope to Cobourg

The sub-cell boundaries from the Reinders (1988) report, the field observations from this study, and results from the longshore sediment modelling were used to map a total of 12 reaches for this SMP update. Port Hope to Cobourg was identified as Reach 7. The 12 reaches covering the study area from west to east are presented in Figure 4.19 to Figure 4.21. Principal findings of this SMP and shoreline management recommendations have been grouped based on these reaches, and are presented in Appendix A.

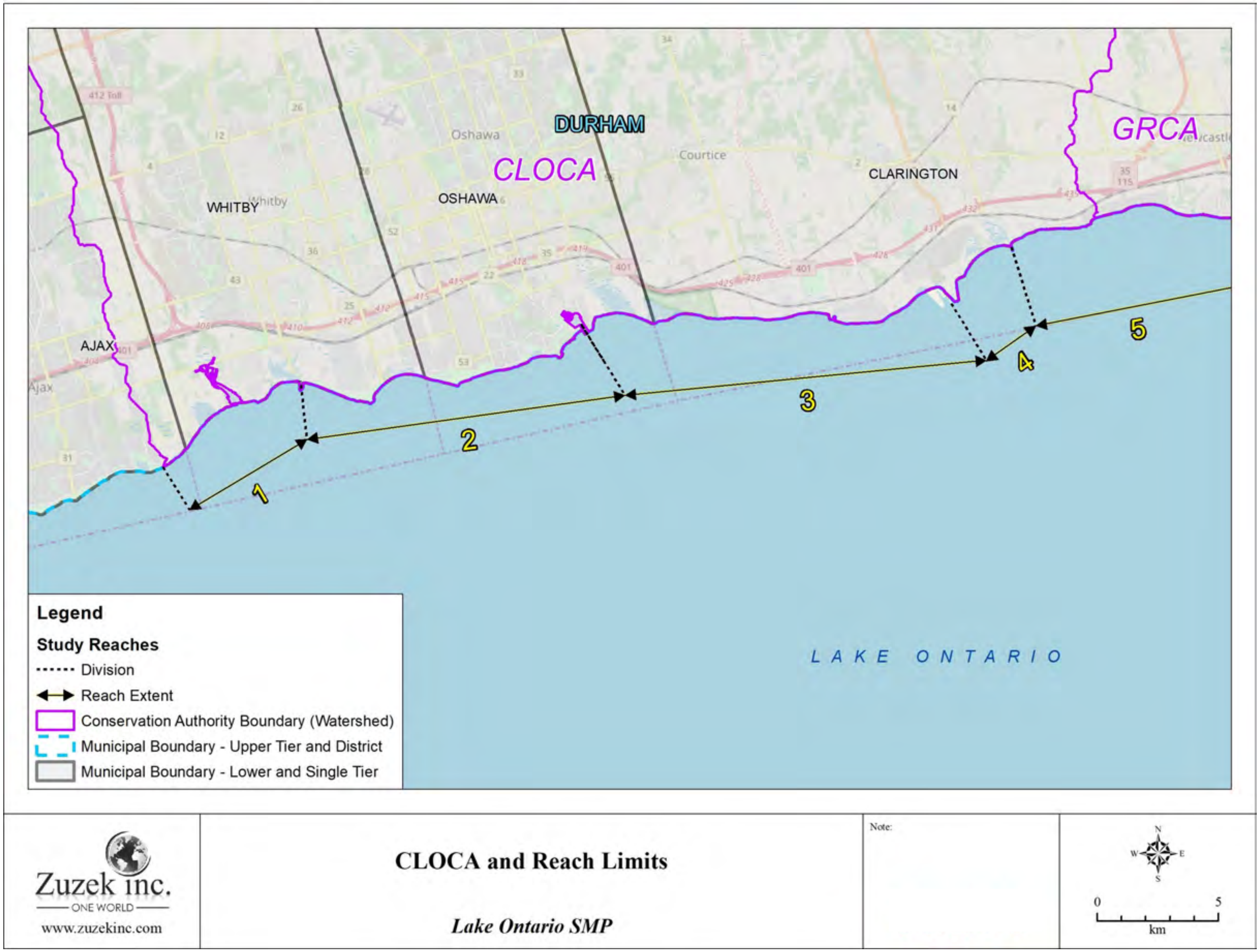


Figure 4.19 CLOCA Shoreline Reaches

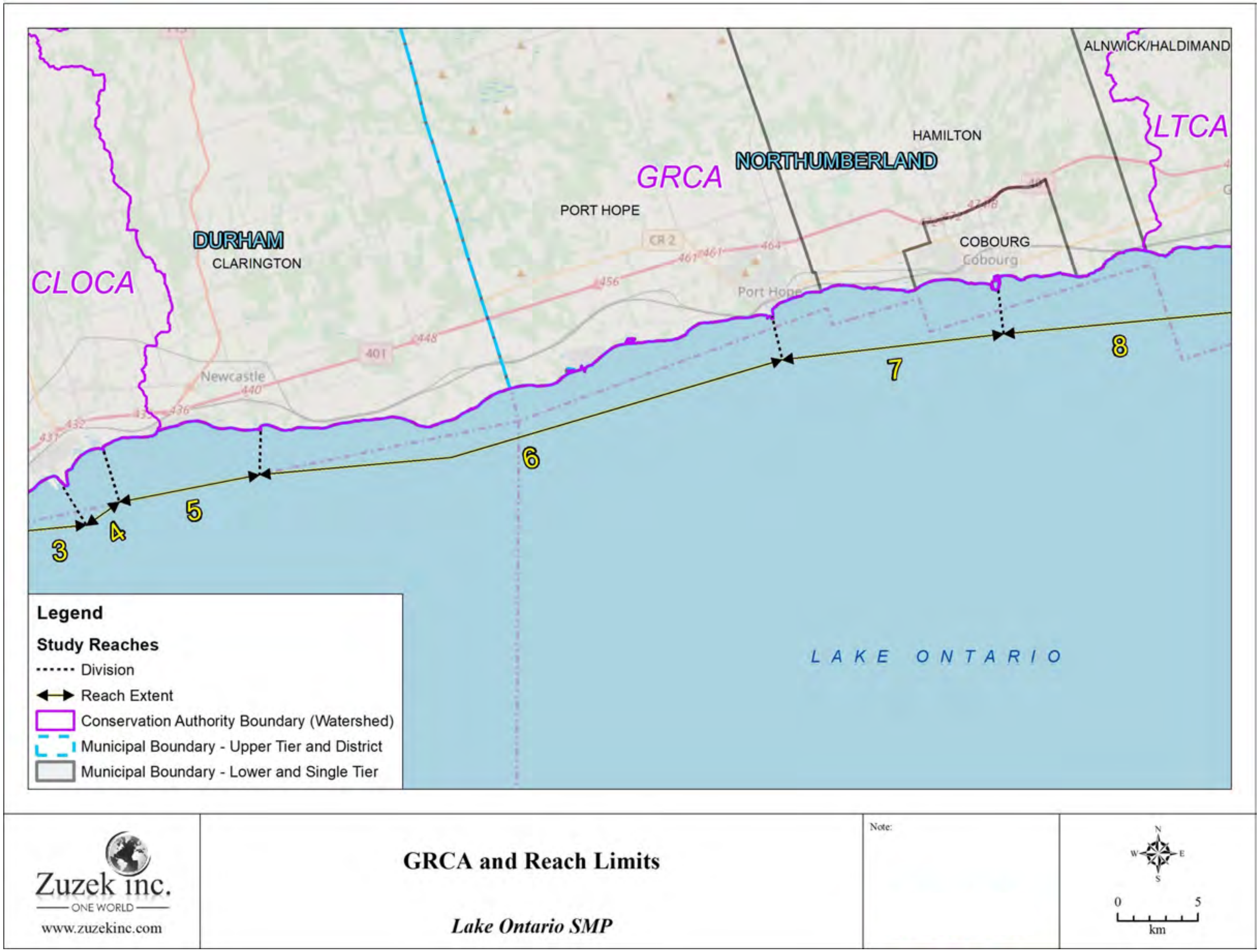


Figure 4.20 GRCA Shoreline Reaches

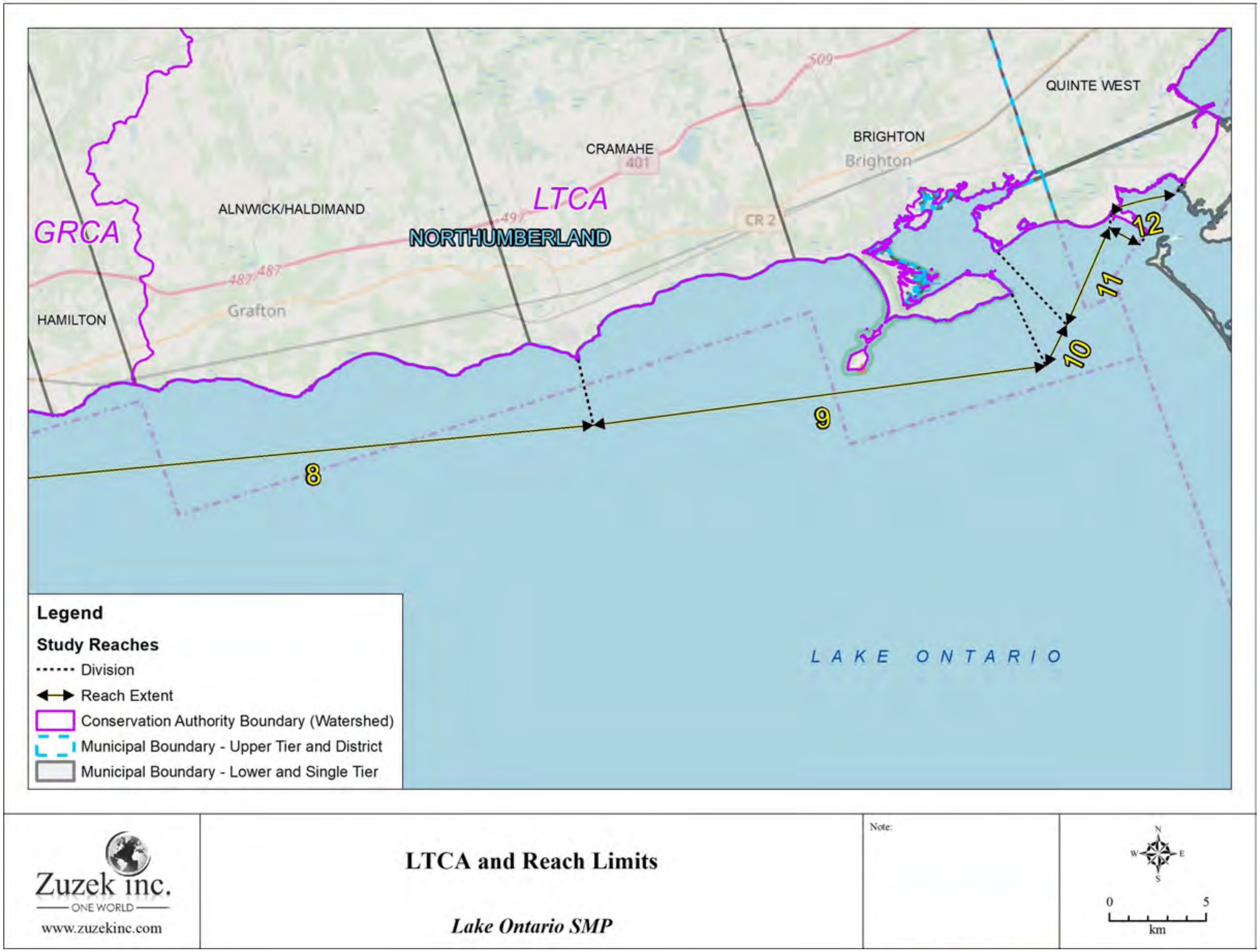


Figure 4.21 LTRCA Shoreline Reaches

5.0 SHORELINE HAZARDS

The process followed to map shoreline hazards, including erosion, flooding, and dynamic beaches, are described in the following sections, along with the key elevation datasets.

5.1 Key Data Sources

High resolution topographic information is a critical dataset to map shoreline hazards as per the Technical Guide (MNR, 2001a) and the Guidelines for Developing Schedules of Regulated Areas (Conservation Ontario and MNR, 2005). Given the recent history of record high water levels on Lake Ontario, the Technical Committee for the study recommended utilizing the most recent high-resolution data available, which in most cases was the 2018 SCOOP digital elevation model (DEM). In some locations, tree canopy obstructed the 2018 SCOOP DEM and the 2017 LiDAR was utilized. Table 5-1 summarizes the available topographic data by CA.

Table 5-1 Available Topographic Elevation Data by CA

CA	Elevation Data Source
CLOCA	2018 LiDAR, 2016 LiDAR
GRCA	2018 SCOOP DEM
LTRCA	2018 SCOOP DEM, 2017 LiDAR, 2009/10 Survey at Prince Edward Estates.

5.2 Defining and Mapping the Erosion Hazard

The erosion hazard setback is defined in the Guidelines for Developing Schedules of Regulated Areas (Conservation Ontario and MNR, 2005) as a 100-year erosion allowance plus a stable slope allowance measured horizontally from the existing stable toe of slope. When the CAs identify their regulated area, an additional allowance of up to 15 metres is added. A schematic of the setback methodology is provided in Figure 5.1.

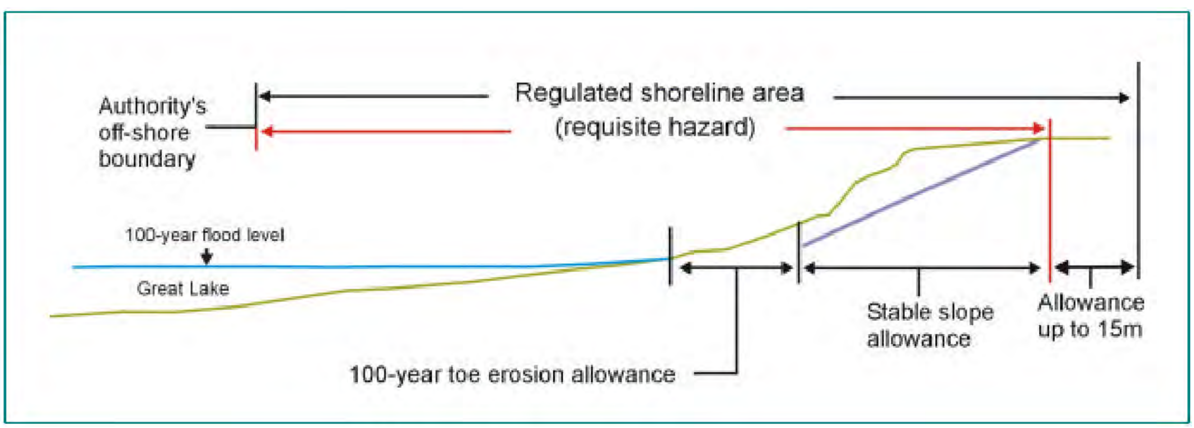


Figure 5.1 Erosion Hazard Setback Approach

For this study, the erosion hazard limit was calculated for both eroding bluff and beach shorelines. Within the GIS mapping environment, the limit of the erosion hazard for the eroding bluff shorelines was mapped using the following steps:

- Calculate the 100-year erosion allowance using the shoreline change information presented in Section 4.5. The erosion allowance was calculated as the Average Annualized Recession Rate (AARR) from the transects plus one standard deviation of the transect population (also annualized), times the 100-year planning horizon. For gullied areas, the rate was calculated from the AARR plus two standard deviations of the transect population to account for the higher risk in these areas and potential rapid growth of new gullies. This setback was measured horizontally from the existing toe of slope line in GIS with a buffer command.

- A horizontal allowance for the stable slope was calculated by estimating the height of the bluff/bank at the inland limit of the erosion allowance and applying a 3:1 (H:V) setback (i.e., height of bluff/bank times three, measured horizontally). For example, a bluff height of 10 m will have a stable slope allowance of 30 m (3 x 10 m). A stable slope of 3:1 (H:V) is the standard approach where detailed geotechnical information is not available, as is presented in the Technical Guide (MNR, 2001a).

Refer to Figure 5.2 for an example of the methodology.

Figure 5.2 Erosion and Stable Slope Allowance/Setback for a High Bluff

Due to the influence of the bluff height on the stable slope allowance, the shoreline was subdivided into sections based on 2 m increments (e.g., 10 to 12 m, 12 to 14 m, etc.). When the elevation increased or decreased by more than 2m, a new stable slope allowance was calculated and added to the erosion allowance. This process was repeated for all bluff areas within the project study limits.

For eroding beach shorelines, the limit of the erosion hazard was mapped in GIS using the following steps:

- Calculate the waterline erosion rate using the shoreline change rates presented in Section 4.5. The waterline erosion rate is calculated as the Average Annualized Recession Rate (AARR) of the transects plus one standard deviation of the transect population (also annualized), times 100.

- From the 100-year flood elevation contour, a setback consisting of the 100-year erosion allowance for the beach was applied (using a buffer command).

This process was repeated for all eroding beach areas within the project study limits. A sample of the methodology is presented in Figure 5.3.

Figure 5.3 Erosion Hazard Setback Methodology for Beach Shorelines

5.3 Defining and Mapping the Flooding Hazard

The flood hazard setback is defined in the Guidelines for Developing Schedules of Regulated Areas (Conservation Ontario and MNR, 2005) as the 100-year level plus a standard 15 m allowance for wave uprush. When the CAs map their regulated area, an optional additional allowance of up to 15 metres also can be added. A schematic of the setback methodology is provided in Figure 5.4. The MNR Technical Guide (2001) provides additional information on the 15 m wave uprush component, including the application of wave runup calculations to define the setback based on site specific nearshore and beach slope, substrate, and local wave conditions. The approach followed for this study was summarized in Section 4.3.3 and includes the site-specific calculation of beach runup for all exposed sections of shoreline.

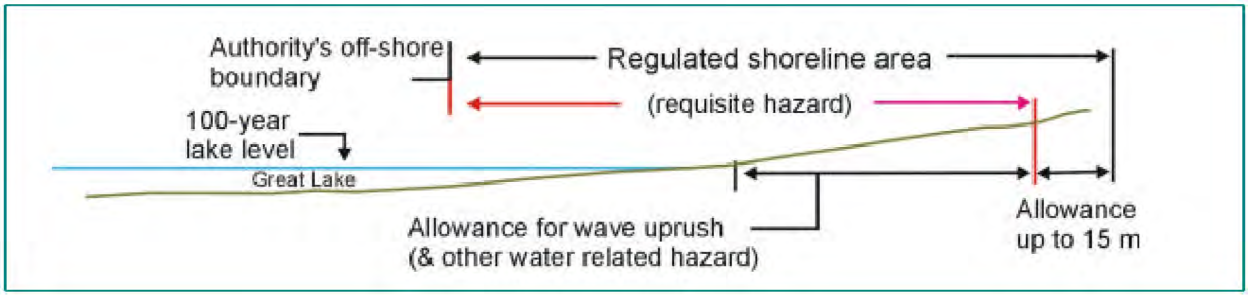


Figure 5.4 Flood Hazard Setback

Figure 5.5 provides a sample of the flood hazard mapping for a section of open coast where the wave uprush limit was calculated using the runup methodology. For the creek valley in the centre of the figure, waves are not able to propagate inland to the 100-year flood elevation and thus the use of the local runup value for wave uprush would not be appropriate. In these regions the standard 15 m setback has been applied. This type of review was completed for the entire study area to select the most appropriate methodology to map the wave uprush component of the flood hazard limit.

Figure 5.5 Sample of the Flood Hazard Limit with Runup Calculations and the 15 m Setback

5.4 Defining and Mapping the Dynamic Beach Hazard

The dynamic beach hazard is defined in the Guidelines for Developing Schedules of Regulated Areas (Conservation Ontario and MNR, 2005) as the 100-year flood level, an allowance for wave uprush, plus a 30 m allowance to account for the dynamic nature of the beach and dune system, including periods of erosion and accretion. When the CAs map their regulated area, an additional allowance of up to 15 metres is added (refer to Figure 5.6).

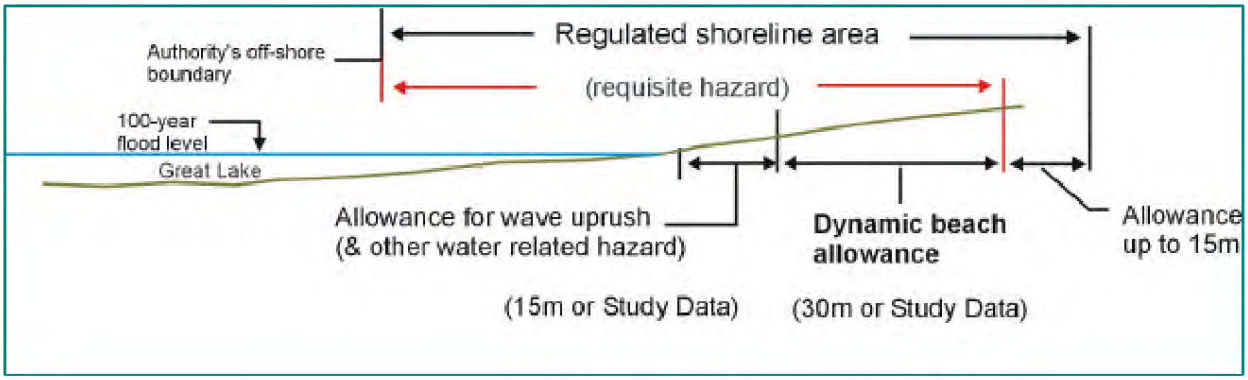


Figure 5.6 Dynamic Beach Hazard Limit

In addition to mapping the onshore limit of the dynamic beach, the offshore limit was also mapped approximately 200 m offshore, which is roughly the 6 m depth contour. Thus, the dynamic beach hazard limit is mapped as a shaded polygon on the hazard maps, recognizing that the nearshore area, beach, and dunes are part of an inter-connected physical system and should be managed as such.

An example of the dynamic beach hazard limit for Iroquois Beach in Whitby is provided in Figure 5.7. The lakeward limit is 200 m offshore of the waterline and the landward limit extends 15 m inland from the 100-year flood level plus 30 m for the dynamic beach allowance. If the setback intersected a feature other than sand beach, such as the road in Figure 5.7, the hazard limit is terminated at the non-dynamic feature.

Figure 5.7 Example of Dynamic Beach Hazard Mapping at Whitby

If the dynamic beach allowance intersects an eroding bank or bluff, the allowance is limited to the toe of the bluff (i.e., the non-dynamic feature). However, if the bank or bluff is eroding, a 100-year erosion allowance plus the stable slope setback are added to the dynamic beach limit to account for the position of the beach in the future based on the annual recession rate.

Similarly, the hazard limit for eroding dynamic barrier beach shorelines must account for future erosion. In Figure 5.8 the landward limit of the barrier beach was identified (dashed bluff line) and 34 m was added to account for 100-years of future barrier beach migration inland.

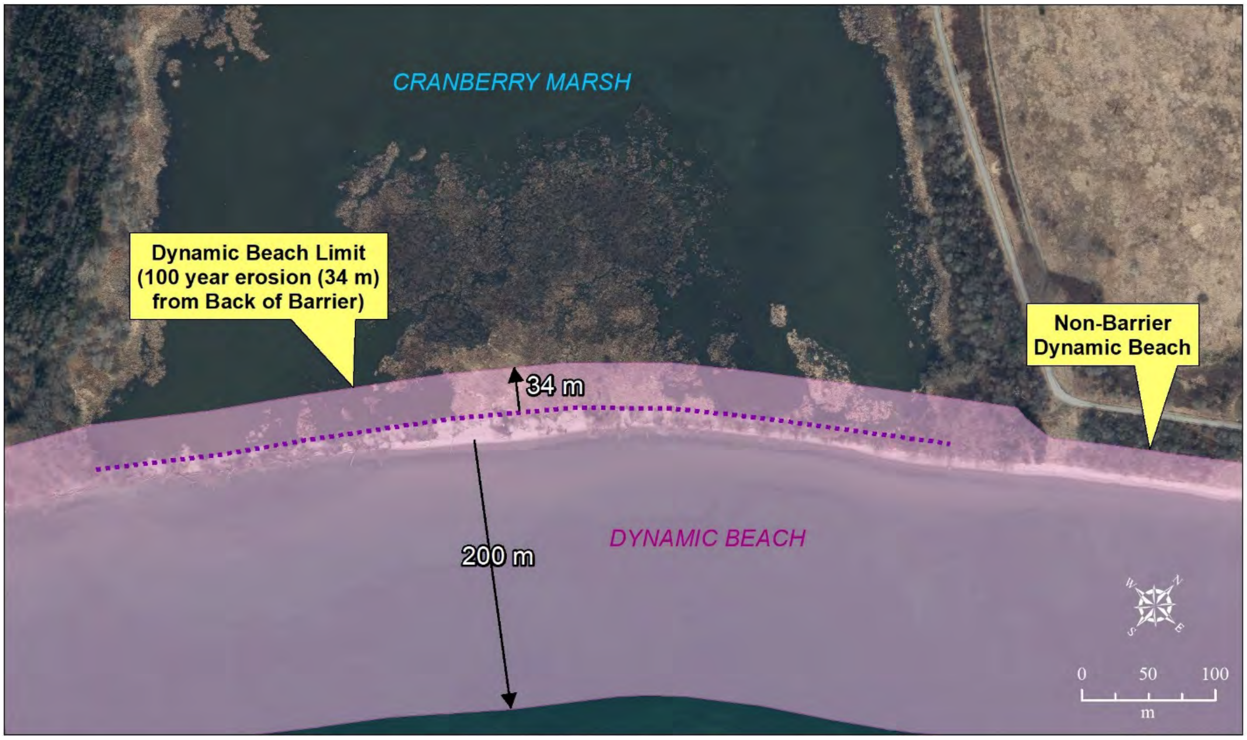


Figure 5.8 Hazard Limit for an Eroding Barrier Beach

5.5 Accounting for Existing Shoreline Protection

If the governing hazard setback includes erosion, historically, a reduced setback would be considered based on the presence of engineered erosion protection. The Technical Guide (2001a) indicates that a credit of up to 35 years may be counted against the 100-year planning horizon for erosion if a suitable, engineered erosion protection structure is in place. In other words, when determining the likely position of the shoreline in the future, the historical erosion rate is extrapolated over a 65-year planning horizon as opposed to 100-year. Other aspects of the erosion hazard including the stable slope or dynamic beach allowance (where applicable) remain valid and must be added to the revised erosion setback. In the past, to qualify for such a credit the erosion protection structure would have to be designed by (new erosion protection structures) or evaluated by (existing erosion protection structures) a qualified professional, and it would have to be shown that the structure has a remaining effective design life of at least 35-years. Moreover, it must be shown that suitable access for construction equipment is maintained throughout the design life of the structure.

As discussed in Section 2.2 of this SMP, the PPS (2020) states that "Planning authorities shall prepare for the impacts of a changing climate that may increase the risk associated with natural hazards". To this effect, if the remaining design life of a structure is evaluated based on design conditions determined from historical data, it may not be an accurate description of design life over the next 35-years. Acceptance of this evaluation and the subsequent reduction to the erosion hazard planning horizon may not be appropriate in the future due to a changing climate. Even under historical conditions private shoreline protection rarely lasts 35 years without significant maintenance. As such, the acceptance of a reduction in the erosion planning horizon due to the existence of engineered shore protection will be at the discretion of the CA on a site by site basis.

5.6 Hazard Mapping for the Individual CAs

A map template was developed in consultation with the CAs to visualize the hazards on full size 24 by 36 inch maps. Each map includes a summary of the hazards, base mapping, definitions, data sources, a PGO and PEO stamp, a disclaimer, and the tile index. Refer to Figure 5.9 for a sample of the template for Map 25 (of 61) from the LTRCA jurisdiction.

The tile index for each CA was prepared to ensure complete coverage of the shoreline hazard mapping. Table 5-2 summarizes the number of tiles per CA and the appropriate appendices for the maps.

Table 5-2 Map Sheets by CA

CA	Map Sheets	Appendix
CLOCA	1 to 37	B
GRCA	1 to 43	C
LTRCA	1 to 61	D
Total Number of Maps = 141		

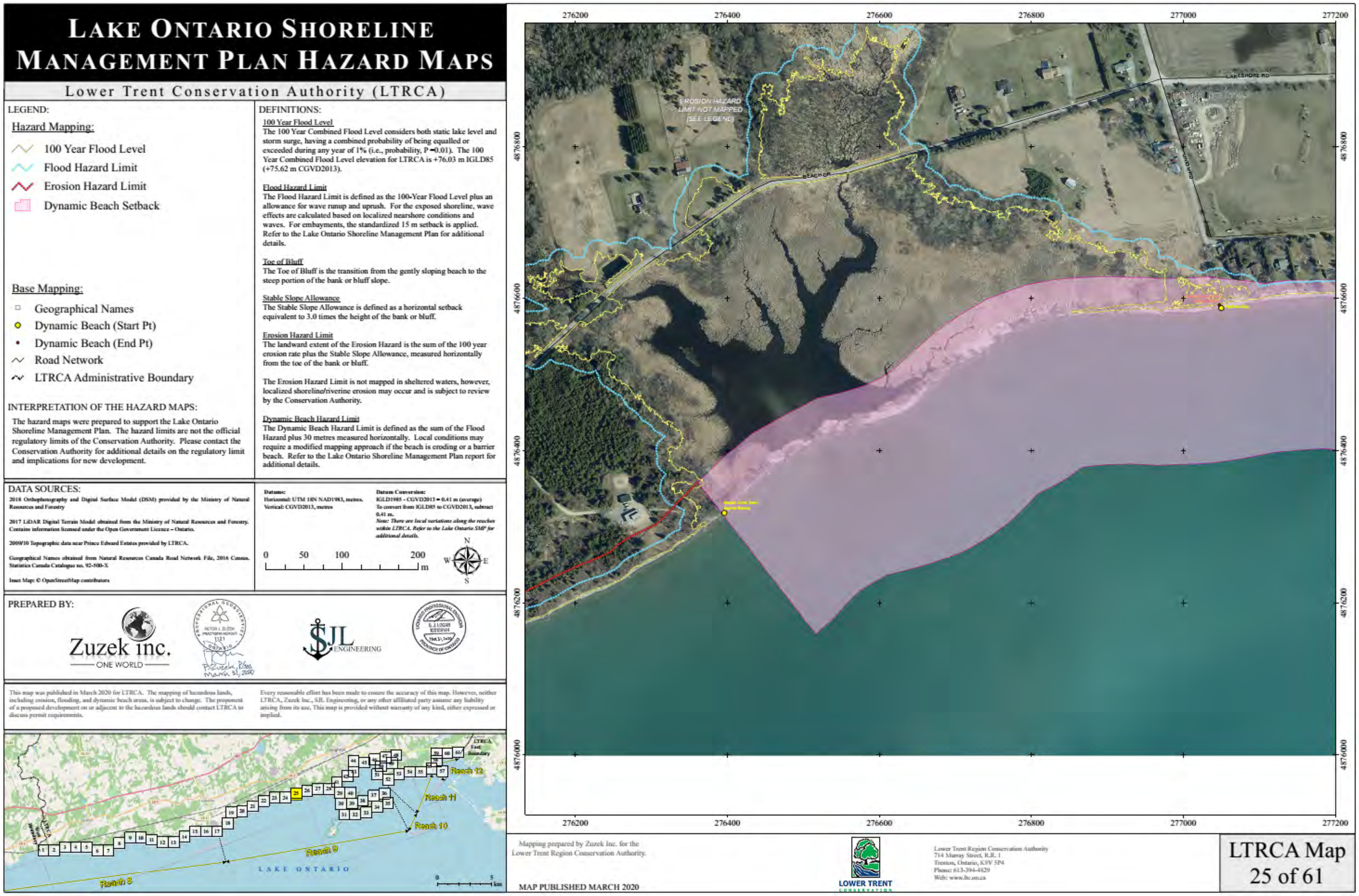


Figure 5.9 Sample of 24*36 Hazard Map for LTRCA (map 25 of 61)

6.0 PUBLIC OPEN HOUSE

Once the technical analysis was complete and a set of draft hazard maps were prepared for the study area, a series of Open Houses were held in early November 2019. An afternoon session was organized for elected officials and Municipal staff, followed by a public session in the evening. The following meetings were hosted by the three CAs:

- CLOCA November 5, 2019: The meeting was held at the Darlington Energy Complex, 1855 Energy Drive, Courtice, Ontario.
- GRCA November 6, 2019: The Venture 13 Lecture Hall, 739 D'Arcy Street, Cobourg was selected for the GRCA Open House.
- LTRCA November 7, 2019: The Keeler Centre meeting room, second floor, 80 Division Street, Colborne was utilized for the Lower Trent meetings.

Following the introductions, a technical presentation was provided on the shoreline observations, technical analysis, draft hazard mapping, range of possible management recommendations for the reaches, and general guidance for constructing new shoreline protection structures. A moderated discussion followed to solicit feedback from the attendees.

Figure 6.1 Hazard Mapping Posters for the GRCA Meeting

Participants at each open house were given an exit survey to list any additional questions, make suggestions for the SMP, and to provide final comments or recommendations. Refer to Figure 6.2 for a copy of the LTRCA exit survey.

EXIT COMMENTS

Lake Ontario Shoreline Management Plan Update

Lower Trent Conservation Authority

1. Do you have any additional questions for the study team?

Name: ____

Address: ____

E-mail: ____

Telephone: ____

Question(s):

____

____

____

____

____

2. Do you have any suggestions for the Shoreline Management Plan:

____

____

____

____

3. Any final comments:

____

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____

Hazard maps will be available on the LTC website once they have been developed and reviewed.

Please hand in the completed Comment Sheet, fax it to 613-394-5226. or return it to the Lower Trent Conservation Authority Office (714 Murray Street, R.R. 1 Trenton, Ontario)

Figure 6.2 Sample of Existing Survey from LTRCA Public Meeting

7.0 SHORELINE MANAGEMENT

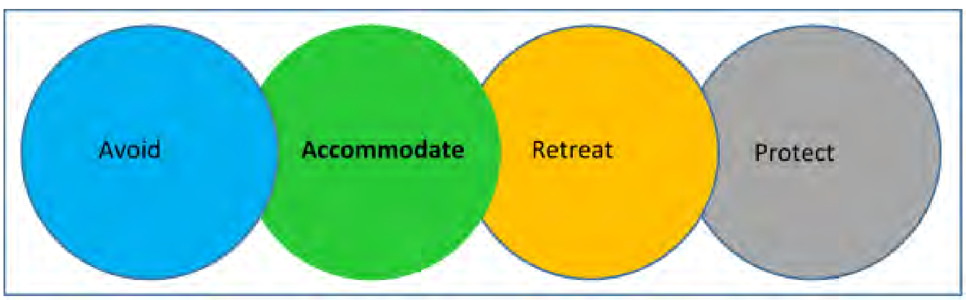
The approach to shoreline management and recommendations developed for each project reach are outlined in the sections that follow.

7.1 Review of Management Approaches

Borrowing from the Climate Change literature on adaptation, four general themes were selected to develop the coastal management approaches in the reaches. They include Avoid, Accommodate, Retreat, and Protect. The rationale and approach to the four concepts is summarized as follows:

- **Avoid**: reduce exposure by ensuring that new development does not occur on hazardous land. Development setbacks for erosion and flooding embrace the principles of 'avoid' and are based on a 100-year planning horizon, as per provincial policy. Adopting a longer planning horizon would increase the longevity of the "avoid" strategy and the overall resilience of the shoreline. This is a highly effective strategy for new development but does not address legacy development, where vulnerability to coastal hazards can be significant.

- **Accommodate**: an adaptive strategy that allows for continued occupation of coastal properties while changes to human activities or infrastructure are made to reduce coastal hazards and vulnerability. For example, raising the foundation of a flood-prone building will reduce vulnerability and may enable continued occupation of the site.



- **Retreat**: a strategic decision to withdraw or relocate public and private assets exposed to coastal hazards when the costs to accommodate or protect are either not affordable, fail to produce a positive benefit-cost ratio, fail to adequately reduce the risk, or are not permitted due to regulations or legislation. For this strategy to be successful, voluntary property acquisition programs with participation and contributions from senior levels of government may be required.

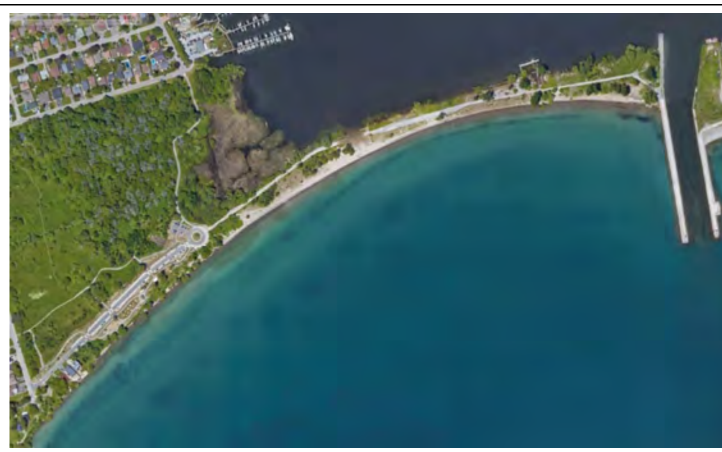
- **Protect**: a reactive strategy to protect people, property, and infrastructure. This is the traditional approach used in the Great Lakes and often the first considered. Examples include grey infrastructure such as armour stone revetments and seawalls, and nature-based solutions such as building coastal dunes, planting vegetation or nourishing beaches. For this strategy to be successful it must be shown that the site-specific risks can be effectively mitigated for the duration of the planning horizon, as per provincial policy.

7.1.1 Coastal Management Examples

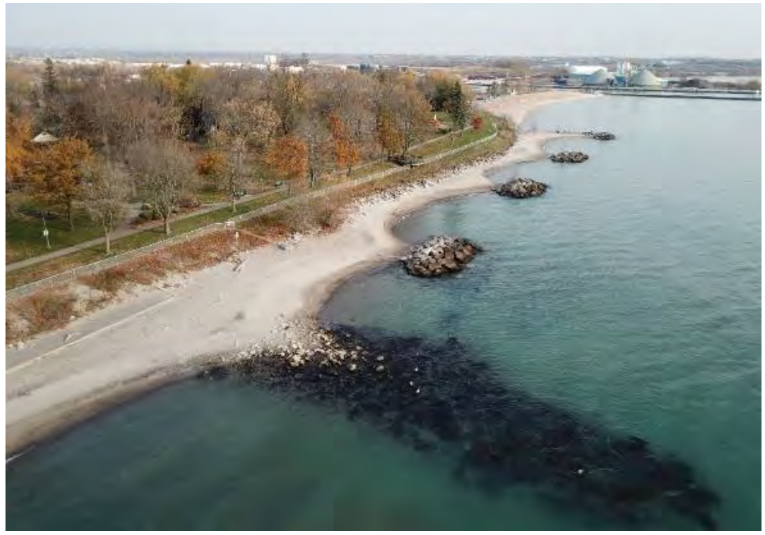
Numerous coastal management approaches reflective of the four broad categories presented above (avoid, accommodate, retreat, and protect) are presented in Table 7-1. Examples include regulatory mapping, natural buffers for eroding shorelines, flood proofing by raising grades around buildings, re-locating buildings and infrastructure further inland, artificially nourished beaches, and grey shore protection such as armour stone revetments and breakwaters. As discussed in Section 2.2, the PPS (2020) hierarchy directs an avoidance approach for new development. Accommodate and protect strategies are only permitted where safe access can be maintained and generally require one or more regulatory approvals.

Table 7-1 Examples of Management Approaches

AVOID	
Regulations and mapping to direct new development away from hazardous lands	
Maintain natural shorelines with vegetated erosion buffers to reduce risk and costs associated with armouring the shoreline	
ACCOMMODATE	
Raise grades around flood-prone building foundation *Regrading should be limited to the footprint of the building and immediate perimeter. Work permits may be required for regrading activities.	

<table>
<tr><td>Raise building foundation and lowest openings above the flood hazard</td><td>
</td></tr>
<tr><td colspan="2">RETREAT OR RE-ALIGNMENT</td></tr>
<tr><td>Relocate buildings further inland if they are threatened by erosion</td><td>
</td></tr>
<tr><td>Re-align coastal highways threatened by erosion (e.g., old and new alignment of Dexter Line, Port Bruce, Lake Erie)</td><td>
</td></tr>
<tr><td>Public acquisition of property within areas of significant risk and/or ecological value. Frenchman’s Bay west barrier beach is a local example were cottage lots were slowly purchased, and the beach was converted to a public asset</td><td></td></tr>
</table>

PROTECT	
Construction of sand dunes at the back of the beach to increase beach width, elevation and resilience	
Artificial beach nourishment with sand trucked from inland sources (e.g., sand pit), dredged from navigation channels or bypassed around harbours	
Construction of share parallel protection, such as armour stone revetments and seawalls	

Construction of beach retention structures, such as offshore breakwaters and groynes (Oshawa)	

*Strategies presented above may require work permits from one or more regulatory body. Work permit requirements should be investigated along with any shoreline management strategy.

7.2 Technical Summaries and Reach Recommendations

Shoreline management recommendations are provided in Appendix A for each project reach and are provided in a standardized reach summary template. Each template includes a map with the reach boundaries, a description of local conditions, a summary of shoreline infrastructure from the structures database (refer to Section 3.3), results from the technical analyses including waves, water levels and sediment transport (Section 4.0), a review of the natural hazards for the reach (Section 5.0), specific threats to infrastructure and the ecosystem, and the shoreline management recommendations. Each reach summary also includes a disclaimer for unauthorized use. Refer to Table 7-2 for a copy of the blank reach summary template. The completed reach summaries are provided in Appendix A.

Table 7-2 Reach Template with Field Descriptions

Reach # – Name	
Map of Reach Boundaries	
Local Conditions	
• Description of reach.	
Typical Photo	*Interesting Photo*
Shoreline Structures	
• Information on shoreline protection structures	
Sediment Supply and Longshore Sediment Transport	
• Summary of sediment transport results and implications	
Summary of Natural Hazards	
• Information on erosion rates, flood levels, dynamic beaches, and waves	
Infrastructure and Ecosystem Threats	
• Summary of threats	
Shoreline Management Recommendations	
• Recommendations for reach specific management actions	
Use Disclaimer	
The information in this reach summary was prepared for the Central Lake Ontario Conservation Authority. If used by a third party, they agree that the information is subject to change without notice. Zuzek Inc. and SJL Engineering Inc. assume no responsibility for the consequences of such use or changes in the information. Under no circumstance will Zuzek Inc. or SJL Engineering Inc. be liable for direct, indirect, special, or incidental damages resulting from, arising out of, or in connection with the use of the information in this summary by a third party.	

7.3 Shoreline Protection Guidance

Guidance for both private and public shoreline protection structures are provided herein for the CLOCA, GRCA and LTRCA shorelines. The information is generally based on regional design conditions commensurate with a 100-year planning horizon and covers the typical shoreline types encountered within the project region. However, the design of shore protection must be completed on a site or project-specific basis, as local shoreline conditions and wave exposure can vary significantly over short distances. Information provided herein should be taken as a general guide only, while site specific advice and engineering should always be sought from a professional engineer specializing in coastal engineering before implementing shore protection works.

In general, sloping shore protection structures such as revetments are preferred over vertical structures due to their superior ability to dissipate wave energy. Vertical structures tend to reflect more wave energy causing increased lakebed erosion directly in front of the structure. This can lead to failures if the structure toe is not designed properly or founded deep enough. Moreover, sloping structures tend to have gradual failure mechanisms such as displacement of structure elements (typically stones) or settlement over relatively long periods of time. By contrast, vertical structures tend to fail abruptly and catastrophically during a major storm event, as is evident by the high percentage of failed vertical structures in the shore protection database discussed in Section 3.3. Sloping structures can be monitored and maintained more readily throughout their design life relative to their vertical counterparts.

Shore protection structures should generally be shore-parallel in order to mitigate potential impacts to longshore sediment transport. Shore-perpendicular structures such as groynes are typically only effective at a community scale and on shorelines with sufficient longshore transport of beach building material (sand, gravel and cobble). Shore-perpendicular structures must be designed by a qualified individual and must consider potential impacts on natural shoreline processes, neighbouring, and downdrift shorelines. These types of structures will generally not be suitable for individual private property shore protection.

Shore protection structures should be constructed from natural stone materials where possible. Natural stone materials such as quarried limestone and field stone are preferred over alternative construction materials such as concrete or steel as they are better for the aquatic environment and more closely replicate natural shoreline conditions and habitat.

The majority of the project shoreline can be classified as either a low bank (1 – 3 metres in height), or a medium to high bank or bluff (3 metres and up). The recommended approach to shore protection for these shorelines is an armour stone revetment. Armour stone revetments typically provide the highest level of protection for the cost and can be designed to be effective for most shoreline types. Figure 7.1 presents examples of armour stone revetments.

For certain regions particularly throughout the LTRCA, field stone (boulders) can be an acceptable and cost-effective alternative to armour stone as it is a naturally occurring material that can be locally sourced. Field stones are smoother and less angular than armour stone however, making them less stable on a slope. They also cannot be placed with as tight a packing density as armour stone therefore resulting in a higher void ratio. As such, field stone revetments must include at least two layers of boulders in the primary stone layer and be carefully designed by a qualified professional. Figure 7.2 presents examples of field stone revetments throughout the project region.

Figure 7.1 Sample armour stone revetments on Lake Ontario

Figure 7.2 Sample field stone revetments on Lake Ontario

Where a vertical or near-vertical structure is preferred over a sloping structure due to space limitations or specific shoreline characteristics, stacked or stepped armour stone seawalls are recommended. Armour stone seawalls are particularly well suited for shorelines with flat, shallow bedrock. Special attention must be given to the design of the structure toe as vertical structures are often accompanied by increased vertical erosion of the lakebed (scour). Crest elevation, drainage and stone size are also critical considerations in the design of vertical or near vertical armour stone structures. Vertical armour stone seawall structures must be carefully designed by a qualified individual. Examples on Lake Ontario are provided in Figure 7.3.

Figure 7.3 Sample armour stone seawalls on Lake Ontario

Shoreline protection is generally not appropriate for dynamic beach environments. However, there may be some circumstances where protection and stabilization at the back of a beach is appropriate for existing development. For this scenario, an armour stone beach curb is recommended. A beach curb is a low-crested wall placed at the back of the beach, behind the beach crest, and founded at least 1 to 2 m below the typical beach crest elevation to account for potential variability in the beach profile. Figure 7.4 presents examples of armour stone beach curbs within the project region.

Figure 7.4 Sample armour stone beach curbs on Lake Ontario

Shoreline structures should generally be founded at sufficient depth so they are not undermined by seasonal variations in the nearshore profile, vertical downcutting (erosion) of the lakebed, and wave scour. Structures should be founded on firm till material or bedrock. Where bedrock is encountered, armour stones can be pinned using steel anchors to improve stability and reduce the necessary stone size. Where firm till or bedrock is not encountered, a bedding stone layer is recommended, and a lower toe stone depth may be required.

In general, structures comprised of items such as pre-cast concrete blocks, gabion baskets, timber and scrap concrete should be avoided throughout the project region. As is evident in the shore protection database discussed in Section 3.3, these forms of shore protection are insufficient to resist the erosive forces of Lake Ontario over the long term and are generally poor for the aquatic and shorelands environment.

Construction cost estimates are provided in Table 7-3 for armour stone revetments and armour stone seawalls for low bank (1 – 3 m) and medium to high bluff shorelines (3 – 10 m). Cost estimates are based on unit rates for projects undertaken throughout Ontario and are indexed to 2019 dollars. Prices vary depending on material availability, location, contractor availability and site access, among other things. Prices listed in Table 7-3 do not include contingencies, design fees or other professional costs associated with the implementation of shore protection. A minimum contingency of 20% should be added to the costs provided when considering the affordability of implementing shoreline protection.

Table 7-3 Construction cost estimates for recommended shore protection concepts and for various shoreline types

Shoreline Type	Shore Protection Concept	Typical Construction Costs*	
Medium to High Bank or Bluff	Armour Stone Revetment	$3,600	/ metre
	Armour Stone Seawall	$3,300	/ metre
Low Bank or Bluff	Armour Stone Revetment	$3,200	/ metre
	Armour Stone Seawall	$2,700	/ metre
Beach	Beach Curb	$1,000	/ metre

*Based on 2019 costs

Shore protection information provided herein are presented as guidelines only and should be supplemented with site-specific information and detailed design by a qualified professional engineer. Typical, concept-level shore protection designs for the CLOCA, GRCA and LTRCA shorelines are presented in cross-section below in Figure 7.5 to Figure 7.11.

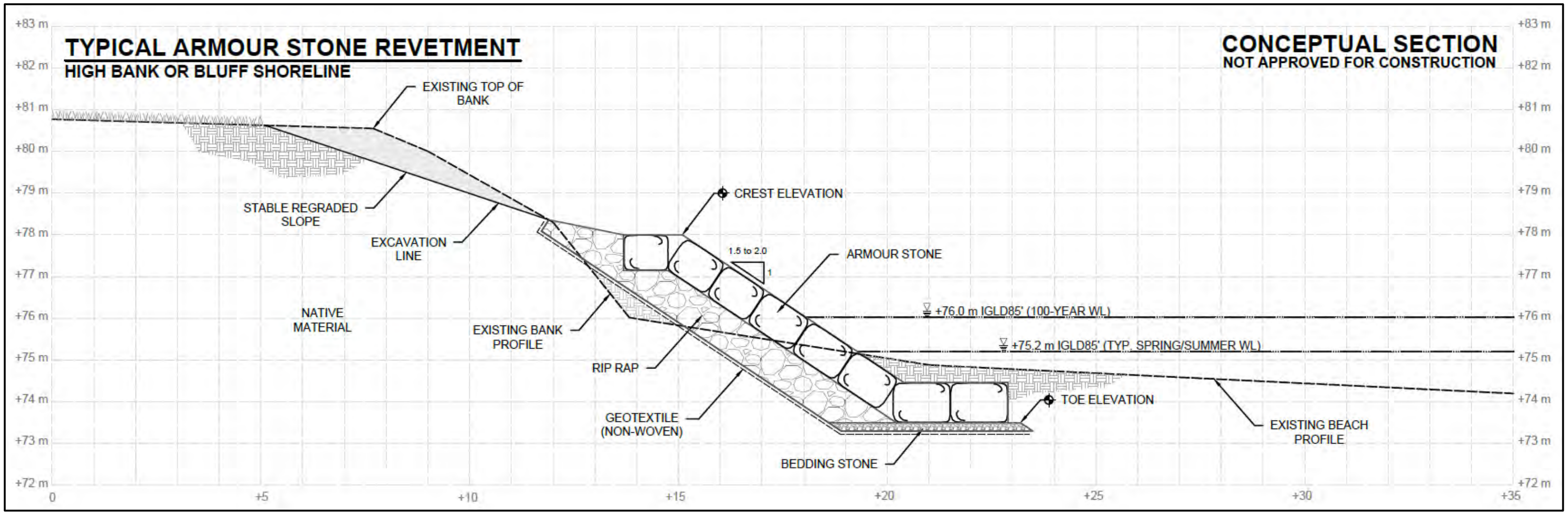


Figure 7.5 Recommended Typical Armour Stone Revetment Concept for a Medium to High Bluff (3 to 10 m)

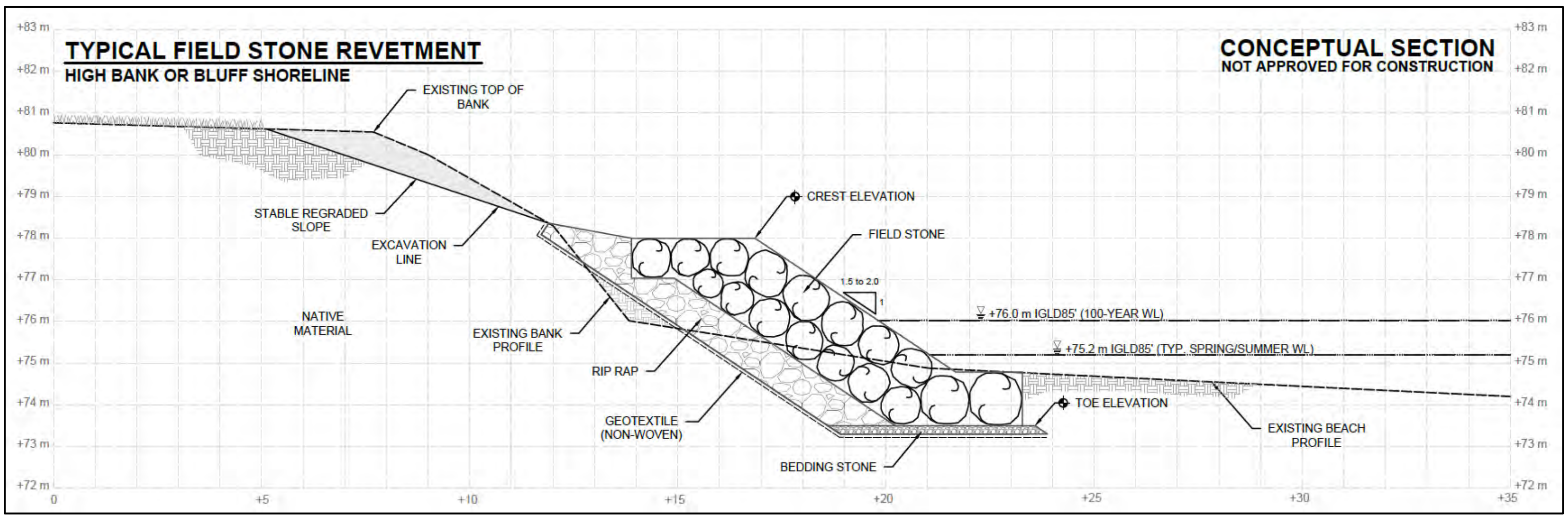


Figure 7.6 Recommended Typical Field Stone Revetment Concept for a Medium to High Bluff (3 to 10 m)

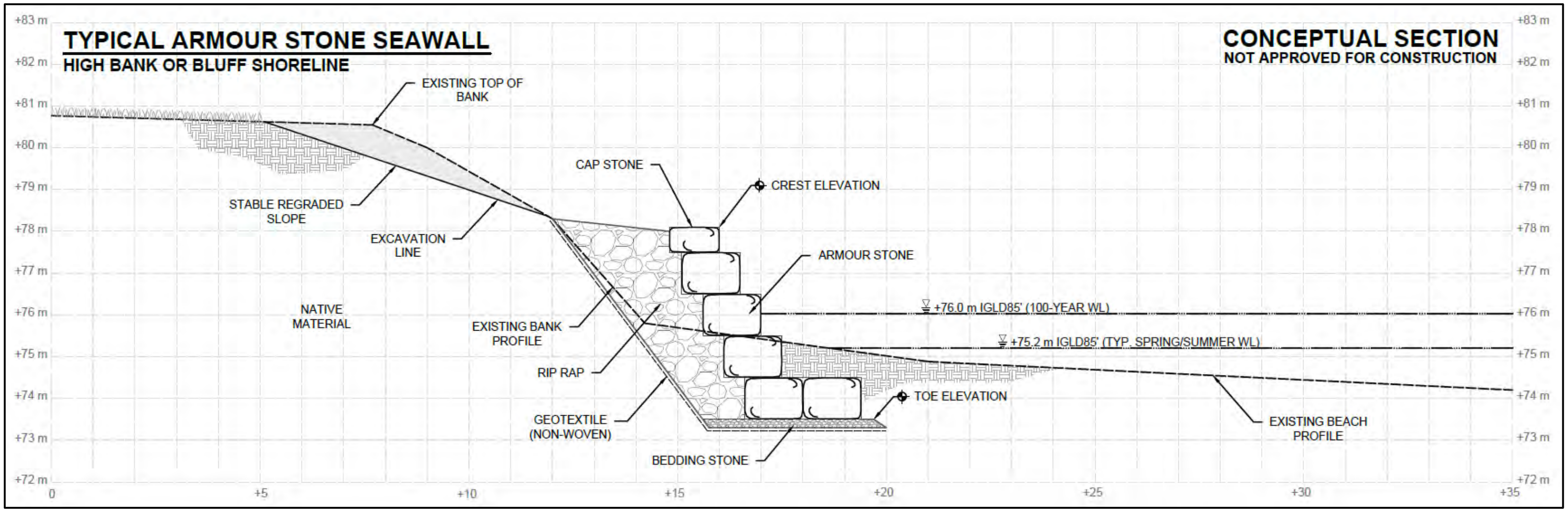


Figure 7.7 Recommended Typical Armour Stone Seawall Concept for a Medium to High Bluff (3 to 10 m)

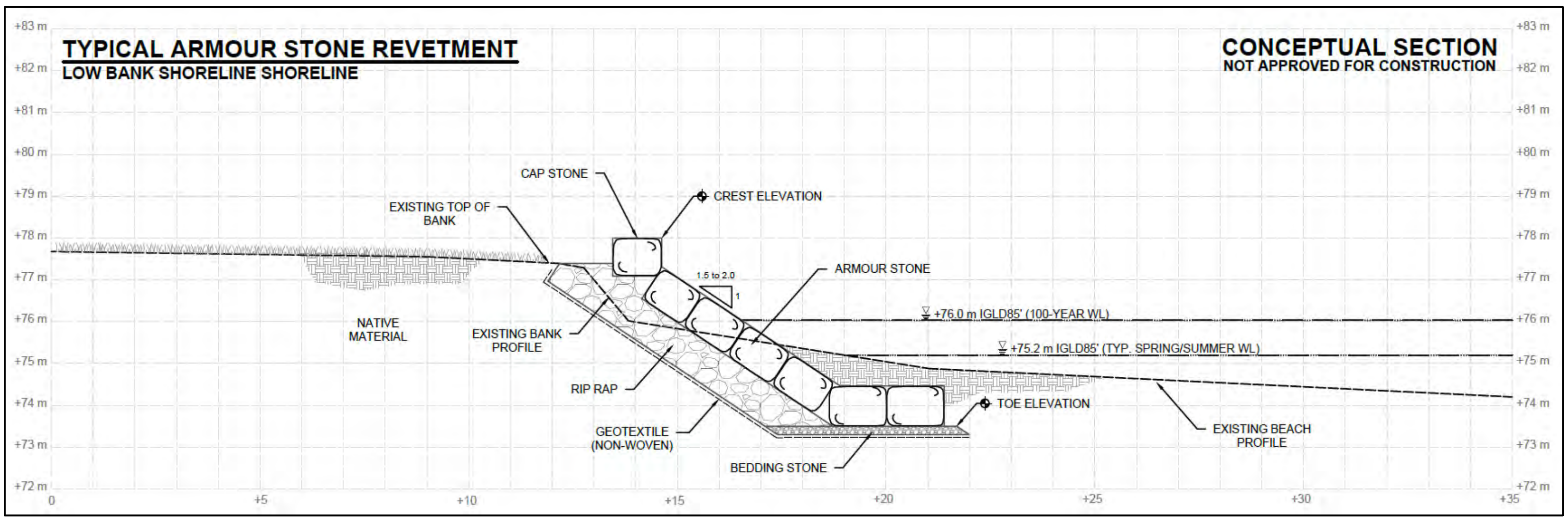


Figure 7.8 Recommended Typical Armour Stone Revetment Concept for a Low Bank (<3 m)

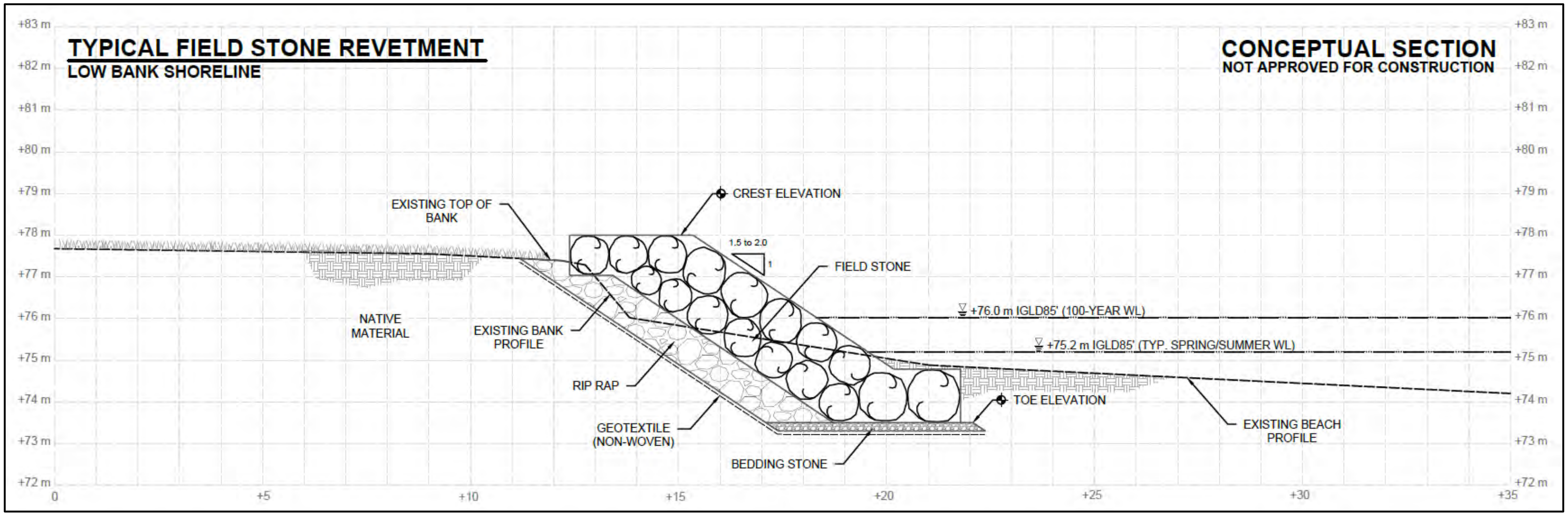


Figure 7.9 Recommended Typical Field Stone Revetment Concept for a Low Bank (<3 m)

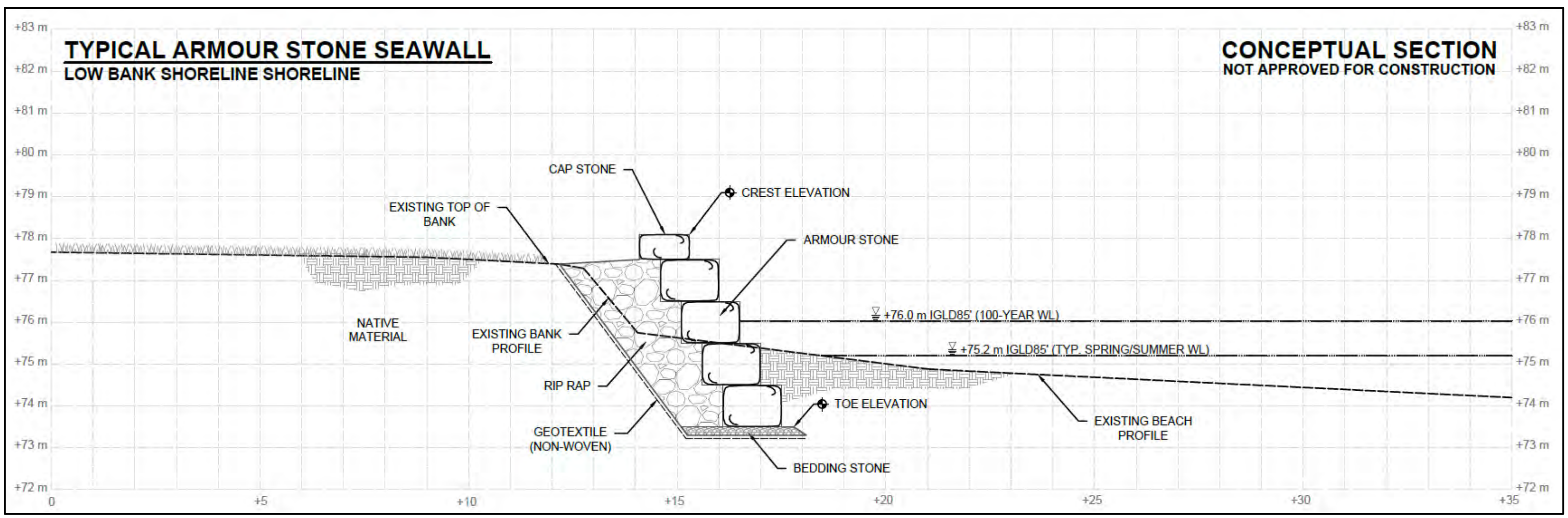


Figure 7.10 Recommended Typical Armour Stone Seawall Concept for a Low Bank (<3 m)

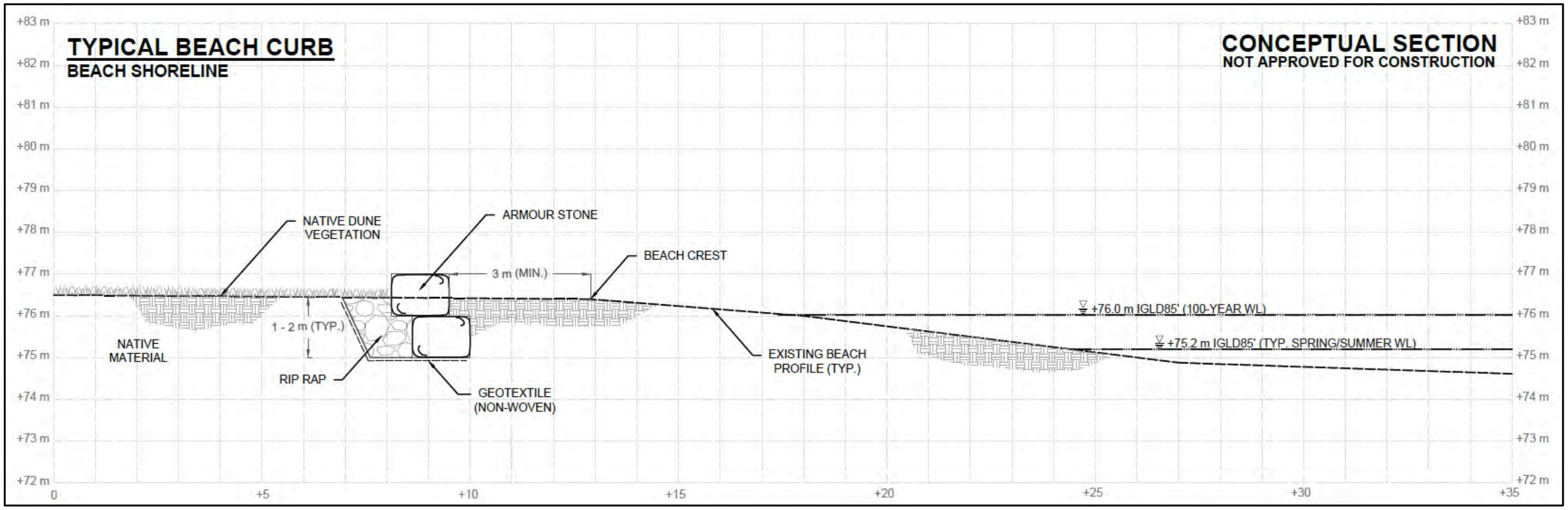


Figure 7.11 Recommended Beach Curb Concept for Back of Beach

7.4 Monitoring and Updating Hazard Mapping

Section 7.4 provides recommendations for future shoreline monitoring and a brief discussion of the necessity of regular updates to the shoreline hazard mapping.

7.4.1 Future Monitoring

Monitoring is critical to assess and quantify shoreline change over time and in the case of climate change, whether the risk profile is changing. For example, if global warming continues and shoreline ice coverage continues to decrease, it is possible that the long-term erosion rates will increase beyond those determined for this SMP and utilized in the updated shoreline hazard mapping.

This study generated detailed top of bank/bluff and waterline mapping for the entire study area. When future updated orthophotographs are available, select high risk locations should be evaluated for the latest position of the top of bluff or beach and compared to the mapping from this study.

Regular monitoring of both public and private shoreline infrastructure is also recommended. Shoreline structures may require maintenance after storm events or due to settlement caused by changes in nearshore sediment dynamics such as reduced sediment supply or scouring of the lakebed. Moreover, the wave exposure of shoreline protection structures may increase in the future due to reduced shoreline ice cover or increased nearshore depths resulting from lakebed downcutting. Maintenance of shoreline infrastructure is a critical component in maximizing their design life and can only be carried out when regular monitoring has identified the current or expected need.

7.4.2 Updating Hazards and Mapping

The erosion hazard mapping generated for this study was based on the toe of slope position (bank or bluff) from 2017 or 2018. In 2030, this mapping will be 12 to 13 years old and thus not representative of the future shoreline position for the 100-year planning horizon. Therefore, future updates of the hazard mapping should be planned, at approximately 10-year intervals and corresponding with updated orthophotographs.

Similarly, the future impacts of climate change on water supplies to the Great Lakes and resulting lake levels should be incorporated progressively as additional research is made available. These impacts are presently under investigation for Lake Ontario (ECCC Internal File 2020) but initial results suggest higher highs should be anticipated across the Great Lakes. Therefore, it would be prudent to evaluate future lake level trends and plan for potential increases in the historical extremes such as the 100-year elevations presented in this SMP and the all-time high established in 2019. If required, the 100-year flood level should be updated and reflective of the best available information at the time.

8.0 CONCLUSIONS AND RECOMMENDATIONS

A significant amount of technical information and a wide range of recommendations are presented in this SMP. Key conclusions and recommended approaches to shoreline management are summarized in this Section. For more detailed, reach specific recommendations, refer to Appendix A. Commentary is also provided on implementation and integration strategies, which are a critical next step for this SMP to have a meaningful impact on the resilience and sustainability of both natural and developed shorelines within the CLOCA, GRCA and LTRCA jurisdictions.

8.1 Major Conclusions and Management Recommendations

- Climate change is already impacting the shoreline, with reductions in ice cover quantified from satellite data, new record high lake levels in 2019, and increase exposure to winter storms. If trends continue, erosion rates will accelerate in the future, and may require adjustments to the 100-year erosion allowance. The influence of climate change on future Lake Ontario water levels is presently under investigation by ECCC and the findings should be monitored.

- Applications for development should not only be evaluated on the basis of shoreline hazards as documented in this SMP, but also in the context of the Natural Heritage Systems and significant ecological areas as identified in Section 3.4. The recommendations provided in these plans should be adhered to and in some cases additional ecological or biological investigations may be required.

- Due to prevalent wind and wave directions and geological and physical characteristics, the north shore of Lake Ontario within the project boundaries is predominantly comprised of bank and bluff shorelines that are eroding. Erosion in this region is a natural process that produces new sources of sand and gravel for the nearshore. However, due to the low percentage of sand in the glacial till and the presence of exposed bedrock in the nearshore particularly in the eastern half of the project region, natural sediment supply is extremely low.

- The historical pre-European littoral cell extended from East Point in Scarborough to Presqu'ile Provincial Park. Today, the study shoreline is artificially sub-divided into a series of sub-cells by the numerous harbours and industrial developments. Therefore, managing the finite sediment sources in each shoreline reach is critical to maintaining local beaches and enhancing shoreline resilience to high lake levels. Sediment by-passing between reaches should also be considered as a long-term strategy to restoring the natural movement of sediment along the shoreline.

- Shoreline armouring should generally not be the first or only option considered when mitigating risks to existing development within shoreline hazards. Shoreline armouring not only impacts the natural supply and movement of sediment, but it also carries significant capital and ongoing maintenance costs. All available strategies (avoid, accommodate, retreat, protect) should be included in the cost-benefit assessment for future risk mitigation from coastal hazards.

- Due to existing shoreline management practices and conservation authority policies and regulations, newer developments have been setback appropriately from erosion hazards. This region features some of the best examples of natural development buffers in Ontario. However, these buffers will eventually disappear and likely faster than the present 100-year planning horizon would indicate if climate change continues to progress as anticipated. Consideration should be given to adopting longer planning horizons and larger erosion buffers to account for uncertainties in climate change.

- Following the record high lake levels in 2017 and 2019, many of the barrier beaches protecting river mouth wetlands and embayments have suffered severe erosion. These barrier systems are not likely to recover fully on their own due to the compartmentalization of the shoreline into littoral sub-cells and the limited sediment supply available. Eroded barrier beaches may require artificial beach nourishment to recover and to provide continued shelter from lake waves to the riverine and coastal wetlands.

- Urban beaches are often groomed and missing key elements of natural beach systems that provide resilience during periods of high-water levels and high wave energy. These elements include vegetated coastal dunes, vegetated (tree/shrub) backshores and naturally sloped beach profiles. Consequently, many of the urban beaches within the project boundaries are low and flat, making them vulnerable to high lake levels and storm events. This was evident in 2017 and 2019 when many urban beaches were inundated, eroded or otherwise rendered virtually unusable.

- Specific developed areas are highlighted in this SMP as being particularly vulnerable to either flooding related risks, erosion, or both. These areas include Crystal Beach Boulevard, Stone Street, Muskoka Avenue, Cedar Crest Beach Road, East Beach Road, West Beach Road, Bond Head, Port Britain, Cobourg East Beach, Grafton Shores, Victoria Beach, Popham Bay, Harbour Street (Brighton), Gosport and Evergreen Lane. The elevated risk in these areas is apparent in the shoreline hazard maps and was illustrated during the record high water levels in 2017 and 2019. These areas should be monitored closely. Management approaches including retreat, accommodate and protect should be considered and evaluated in the near-term at a community scale as opposed to lot by lot. The selection of an approach should consider the vulnerability of the community, social, economic, and environmental concerns, and should include a long-term cost-benefit analysis.

- A wide variety of riparian shoreline protection exists throughout the region, in terms of age, condition, protection type and performance. Much of the shore protection can be described as non-engineered or ad-hoc and is in a state of significant disrepair after the high-water levels experienced in 2017 and 2019. Most private shore protection has been historically implemented on a lot by lot basis, resulting in abrupt changes in shoreline orientation and alignment due to ongoing erosion and degradation of infrastructure. Piecewise protection schemes that vary in age, quality and performance result in an overall decrease in the resilience of the shoreline which is only as resilient as its most vulnerable part. In the future, where shoreline protection is determined to be an appropriate strategy, it should be implemented at a community scale whenever possible.

- A significant number of vertical structures comprised of manmade materials such as precast concrete blocks, cast-in-place concrete and steel are encountered throughout the project shoreline. On exposed coastlines these structures can cause accelerated erosion of the nearshore lakebed resulting in deeper water and increased exposure to waves. If not founded deep enough, constructed high enough or built with adequate drainage, these structures become susceptible to failure due to lakebed scour or overtopping. Vertical shore protection structures should only be implemented where necessary due to spatial constraints and should be designed by a qualified individual.

- Sloping structures are also prevalent throughout the region but in many cases have been constructed without proper designs and using scrap materials such as concrete rubble. These structures create negative impacts on the aquatic environment and do not provide adequate protection against storm waves during periods of high-water levels. Sloping shore protection structures should be designed by a qualified coastal engineer and should be in the form of armour stone or field stone revetments. Guidance for shore protection design is provided in Section 7.3.

8.2 Integration

- Linkages between this SMP update and Municipal Official Plans should be explored and integrated where possible. It is recommended that municipalities review their existing Official Plans and consider updates to land use zoning commensurate with the findings and recommendations of this SMP.

- This SMP update is largely focused on mapping hazardous lands, regulating new development, and managing existing development within the hazardous lands. Other aspects of shoreline management, such as species protection, habitat creation, and natural heritage system management should be considered and integrated with the SMP. Continued partnerships with other government agencies and environmental non-government organizations should be pursued to ensure ecological considerations are part of future development decisions.

8.3 SMP Implementation and Next Steps:

- Reach specific recommendations are provided for the study shoreline in Appendix A recognizing the unique physical characteristics, ecosystems and habitat, development, and risk. Benefiting parties should establish priorities and collaborate on actions to reduce coastal risks and increase community resilience.

- Shoreline change rates should be carefully monitored over time whenever more recent orthophotographs are made available. The 100-year erosion allowance should be updated whenever new information becomes available or at higher frequency in high risk areas as necessary.

- The 100-year combined flood level should be regularly updated, especially in response to periods of extreme high-water levels on Lake Ontario.

- Ongoing research from ECCC and others on the implications of a non-stationary climate for future erosion rates and extreme lake levels should be continuously monitored and integrated into the SMP and shoreline hazard mapping following available technical guidance as new information becomes available, as stated in the PPS (2020). For example, new erosion rates may be required for erosion hazard setbacks that account for reduced ice cover on Lake Ontario in the future.

- Municipalities, in partnership with Conservation Authorities, should conduct flood and erosion vulnerability studies, prioritize actions, and develop resiliency and emergency response plans for at-risk communities at a higher spatial resolution than is provided in this SMP. Strategies investigated by municipalities should be implemented in concert with Conservation Authorities and the recommendations provided herein.

- Municipalities, in partnership with Conservation Authorities should engage with senior levels of government regarding the need for a collaborative approach to mitigating risk in communities where the risks to private and public assets as well as human safety due to shoreline hazards are significant.

- Property owners and municipalities should evaluate a wide variety of options when considering shoreline protection including nature-based and soft-engineering options. Shore protection should be implemented at a community scale wherever possible and should be carefully designed based on local conditions by a qualified coastal engineer.

- All shoreline infrastructure should be monitored regularly and maintained in a proactive manner to avoid failures and mitigate future risk.

- All aspects of this SMP should be re-evaluated as new data, improved scientific methodologies, climate projections and policy updates become available.

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APPENDIX A

SUMMARY CONDITIONS AND RECOMMENDATIONS BY SHORELINE REACH

Reach 1 – Lakeside Neighbourhood Park to Whitby Harbour

Local Conditions

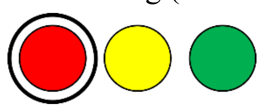
- Reach Length = approximately 5 km.
- Lakeside Neighbourhood Park to Whitby Harbour is a sub-cell at the western limit of the CLOCA jurisdiction.
- Eroding bluff shoreline in the west featuring hard glacial till, eroding barrier beaches in the central region, with Whitby Harbour defining the east boundary.
- Naturalized meadow vegetation at Lakeside Neighbourhood Park absorbs rainfall and helps stabilize bluff slope, resulting in a low long-term erosion rate.
- Sand and gravel eroded from the bluff supply sediment to the barrier beaches in Lynde Shores Conservation Area and the fillet beach at Whitby Harbour.
- Lynde Shores Conservation Area is part of a 550-hectare High Biodiversity area (Canadian Wildlife Service). The protective barrier beaches were negatively impacted by high lake levels in 2017 and 2019, threatening the previously sheltered marsh ecosystem.

Naturalized Tablelands at Bluff Crest

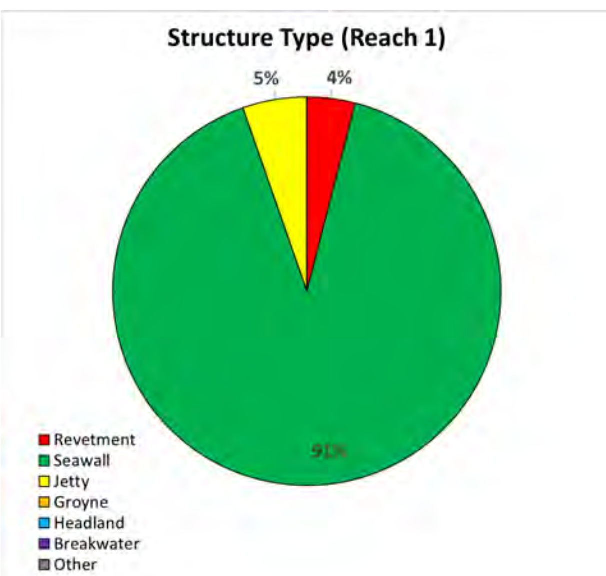
High Water Impacts on Barrier Beach

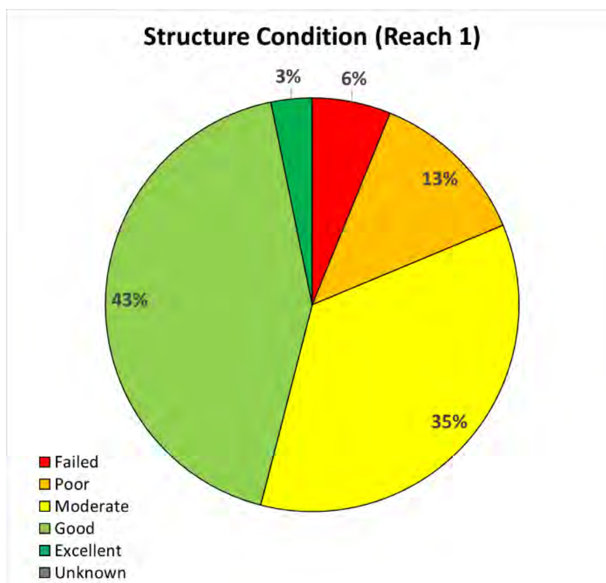
Shoreline Structures

- Reach 1 is 36% armoured, 64% natural.
- Armoured shoreline is predominantly located in front of Ontoro Blvd. in the west and Ontario Shores Hospital and Whitby Harbour in the east.
- Many shoreline protection structures fronting Ontoro Blvd. properties are under-engineered, vertical seawall-type structures comprised of undersized pre-cast concrete blocks. Many have failed or are susceptible to failure. Vertical structures are accelerating lakebed erosion (scour) and impeding the deposition of beach material.
- Ontario Shores Hospital structure is a well-engineered stepped armour stone seawall. This structure is old, but in reasonable condition. It should be monitored and maintained as required.
- Whitby Harbour is protected by an aging sheet pile seawall that is overtopped regularly. This structure should be monitored, and upgrades considered to increase longevity, promote beach growth and reduce overtopping.
- The jetties at Whitby Harbour are in generally good condition. Structures should be monitored and maintained throughout their lifetime, as required.
- The armoured bluff shoreline at Ontoro Blvd. and Ontario Shores Hospital limits the sediment supply available to the barrier beaches at Lynde Shores Conservation Area and the fillet beach at Whitby Harbour. These features are already sediment starved.
- Tolerance for additional shoreline armouring (**low**/medium/high):



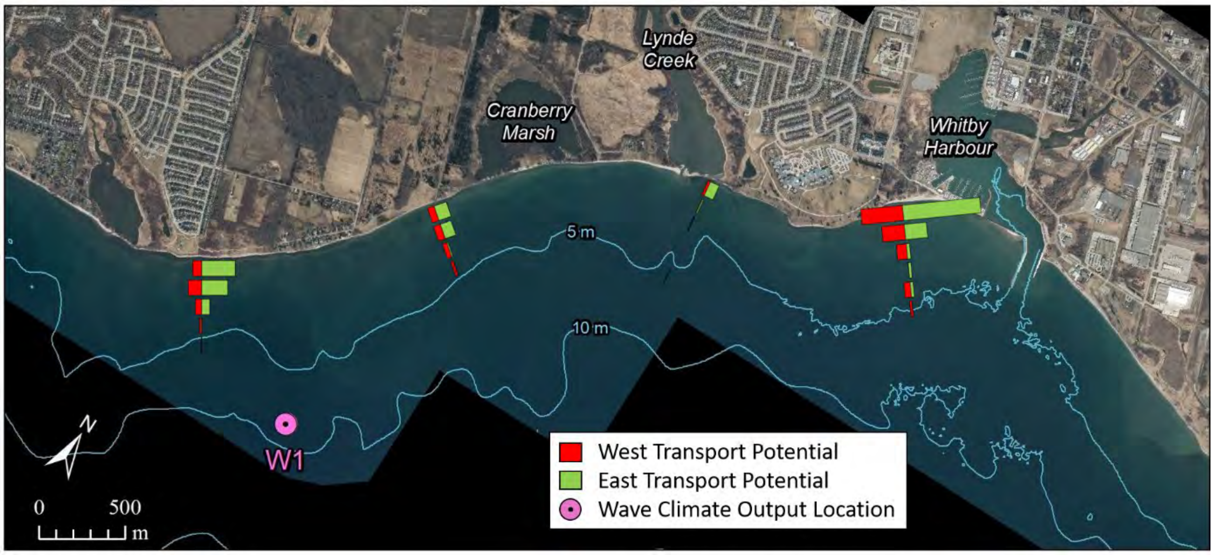
- Sample statistics (for armoured portion of shoreline):





Sediment Supply and Longshore Sediment Transport

- Longshore sediment transport is predominantly from west to east, with a net transport potential on the order of 5,000 to 30,000 m^3/year. The actual transport is likely much lower due to limited sediment supply.
- Sediment from shoreline erosion is the primary source of sand and gravel for local beaches in Reach 1, however, shoreline armouring in Reach 1 and further to the west has reduced the historical supply. Littoral barriers further to the west have also reduced the historical sediment supply to Reach 1.
- The jetties at Whitby Harbour present a partial barrier to longshore sediment transport at the east end of Reach 1.



Summary of Natural Hazards

- 100-year Erosion Rate (Stable Slope not included):

Start (lat, long)	End (lat, long)	100-year Erosion Rate (m/year)	Bluff Crest or Waterline
43.8285, -78.9792	43.8385, -78.9657	0.15	Bluff Crest
43.8458, -78.949	43.8491, -78.939	0.15	Bluff Crest

- 100-year Flood Level and Flood Hazard Limit (including wave uprush):

Start (lat, long)	End (lat, long)	100-year Flood Level (m IGLD85')	Flood Hazard (m IGLD85')
43.8285, -78.9792	43.8458, -78.9490	+76.01	+77.68
43.8458, -78.9490	43.8491, -78.9391	+76.01	+77.82
43.8491, -78.9391	43.8515, -78.9291	+76.01	+77.59

- Dynamic Beach(es):

Start (lat, long)	End (lat, long)	100-year Erosion Rate (m/year) or Stable	Dynamic Beach Name
43.8385, -78.9657	43.8433, -78.9585	0.34	Cranberry Marsh
43.8433, -78.9585	43.845, -78.954	0.15	Eastbourne Beach Road
43.845, -78.954	43.8458, -78.949	0.34	Lynde Creek Barrier
43.8491, -78.939	43.8511, -78.9353	Stable	Iroquois Beach

- Wave climate ~1 km offshore (output location W1):

ARI (years)	Depth (m)	Hs (m)	DIR (deg)	Tp (s)
5	10.0	4.11	200	9.0
10	10.0	4.29	200	9.0
25	10.0	4.50	200	9.5
50	10.0	4.61	200	9.5
100	10.0	4.77	200	10.0

Infrastructure and Ecosystem Threats

- Additional shoreline hardening will have a significant impact on local beaches.
- Barrier beaches are sediment starved and eroding. If they don't recover naturally, artificial restoration will be necessary to protect the marsh ecosystems from direct wave attack, which will permanently change the energy regime in these formerly sheltered areas.
- Non-engineering and failed shore protection along Ontoro Blvd. may threaten homes.
- Steel sheet pile wall that shelters Whitby Harbour should be monitored, with considerations for future upgrades (e.g., toe protection).

Shoreline Management Recommendations

- Monitor top of bank recession at Lakeside Neighbourhood Park and re-align multi-use path when necessary. Add more signage about bluff risks. Maintain natural shoreline areas as buffers against erosion and future sediment supply areas.
- Private and government landowners should monitor shoreline protection stability and erosion flanking potential, especially along Ontoro Blvd.
- Monitor the Steel Sheet Pile Wall at Whitby Harbour and consider a toe protection upgrade to extend the design life of the structure.
- A long-term barrier beach restoration plan is recommended for Lynde Shores Conservation Area, including beach nourishment and re-vegetation to improve the resilience of the barrier.
- Iroquois Beach: Missing dune grass ecosystem between the open beach and forest vegetation, which can act as a sediment sink to buffer against shore erosion events. Access should be limited to formalized nodes with dune grass restoration in the remaining areas.

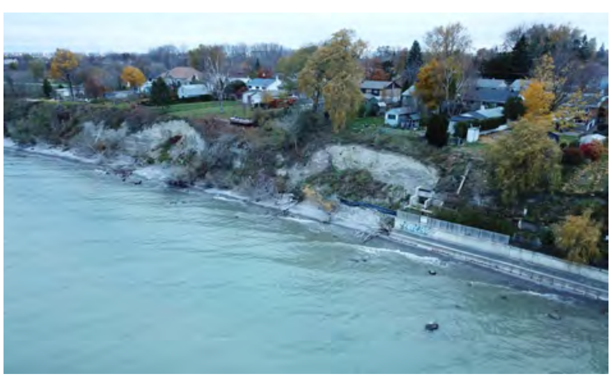
Use Disclaimer

Reach 2 – Whitby Harbour to Oshawa Harbour

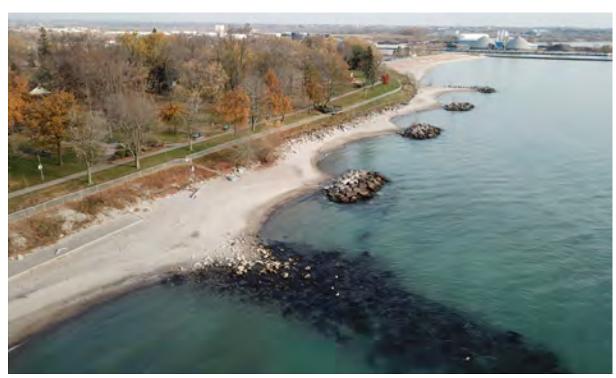
Local Conditions

- Reach Length = approximately 9 km.
- Whitby Harbour to Oshawa Harbour is a sub-littoral cell within the CLOCA Lake Ontario boundaries.
- The shoreline features eroding bluffs and headlands separated by low lying river valleys and embayments (e.g., Pumphouse Marsh Wildlife Reserve).
- Public open space is found throughout Reach 2, including the Whitby Harbour, Gordon Richards Park, Ronald C. Deeth Park, Lakefront West Park, Stone Street Park, Lakewoods Park, and Lakeview Park adjacent to the Oshawa Harbour.
- The centre of the reach features contrasting shoreline development patterns. The older development south of Stone Street is threatened by active bluff erosion while the community to the west around Renaissance Drive is setback from the coastal hazards by approximately 200 m and features a natural area and waterfront trail.

Eroding Bluff at Stone Street, Oshawa

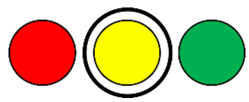


Lakeview Park, Oshawa

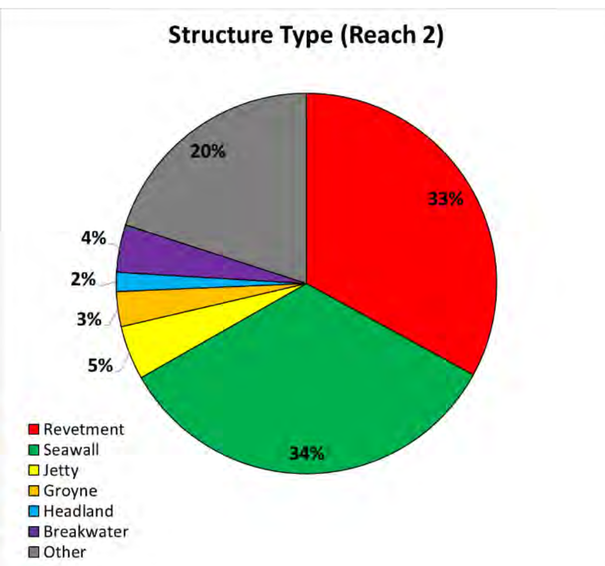


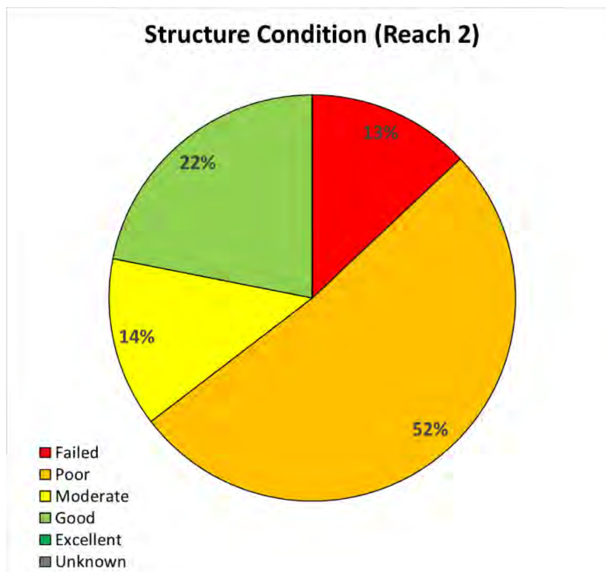
Shoreline Structures

- Reach 2 is 19% armoured, 81% natural.
- Armoured shoreline is predominantly located in front of Crystal Beach Blvd., Stone Street and Lakeview Park.
- Shoreline protection fronting Crystal Beach Blvd. and Stone Street is predominantly ad-hoc or under-designed. Structures should be monitored, and improvements should be considered.
- Flanking of protected portions of shoreline is prevalent along Stone Street where neighbouring properties are unprotected and erosion is ongoing.
- Lakeview Park features well engineered offshore breakwaters with tombolo's during periods of typical water levels, a termination groyne and beach curb. Structures should be monitored, and maintenance should be performed as required.
- The jetty at Oshawa Harbour is in moderate to good condition but should be monitored and maintained as required.
- Tolerance for additional shoreline armouring (low/**medium**/high):



- Sample statistics (for armoured portion of shoreline):





Sediment Supply and Longshore Sediment Transport

- Southwest facing portions of shoreline from Whitby Harbour to Thickson Point and those fronting Lakefront Park West have a small (less than 10,000 m^3/year) westerly net transport potential, opposite the predominant direction for the north shore of Lake Ontario. The net transport direction through the remainder of the reach is west to east.
- The east half of the reach has a more consistent, south facing shoreline orientation and features a higher net transport potential of upwards of 80,000 m^3/year to the east.

- The actual sediment transport volume throughout the reach is likely significantly smaller (less than 10,000 m^3/year) due to the limited sediment supply, which is primarily from local eroding bluffs within the reach.
- The principal sediment sinks within the reach are the small fillet beach east of Whitby Harbour (for material moving westward), the barrier beach east of Crystal Beach Blvd. (for both east and west transport), and the fillet beach fronting Lakeview Park immediately west of Oshawa Harbour (for material moving eastward).
- Shoreline armouring in Reach 1 (Crystal Beach Blvd. and Stone Street) has a small impact on sediment supply within the reach, however the primary limitation to the supply of sediment is the variable shoreline orientation and the jetties at both the west (Whitby Harbour) and east (Oshawa Harbour) ends of the reach. These jetties present significant barriers to longshore transport resulting in this reach being predominantly an independent littoral cell (some transport around the jetties is expected).

Summary of Natural Hazards

- 100-year Erosion Rate (Stable Slope not included):

Start (lat, long)	End (lat, long)	100-year Erosion Rate (m/year)	Bluff Crest or Waterline
43.8499, -78.9204	43.8528, -78.8929	0.27	Bluff Crest
43.8525, -78.8817	43.8504, -78.8698	0.4	Bluff Crest
43.8504, -78.8698	43.8521, -78.8648	0.34	Waterline
43.8521, -78.8648	43.8544, -78.8554	0.34	Bluff Crest
43.8544, -78.8554	43.8572, -78.8431	0.22	Bluff Crest
43.8583, -78.8367	43.8636, -78.8263	0.22	Bluff Crest

- 100-year Flood Level and Flood Hazard Limit (including wave uprush):

Start (lat, long)	End (lat, long)	100-year Flood Level (m IGLD85')	Flood Hazard (m IGLD85')
43.8510, -78.9273	43.8489, -78.9169	+76.01	+77.68
43.8489, -78.9169	43.8481, -78.9004	+76.01	+77.76
43.8481, -78.9004	43.8521, -78.8945	+76.01	+77.82
43.8521, -78.8945	43.8525, -78.8816	+76.01	+77.68
43.8525, -78.8816	43.8509, -78.8720	+76.01	+77.82

43.8509, -78.8720	43.8510, -78.8690	+76.01	+77.76
43.8510, -78.8690	43.8584, -78.8331	+76.01	+77.68
43.8584, -78.8331	43.8593, -78.8311	+76.01	+77.76
43.8593, -78.8311	43.8601, -78.8306	+76.01	+77.82
43.8601, -78.8306	43.8652, -78.8232	+76.01	+77.59

- Dynamic Beach(s):

Start (lat, long)	End (lat, long)	100-year Erosion Rate (m/year) or Stable	Dynamic Beach Name
43.851, -78.9273	43.8499, -78.9204	Stable	Whitby East Beach
43.8528, -78.8929	43.8532, -78.8847	0.34	Crystal Beach Blvd.
43.8532, -78.8847	43.8525, -78.8817	0.4	Intrepid Park
43.8572, -78.8431	43.8583, -78.8367	0.22	Pumphouse Marsh Barrier
43.8636, -78.8263	43.8652, -78.8232	Stable	Lakeview Park

- Wave climate ~1 km offshore (output location W2):

ARI (years)	Depth (m)	Hs (m)	DIR (deg)	Tp (s)
5	16.1	4.30	211	9.0
10	16.1	4.56	211	9.0
25	16.1	4.99	211	9.5
50	16.1	5.26	211	9.5
100	16.1	5.65	211	10.0

Infrastructure and Ecosystem Threats

- Additional shoreline hardening would have a discernable impact on the sediment supply within the reach.
- Erosion at Whitby East Beach impacting the board walk.
- High risk houses at the western and eastern end of Crystal Beach Blvd.
- Under-designed or aging shore protection and unprotected properties on Crystal Beach Blvd. and Stone Street may soon threaten homes.
- Erosion of barrier beach east of Crystal Beach Blvd. and barrier beach fronting Pumphouse Marsh Wildlife Area threatens ecosystems in lee.

Shoreline Management Recommendations

- Preserve natural bluff conditions from Whitby Harbour to Thickson Point, which is the natural source of beach material for Whitby East Beach.
- Re-align the Whitby East Beach boardwalk to protect from erosion and flooding hazards.
- Develop long-term retreat strategy for high risk buildings on eroding shorelines.
- Shoreline hardening should be limited to high density development areas. Maintain natural eroding bluffs where possible (e.g., Lakefront Park).
- Maintain erosion buffers and natural areas west of Stone Street. Re-align trail inland as necessary.
- Stone Street Residential Area: develop a long-term community scale armouring solution or a retreat plan that re-locates homes and naturalizes the shoreline. Further armouring will negatively impact the barrier beach at Pumphouse Marsh Wildlife Area.
- Stone Street Park: consider upgrades to shoreline to enhance access to the waters edge.

- Lakewoods Park Lookout (Bonnie Brae Point) and Lakeview Park: monitor trails and fencing to ensure park user safety is addressed. Expand and implement maintenance on beach building structures as required in the future.
- Lakeview Park Beach: consider building artificial dune at the back of the beach increase elevation and reduced aeolian transport into the parking lot.
- Oshawa Harbour: re-use dredged sediment if suitable for beach building and meets environmental requirements for in-water disposal.

Use Disclaimer

The information in this reach summary was prepared for the Central Lake Ontario Conservation Authority, the Ganaraska Region Conservation Authority, and the Lower Trent Region Conservation Authority. If used by a third party, they agree that the information is subject to change without notice. Zuzek Inc. and SJL Engineering Inc. assume no responsibility for the consequences of such use or changes in the information. Under no circumstance will Zuzek Inc. or SJL Engineering Inc. be liable for direct, indirect, special, or incidental damages resulting from, arising out of, or in connection with the use of the information in this summary by a third party.

Reach 3 – Oshawa Harbour to St. Mary's

Local Conditions

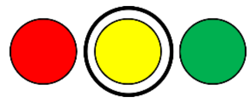
- Reach Length = approximately 11 km.
- The Port of Oshawa and St. Mary's loading facility represent the boundaries of a sub-littoral cell.
- The McLaughlin Bay Wildlife Reserve, Second Marsh Wildlife Area, and Darlington Provincial Park represent a significant natural heritage corridor in Reach 3.
- The three natural areas feature extensive coastal wetlands.
- The Darlington Nuclear Generating Station is also a significant development and covers approximately two kilometres of shoreline in Reach 3.
- There is no residential development along the shoreline in Reach 3 and a small amount of agricultural land.

Natural Beach & Embryo Dunes at Darlington Prov. Park.

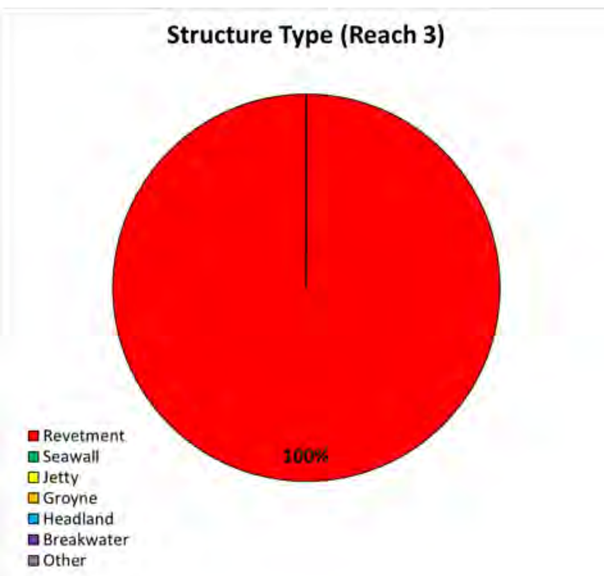
Shore Protection fronting Darlington Nuclear Power Plant

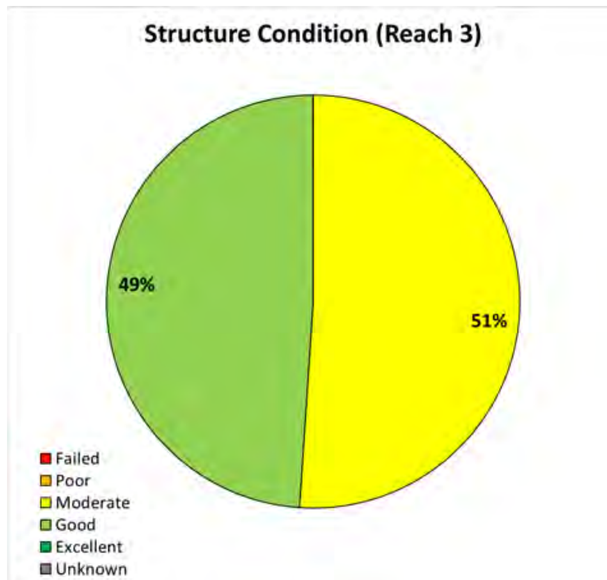
Shoreline Structures

- Reach 3 is 28% armoured, 72% natural.
- Armoured portions of shoreline are limited to shoreline immediately east of Oshawa Harbour, and the shoreline fronting Darlington Nuclear Power Plant and St. Mary's Cement Plant.
- Shoreline protection throughout the reach is generally well engineered armour stone revetments in moderate to good condition.
- Shoreline protection fronting St. Mary's is ad-hoc in places and should be monitored and maintained as required.
- Tolerance for additional shoreline armouring (low/**medium**/high):



- Sample statistics (for armoured portion of shoreline):





Sediment Supply and Longshore Sediment Transport

- Longshore sediment transport potential is very low (0 to 5,000 m^3/year) west of Darlington Provincial Park, with nearly equal eastward and westward components.
- Longshore sediment transport potential east of Darlington Provincial Park is very high, with the net transport potential being upwards of 100,000 m^3/year from west to east. Actual transport is however likely less than 10% of the potential due to the limited sediment supply, which is predominantly from eroding bluffs between the Provincial Park and Nuclear Power Plant.
- A significant shoal offshore of Darlington Provincial Park likely creates a depositional area in its lee (i.e. Darlington Beach).
- The Nuclear Power Plant and St. Mary's Cement Plant both present partial obstructions to longshore transport, however this effect is likely secondary to the small amount of

actual sediment availability and transport through the reach, as is evident by the lack of significant fillet beaches on the west side of these landmarks.

Summary of Natural Hazards

- 100-year Erosion Rate (Stable Slope not included):

Start (lat, long)	End (lat, long)	100-year Erosion Rate (m/year)	Bluff Crest or Waterline
43.8649, -78.8209	43.8686, -78.8185	0.25	Bluff Crest
43.8691, -78.7793	43.87, -78.7376	0.25	Bluff Crest
43.8672, -78.7169	43.8738, -78.7	0.25	Bluff Crest
43.8749, -78.6951	43.8725, -78.6863	0.25	Bluff Crest

- 100-year Flood Level and Flood Hazard Limit (including wave uprush):

Start (lat, long)	End (lat, long)	100-year Flood Level (m IGLD85')	Flood Hazard (m IGLD85')
43.8648, -78.8209	43.8684, -78.8187	+76.01	+77.88
43.8684, -78.8187	43.8684, -78.7762	+76.01	+77.64
43.8684, -78.7762	43.8749, -78.6952	+76.01	+77.74
43.8749, -78.6952	43.8782, -78.6843	+76.01	+77.83

- Dynamic Beach(es):

Start (lat, long)	End (lat, long)	100-year Erosion Rate (m/year) or Stable	Dynamic Beach Name
43.8686, -78.8185	43.8696, -78.8131	0.25	Oshawa East Beach
43.8696, -78.8131	43.869, -78.8038	0.73	McLaughlin Bay Barrier Beach A
43.869, -78.8038	43.868, -78.7999	0.25	McLaughlin Bay Beach
43.868, -78.7999	43.8693, -78.7867	0.73	McLaughlin Bay Barrier Beach B
43.8693, -78.7867	43.8691, -78.7793	0.25	Port Darlington PP Beach
43.87, -78.7376	43.8694, -78.7318	0.25	Port Darlington Power Plant Fillet Beach
43.8738, -78.7	43.8749, -78.6951	Stable	St. Mary's West Fillet Beach

- Wave climate ~1 km offshore (output location W3):

ARI (years)	Depth (m)	Hs (m)	DIR (deg)	Tp (s)
5	12.4	4.55	213	9.0
10	12.4	4.85	211	9.5
25	12.4	5.03	211	9.5
50	12.4	5.20	209	10.0
100	12.4	5.27	209	10.0

Infrastructure and Ecosystem Threats

- Barrier beach in Provincial Park (McLaughlin Bay) is actively migrating inland.
- Nuclear Plant: unprotected shoreline at east end of the plant will require shore protection.

Shoreline Management Recommendations

- Maintain natural bluff environments and buffers.
- Monitor existing shoreline protection at the Nuclear Plant.
- Monitor shore protection at St. Mary's Plant.

Use Disclaimer

Reach 4 – St. Mary's to Bowmanville Harbour

Local Conditions

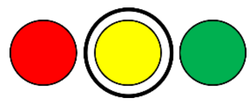
- Reach Length = approximately 2.5 km.
- St. Mary's to Bowmanville Harbour is a small littoral sub-cell in the Central Lake Ontario Conservation Authority jurisdiction.
- The Cedar Crest Beach Road community in the western half of the Reach features lakefront properties constructed on the sand spit that separated the lake from the marsh. The buildings are close to the lake and vulnerable to coastal flooding.
- The St. Mary's quarry is located inland of Cedar Crest Beach. St. Mary's Pier is located at the west end of the sub-cell and features land reclamation and pier infrastructure protruding approximately 600 m into Lake Ontario from the historical shoreline location.
- The eastern half of the reach features Port Darlington West Barrier Beach, with Bowmanville Marsh in lee. The homes along the beach are setback approximately 50 m from the lake and less vulnerable to coastal hazards than the western half of the reach. The east end of the beach is public, accessible by boardwalks which were constructed to protect the native dune grasses and beach material.
- Two armour stone jetties stabilize the navigation channel for the outlet of Bowmanville Creek and have been trapping sand on the west side since at least the early 1950s.

Cedar Crest Beach Blvd. during Record High Water Levels (May 2019)

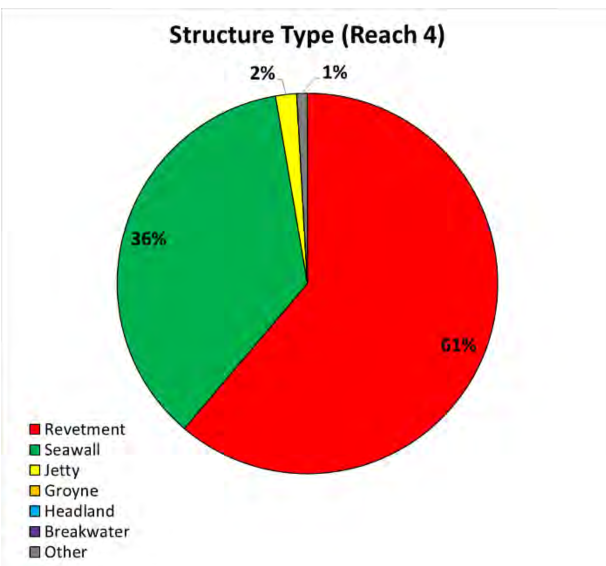
Fillet Beach and Jetties at Port Darlington (November 2018)

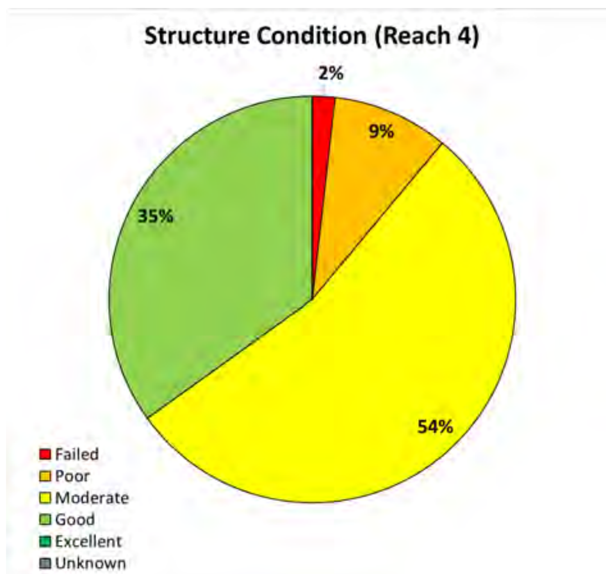
Shoreline Structures

- Reach 4 is 57% armoured, 43% natural.
- The east facing shoreline of St. Mary's land is armoured with an ad-hoc rubble revetment. This protection may require upgrades to prevent erosion and should be monitored.
- The shoreline fronting Cedar Crest Beach Road is almost entirely armoured and features a wide variety of structure types, levels of design and condition. All structures have a very low crest due to the low land elevation and suffer from settlement during periods of high lake levels due to ongoing vertical erosion of the lakebed.
- The west jetty at Bowmanville Creek is in extremely poor condition and requires significant repairs and/or upgrades. The structure has limited ability to trap sand or to dissipate wave energy due to its porosity and low crest. The structure roundhead which features a navigation light is in good condition.
- Tolerance for additional shoreline armouring (low/**medium**/high):



- Sample statistics (for armoured portion of shoreline):





Sediment Supply and Longshore Sediment Transport

- Longshore sediment transport potential is generally very low in Reach 4 with sediment moving in both directions depending on wave conditions, away from the centre of the reach.
- Deposition occurs at the west end of the reach against the St. Mary's lands, and at the east end of the reach in the form of a fillet beach against the Bowmanville Creek west jetty.

- The majority of the reach is a barrier beach complex that protects a marsh in its lee. The natural migration of the barrier has been altered through residential development and shore protection.

Summary of Natural Hazards

- 100-year Erosion Rate (Stable Slope not included):

Start (lat, long)	End (lat, long)	100-year Erosion Rate (m/year)	Bluff Crest or Waterline
43.8725, -78.6863	43.8781, -78.6843	0.25	Bluff Crest
43.8793, -78.6826	43.8805, -78.681	0.33	Bluff Crest

- 100-year Flood Level and Flood Hazard Limit (including wave uprush):

Start (lat, long)	End (lat, long)	100-year Flood Level (m IGLD85’)	Flood Hazard (m IGLD85’)
43.8782, -78.6843	43.8857, -78.6750	+76.01	+77.74
43.8857, -78.6750	43.8878, -78.6648	+76.01	+77.64

- Dynamic Beach(es):

Start (lat, long)	End (lat, long)	100-year Erosion Rate (m/year) or Stable	Dynamic Beach Name
43.8781, -78.6843	43.8793, -78.6826	Stable	St. Mary's East Fillet Beach
43.8805, -78.681	43.8857, -78.6748	0.22	Cedar Crest Beach Rd.
43.8857, -78.6748	43.8873, -78.67	0.22	Cove Road
43.8873, -78.67	43.8877, -78.6648	Stable	Port Darlington West Fillet Beach

- Wave climate ~1 km offshore (output location W4):

ARI (years)	Depth (m)	Hs (m)	DIR (deg)	Tp (s)
5	14.1	3.01	206	9.0
10	14.1	3.28	204	9.5
25	14.1	3.51	203	9.5
50	14.1	3.84	201	10.0
100	14.1	4.06	201	10.0

Infrastructure and Ecosystem Threats
• Flooding and erosion threats for existing development along Cedar Crest Beach Road. • West jetty at Bowmanville Creek requires a significant structural upgrade.
Shoreline Management Recommendations
Cedar Crest Beach Road and West Beach Road: • Long-term incremental voluntary land disposition program required for the lands subject to acute risks due to lack of safe access during the 100-year flood and the location of development on a low-lying eroding dynamic barrier beach. • Short- and medium-term management options include continuing to facilitate private shore protection works by individual or, preferably, community scale beach nourishment and shore protection; road reprofiling. • West Jetty at Bowmanville Creek: structure requires upgrade to eliminate wave and sediment transmission into the navigation channel. Dune restoration to eliminate aeolian transport into the channel from the west fillet beach. • Sediment dredged from the navigation channel and fillet beach could be hydraulically bypassed to nourish the Port Darlington East Beach Park.
Use Disclaimer
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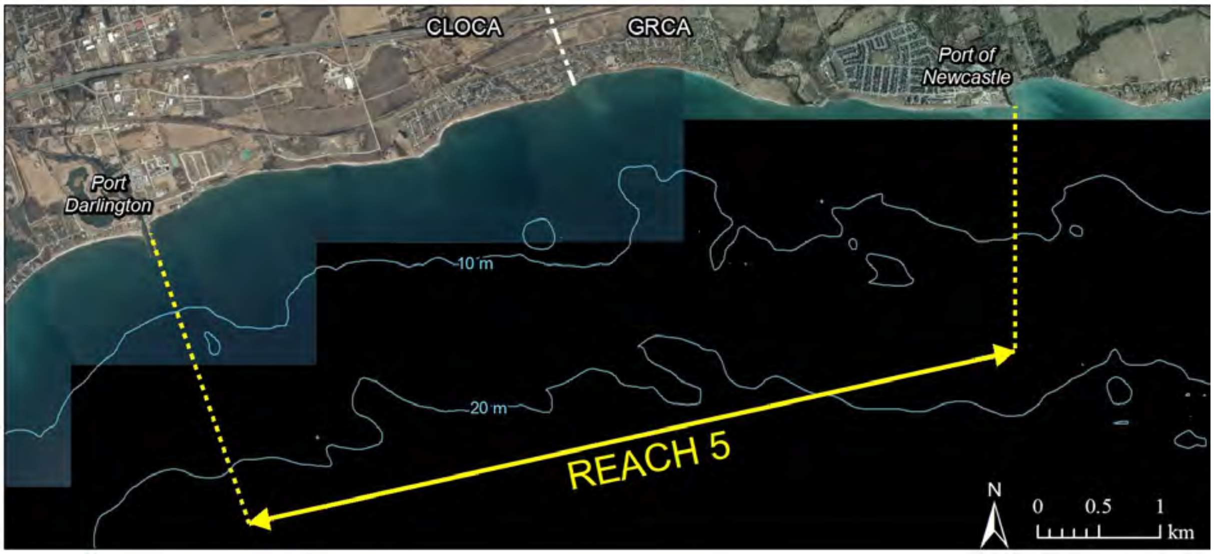
Reach 5 – Port Darlington to Port of Newcastle

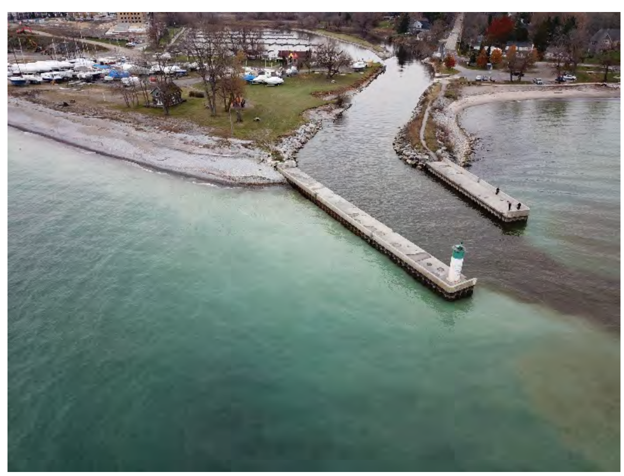


Local Conditions

- Reach Length = approximately 7.1 km.
- The jettied entrances to Port Darlington the Port of Newcastle define a littoral sub-cell along the north shore of Lake Ontario.
- The boundary between the Central Lake Ontario Conservation Authority and the Ganaraska Region Conservation Authority is in the centre of Reach 5.
- Significant sedimentation is ongoing in the navigation channel in Port Darlington.
- Two new residential developments are under construction along the eroding bluff shoreline east and west of Lambs Road.
- The Wilmont Creek Community stretches along almost 3 km of the eroding bluffs.
- The Port of Newcastle community is located west of the jettied rivermouth.

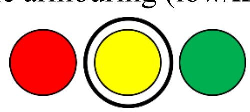
Eroding Bluffs and Failed Shore Protection East of Port Darlington

Cobble Fillet Beach and Jetties at Port of Newcastle

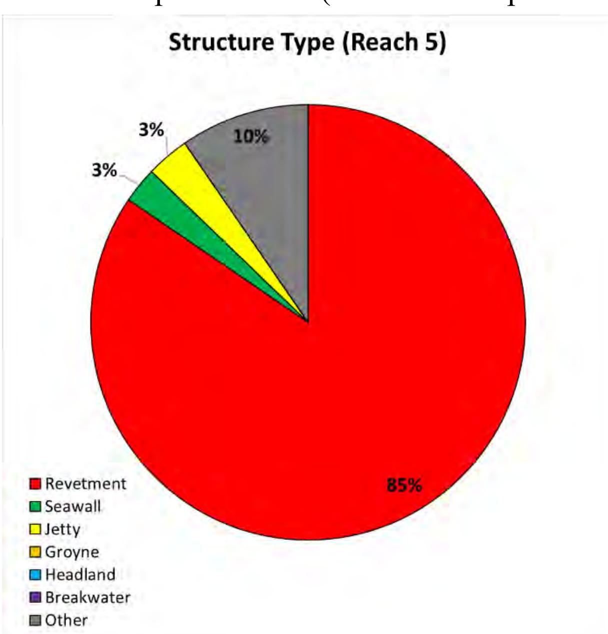


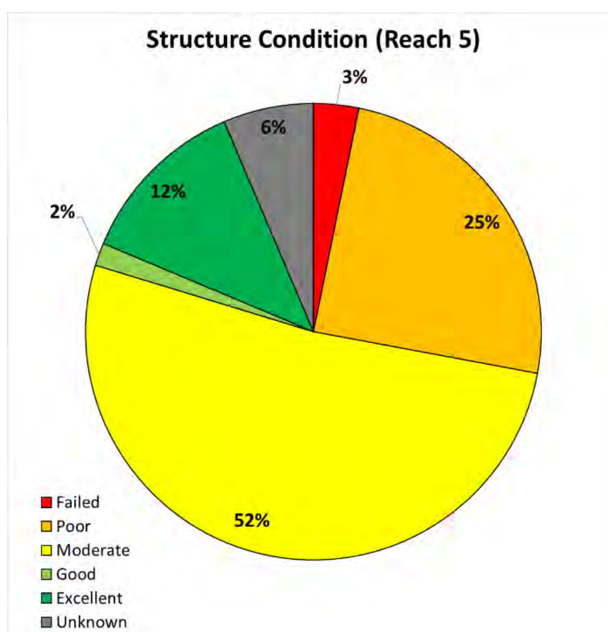
Shoreline Structures

- Reach 5 is 25% armoured, 75% natural.
- The west end of the reach features well engineered and recently constructed shore protection fronting Port Darlington East Beach. This structure is robust and in excellent condition.
- Immediately east of Port Darlington East Beach there are a number of properties sitting atop a high, rapidly eroding bluff. Some properties feature shore protection of varying quality and condition, while others are unprotected and continue to erode. These properties are at high risk due to their proximity to the bluff crust.
- The majority of shore protection within the reach is found in along the shores of Wilmot Creek, a retirement community that spans the border between the Central Lake Ontario Conservation Authority and the Ganaraska Region Conservation Authority. This structure has been engineered and implemented in the last decade, however it is only an interim, porous structure comprised of an armour stone berm resting directly on the beach at the toe of the bluff. Some vertical beach erosion and horizontal recession of the bluff is expected to continue behind the structure during periods of extreme lake levels.
- The jetties at Graham Creek (Port of Newcastle) are composite gravity structures and are both in moderate condition. The root of both structures is comprised of native fill material with a thin layer of minimal rock protection. These areas have suffered significant damage during the high-water periods in 2017 and 2019 and have nearly breached, particularly on the east side at Bond Head Parkette. These structures should be repaired and upgraded to prevent the propagation of waves and sediment into Graham Creek.
- Tolerance for additional shoreline armouring (low/**medium**/high):



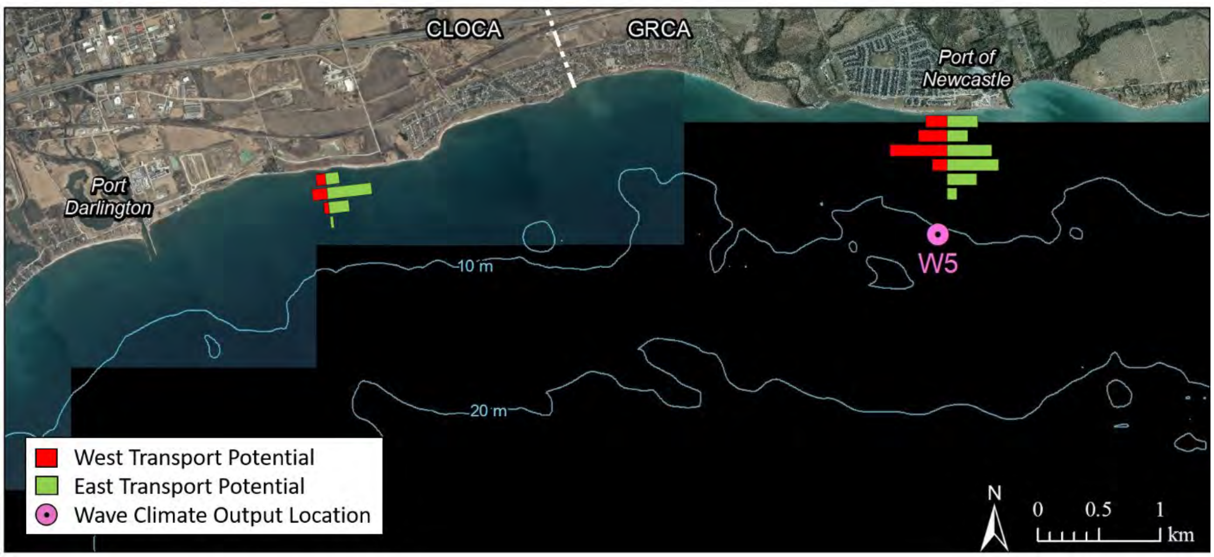
- Sample statistics (for armoured portion of shoreline):





Sediment Supply and Longshore Sediment Transport

- Net longshore sediment transport potential is from west to east through reach 5 with a potential volume of 80,000 to 100,000 m³/year. The actual transport is likely less than 10,000 m³/year as the supply of sediment is predominantly limited to local bluff erosion within the reach.
- Deposition occurs primarily in the fillet beach to the west of the Graham Creek jetties, as is evident by the significant offset in shoreline position from the west side to the east (~140 m).
- Some deposition occurs at the west end of the cell at Port Darlington East Beach during periods of wave action from the southeast quadrant.
- The significant amount of hardened shoreline fronting the Wilmot Creek Retirement Community reduces the sediment supply to the reach, however the structure is reasonably low crested and porous and therefore does not completely mitigate the bluff erosion that contributes sediment to the region.



Summary of Natural Hazards

- 100-year Erosion Rate (Stable Slope not included):

Start (lat, long)	End (lat, long)	100-year Erosion Rate (m/year)	Bluff Crest or Waterline
43.8891, -78.663	43.8976, -78.6203	0.24	Bluff Crest
43.8976, -78.6203	43.8959, -78.5975	0.24	Bluff Crest
43.8962, -78.5947	43.8953, -78.5815	0.24	Bluff Crest

- 100-year Flood Level and Flood Hazard Limit (including wave uprush):

Start (lat, long)	End (lat, long)	100-year Flood Level (m IGLD85')	Flood Hazard (m IGLD85')
43.8885, -78.6624	43.8895, -78.6617	+76.01	+77.64
43.8895, -78.6617	43.8967, -78.6257	+76.01	+77.77
43.8967, -78.6257	43.8956, -78.5767	+76.01	+77.77

- Dynamic Beach(es):

Start (lat, long)	End (lat, long)	100-year Erosion Rate (m/year) or Stable	Dynamic Beach Name
43.8885, -78.6641	43.8891, -78.663	Stable	Port Darlington East Park
43.8959, -78.5975	43.8962, -78.5947	0.11	Wilmot Creek Barrier Beach
43.8953, -78.5815	43.8955, -78.5764	Stable	Newcastle Beach

- Wave climate ~1 km offshore (output location W5):

ARI (years)	Depth (m)	Hs (m)	DIR (deg)	Tp (s)
5	13.1	4.72	211	9.5
10	13.1	4.82	211	9.5
25	13.1	5.02	208	10.0
50	13.1	5.08	208	10.0
100	13.1	5.13	208	10.0

Infrastructure and Ecosystem Threats

- West jetty at Bowmanville Creek requires a significant structural upgrade to mitigate wave and sediment transmission into the navigation channel (reported in Reach 4).
- Port Darlington East Beach suffers from a sediment deficit.
- Residences atop bluff east of Port Darlington East Beach are threatened by erosion.
- Wilmot Creek: interim shore protection that only provides partial erosion mitigation.
- Jetties at Graham Creek require significant repairs/upgrades to their roots to mitigate wave and sediment transmission into Graham Creek.
- Jetties at the Graham Creek trap longshore sediment transport and starve the downdrift shoreline to the east (Bond Head).

Shoreline Management Recommendations

- Impacts of additional shoreline armouring: moderate impacts within Reach 5 but significant negative impacts to Reach 6 to the east.
- West jetty at Bowmanville Creek requires significant structural upgrade to mitigate wave and sediment transmission into the navigation channel.
- Implement a sediment bypassing program from the Port Darlington west fillet beach to nourish Port Darlington East Beach Park.
- A long-term community scale solution is required for Port Darlington East Beach community to reduce erosion and flood hazards, such as protection or retreat. For example, a long-term voluntary land acquisition program for lands subject to acute hazards could be implemented to return the shore lands to public open space.
- Maintain naturally eroding bluff environments.
- Wilmot Creek Development: monitor shore protection and upgrade structures as required to provide the necessary protection.
- Monitor trail location at Newcastle and relocate inland when threatened by erosion.
- No further development in the floodplain west of Graham Creek (Port of Newcastle).
- Root of jetties at Graham Creek require significant repairs/upgrades.
- Implement a sediment bypassing program for the west fillet beach at Port of Newcastle to nourish the eroding east beach (Bond Head Parkette, Boulton Street).

Use Disclaimer

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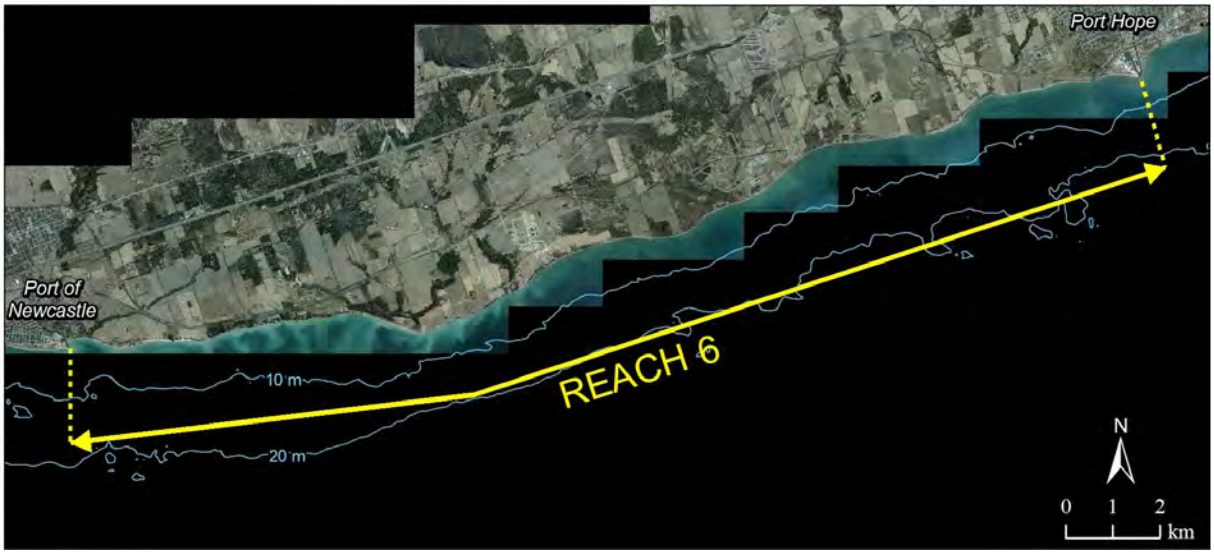
Reach 6 – Bond Head to Port Hope West Beach

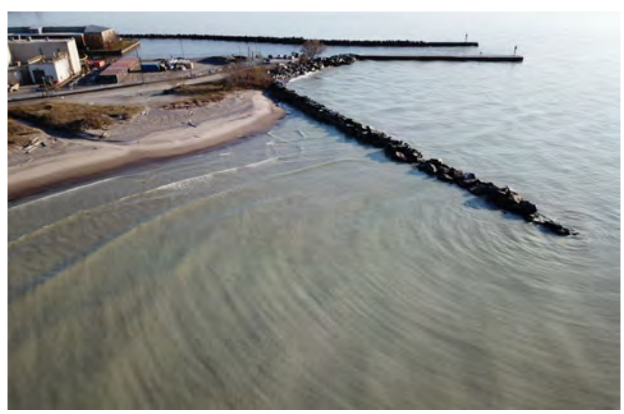


Local Conditions

- Reach Length = approximately 23.4 km.
- This long reach stretches from the Port of Newcastle to Port Hope West Beach.
- East of the Port of Newcastle, the Bond Head bluffs and gullies dominate the shoreline.
- The central portion of the reach features large tracks of agricultural land and small shoreline communities, such as Port Granby and Port Britain.
- The Ontario Power Generation Wesleyville Storage is located 8 km west of Port Hope.
- Port Hope west beach is a large deposition sink for the sand and gravel transported west to each in this reach.
- Immediately west of West Beach, the railway into Port Hope runs right along the bluff crest and will soon require shoreline protection to stabilize the slope.

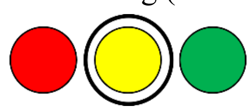
Eroding Bluffs at Bond Head

Port Hope West Beach and Jetties

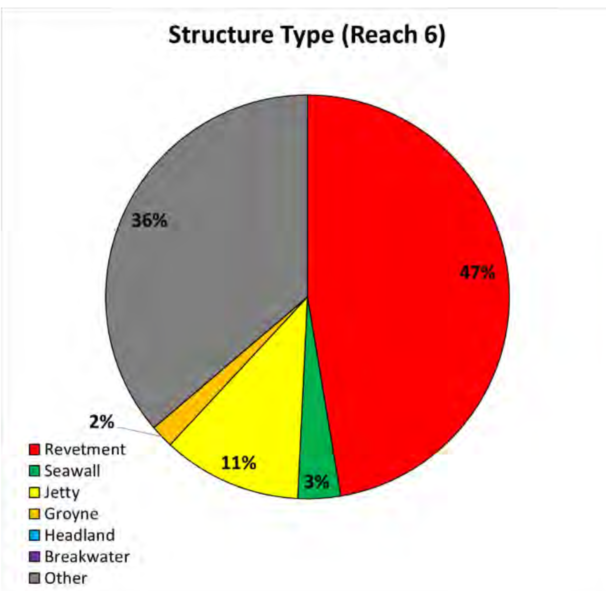


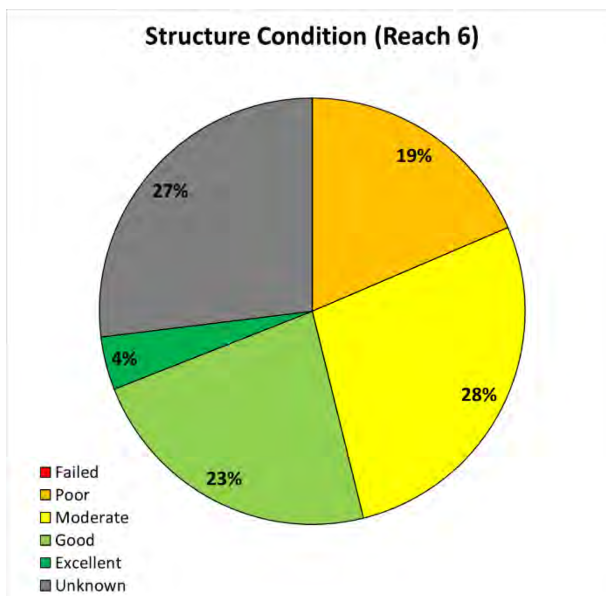
Shoreline Structures

- Reach 6 is 7% armoured, 93% natural.
- The jetties at Graham Creek at the west end of the reach are in poor condition at their root, where the structures were close to breaching during record high lake levels in 2019.
- There is a significant offset in shoreline position from the west side of Graham Creek (Reach 5) to the east side, where the Bond Head Parkette and properties along Boulton street have suffered significant erosion due to a lack of sediment supply. The Parkette and neighbouring properties have all been hardened to some degree to mitigate ongoing erosion. These structures are mostly well engineered and in good condition, with a few exceptions.
- Lakeshore Road is protected by an engineered armour stone revetment and is in generally good condition.
- The high bluff shoreline from Bond Head to Port Britain, a distance of over 17 km, is entirely natural and unprotected.
- Many private properties at Port Britain feature mostly ad-hoc shore protection. This protection is generally in poor to moderate condition and may require upgrades.
- Tolerance for additional shoreline armouring (low/**medium**/high):



- Sample statistics (for armoured portion of shoreline):

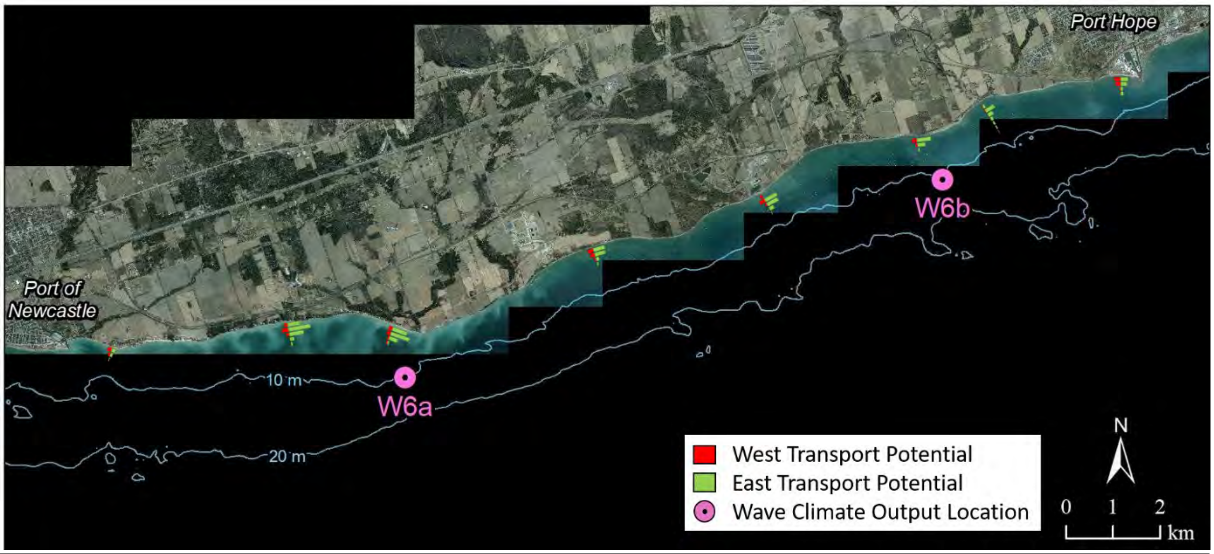




Sediment Supply and Longshore Sediment Transport

- Longshore sediment transport potential is very low in the embayment at the west end of the reach (Boulton Street), with very little sediment entering this region from either direction.

- Net longshore sediment transport potential from Bond Head to Port Hope is from west to east with net potential transport volumes in excess of 100,000 m^3/year at several locations.
- A significant percentage of this transport potential is likely realized, perhaps up to 50% and particularly during high lake levels, due to the significant length of unprotected eroding bluff that contributes sediment to the reach and the nearshore lakebed which is comprised primarily of sand and cobble.
- Deposition occurs primarily at the Port Hope west fillet beach to the west of Port Hope Harbour jetties, as is evident by the significant offset in shoreline position from the west side of the harbour to the east (over 300 m).



Summary of Natural Hazards

- 100-year Erosion Rate (Stable Slope not included):

Start (lat, long)	End (lat, long)	100-year Erosion Rate (m/year)	Bluff Crest or Waterline
43.8956, -78.5759	43.8965, -78.4836	0.59	Bluff Crest
43.8965, -78.4836	43.9033, -78.4591	0.17	Bluff Crest
43.9033, -78.4591	43.9134, -78.4132	0.41	Bluff Crest
43.9134, -78.4132	43.9166, -78.408	0.29	Waterline
43.9202, -78.3955	43.9229, -78.3889	0.29	Waterline
43.9229, -78.3889	43.9282, -78.3803	0.2	Bluff Crest
43.9308, -78.3605	43.936, -78.3355	0.2	Bluff Crest
43.936, -78.3355	43.9372, -78.3337	0.29	Waterline
43.9384, -78.3286	43.9409, -78.3019	0.2	Bluff Crest

- 100-year Flood Level and Flood Hazard Limit (including wave uprush):

Start (lat, long)	End (lat, long)	100-year Flood Level (m IGLD85’)	Flood Hazard (m IGLD85’)
43.8965, -78.5766	43.8973, -78.5718	+76.01	+77.67
43.8973, -78.5718	43.8958, -78.5656	+76.01	+77.77
43.8958, -78.5656	43.8961, -78.5567	+76.01	+77.85
43.8961, -78.5567	43.9045, -78.4563	+76.01	+77.77
43.9045, -78.4563	43.9335, -78.3393	+76.01	+77.77

43.9335, -78.3393	43.9406, -78.3032	+76.01	+77.86
43.9406, -78.3032	43.9408, -78.2913	+76.01	+77.77

- Dynamic Beach(es):

Start (lat, long)	End (lat, long)	100-year Erosion Rate (m/year) or Stable	Dynamic Beach Name
43.9166, -78.408	43.918, -78.4046	0.2	Wesleyville Beach
43.918, -78.4046	43.9191, -78.4003	0.29	Wesleyville Beach
43.9191, -78.4003	43.9195, -78.3975	0.2	Wesleyville Beach
43.9195, -78.3975	43.9202, -78.3955	0.29	Wesleyville Beach
43.9282, -78.3803	43.9299, -78.3731	0.2	Willow Beach
43.9299, -78.3731	43.9302, -78.3681	0.29	Willow Beach
43.9302, -78.3681	43.9308, -78.3605	0.2	Port Britain Road
43.9372, -78.3337	43.9384, -78.3286	0.2	Unknown
43.9409, -78.3019	43.9409, -78.2926	Stable	Port Hope West Beach

- Wave climate ~1 km offshore, west portion (output location W6a):

ARI (years)	Depth (m)	Hs (m)	DIR (deg)	Tp (s)
5	12.5	4.03	207	9.5
10	12.5	4.20	207	9.5
25	12.5	4.59	205	10.0
50	12.5	4.77	205	10.0
100	12.5	4.94	205	10.0

- Wave climate ~1 km offshore, east portion (output location W6b):

ARI (years)	Depth (m)	Hs (m)	DIR (deg)	Tp (s)
5	12.2	4.34	210	9.5
10	12.2	4.51	210	9.5
25	12.2	4.90	208	10.0
50	12.2	5.06	208	10.0
100	12.2	5.22	208	10.0

Infrastructure and Ecosystem Threats

- Jetties at Graham Creek are at risk of breaching at their structure roots (north of composite sections).
- Boulton Street and Bond Head Parkette threated by erosion due to sediment deficit.
- Bond Head Bluffs: high erosion rates and large gullies threaten homes close to the bluff edge.
- West rail line (CN and CP) entering Port Hope is at the crest of an eroding bluff.

Shoreline Management Recommendations

- Sediment bypassing from west fillet beach at Graham Creek to sediment starved shoreline fronting Bond Head Parkette and Boulton Street.
- Bond Head Bluffs: Avoid further development on hazardous lands. Monitor proximity of bluff crest to existing development and slope stability. Relocate homes at risk.
- Conservation Authority should regularly update hazard mapping at Bond Head to account for latest toe of slope, slope stability, and erosion. The 2020 hazard mapping must be updated frequently.

- Maintain naturally eroding bluff environments. Avoid rezoning agricultural land for residential development along gully dominated shoreline.
- Relocated buildings along high bluff environments susceptible to erosion and slope stability hazards.
- Implement floodproofing measures for development on low lying lands adjacent to the lake (Port Granby, Port Britain).
- Monitor rail line west of Port Hope and upgrade shore protection as required.
- West Beach at Port Hope would benefit from dune and vegetation restoration to stabilize the back beach and enhance local habitat.
- Mechanical bypassing of sediment from Port Hope West Beach to East Beach to avoid sedimentation in the navigation channel.

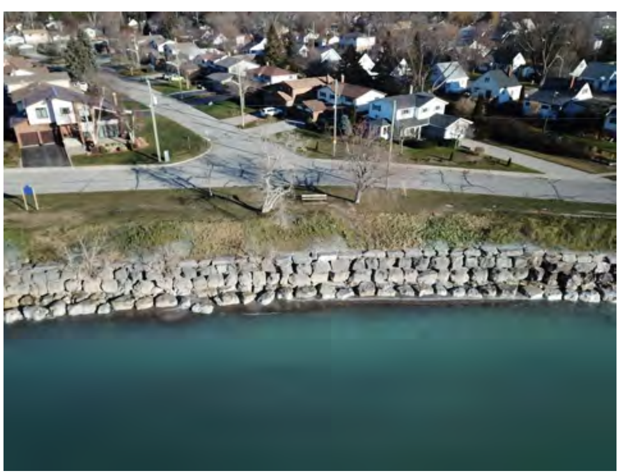
Use Disclaimer

Reach 7 – Port Hope to Cobourg

Local Conditions

- Reach Length = approximately 10.2 km.
- The jetties in Port Hope and Cobourg Harbour are the boundaries of a large littoral sub-cell with the Ganaraska Region Conservation Authority.
- Port Hope features sand accumulation in West Beach and a very narrow beach deposit on the east side of the jetties.
- Cobourg also features a large west beach that accumulates against the harbour. The east beach has been increasing in size since the 1950’s partially due to sand that is dredged from the entrance to the port and hydraulically pumped onto the beach.
- Between Port Hope and Cobourg the shoreline is largely undeveloped and features a natural shoreline and the Carr’s Marsh Conservation Area.

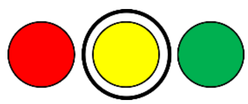
Municipal Shore Protection, Monk Street, Cobourg



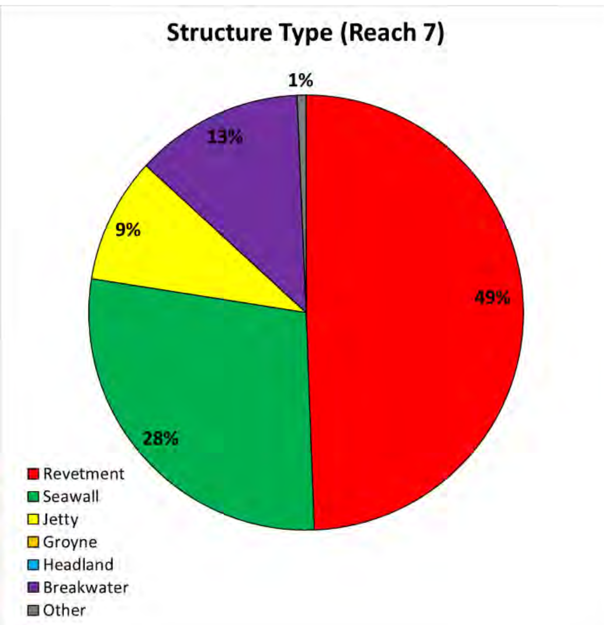
West Fillet Beach at Cobourg

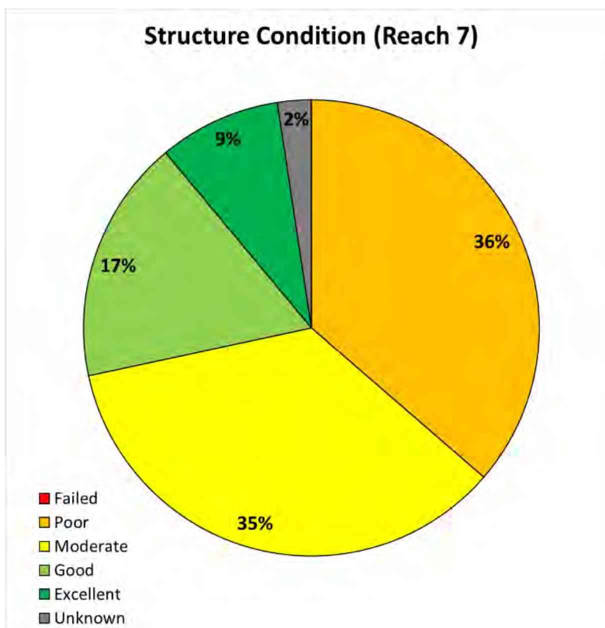
Shoreline Structures

- Reach 7 is 34% armoured, 66% natural.
- Armoured shorelines in Reach 7 are generally found in the built-up areas of Port Hope and Cobourg.
- Port Hope East Beach and the portion of shoreline fronting Lake Street features ad-hoc shore protection in the form of scrap concrete and rubble mound revetments. These structures are generally non-engineered and are in poor to moderate condition. Upgrades should be considered to mitigate erosion east of Port Hope.
- A significant portion of the shoreline west of Cobourg is armoured, with the majority being private property shore protection and some municipal shore protection (Monk Street). Private property shore protection is generally a mix of well-engineered and moderately engineered structures, most of which are in good condition. Some ad-hoc structures exist in poor condition and require upgrades to be effective.
- Municipal shore protection fronting Monk Street is significant and robust; however, it has a reasonably low crest and unprotected backshore. Upgrades to this structure including a properly engineered rip rap filter layer, crest protection and improved toe protection are recommended to improve its longevity.
- Tolerance for additional shoreline armouring (low/**medium**/high):



- Sample statistics (for armoured portion of shoreline):





Sediment Supply and Longshore Sediment Transport

- Longshore sediment transport is predominantly from west to east in Reach 7 with a net transport potential of upwards of 100,000 m³/year at several locations throughout the reach.

- The actual transport rates in Reach 7 are likely less than 20% of the potential rate due to a lack of sediment supply and an intermittent exposed bedrock lakebed.
- Sediment supply is mostly limited to local bluff erosion between Port Hope and Cobourg with a small amount of sediment naturally bypassing the jetties at Port Hope.
- Deposition occurs primarily at the Cobourg west fillet beach which features an offset of over 200 m in shoreline position from the west side of Cobourg Harbour to the east.
- Some deposition occurs at the Port Hope east beach during periods of wave action arriving from the southeast quadrant.

Summary of Natural Hazards

- 100-year Erosion Rate (Stable Slope not included):

Start (lat, long)	End (lat, long)	100-year Erosion Rate (m/year)	Bluff Crest or Waterline
43.9464, -78.2866	43.95, -78.2732	0.5	Waterline
43.9532, -78.245	43.9521, -78.2291	0.5	Waterline
43.9512, -78.2142	43.955, -78.2018	1.2	Waterline
43.955, -78.2018	43.9541, -78.18	0.36	Waterline
43.9541, -78.18	43.9541, -78.1776	0.17	Waterline

- 100-year Flood Level and Flood Hazard Limit (including wave uprush):

Start (lat, long)	End (lat, long)	100-year Flood Level (m IGLD85')	Flood Hazard (m IGLD85')
43.9408, -78.2913	43.9553, -78.2008	+76.01	+77.77
43.9553, -78.2008	43.9536, -78.1687	+76.01	+77.86

- Dynamic Beach(es):

Start (lat, long)	End (lat, long)	100-year Erosion Rate (m/year) or Stable	Dynamic Beach Name
43.9439, -78.2908	43.9464, -78.2866	Stable	Port Hope East Beach
43.95, -78.2732	43.9507, -78.2692	0.5	Marsh Lookout Beach
43.9507, -78.2692	43.9509, -78.2652	0.5	Marsh Lookout Beach
43.9509, -78.2652	43.9529, -78.2577	0.5	Unknown
43.9529, -78.2577	43.9535, -78.2501	0.5	Unknown

43.9535, -78.2501	43.9532, -78.245	0.5	Unknown
43.9521, -78.2291	43.9512, -78.2142	1.2	Carr's Marsh
43.9541, -78.1776	43.9536, -78.1686	Stable	Cobourg West Beach
43.9528, -78.1679	43.9552, -78.1674	Stable	Cobourg Inner Harbour

- Wave climate ~1 km offshore (output location W7):

ARI (years)	Depth (m)	Hs (m)	DIR (deg)	Tp (s)
5	15.3	4.16	214	10.0
10	15.3	4.39	213	10.0
25	15.3	4.70	212	10.5
50	15.3	4.85	212	10.5
100	15.3	5.00	212	10.5

Infrastructure and Ecosystem Threats

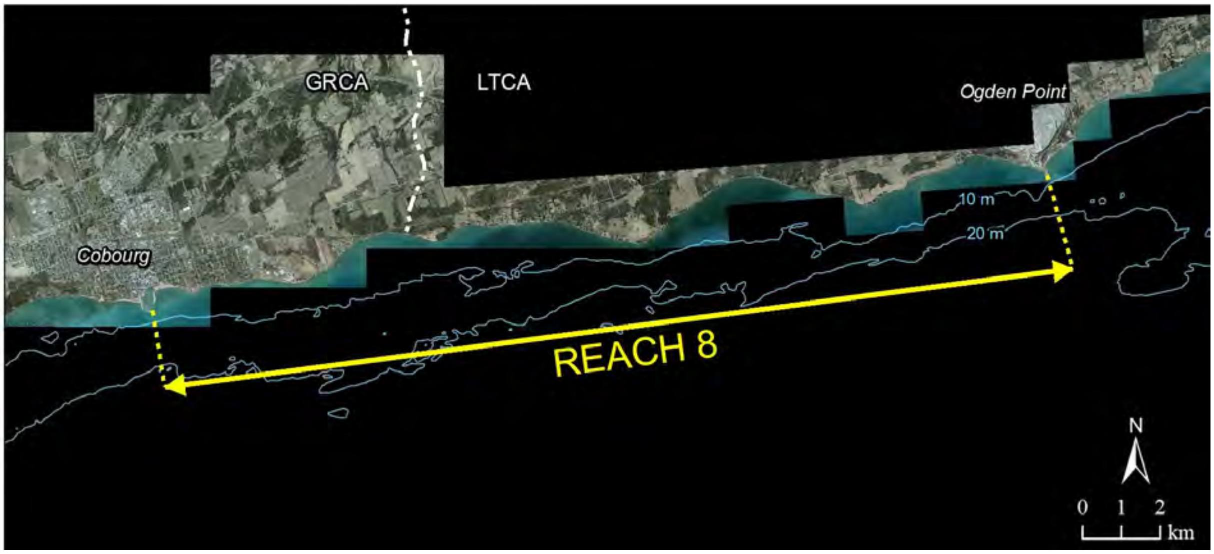
- Shore protection and the parking lot at the foot of King Street (Port Hope) has deteriorated and slope is threatened.
- Private properties west of Cobourg (Pebble Beach Drive, Cedar Lea St., King Street W.) are vulnerable to flooding and erosion hazards. Lot by lot protection schemes.
- South-facing portion of west breakwater protecting Cobourg Harbour is overtopped during storms and in significant disrepair.

Shoreline Management Recommendations

- Bypass sediment from west fillet beach to nourish east fillet beach at Port Hope and at Cobourg.
- Shore protection east of Port Hope and along Lake Street should be upgraded from ad-hoc to well-engineered.
- Protect barrier beaches and wetland complexes from further development east of Port Hope and south of CN/CP rail line. This region would also benefit from sediment bypassing at Port Hope.
- Private properties west of Cobourg with ad-hoc or no shore protection require engineered erosion protection structures to reduce vulnerability to coastal hazards. Existing shore protection should be monitored and maintained as necessary.
- Monk Street revetment requires continuous monitoring and maintenance. Consider upgrades to accommodate wave overtopping such as a properly engineered rip rap filter layer and slope protection behind the structure crest. Improved toe protection should also be considered.
- Cobourg West Beach: maintain boardwalk and continue with naturalization with dune vegetation and shrubs.
- Upgrade the south-facing portion of the west breakwater and implement living shoreline restoration concepts to enhance habitat in the marina basin.

Use Disclaimer

Reach 8 – Cobourg Harbour to Ogden Point



Local Conditions

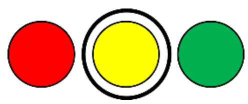
- Reach Length = approximately 23 km.
- Cobourg Harbour extends more than 500 m into Lake Ontario and represents the west boundary of Reach 8. The east boundary is defined by the lakefill at St. Marys Cement that extends 400 m into Lake Ontario.
- Cobourg Harbour features a large sheltered basin for recreational boats that features an easterly facing opening to the lake.
- Hydraulic dredging from the harbour entrance is pumped to the east fillet beach to increase beach width.
- Bedrock exposures are prominent east of the Cobourg Harbour for 2 km then the shoreline transitions to an eroding bluff.
- The bluff shoreline from Cobourg to Ogden Point alternates between natural areas and shoe-string development with intermittent shore protection.
- The local beaches are important migratory habitat for birds and insects.

Cobourg Harbour East Beach

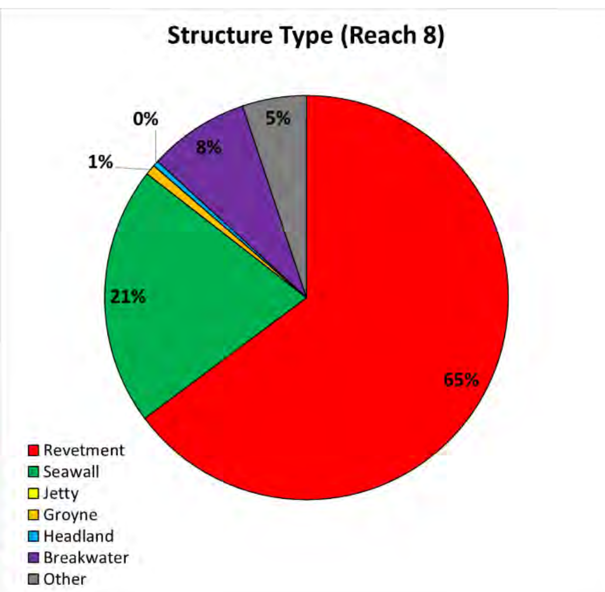
Bedrock Shoreline and Nearshore

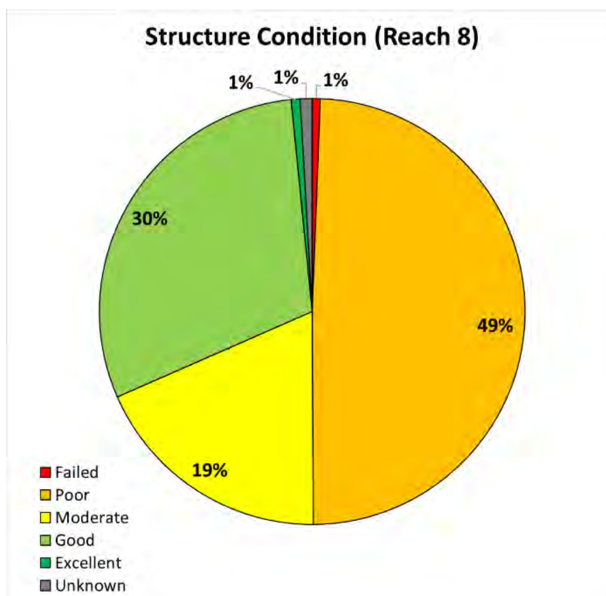
Shoreline Structures

- Reach 8 is 26% armoured, 74% natural.
- The majority of armoured shoreline within Reach 8 is private property shore protection and is located east of Cobourg East Beach, in the town of Spicer, and intermittently through the Grafton Shores area.
- Private property shore protection east of Cobourg is a combination of older, ad-hoc structures in generally poor condition, and newer, well-engineered structures in generally good condition.
- The majority of private properties east of Cobourg remain unprotected, however they benefit from the natural protection provided by an extensive limestone bedrock shelf along the shoreline and in the nearshore.
- Shore protection fronting the Pentecostal Camp at Spicer and adjacent CN rail line to the east is generally ad-hoc revetment-type protection built from a combination of stone and scrap concrete. This shore-protection is generally in poor condition and is vulnerable during extreme events.
- Intermittent shore protection throughout the Grafton Shores region is generally well-engineered and in good condition. The majority of properties remain unprotected and have suffered significant erosion in recent years.
- Tolerance for additional shoreline armouring (low/**medium**/high):



- Sample statistics (for armoured portion of shoreline):

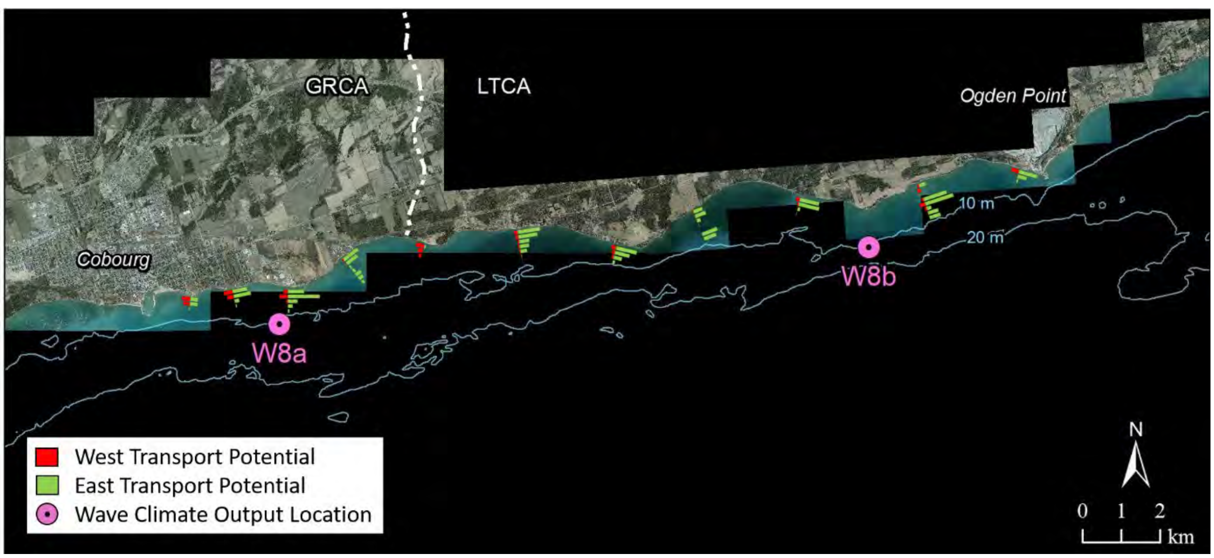




Sediment Supply and Longshore Sediment Transport

- Longshore sediment transport is predominantly from west to east in Reach 8 with fairly high net transport potential of upwards of 150,000 m^3/year at several locations throughout the reach.

- The actual transport rate in the west portion of the reach from Cobourg to Spicer is likely very small (0 to 10,000 m³/year). This is due to the obstruction Cobourg Harbour presents to longshore sediment supply arriving from the west, in combination with the exposed bedrock shoreline and nearshore.
- The actual transport rates east of Spicer to Ogden Point are more significant but likely less than 20% of the potential transport rates due to the limited supply of sediment. Sediment comes from two main sources, the first being sand and gravel provided by local eroding bluffs and the second being shingle material provided by eroding bedrock in the nearshore.
- Longshore transport from Spicer to Ogden Point is generally west to east and is partially contained within several sub-cells. These sub-cells exist within small embayments, in which the headlands at either end typically feature significant exposed bedrock in the nearshore (such as at Chub Point). Sub-cells within Reach 8 include:
    - Spicer to west of Hortop Conservation Area
    - Hortop Conservation Area to Chub Point (Grafton Shores)
    - East of Chub Point to McGlennon Road
    - McGlennon Road to Ogden Point
- Sediment moves from west to east within each sub-cell. In the Grafton Shores region this process is apparent with significant bluff erosion taking place along Lakeshore Road and significant sand and cobble deposits overlying bedrock off of Chub Point.



Summary of Natural Hazards

- 100-year Erosion Rate (Stable Slope not included):

Start (lat, long)	End (lat, long)	100-year Erosion Rate (m/year)	Bluff Crest or Waterline
43.9567, -78.155	43.9581, -78.132	0.12	Bluff Crest
43.9581, -78.132	43.9572, -78.115	0.36	Bluff Crest
43.9572, -78.115	43.9672, -78.0832	0.31	Waterline
43.9672, -78.0832	43.9667, -78.0794	0.74	Waterline
43.9667, -78.0794	43.9653, -78.0726	0.36	Bluff Crest
43.9653, -78.0726	43.9688, -78.0612	0.74	Waterline

43.9688, -78.0612	43.969, -78.0371	0.36	Bluff Crest
43.9679, -77.9986	43.9707, -77.9919	0.36	Bluff Crest
43.9707, -77.9919	43.9727, -77.9876	0.14	Waterline
43.9747, -77.9584	43.9716, -77.9405	0.14	Waterline
43.9716, -77.9405	43.97, -77.9341	0.1	Bluff Crest
43.97, -77.9341	43.979, -77.9053	0.14	Waterline
43.9794, -77.9034	43.9805, -77.9018	0.14	Waterline
43.9784, -77.8854	43.9756, -77.8771	0.1	Bluff Crest

- 100-year Flood Level and Flood Hazard Limit (including wave uprush):

Start (lat, long)	End (lat, long)	100-year Flood Level (m IGLD85')	Flood Hazard (m IGLD85')
43.9536, -78.1687	43.9570, -78.1560	+76.01	+77.77
43.9570, -78.1560	43.9609, -78.1063	+76.01	+77.55
43.9609, -78.1063	43.9673, -78.0823	+76.01	+77.97
43.9673, -78.0823	43.9647, -78.0171	+76.03	+77.91
73.9647, -78.0171	43.9665, -77.9999	+76.03	+78.06
43.9665, -77.9999	43.9747, -77.9584	+76.03	+77.91
43.9747, -77.9584	43.9743, -77.9222	+76.03	+78.00
43.9743, -77.9222	43.9774, -77.9096	+76.03	+77.91
43.9774, -77.9096	43.9784, -77.8856	+76.03	+77.43
43.9784, -77.8856	43.9756, -77.8765	+76.03	+77.58

- Dynamic Beach(es):

Start (lat, long)	End (lat, long)	100-year Erosion Rate (m/year) or Stable	Dynamic Beach Name
43.9563, -78.164	43.9567, -78.155	Stable	Cobourg East Beach
43.969, -78.0371	43.9678, -78.0287	0.36	Grafton Shores
43.9678, -78.0287	43.967, -78.0269	0.14	Nawautin Beach
43.967, -78.0269	43.9654, -78.0027	0.36	Grafton Shores
43.9654, -78.0027	43.9679, -77.9986	0.14	Ruttan Road
43.9727, -77.9876	43.9752, -77.9829	0.36	Unknown
43.9752, -77.9828	43.9774, -77.9743	0.14	Jubalee Beach
43.9774, -77.9743	43.9747, -77.9584	0.1	Wicklow Beach
43.979, -77.9053	43.9794, -77.9034	0.1	Lakeport West
43.9805, -77.9018	43.9796, -77.8904	0.35	Lakeport East
43.9796, -77.8904	43.9784, -77.8854	0.1	Ogden Point West

- Wave climate ~1 km offshore, west portion (output location W8a):

ARI (years)	Depth (m)	Hs (m)	DIR (deg)	Tp (s)
5	12.6	4.59	217	10.0
10	12.6	4.82	217	10.0
25	12.6	5.14	216	10.5
50	12.6	5.25	216	10.5
100	12.6	5.35	216	10.5

- Wave climate ~1 km offshore, east portion (output location W8b):

ARI (years)	Depth (m)	Hs (m)	DIR (deg)	Tp (s)
5	13.4	4.59	214	10.5
10	13.4	4.81	213	10.5
25	13.4	5.06	213	10.5
50	13.4	5.21	213	10.5
100	13.4	5.30	213	10.5

Infrastructure and Ecosystem Threats

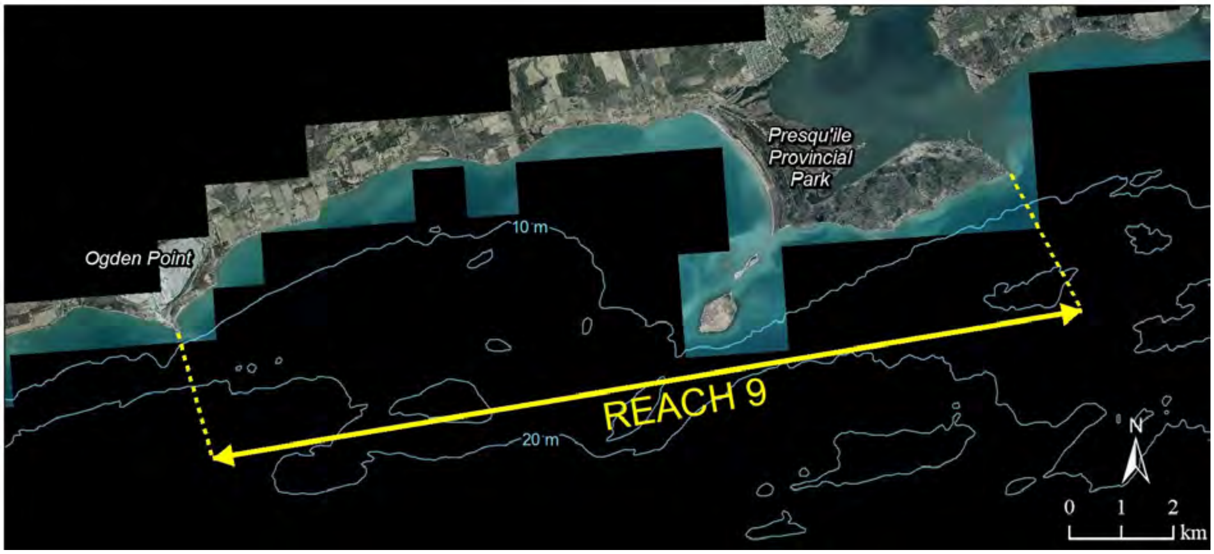
- The Cobourg East Beach is low lying and vulnerable to high lake levels, as 2019 demonstrated.
- Sedimentation in the Cobourg Harbour entrance is a navigation risk but managed with maintenance dredging.
- Properties east of Cobourg are vulnerable to high lake levels (protected by bedrock shelf at low to average levels).
- Buildings and parking lots east of Lucas Point Park are vulnerable to shoreline erosion and gullying due to overland drainage.
- The rail corridor east of Spicer is at the waters edge and very vulnerable to shore erosion.
- Pentecostal Camp and CN Rail Line: lakefront development and buildings impacted by flood and erosion hazards.
- Grafton Shores Subdivision: highly erosive bluff threatens existing development.
- Wicklow Beach Road is very close to the lake.

Shoreline Management Recommendations

- Continue with beach nourishment program for east fillet beach and consider construction of an artificial dune and foredune complex to inflate the elevation of the beach.
- Lucas Point Industrial Area: parking lots and buildings are on hazardous lands and will require relocation. Landside drainage should also be addressed.
- Pentecostal Camp and CN Rail Line: shoreline protection requires upgrades for the entire property and the CN Rail Line.
- Hortop Subdivision: Community scale solution for a protection option is a good model for other high-risk areas.
- Grafton Shores Dynamic Beach: avoid shore perpendicular structures that may disrupt the natural transport of sediment alongshore. If armouring is required, shore parallel structures should be implemented.
- Wicklow Beach Road: monitor. Protection or re-alignment likely required in the future.
- For undeveloped shorelines, consider erosion hazard setbacks greater than the standard 100-year distance.

Use Disclaimer

Reach 9 – Ogden Point to Presqu'ile Provincial Park

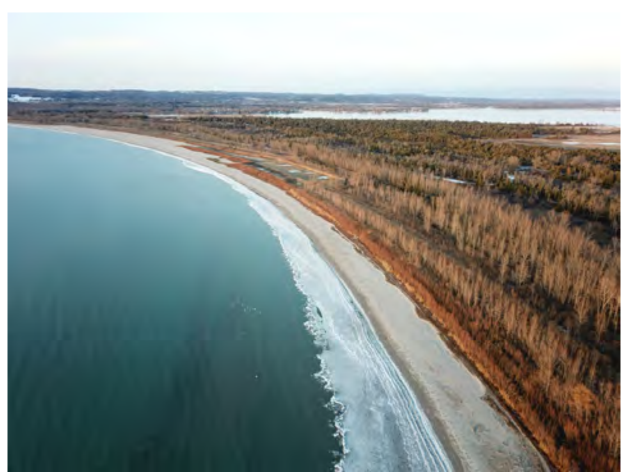


Local Conditions

- Reach Length = approximately 16.4 km.
- Ogden Point to Presqu'ile Provincial Park is the final littoral sub-cell that was once part of a large littoral cell that extended from East Point Park in Scarborough to Presqu'ile Provincial Park (Reinders, 1988).
- The eroding bluff shoreline east of Ogden Point features shoestring development along the bluff crest.
- The central portion of the reach is primarily agricultural lands and natural areas.
- The shoestring development begins again in Popham Bay and extends to the northwest boundary of the Provincial Park.
- The Provincial Park is a major sediment sink as evident by the successive beach ridges that have formed over time and now connected to Gull Island.

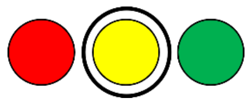
Eroding Bluff Shoreline, Victoria Beach

Presqu'ile Beach, Presqu'ile Prov. Park

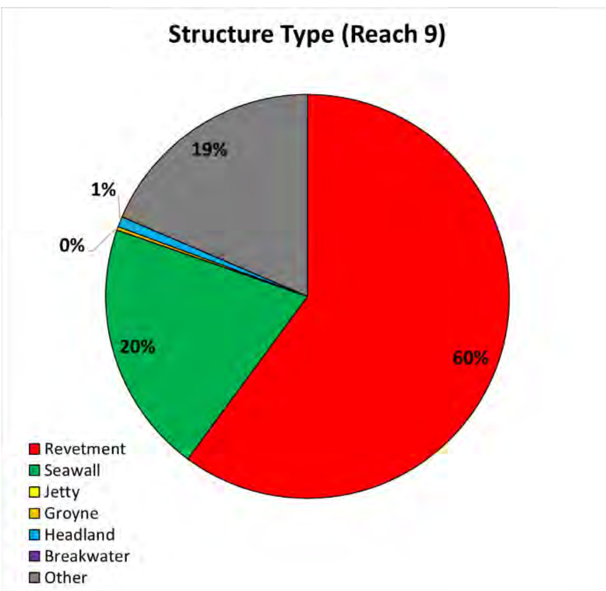


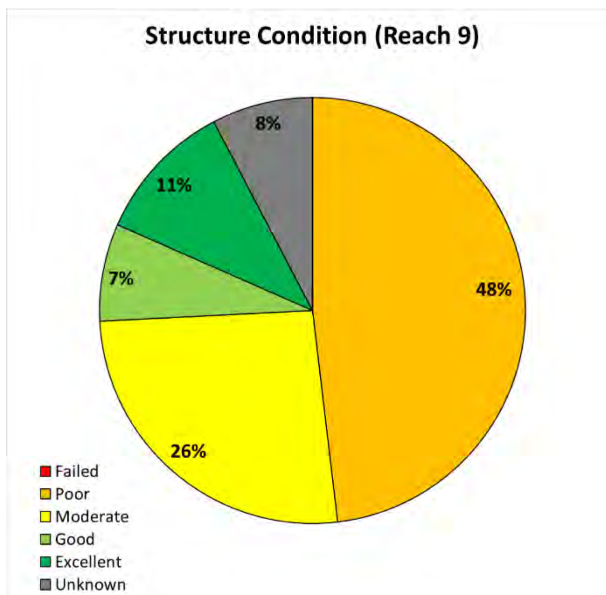
Shoreline Structures

- Reach 9 is 18% armoured, 82% natural.
- Shore protection is sporadic throughout the reach and limited to private property infrastructure. Most structures are boulder revetments or concrete rubble revetments and concrete seawalls, most of which are ad-hoc and in poor condition.
- Significant variability in armoured vs. natural shoreline, level of design, type of shore protection and structure condition exists throughout the reach.
- A great deal of flanking exists throughout the region where an unprotected property has continued to erode adjacent to a protected or partially protected property.
- Shore protection throughout Popham Bay is particularly vulnerable to being overtopped due to the bedrock shelves that are prevalent in the nearshore and the extremely low land elevation.
- Tolerance for additional shoreline armouring (low/**medium**/high):



- Sample statistics (for armoured portion of shoreline):

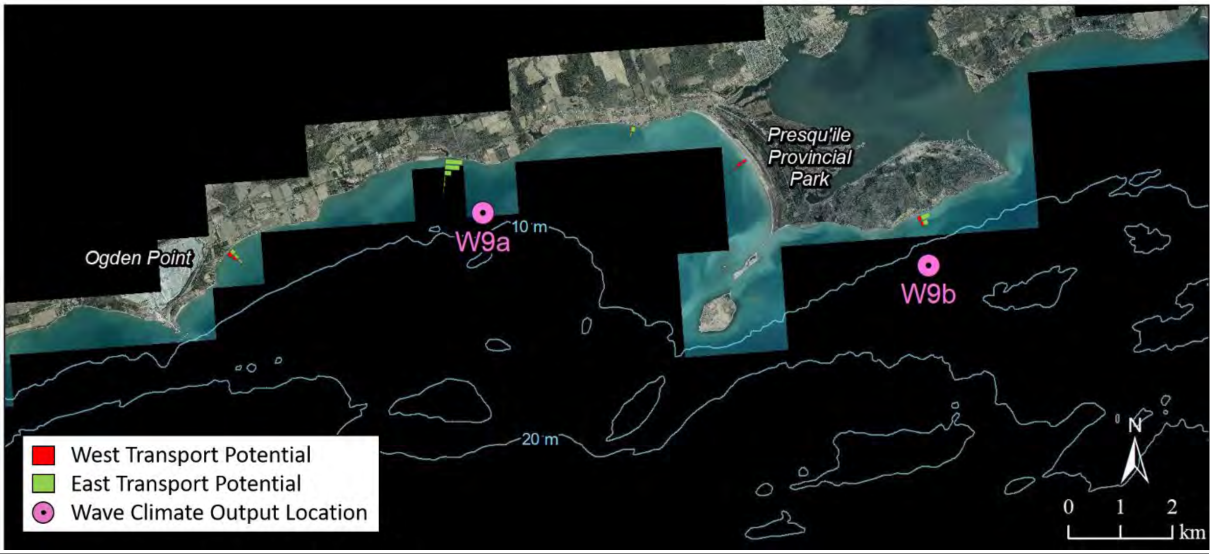




Sediment Supply and Longshore Sediment Transport

- Longshore sediment transport is predominantly from west to east in Reach 9 with a net transport potential of 30,000 to 50,000 m^3/year.
- Sediment transport is especially limited at the west end of the reach in the Victoria Beach region, where the net transport potential is virtually zero. This region appears to feature a sediment sink offshore, however the shoreline itself is highly erosive.
- East of Victoria Beach sediment transport occurs from west to east, but the actual transport is likely significantly lower than the potential transport for the region due to a lack of sediment supply.

- The primary depositional area for the reach is Presqu'ile Beach, which historically received much of the west to east transport along the entire project shoreline before the shoreline became fragmented into several sub-cells due to human development.
- The Popham Bay shoreline immediately west of Presqu'ile Beach is characterized by shallow bedrock shelves, which typically only house cobble and shingle beaches comprised of eroded bedrock material. Smaller silts and sands appear to typically move further offshore until they are deposited at Presqu'ile Beach.



Summary of Natural Hazards

- 100-year Erosion Rate (Stable Slope not included):

Start (lat, long)	End (lat, long)	100-year Erosion Rate (m/year)	Bluff Crest or Waterline
43.9758, -77.8767	43.9776, -77.8774	0.33	Bluff Crest
43.9837, -77.8673	43.986, -77.8674	0.33	Bluff Crest
43.9876, -77.8658	43.9927, -77.8534	0.33	Bluff Crest
43.9927, -77.8534	44.0043, -77.811	0.36	Waterline
44.0038, -77.8063	44.0028, -77.7974	0.17	Bluff Crest
44.0028, -77.7974	44.006, -77.7892	0.36	Waterline

- 100-year Flood Level and Flood Hazard Limit (including wave uprush):

Start (lat, long)	End (lat, long)	100-year Flood Level (m IGLD85')	Flood Hazard (m IGLD85')
43.9756, -77.8765	43.9935, -77.8505	+76.03	+77.81
43.9935, -77.8505	43.9946, -77.8421	+76.03	+77.43
43.9946, -77.8421	43.9970, -77.8408	+76.03	+78.00
43.9970, -77.8408	44.0027, -77.8015	+76.03	+77.91
44.0027, -77.8015	44.0060, -77.7892	+76.03	+78.00
44.0060, -77.7892	44.0090, -77.7761	+76.03	+77.91
44.0090, -77.7761	44.0107, -77.7513	+76.03	+77.43
44.0107, -77.7513	43.9884, -77.7334	+76.03	+77.81
43.9884, -77.7334	43.9978, -77.6755	+76.03	+77.43

- Dynamic Beach(es):

Start (lat, long)	End (lat, long)	100-year Erosion Rate (m/year) or Stable	Dynamic Beach Name
43.9776, -77.8774	43.9837, -77.8673	Stable	Ogden Point East
43.986, -77.8674	43.9876, -77.8658	0.36	Victoria Beach West
44.0043, -77.811	44.0042, -77.809	0.36	Beach Drive West
44.0042, -77.809	44.0038, -77.8063	0.36	Beach Drive West
44.006, -77.7892	44.0086, -77.7812	0.36	Beach Drive East Barrier Beach
44.0086, -77.7812	44.0107, -77.751	0.17	Popham Bay
44.0107, -77.751	43.9884, -77.7334	Stable	Presqu'ile Beach

- Wave climate ~1 km offshore, west portion (output location W9a):

ARI (years)	Depth (m)	Hs (m)	DIR (deg)	Tp (s)
5	9.5	3.82	211	10.5
10	9.5	3.89	212	10.5
25	9.5	3.96	212	10.5
50	9.5	4.00	212	10.5
100	9.5	4.02	212	10.5

- Wave climate ~1 km offshore, east portion (output location W9b):

ARI (years)	Depth (m)	Hs (m)	DIR (deg)	Tp (s)
5	15.8	4.23	222	10.5
10	15.8	4.41	222	10.5
25	15.8	4.61	222	10.5
50	15.8	4.73	222	10.5
100	15.8	4.81	222	10.5

Infrastructure and Ecosystem Threats

- Victoria Beach: erosion threat is high.
- Popham Bay: select waterfront properties susceptible to shoreline erosion and flooding.
- Lakehurst Street: high flood vulnerability due to low land elevations.

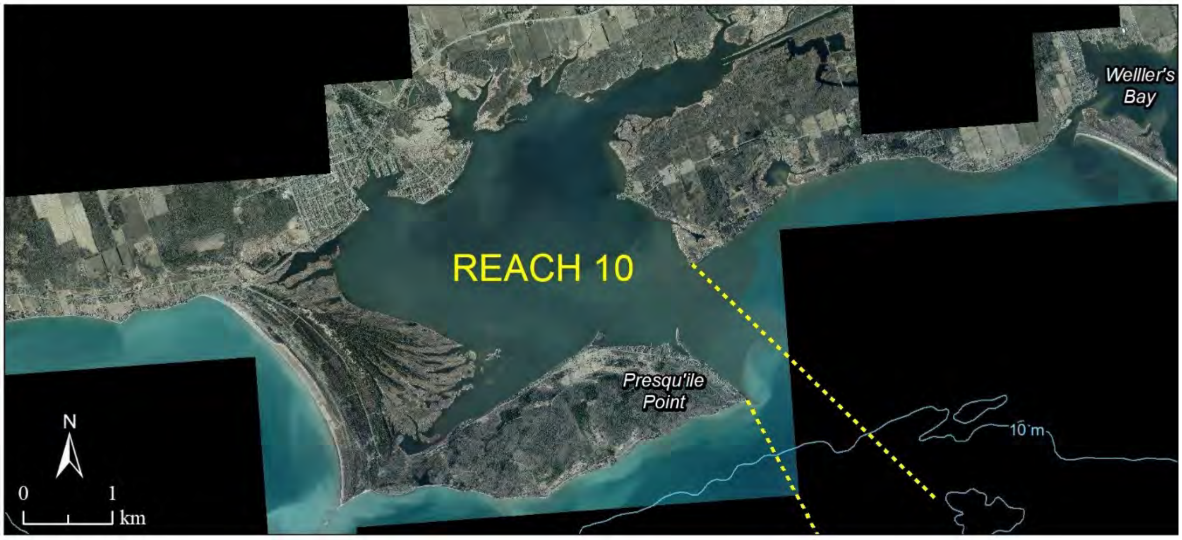
Shoreline Management Recommendations

- Victoria Beach: community scale erosion mitigation or a managed retreat approach (vacant land landward).
- Popham Bay Dynamic Beach: avoid shore perpendicular structures that will impede longshore sediment transport. If protection is constructed, it should be placed at the toe of the bank and placed on native bedrock (not cobble substrate). Flood hazard mitigation strategies such as floodproofing should also be implemented for low lying properties.
- Lakehurst Street: consider artificial dune construction to provide nature-based flood mitigation.

Use Disclaimer

The information in this reach summary was prepared for the Central Lake Ontario Conservation Authority, the Ganaraska Region Conservation Authority, and the Lower Trent Region Conservation Authority. If used by a third party, they agree that the information is subject to change without notice. Zuzek Inc. and SJL Engineering Inc. assume no responsibility for the consequences of such use or changes in the information. Under no circumstance will Zuzek Inc. or SJL Engineering Inc. be liable for direct, indirect, special, or incidental damages resulting from, arising out of, or in connection with the use of the information in this summary by a third party.

Reach 10 – Presqu'ile Point to Shoal Point



Local Conditions

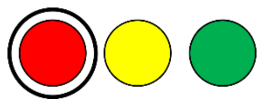
- Reach Length = approximately 22.0 km.
- Reach 10 is sheltered from Lake Ontario waves by Presqu'ile Provincial Park. The sandy bay extends from Presqu'ile Point to Shoal Point.
- Several of the communities were constructed on former coastal wetlands and are very vulnerable to high lake levels, as seen in 2017 and 2019.
- Undeveloped areas of the bay feature extensive coastal wetlands, including the eastern shore of the Provincial Park.
- The Trent-Severn Waterway is a constructed canal that connects the northeast corner of the bay with the Bay of Quinte near Trenton.

Concrete Seawalls, Presqu'ile Backside

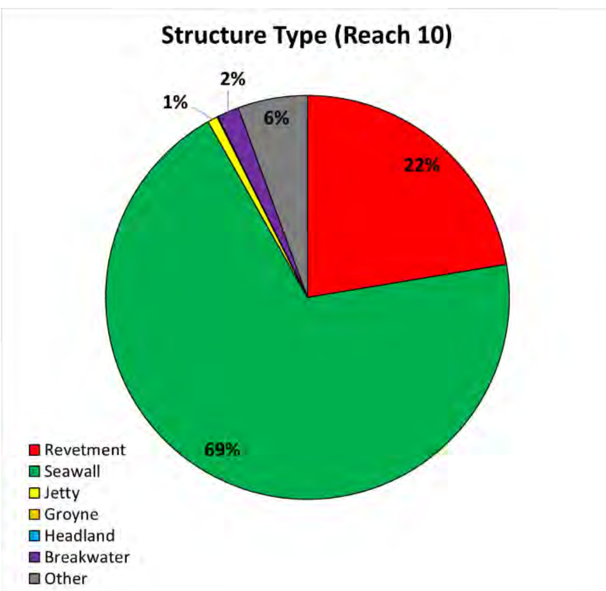
Flooded Properties in Gosport (May, 2019)

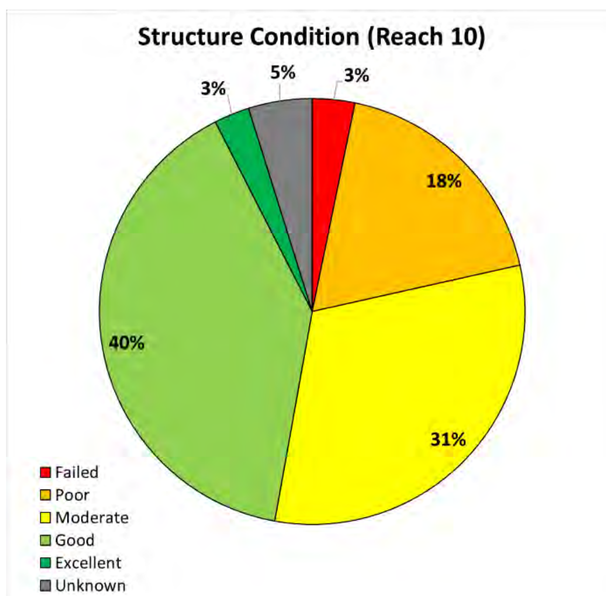
Shoreline Structures

- Reach 10 is 32% armoured, 68% natural.
- Shore protection is prevalent through all developed portions of Presqu'ile Bay including the north side of Presqu'ile Peninsula, Brighton and Gosport.
- The vast majority of shore protection is concrete seawalls, many of which are 40 to 50 years old. Most are in moderate to good condition, though some require repairs.
- Some newer developments in Brighton were built on reclaimed land using steel sheet piling doubling as a seawall.
- Damaged or failing shoreline infrastructure in Presqu'ile Bay is primarily the result of poor drainage, freeze thaw, ice impacts or deterioration with time. The bay is extremely sheltered from wave action on Lake Ontario.
- Unprotected portions of shoreline within Presqu'ile Bay are rich ecological areas with significant amounts of coastal habitat.
- Tolerance for additional shoreline armouring of developed areas (**low**/medium/high):



- Sample statistics (for armoured portion of shoreline):





Sediment Supply and Longshore Sediment Transport

- Sediment transport in Reach 10 is mostly limited to sediment moving along the east end of Presqu'ile Peninsula and into Presqu'ile Bay. Coarser sediments such as sand are deposited on shoals near the entrance to the bay while smaller sediment such as silt is deposited within and circulated throughout the bay.
- The net sediment transport potential along the backside of Presqu'ile from the lighthouse to Atkins Reef is on the order of 50,000 m3/year traveling from south to north (into the bay). The actual net transport is likely much smaller as sediment supply around

Presqu'ile Point is significantly limited by the presence of an extensive bedrock shelf in the nearshore.

Summary of Natural Hazards

- 100-year Erosion Rate (Stable Slope not included):

Start (lat, long)	End (lat, long)	100-year Erosion Rate (m/year)	Bluff Crest or Waterline
43.9981, -77.6753	43.995, -77.7182	Stable Slope Allowance Only	n/a

- 100-year Flood Level and Flood Hazard Limit (including wave uprush):

Start (lat, long)	End (lat, long)	100-year Flood Level (m IGLD85')	Flood Hazard (m IGLD85')
-	-	+76.03	+77.17

- Dynamic Beach(s): n/a
- Wave climate ~1 km offshore (output location W10):

ARI (years)	Depth (m)	Hs (m)	DIR (deg)	Tp (s)
5	3.7	1.43	160	10.5
10	3.7	1.45	160	10.5
25	3.7	1.47	160	10.5
50	3.7	1.48	160	10.5
100	3.7	1.49	160	10.5

Infrastructure and Ecosystem Threats

- Aging shoreline protection, especially on the north side of the Presqu'ile Peninsula.
- Harbour Street and Gosport Community: low and flood prone.

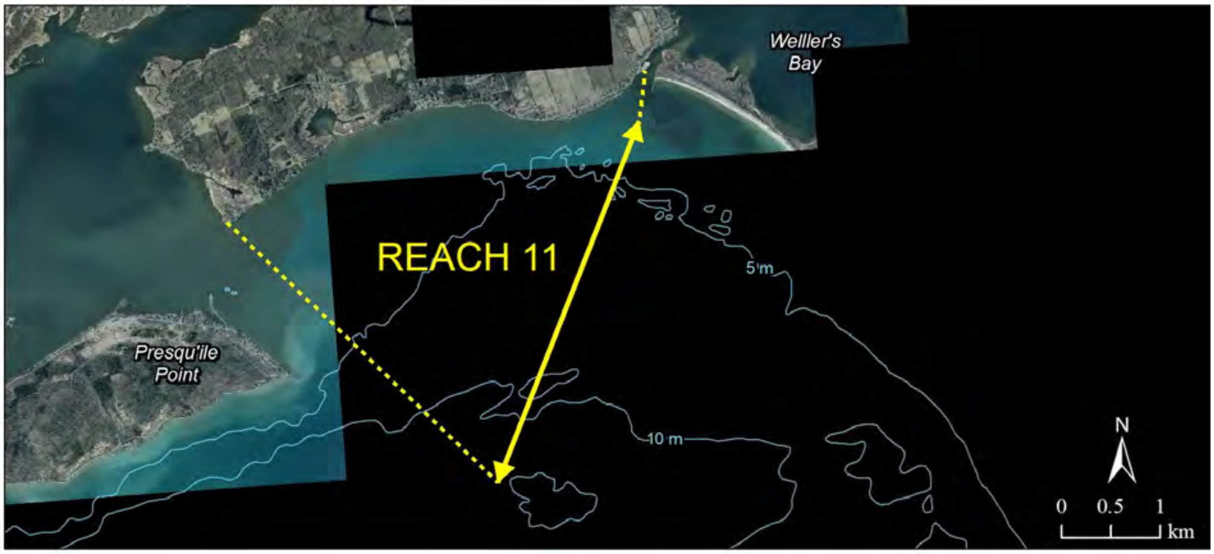
Shoreline Management Recommendations

- Monitor and maintain existing shoreline protection infrastructure in Presqu'ile Bay.

- Incorporate appropriate drainage in shore protection upgrades to prevent hydrostatic pressure buildup and freeze-thaw damage behind concrete seawalls.
- Harbour Street and Gosport Community: further investigate the elevation of ingress and egress routes in the community and implement upgrades where necessary to ensure safe access during the 100-year storm event.
- Prohibit further development on wetlands and ecologically sensitive area around Presqu'ile Bay.
- Floodproofing existing development located within the coastal floodplain (i.e., below the 100-year Flood Level).

Use Disclaimer

Reach 11 – Shoal Point to Wellers Bay



Local Conditions

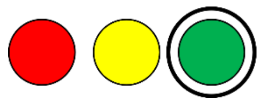
- Reach Length = approximately 16 km.
- The shoreline is extensively developed with permanent and seasonal homes. A significant percentage is already armoured with a variety of shoreline protection structures.
- Boat Harbour is a large sheltered embayment with a natural shoreline.
- Two sections of Barcovan Beach Road are very close to the waters edge and should be monitored.
- The development along Evergreen Lane is located on lands below the 100-year flood level and extremely vulnerable to flooding during high lake levels and storms. A long-term community scale mitigation strategy is needed for this community.

Flood Prone Properties, Evergreen Lane (May 2019)

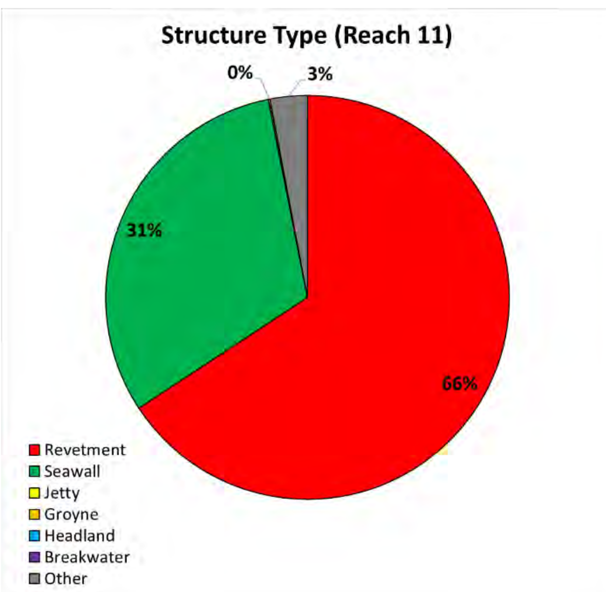
Exposed Bedrock Shoreline, Barcovan Beach Road (November 2018)

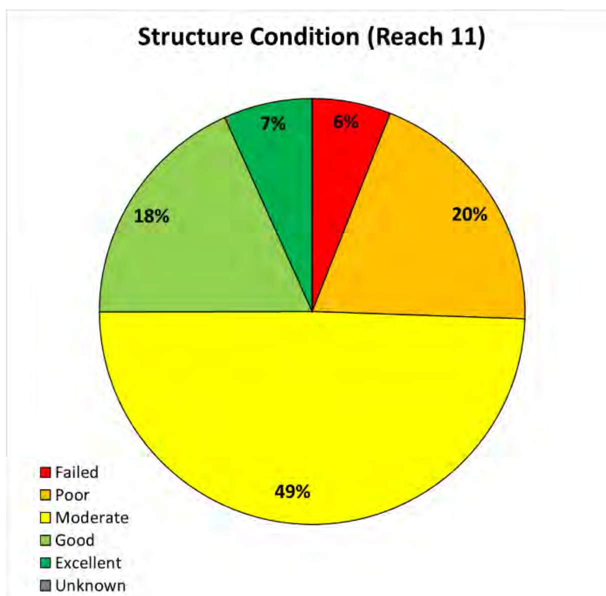
Shoreline Structures

- Reach 11 is 74% armoured, 26% natural.
- The vast majority of Reach 11 is privately owned, hardened shoreline, with a wide range of shore protection types, levels of design and condition.
- Most structures fall under the revetment (boulder or armour stone) or seawall (concrete or stacked armour stone) categories.
- Most structures (65%) are moderately to well-engineered and in moderate to good condition.
- 35% of protection structures are ad-hoc, many of which are in poor condition.
- West of boat harbour, shore protection is generally founded on sandy lakebed. East of boat harbour along Barcovan Beach Road the shore protection is generally founded on exposed bedrock. A highly erodible layer of native soils sits atop the exposed bedrock, with unprotected properties suffering significant and ongoing erosion as a result.
- Tolerance for additional shoreline armouring (low/medium/**high**):



- Sample statistics (for armoured portion of shoreline):

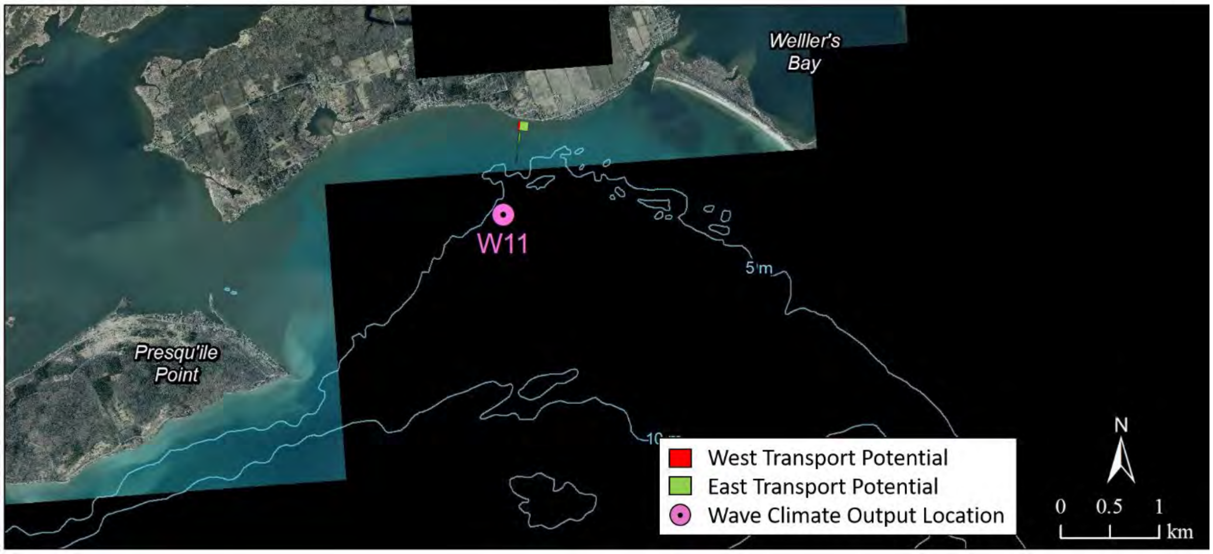




Sediment Supply and Longshore Sediment Transport

- Sediment transport in Reach 11 is generally from west to east, with the net transport potential being on the order of 15,000 to 20,000 m^3/year.
- The actual transport may be upwards of 50% of the potential as the majority of the nearshore features an extensive sand deposit that is mobilized during significant wave events. The movement of sediment is likely in a narrow band near the shoreline.
- The principal depositional areas in Reach 11 are the Boat Harbour barrier beaches in the western half of the reach and the entrance to Weller's Bay at the east end of the reach.

The Weller's Bay navigation channel is dredged with some frequency to maintain navigable depths.



Summary of Natural Hazards

- 100-year Erosion Rate (Stable Slope not included):

Start (lat, long)	End (lat, long)	100-year Erosion Rate (m/year)	Bluff Crest or Waterline
44.0132, -77.6784	44.0179, -77.6704	0.23	Waterline
44.0204, -77.663	44.0242, -77.6289	0.23	Waterline

- 100-year Flood Level and Flood Hazard Limit (including wave uprush):

Start (lat, long)	End (lat, long)	100-year Flood Level (m IGLD85')	Flood Hazard (m IGLD85')
44.0118, -77.6827	44.0210, -77.6471	+76.03	+77.81
44.0210, -77.6471	44.0221, -77.6320	+76.03	+77.58
44.0221, -77.6320	44.0242, -77.6290	+76.03	+77.91

- Dynamic Beach(es):

Start (lat, long)	End (lat, long)	100-year Erosion Rate (m/year) or Stable	Dynamic Beach Name
44.0179, -77.6704	44.0204, -77.663	0.23	Boat Harbour Barrier Beach

- Wave climate ~1 km offshore (output location W11):

ARI (years)	Depth (m)	Hs (m)	DIR (deg)	Tp (s)
5	7.2	2.38	198	10.5
10	7.2	2.41	198	10.5
25	7.2	2.45	198	10.5
50	7.2	2.47	198	10.5
100	7.2	2.48	198	10.5

Infrastructure and Ecosystem Threats

- Evergreen Lake/Shoal Point community is below the 100-year flood hazard limit.

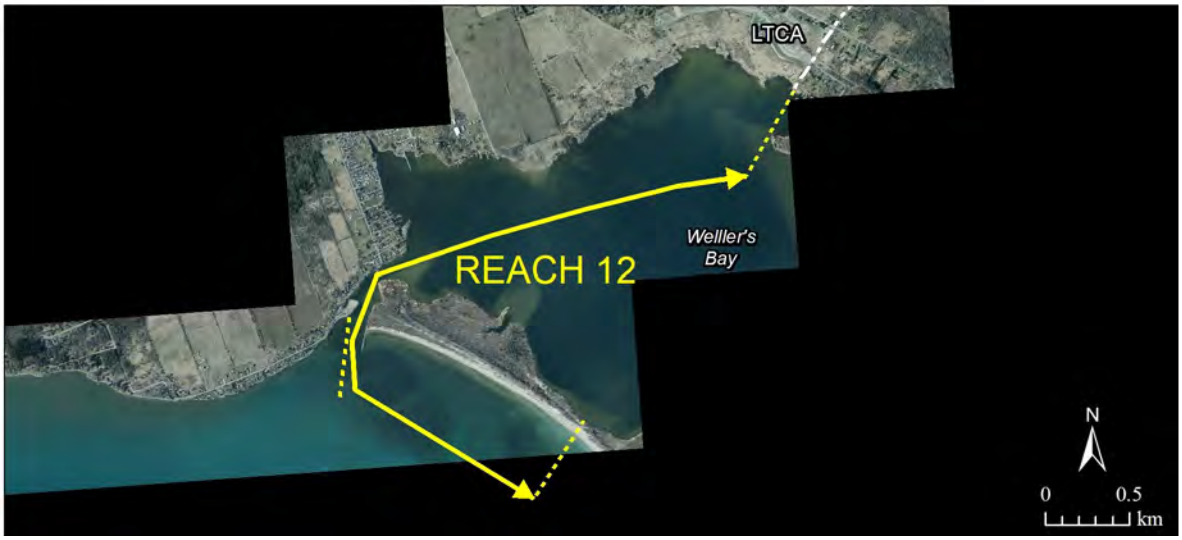
- Clifford Street and Barcovan Beach Road are vulnerable to erosion in locations.
- At entrance to Wellers Bay, Barcovan Beach Road is in the 100-year flood hazard limit.

Shoreline Management Recommendations

- Evergreen Lane/Shoal: existing development requires floodproofing at the community scale, including ensuring safe ingress/egress and functioning private septic systems, or managed re-alignment/retreat for the entire community.
- Monitor and maintain existing shoreline protection structures throughout reach.
- Monitor shoreline erosion at Clifford Street and Barcovan Beach Road where shoreline is in proximity to bluff crest and within the erosion hazard setback.
- Upgrade roads that are below the 100-year flood hazard limit including Barcovan Beach Road at the entrance to Wellers Bay.

Use Disclaimer

Reach 12 – Wellers Bay and Barrier Beach



Local Conditions

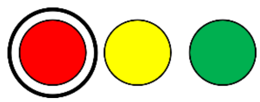
- Reach Length = approximately 3 km.
- Low energy shoreline sheltered from Lake Ontario wave action.
- Mixture of natural shoreline with coastal wetlands and high-density development.
- Single rock jetty protects the navigation channel to the bay. Sediment that accumulates in the channel is dry-docked and disposed upland.
- Wellers Bay and the barrier islands were established as a National Wildlife Area in 1978 for the rare coastal habitats including natural beach, sand dunes, wetlands, and deciduous forest. The habitat is used by migratory waterfowl, nesting shore birds (see adjacent Belted Kingfisher), and several federally listed species at risk.

Armoured Shoreline at Trailer Park

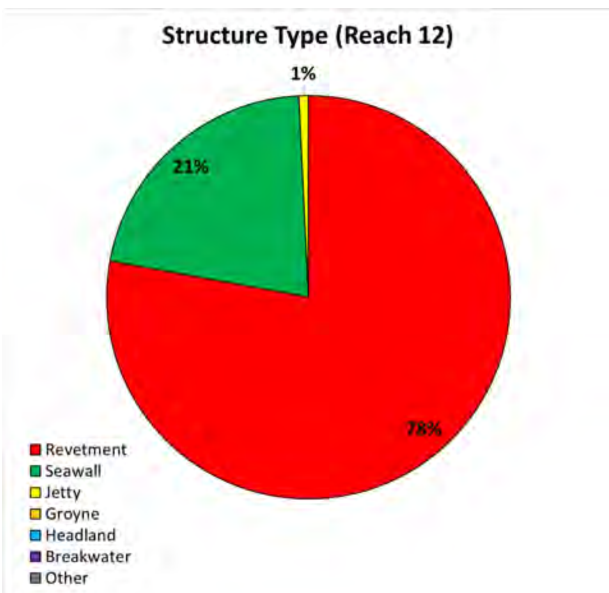
Entrance to Wellers Bay

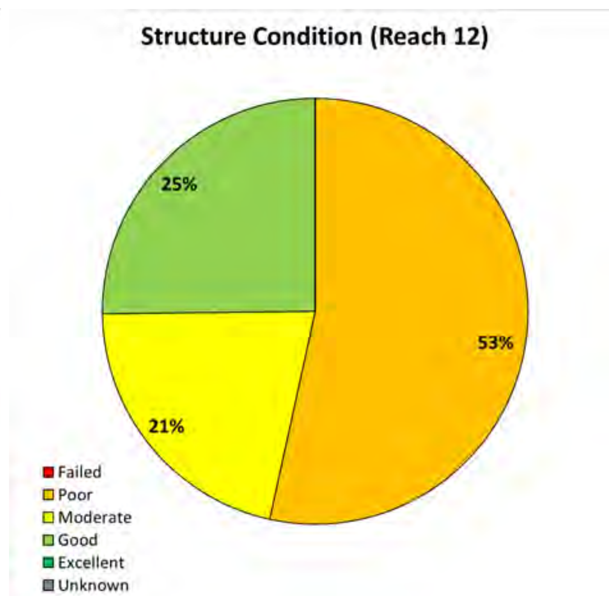
Shoreline Structures

- Reach 12 is 22% armoured, 78% natural.
- Shoreline protection is limited to the north shore of the entrance to Wellers Bay and the east facing shoreline along Carter Road, which is primarily occupied by private cottages and trailer parks.
- Most shoreline armouring is ad-hoc quarried stone or boulder revetments and concrete seawalls. Most structures are in poor to moderate condition; however, this is primarily due to age and not wave or ice related damage. Protection structures are exposed to little wave action.
- The Wellers Bay barrier beach complex is anchored by a 220 m long rock jetty on the east side of the Wellers Bay navigation channel. The jetty is in a state of deterioration and requires upgrades to be effective in mitigating sand and wave transmission into the navigation channel.
- Tolerance for additional shoreline armouring (**low**/medium/high):



- Sample statistics (for armoured portion of shoreline):



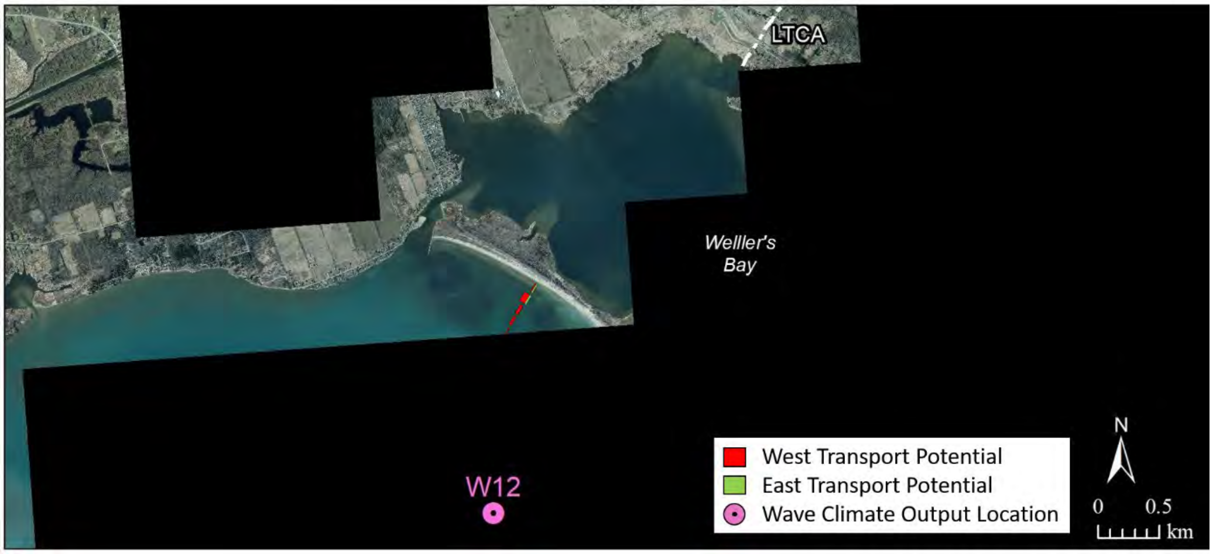


Sediment Supply and Longshore Sediment Transport

- Sediment transport is limited to the exposed portions of Reach 12 such as the Wellers Bay barrier beach complex and navigation channel.
- Sediment is driven into and deposited within the Wellers Bay navigation channel from Barcovan Beach Road to the west (Reach 11).
- The net sediment transport potential along the exposed portions of the Wellers Bay barrier beach complex is from southeast to northwest (towards the Wellers Bay navigation channel). The potential transport rate is on the order of 10,000 m^3/year. This

material moves along the beach face and is deposited against the Wellers Bay navigation channel jetty or transmitted into the navigation channel itself.

- Within Wellers Bay there are no new sources of sand or gravel, and sediment transport is limited to small particles such as silt circulating throughout the bay dependent on currents and waves within the bay.



Summary of Natural Hazards

- 100-year Erosion Rate (Stable Slope not included): n/a
- 100-year flood level and *Flood Hazard Limit* (including wave uprush):

Start (lat, long)	End (lat, long)	100-year Flood Level (m IGLD85')	Flood Hazard (m IGLD85')
44.0242, -77.6290	44.0234, -77.6277	+76.03	+77.17
44.0234, -77.6277	44.0174, -77.6125	+76.03	+77.81
Within Wellers Bay		+76.03	15 m setback (typ.)

- Dynamic Beach(es):

Start (lat, long)	End (lat, long)	100-year Erosion Rate (m/year) or Stable	Dynamic Beach Name
44.0234, -77.6277	44.0175, -77.6124	Stable	Wellers Bay Barrier Beach

- Wave climate ~1 km offshore (output location W12):

ARI (years)	Depth (m)	Hs (m)	DIR (deg)	Tp (s)
5	9.8	2.88	218	10.5
10	9.8	2.93	218	10.5
25	9.8	2.97	218	10.5
50	9.8	2.99	218	10.5
100	9.8	3.01	218	10.5

Infrastructure and Ecosystem Threats

- Shoreline development and dock infrastructure is on low lying land and flood prone.
- Sedimentation in the navigation channel and ongoing maintenance.

Shoreline Management Recommendations

- Additional shoreline armouring impacts are low. However, shore protection does alter the natural shoreline habitat in Wellers Bay.
- Avoid protection of remaining natural shoreline and coastal wetlands areas. Consider greater setbacks for future development, permanent or seasonal, from hazardous lands and wetlands.
- Monitor barrier beach for stability and re-use dredged sediment from navigation channel to re-build barrier beach if required.
- Pursue habitat restoration projects to enhance local wetlands.

Use Disclaimer

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APPENDIX B

HAZARD MAPS – CENTRAL LAKE ONTARIO CONSERVATION AUTHORITY

Sample Map Provided (contact CLOCA for additional maps)

Lake Ontario Shoreline Management Plan Hazard Maps

Central Lake Ontario Conservation Authority (CLOCA)

LEGEND:

Hazard Mapping:

- 100 Year Flood Level
- Erosion Hazard Limit
- Flood Hazard Limit
- Dynamic Beach Hazard Limit

Base Mapping:

- Geographical Names
- Dynamic Beach (Start Pt)
- Dynamic Beach (End Pt)
- Road Network
- Topographic Contours (2 m interval)
- CLOCA Administrative Boundary

INTERPRETATION OF THE HAZARD MAPS:

The hazard maps were prepared to support the Lake Ontario Shoreline Management Plan. The hazard limits are not the official regulatory limits of the Conservation Authority. Please contact the Conservation Authority for additional details on the regulatory limit and implications for new development.

DEFINITIONS:

100 Year Flood Level
The 100 Year Combined Flood Level considers both static lake level and storm surge, having a combined probability of being equalled or exceeded during any year of 1% (i.e., probability, P = 0.01). The 100 Year Combined Flood Level elevation for CLOCA is +76.01 m IGLD85 (+75.55 m CGVD2013).

Flood Hazard Limit
The Flood Hazard Limit is defined as the 100-Year Flood Level plus an allowance for wave runup and uprush. For the exposed shoreline, wave effects are calculated based on localized nearshore conditions and waves. For embayments, the standardized 15 m setback is applied. Refer to the Lake Ontario Shoreline Management Plan for additional details.

Toe of Bluff
The Toe of Bluff is the transition from the gently sloping beach to the steep portion of the bank or bluff slope.

Stable Slope Allowance
The Stable Slope Allowance is defined as a horizontal setback equivalent to 3.0 times the height of the bank or bluff.

Erosion Hazard Limit
The landward extent of the Erosion Hazard is the sum of the 100 year erosion rate plus the Stable Slope Allowance, measured horizontally from the toe of the bank or bluff.

The Erosion Hazard Limit is not mapped in sheltered waters, however, localized shoreline/riverine erosion may occur and is subject to review by the Conservation Authority.

Dynamic Beach Hazard Limit
The Dynamic Beach Hazard Limit is defined as the sum of the Flood Hazard plus 30 metres measured horizontally. Local conditions may require a modified mapping approach if the beach is eroding and/or a barrier beach. Refer to the Lake Ontario Shoreline Management Plan report for additional details.

DATA SOURCES:

2018 Orthophotography provided by © First Base Solutions

2018 Digital Terrain Model provided by © First Base Solutions

2016 LiDAR Digital Terrain Model obtained from the Ministry of Natural Resources and Forestry. Contains information licensed under the Open Government Licence – Ontario.

Geographical Names obtained from Natural Resources Canada Road Network File, 2016 Census. Statistics Canada Catalogue no. 92-500-X

Inset Map: © OpenStreetMap contributors

Datums:
Horizontal: UTM 17N NAD1983, metres.
Vertical: CGVD2013, metres

Datum Conversion:
IGLD1985 - CGVD2013 = 0.46 m (average)
To convert from IGLD85 to CGVD2013, subtract 0.46 m.
Note: There are local variations along the reaches within CLOCA. Refer to the Lake Ontario SMP for additional details.

0 50 100 200 m

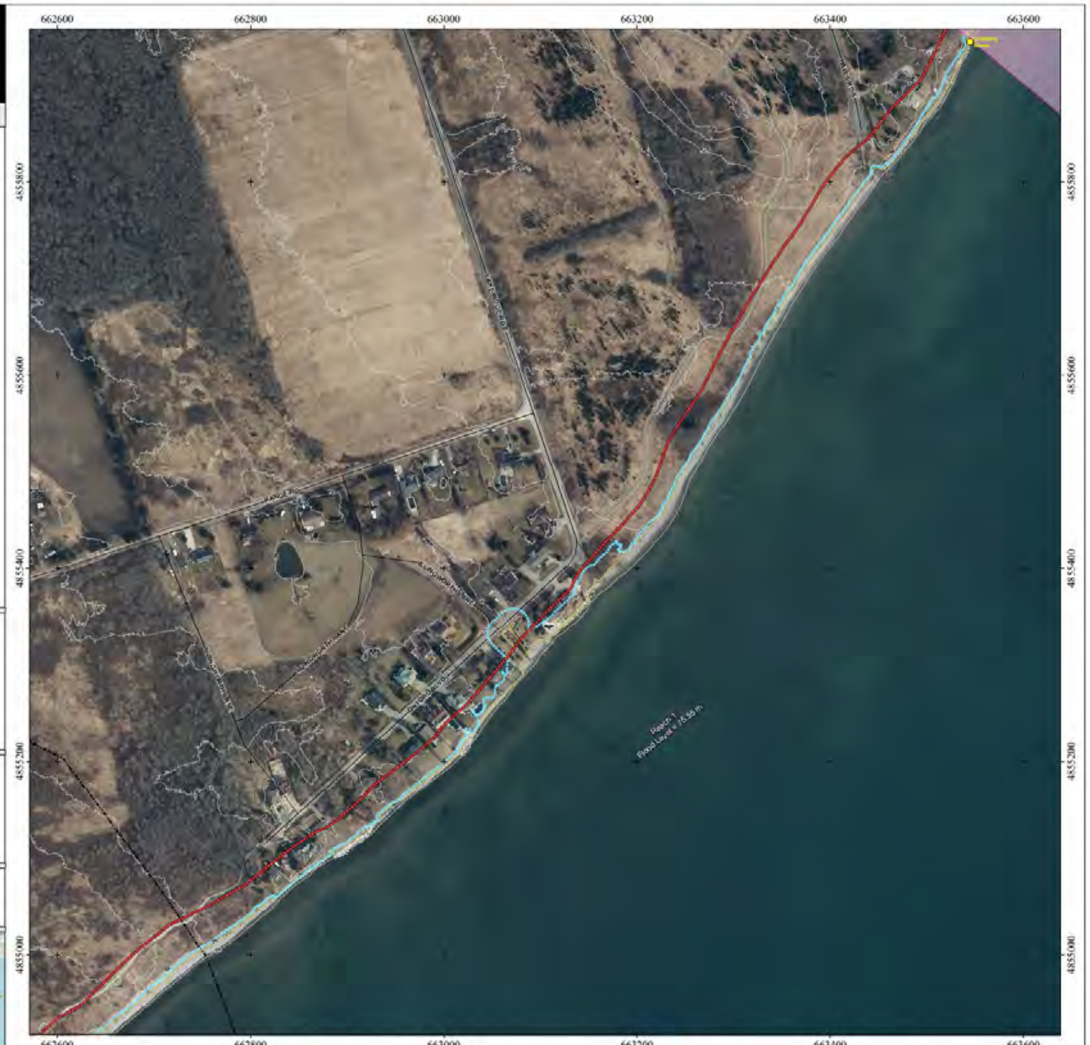
PREPARED BY:

Zuzek inc. — ONE WORLD —

SJL ENGINEERING

This map was published March 2020 for the Central Lake Ontario Conservation Authority (CLOCA). The mapping of hazardous lands, including erosion, flooding, and dynamic beach areas, is subject to change. The proponent of a proposed development on or adjacent to the hazardous lands should contact CLOCA to discuss permit requirements.

Every reasonable effort has been made to ensure the accuracy of this map. However, neither CLOCA, Zuzek Inc., SJL Engineering, or any other affiliated party assume any liability arising from its use. This map is provided without warranty of any kind, either expressed or implied.



Mapping prepared by Zuzek Inc. for the Central Lake Ontario Conservation Authority, with support from Durham Region.

MAP PUBLISHED MARCH 2020

Central Lake Ontario CONSERVATION

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100 Whiting Avenue
Oshawa, Ontario L1H 3T3
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Web: www.cloca.com/

DURHAM REGION

Durham Region
605 Rossland Road East
Whitby, Ontario L1N 6A3
Telephone: 905-668-7711
Toll-Free: 1-800-372-1102
Web: www.durham.ca

CLOCA Map
1 of 37

APPENDIX C

HAZARD MAPS – GANARASKA REGION CONSERVATION AUTHORITY

Sample Map Provided (contact GRCA for additional maps)

Lake Ontario Shoreline Management Plan Hazard Maps

Ganaraska Region Conservation Authority (GRCA)

LEGEND:

Hazard Mapping:

- 100 Year Flood Level
- Flood Hazard Limit
- Erosion Hazard Limit
- Dynamic Beach Setback

Base Mapping:

- Geographical Names
- Dynamic Beach (Start Pt)
- Dynamic Beach (End Pt)
- Road Network
- GRCA Administrative Boundary

INTERPRETATION OF THE HAZARD MAPS:

The hazard maps were prepared to support the Lake Ontario Shoreline Management Plan. Wetland and riverine floodplains are not included on these hazard maps. The Dynamic Beach Setback is the onshore limit of the shaded pink polygon. The offshore limit in the lake highlights the linkages between overall beach stability and health, nearshore sediment resources, and longshore sediment transport. The hazard limit(s) are not the official regulatory limits of the Conservation Authority. Please contact the Conservation Authority for details on the regulatory limit and implications for any proposed work.

DEFINITIONS:

100 Year Flood Level

The 100 Year Combined Flood Level considers both static lake level and storm surge, having a combined probability of being equalled or exceeded during any year of 1% (i.e., probability, P = 0.01). The 100 Year Combined Flood Level elevation for GRCA is +76.01 m IGLD85 (+75.55 m to +75.60 m CGVD2013).

Flood Hazard Limit

The Flood Hazard Limit is defined as the 100-Year Flood Level plus an allowance for wave runup and uprush. For the exposed shoreline, wave effects are calculated based on localized nearshore conditions and waves. For embayments, the standardized 15 m setback is applied. Refer to the Lake Ontario Shoreline Management Plan for additional details.

Toe of Bluff

The Toe of Bluff is the transition from the gently sloping beach to the steep portion of the bank or bluff slope.

Stable Slope Allowance

The Stable Slope Allowance is defined as a horizontal setback equivalent to 3.0 times the height of the bank or bluff.

Erosion Hazard Limit

The landward extent of the Erosion Hazard is the sum of the 100 year erosion rate plus the Stable Slope Allowance, measured horizontally from the toe of the bank or bluff.

The Erosion Hazard Limit is not mapped in sheltered waters, however, localized shoreline/riverine erosion may occur and is subject to review by the Conservation Authority.

Dynamic Beach Hazard Limit

The Dynamic Beach Hazard Limit is defined as the sum of the Flood Hazard plus 30 metres measured horizontally. If the dynamic beach is eroding, an additional erosion allowance is included and a separate Erosion Hazard Limit is not shown. Refer to the Lake Ontario Shoreline Management Plan report for additional details.

DATA SOURCES:

2018 Orthophotography and Digital Surface Model (DSM) provided by the Ministry of Natural Resources and Forestry.

2016-2017 LiDAR Digital Terrain Model obtained from the Ministry of Natural Resources and Forestry. Contains information licensed under the Open Government Licence – Ontario.

Geographical Names obtained from Natural Resources Canada Road Network File, 2016 Census. Statistics Canada Catalogue no. 92-500-X.

Inset Map: © OpenStreetMap contributors

Datums:
Horizontal: UTM 17N NAD1983, metres.
Vertical: CGVD2013, metres

Datum Conversion:
IGLD1985 - CGVD2013 = 0.42 m (average)
To convert from IGLD85 to CGVD2013, subtract 0.42 m.
Note: There are local variations along the reaches within GRCA. Refer to the Lake Ontario SMP for additional details.

0 50 100 200 m

N E S W

PREPARED BY:

Zuzek inc. — ONE WORLD —

SJL ENGINEERING

This map was published March 2020 for the Ganaraska Region Conservation Authority (GRCA). The mapping of hazardous lands, including erosion, flooding, and dynamic beach areas, is subject to change. The proponent of a proposed development on or adjacent to the hazardous lands should contact GRCA to discuss permit requirements.

Every reasonable effort has been made to ensure the accuracy of this map. However, neither GRCA, Zuzek Inc., SJL Engineering, or any other affiliated party assume any liability arising from its use. This map is provided without warranty of any kind, either expressed or implied.

Mapping prepared by Zuzek Inc. for the Ganaraska Region Conservation Authority.

MAP PUBLISHED MARCH 2020

Ganaraska CONSERVATION

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Phone: (905) 885-8173
Web: www.grca.on.ca

GRCA Map
1 of 43

APPENDIX D

HAZARD MAPS – LOWER TRENT REGION CONSERVATION AUTHORITY

Sample Map Provided (contact LTRCA for additional maps)

Lake Ontario Shoreline Management Plan Hazard Maps

Lower Trent Region Conservation Authority (LTRCA)

LEGEND:

Hazard Mapping:

- 100 Year Flood Level
- Flood Hazard Limit
- Erosion Hazard Limit
- Dynamic Beach Setback

Base Mapping:

- Geographical Names
- Dynamic Beach (End Pt)
- Dynamic Beach (Start Pt)
- Road Network
- LTRCA Administrative Boundary

INTERPRETATION OF THE HAZARD MAPS:

The hazard maps were prepared to support the Lake Ontario Shoreline Management Plan. The hazard limits are not the official regulatory limits of the Conservation Authority. Please contact the Conservation Authority for additional details on the regulatory limit and implications for new development.

DEFINITIONS:

100 Year Flood Level
The 100 Year Combined Flood Level considers both static lake level and storm surge, having a combined probability of being equalled or exceeded during any year of 1% (i.e., probability, P =0.01). The 100 Year Combined Flood Level elevation for LTRCA is +76.03 m IGLD85 (+75.62 m CGVD2013).

Flood Hazard Limit
The Flood Hazard Limit is defined as the 100-Year Flood Level plus an allowance for wave runup and uprush. For the exposed shoreline, wave effects are calculated based on localized nearshore conditions and waves. For embayments, the standardized 15 m setback is applied. Refer to the Lake Ontario Shoreline Management Plan for additional details.

Toe of Bluff
The Toe of Bluff is the transition from the gently sloping beach to the steep portion of the bank or bluff slope.

Stable Slope Allowance
The Stable Slope Allowance is defined as a horizontal setback equivalent to 3.0 times the height of the bank or bluff.

Erosion Hazard Limit
The landward extent of the Erosion Hazard is the sum of the 100 year erosion rate plus the Stable Slope Allowance, measured horizontally from the toe of the bank or bluff.

The Erosion Hazard Limit is not mapped in sheltered waters, however, localized shoreline/riverine erosion may occur and is subject to review by the Conservation Authority.

Dynamic Beach Hazard Limit
The Dynamic Beach Hazard Limit is defined as the sum of the Flood Hazard plus 30 metres measured horizontally. Local conditions may require a modified mapping approach if the beach is eroding or a barrier beach. Refer to the Lake Ontario Shoreline Management Plan report for additional details.

DATA SOURCES:

2018 Orthophotography and Digital Surface Model (DSM) provided by the Ministry of Natural Resources and Forestry

2017 LiDAR Digital Terrain Model obtained from the Ministry of Natural Resources and Forestry. Contains information licensed under the Open Government Licence – Ontario.

2009/10 Topographic data near Prince Edward Estates provided by LTRCA.

Geographical Names obtained from Natural Resources Canada Road Network File, 2016 Census. Statistics Canada Catalogue no. 92-500-X

Inset Map: © OpenStreetMap contributors

Datums:
Horizontal: UTM 17N NAD1983, metres.
Vertical: CGVD2013, metres

Datum Conversion:
IGLD1985 - CGVD2013 = 0.41 m (average)
To convert from IGLD85 to CGVD2013, subtract 0.41 m.
Note: There are local variations along the reaches within LTRCA. Refer to the Lake Ontario SMP for additional details.

0 50 100 200 m

N W E S

PREPARED BY:

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SJL ENGINEERING

S. J. LOGAN 100189144 Mar 31, 2020 PROVINCE OF ONTARIO

This map was published in March 2020 for LTRCA. The mapping of hazardous lands, including erosion, flooding, and dynamic beach areas, is subject to change. The proponent of a proposed development on or adjacent to the hazardous lands should contact LTRCA to discuss permit requirements.

Mapping prepared by Zuzek Inc. for the Lower Trent Region Conservation Authority.

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