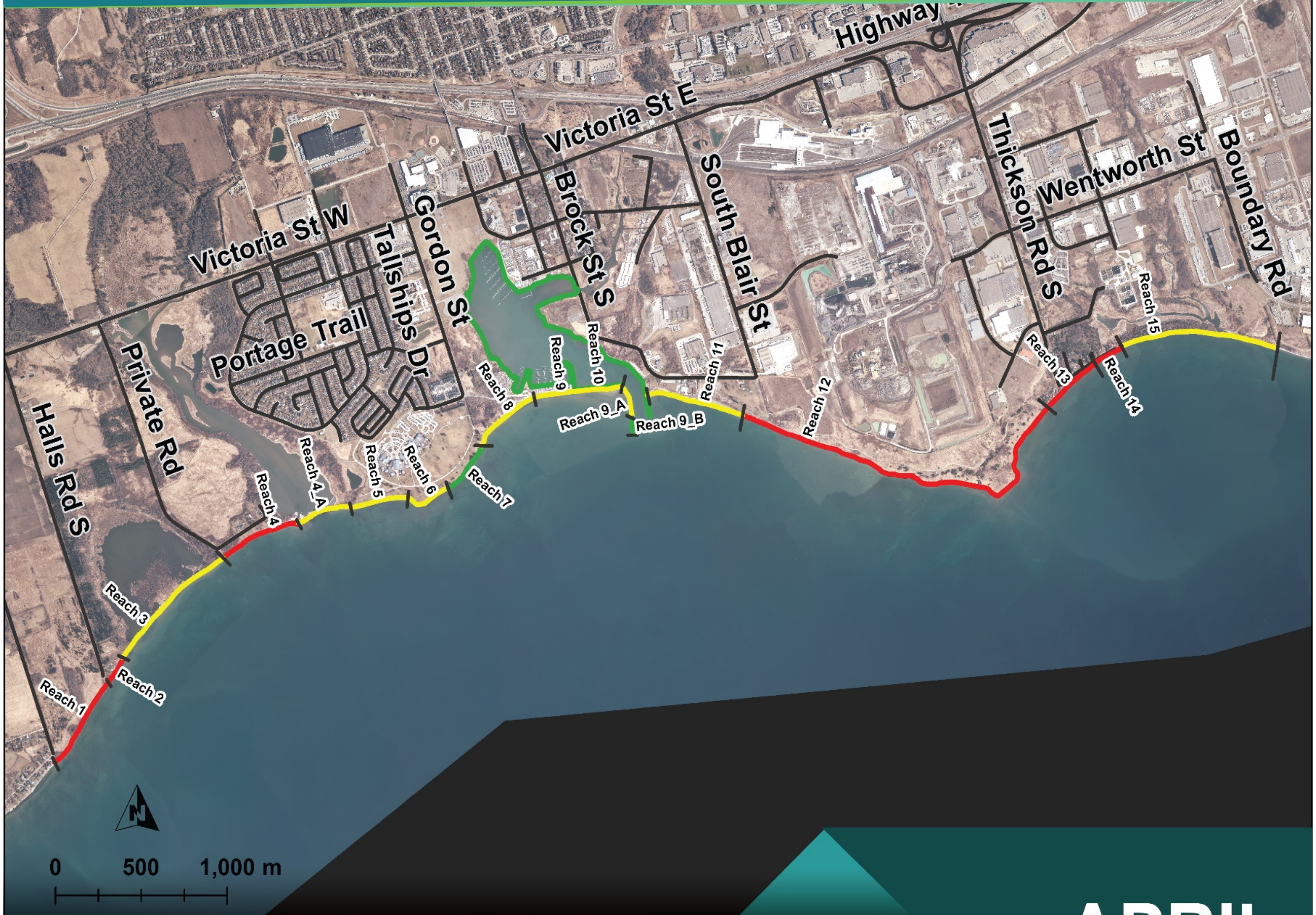

Whitby Coastal Flood Risk Assessment and Municipal Class Environmental Assessment

APRIL 2021

AHYDTECH GEOMORPHIC
ADVANCED HYDROLOGY HYDRAULIC GEOMORPHOLOGY

Central Lake Ontario Conservation

Whitby
Town Of Whitby

AHYDTECH GEOMORPHIC
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Telephone: 519-400-0264 | Fax: 519-341-7109 | Website: www.ahydtech.ca

April 6, 2021

Mr. Antony Manoharan
Town of Whitby
575 Rossland Road East
Whitby, ON L1N 2M8

Perry Sisson, P.Eng.
Central Lake Ontario Conservation Authority
100 Whiting Avenue, Oshawa, ON

Re: Technical Report for Whitby Coastal Flood Hazard Risk Assessment

Dear Mr. Antony Manoharan and Perry Sisson,

I am pleased to submit this technical report of the **Whitby Coastal Flood Hazard Risk Assessment and Municipal Class Environmental Assessment Project.** The bound report includes reduced scale copies of the shoreline hazard mapping. The CD bound within the report includes digital copies of the mapping and final report, 2D coastal engineering models (ADCIRC and STWAVE) and a One-dimensional Coastal model (SBEACH). We have confidently satisfied all the objectives through undertaking very high-quality field investigation, topographic/bathymetry survey, necessary background and technical information collection and review, wind-wave and dynamic beach model development for the assessment of the coastal flood hazard risk including erosion hazard assessment along the Whitby shoreline. AHYDTECH have applied Municipal Class EA processes, and identified and evaluated potential alternative solutions for the mitigation of the flooding and erosion concerns/issues in the study area.

We thank you for the opportunity to have worked on this project and would be pleased to provide our services on any desired follow-up work.

Regards,

Bahar SM
Managing Director, Senior Fluvial Geomorphologist and Coastal Engineer
AHYDTECH Geomorphic Ltd.
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Executive Summary

AHYDTECH Geomorphic Ltd. is retained to provide Environmental Assessment of the Whitby shoreline study area (as shown in figure 1 on Page 2), which has been experiencing localized flooding and erosion. Whitby shoreline is about 12 km long and extends from Lakeridge Road to Boundary Road within the Town limit (Figure 1), and consists of residential homes, boat homes, municipal roads, water sanitary storm sewer infrastructures, personal watercraft, and waterfront trail network, parkland, beach, bluff (high & low) and some sections with coastal wetland.

The water level of Lake Ontario was near the 100-year high water mark in 2017, which resulted in severe erosion along the Whitby shoreline. The residential neighborhood along the Whitby waterfront including, Whitby Harbor, Eastbourne Beach and Crystal Beach are susceptible to similar damages in future and need an informed risk assessment of existing public and private lands and infrastructure to help with mitigation planning and related prioritization. The purpose of this study was to identify anticipated 100-year flood hazards and inundation zones along the Whitby shoreline and to complete Whitby Coastal Flood Hazard Risk mapping for flood mitigation, emergency management and future capital planning of the Town. The study has provided an evaluation of alternative solutions to the flood and erosion issues, as well as finalized the preliminary design for the preferred alternative for mitigation of future damages. Interested parties and the general public were invited to participate and provide comments at different stages of the EA process.

AHYDTECH Geomorphic Ltd. and its project team has completed all required components of the CLASS EA Whitby Coastal Flood Hazard Risk Assessment. By closely adhering to the Municipal Class Environmental Assessment (EA), AHYDTECH has provided high quality professional work in a timely manner following Phases 1 through 2 for Schedule “B” projects from Study Commencement to successful completion of the study report and all required filings and approvals from the Ministry of Environment, Conservation and Park (MOECP).

The project team have collected data and information of the existing environmental conditions, including natural, social, economic and cultural factors and analyzed them. A review and inventory of environmental features were performed to support the evaluation of potential project impacts.

AHYDTECH has created seven preliminary alternative solutions to the issues. They are as follows:

Alternative 1: Do Nothing: Maintain the existing infrastructure, bluff, natural features, shoreline structures and water course outlets. This alternative does not solve the problem.

Alternative 2: Modification & Improvement of the existing municipal infrastructure.
Alternative 3: Modification & Improvement to bluff.
Alternative 4: Repair & Replacement of existing shoreline structures, such as seawall, revetment, sheet pile, groyne & marina structures.
Alternative 5: Installation of new shoreline structures, such as seawall, revetment, sheet pile, groyne & marina structures.
Alternative 6: Modification & Improvement to natural features, such as natural shoreline, wetlands, aquatic habitat and water course/creek outlets.
Alternative 7: Combination of Alternative 2 to 6.

After completing background research, field data collection, and gathering input from stakeholders and the public, and technical analysis, AHYDTECH with assistance from the Town of Whitby and Central Lake Ontario Conservation Authority (CLOCA) has selected the preferred alternative solutions as follows.

The communication and public consultation plan were prepared in accordance with Municipal Class EA Schedule Process to ensure that the public and key stakeholders have the opportunity to become engaged with the project over the course of the EA in a way that is important to them. The comments provided by the public were considered throughout the project. Two Community Open House (COH) were organized on June 4, 2019 and October 30, 2019 as part of the Class EA process to provide project details and obtain feedback from the public and stakeholders. The COHs were advertised in local newspapers and on the Town's website.

AHYDTECH has performed 2D hydrodynamic, Wave Uprush, Dynamic Beach and Shoreline Recession analyses to compute flow fields, near-shore wave parameters (wave height and peak period) and recession rates. According to the 2D analysis for 100-year wind-wave return period condition, the maximum wave (flood) height along the shoreline of the study area is 2.22m. However, the wave uprush method estimated 2.64m of flood height. Since the wave uprush method estimates more conservative flood height than the model simulated flood height, the former method's flood height is applied for selection of the preferred alternatives and assessment of the flooding risk. AHYDTECH has done shoreline recession analysis of the Whitby shoreline. A long-term average recession/erosion rate along the shoreline is about 0.21 m per year. From the recession rates, an erosion hazard limit been suggested for each of the reaches in the study area. Dynamic beach analysis was performed for the reaches (Reach 8 and Reach 11) which exhibits dynamic beach properties. Based on the dynamic beach analysis results, a hazard allowance of 15 to 25 meters from the 100-Year water level shoreline has been recommended. Figure S02 to Figure S04 represent different hazard limit within the study area.

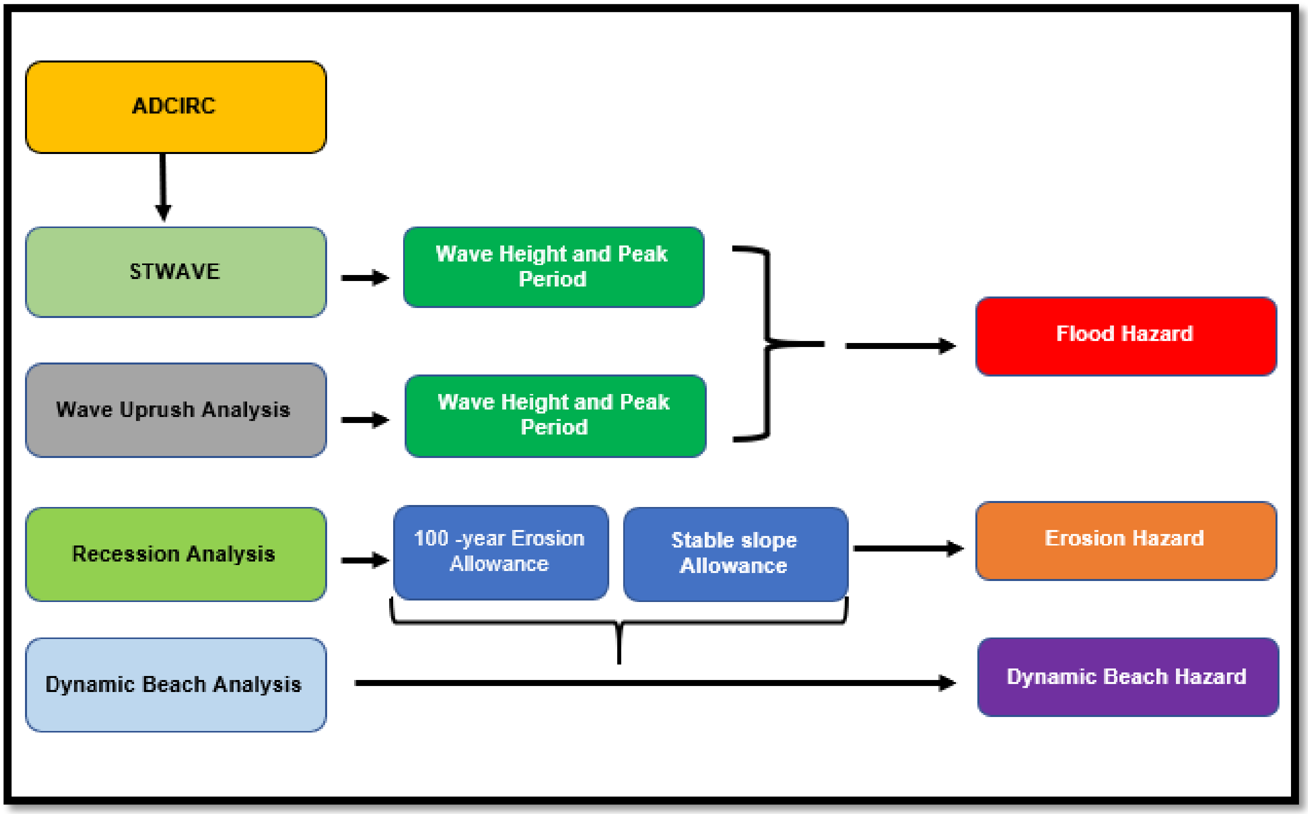

Figure S01: Different analysis flow chart

Upon completion of the "Whitby Coastal Flood Risk Assessment and Municipal Class Environmental Assessment, detailed engineering design of the shoreline structures will be required. Construction and modification of the shoreline structure should be done according to the priority list of the reaches prepared by this study. The priority list has three categories:

A) Immediate actions for Construction and Modification work for Reach 9, Reach 9b, Reach12, Reach13, and in Reach 14,

B) Necessary actions require within 5 years for Reach 02, Reach 9a, Reach 10 and Reach 11, and

C) Construction and Modification work should be done within 10 years for Reach 3, Reach 5, Reach 6, Reach 7 and Reach 15.

These recommendations have been summarized in Table S01. For conducting work along a shoreline and on crownland of Lake Ontario, a work permit will be required from the regulating agencies before working in water and along the shoreline. A work permit ensures that specific construction activities on public lands and shore lands have addressed any concern/issue of the environment including other users and neighboring landowners.

Approvals from the regulating agencies and information required in a work permit application for shoreline erosion protection projects are given below:

1. Permit Application Form of Central Lake Conservation Authority (CLOCA) – O. Reg. 42/06: Central Lake Ontario Conservation Authority: (Regulation of development, interference with wetlands and alterations to shorelines and watercourses)
2. Application for Work Permit Part 1 – MNRF
3. Application to Do Work on Shore Lands Part 3 - MNRF
4. Agent Sign Off Form/Agent Authorization form
5. Proof of Ownership-Copy of deed, Tax Bill or PIN (obtained from Land Registry Office)
6. Municipal Comment Form- application for a work permit under Ontario Regulation 975, Public Lands Act
7. Notice for adjacent property owners- Application for Work Permit under the Public Lands Act- MNRF
8. Fisheries and Oceans Canada (DFO) Review – MNRF requires applicants confirm whether their project requires DFO review
9. A species at risk permit from the MECP may be required.
10. As Reach 9b and 10 are owned by Transport Canada, to do any work at those reaches will require permit from them.
11. Work plan drawing details & requirements

Figure S02: Hazard line for Different Reaches-1

Figure S03: Hazard line for Different Reaches-2

Figure S04: Hazard line for Different Reaches-3

Table S01: Preliminary preferred alternative and initial cost for each reach

Reach Name	Preliminary Preferred alternative	Name of the alternative	Initial cost (millions $)	Prioritization	Schedule Classification
Reach 01	Alternative 6	Modification & Improvement to natural features	1.92	Action required in 10 years	Schedule B
Reach 02	Alternative 4	Repair & Replacement of existing shoreline structures	0.73	Action required in 5 years	Schedule A+
Reach 03	Alternative 1 or Alternative 6	Do Nothing/Modification & Improvement to natural features	2.84	Action required in 10 years	Schedule B
Reach 04	Alternative 1	Do Nothing	0.00	No action required	NA
Reach04_a	Alternative 1	Do Nothing	0.00	No action required	NA
Reach 05	Alternative 4	Repair & Replacement of existing shoreline structures	1.36	Action required in 10 years	Schedule A+
Reach 06	Alternative 6	Modification & Improvement to natural features	0.96	Action required in 10 years	Schedule B
Reach 07	Alternative 4	Repair & Replacement of existing shoreline structures	1.41	Action required in 10 years	Schedule A+
Reach 08	Alternative 1	Do Nothing	0.00	No action required	NA
Reach 09	Alternative 4	Repair & Replacement of existing shoreline structures	2.84	Immediate action required	Schedule A+
Reach09_a	Alternative 1 or Alternative 4	Do Nothing/Repair & Replacement of existing shoreline structures	0.86	Action required in 5 years	Schedule A+
Reach09_b	Alternative 4	Repair & Replacement of existing shoreline structures	0.45	Immediate action required	Schedule A+
Reach 10	Alternative 4	Repair & Replacement of existing shoreline structures	1.38	Action required in 5 years	Schedule A+
Reach 11	Alternative 6	Modification & Improvement to natural features	2.02	Action required in 5 years	Schedule B
Reach 12	Alternative 6	Modification & Improvement to natural features	8.83	Immediate action required	Schedule B
Reach 13	Alternative 5	Installation of new shoreline structures	2.95	Immediate action required	Schedule C
Reach 14	Alternative 4	Repair & Replacement of existing shoreline structures	1.42	Immediate action required	Schedule A+
Reach 15	Alternative 6	Modification & Improvement to natural features	3.24	Action required in 10 years	Schedule C

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Abbreviations

ADCIRC	ADvanced CIRCulation model
ANPM	Advanced Nearshore Profile Model
ACES	Army Corps of Engineers
ACES	Automated Coastal Engineering System
CLOCA	Central Lake Ontario Conservation Authority
COH	Community Open House
DSM	Digital Surface Model
DTM	Digital Terrain Model
DEM	Digital Elevation Model
DSAS	The Digital Shoreline Analysis System
DFO	Department of Fisheries and Ocean
EA	Environmental Assessment
EPR	End Point Rate
GPS	Global Positioning System
GIS	Geographic Information System
IGLD	International Great Lakes Datum
LOSMPU	Lake Ontario Shoreline Management Plan Update
LOISS	Lake Ontario Integrated Shoreline Strategy
MOECP	Ministry of Environment, Conservation and Park
MEA	Municipal Engineers Association
MNRF	Ministry of Natural Resources and Forestry
ON	Ontario
RTK	Real-time kinematic
ROD	Region of Durham
STWAVE	STeady State spectral WAVE
SBEACH	Storm-induced BEAch CHange model
SMS	Surface Water Modeling
TOB	Top of Bank
TIN	Triangular Irrigated Networks
USACE	United States Army Corps of Engineers
WIS	Wave Information Studies
WLR	Weighted Linear Regression

1. Introduction

AHYDTECH Geomorphic Ltd. is retained to provide Environmental Assessment of the Whitby shoreline study area (as shown in figure 1), which has been experiencing localized flooding and erosion. AHYDTECH has undertaken the Environmental Assessment (EA) process outlined by the Municipal Engineers Association (MEA), Municipal Class Environmental Assessment, October 2000 (as amended in 2007 and 2011 and 2015) approved under the Ontario Environmental Assessment Act (1990). This study has investigated the causes of the flooding and erosion, provided an evaluation of alternative solutions to the flooding issue, and finalized the preliminary design for the preferred alternative for flood remediation. AHYDTECH will prepare the preliminary design of the preferred alternative based on the ecological, coastal engineering, hydrologic, hydraulic, and flooding hazard analysis.

1.1 Purpose and Objective

The water level of Lake Ontario was near the 100-year high water mark in 2017, which resulted in severe erosion along the Whitby shoreline. The residential neighborhood along the Whitby waterfront including Whitby Harbor, Eastbourne Beach and Crystal Beach is susceptible to similar damages in future and need an informed risk assessment of existing public and private lands, and infrastructure to help with mitigation planning and related prioritization. The purpose of this study is to identify anticipated 100-year flood hazards, inundation and erosion zones along the Whitby shoreline. This study completes Whitby Coastal Flood and Erosion Hazard Risk mapping, emergency management and future capital planning for the Town. The study provides an evaluation of alternative solutions to the flood and erosion issues, as well as finalize the preliminary design for the preferred alternative for mitigation of potential damages.

1.2 Description of Study Area

Whitby shoreline is about 12 km long and extends from Lakeridge Road to Boundary Road within the Town limit (Figure 1), and consists of residential homes, boat homes, municipal roads, water sanitary storm sewer infrastructures, personal watercraft, and waterfront trail network, parkland, beach, bluff (high & low) and some sections with coastal wetland. In 2017, water levels in Lake Ontario were near the 100-year high water mark and as a result, severe erosion had been observed along Whitby's waterfront for a length of 2 km, especially from Heydenshore Pavilion to Thickson Road including some damages to Whitby Harbor structures.

Figure 1: Study Area

1.3 Problem Statement

North-eastern section of the study area, which is located in the Iroquois shoreline, is marked by bluffs or gravel bars, with boulder pavement and sandy offshore deposits to the immediate south. These bluffs are comprised with predominantly fine-grained (silt and clay) sediments, which make the shoreline relatively weak and susceptible to erosion by wave action. In 2017, due to high water level in Lake Ontario (near 100-year high water mark) Whitby's waterfront for a length of 2 km, especially from Heydenshore Pavilion to Thickson Road, was subjected to severe erosion. The shoreline can be confronting to similar disaster in future. The residential neighborhoods along the Whitby waterfront, having the highest risk are Whitby Harbor, Eastbourne Beach and Crystal Beach. In order to protect the residential areas as well as the municipal roads, waterfront trail network, parkland, beach, bluff (high & low) and other infrastructures, it is necessary to identify 100-year flood hazards and inundation zones.

1.4 EA Master Plan process overview

The planning of major municipal projects or activities in Ontario is subjected to the Environmental Assessment Act, R.S.O. 1990, Chapter E.18. The purpose of the Act is: "the betterment of the people of the whole or any part of Ontario by providing for the protection, conservation and wise management in Ontario of the environment."

Within the definitions of the Act, "environment" includes social, economic, cultural and natural conditions at a site. The Act requires a Municipality to complete an environmental assessment for major municipal projects, describing the existing environment, the rationale for the undertaking, advantages and disadvantages of various alternative solutions, and the results of public consultation for the project.

The Municipal Class Environmental Assessment (MCEA) process was developed by the Municipal Engineers Association (MEA 2000, amended 2015), to streamline the EA process for recurring municipal projects that are similar in nature, usually limited in scale, and with a predictable range of environmental effects that are responsive to mitigating measures. The Municipal Class EA process is outlined in Appendix A.

Projects undertaken by municipalities vary in their potential for environmental impact. As a result, projects are classified according to their potential for adverse environmental effect. The RFP suggested that the proponent should conduct this study following Class EA for Schedule "B" projects from Study Commencement to successful completion of the study report and all required filings and approvals from Ministry of Environment, Conservation and Park (MOECP) approvals. Therefore, AHYDTECH completed Phase 1 and 2 of the MCEA process (See charts in Figure 2) and submitted a Notice of Completion to review agencies and the public).

The study has been undertaken as a Master Plan and AHYDTECH has completed the MCEA process following approach #2. Approach #2 for Master Plan studies are completed where the level of investigation, consultation and documentation are completed at a project-specific level for each of the Schedule B projects identified within it. Those identified Schedule B projects are completing the EA process through the Master Plan study and the final public notice will become the Notice of Completion for those identified Schedule B projects.

AHYDTECH Geomorphic and its project team followed the Municipal Engineers Association (MEA) Class EA – October 2000 (as amended 2007 and 2011 and 2015) process. The Class EA document has identified five phases (See Class EA process charts in **Figure 2**):

Phase 1 – Identify the Problem or Opportunity

Stage 1: The problem or opportunity identification and description

Stage 2: A Notice of Commencement for the entire study area & Public consultation

Phase 2 – Alternative Solutions

Stage 1: Inventory and description of the natural, social, economic and cultural environments in the study area

Stage 2: Identification of alternative solutions to the problem, their impact on the environment and mitigation measures

Stage 3: Evaluation of the alternative solutions relative to the environmental feature identified in Stage 2. Consultation with the public and review agencies.

Phase 3 – Alternative Design Concepts for a Preferred Solution

Stage 1: Preliminary identification of a preferred solution

Stage 2: Consultation with the public and review agencies

Stage 3: Confirmation of the preferred solution

Phase 4 – Environmental Study Report

Phase 5 – Implementation

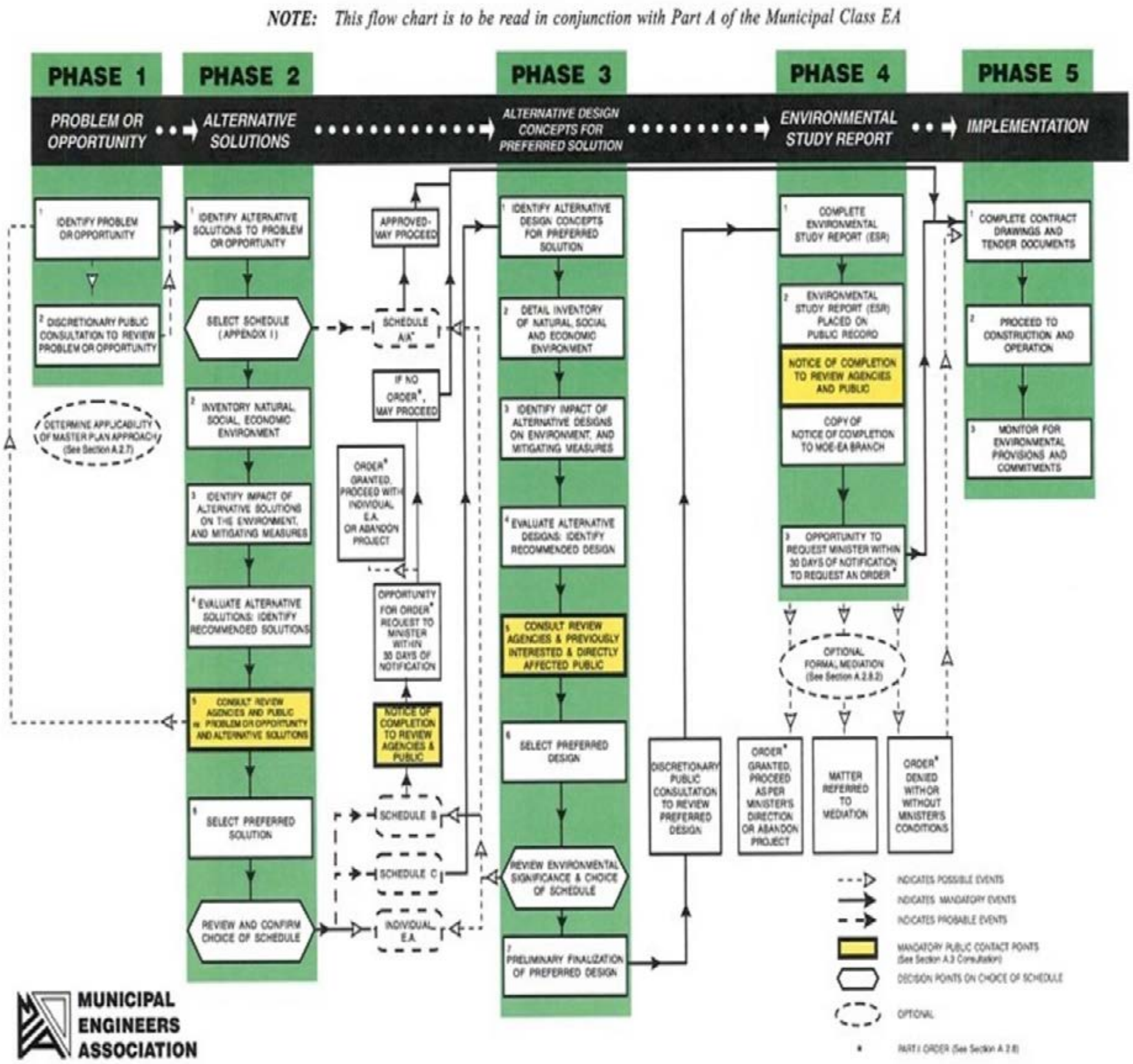


Figure 2 Class EA Process chart

1.5 Consultation

Public Consultation:

To complete the works related to the Coastal Flood Hazard Risk Assessment and Class EA study, AHYDTECH sought acknowledgment and permission letters form the concerned residents to enter upon their property. These acknowledgement forms were received between March 06, 2019 and April 13, 2019 (Appendix B_1). A complete agency stakeholder list has been provided in Appendix B_1. AHYDTECH sent notifications of Community Open Houses to them and gathered comments. Comments from the stakeholders were taken into consideration while developing the possible alternative options.

The notice of commencement and other public notices were published in a local newspaper as well as at the Whitby website. Communications with the stakeholders regarding these notices have been added in Appendix B_1. The Town also sent these notices to public by mail.

Notice of Study Commencement – The notice was published in a local newspaper and at the Whitby website.

Notice of Community Open House 1 (C.O.H. 1) –This Notice was first issued on May 23, 2019. C.O.H 1 was held on June 4, 2019 at the Port Whitby Marina 301 Watson Street West, Whitby and presented existing and future conditions, the Problem and Opportunity statement. The notice of Community Open House (COH) 1 and its display boards has been attached to the Appendix B_1.

Overview of Community Open House No. 1

The COH was conducted in an open house (drop-in) format with display material available for review. The COH was conducted to update and present the existing conditions of the study area. The presentation highlights the areas at erosion risk, and the findings of the structural assessment. Interested members of public, residents within the study area, agencies, indigenous communities, stakeholders, as listed on the contact list were invited by mail, and email.

There were 42 attendees that signed in at the COH No.1 in addition to the study team members. Participants were primarily residents in the study area. There were also representatives from CLOCA, The Town of Whitby, AHYDTECH and the Stakeholders. Participants were invited to speak individually one on one with study team members and view the information display boards. **Ten (10)** comment sheets were submitted to the study team (see. **Eight (8)** of the **ten (10)** respondents that submitted the comment forms indicated they found the information provided was helpful and informative. The other **two (2)** respondents did not provide a response.

Notice of Community Open house 2 (COH 2) – This Notice was first issued on October 17, 2019. C.O.H 2 was held on October 30, 2019 at the Port Whitby Marina 301 Watson Street West, Whitby and presented existing and future conditions, the Problem and Opportunity statement the identification and evaluation of alternative corridors, including the recommendation of a preliminary preferred corridor. The notice of community open House 2 and the COH 2 display boards has been attached to the Appendix B_1.

Overview of Community Open House No. 2

The COH was conducted in an open house (drop-in) format with display material available for review. The information presented at the COH includes results of Coastal Analysis, Wave Uprush and Flood Frequency analysis, Shoreline Recession and Erosion Hazard analysis Dynamic Beach Analysis and the Class EA study. AHYDTECH presented the preliminary preferred alternatives for each reach. Interested members of public, residents within the study area, agencies, indigenous communities, stakeholders, as listed on the contact list were invited by mail, or email. There were 26 attendees that signed in at the COH No.2 in addition to the study team members. Participants were primarily residents in the study area. There were also representatives from CLOCA, The Town of Whitby, AHYDTECH and the stakeholders. Participants were invited to speak individually one on one with study team members and view the display boards. **Six (6)** comment sheets were submitted to the study team.

On May 3, 2020, all the stakeholders (a complete list has been provided in Appendix B_1) were provided a draft report for review. Additionally, in August 2020, Town has contacted the private property owners along Whitby shoreline to provide an update on the study. Town explained the purpose and recommendation of the study to mitigate the shoreline erosion including the Town's policy on private lands. Town also provided a digital copy of the study report for their use. A list of contacted properties, the comment sheets as well as the proponent's responses to comments received from the community open houses can be found in Appendix B_1.

Technical Committee Meetings

Two technical committee meetings were held on July 18th and September 13th in 2019. The Technical Committee for the project is comprised of the Town of Whitby, Central Lake Ontario Conservation Authority (CLOCA) and AHYDTECH Geomorphic Ltd. Documentation related to these meetings are provided in Appendix B_4. Other than these, Project update meetings were held at regular intervals throughout the study to present the project updates and direct feedback were sought. Suggestions from those meetings are incorporated in this report as well.

Indigenous Community Consultation

AHYDTECH notified the concerned indigenous communities about their activities on regular basis. These notifications were given via email and a few responses were also received. Appendix B_3 compiles the consultation history with the indigenous communities. Email addresses of every first nation representatives were kept in the mailing list. In the email of March 24, 2020, a confirmation that aboriginal groups were made aware of the project that might affect them was sought. Two emails were received in response (attached in Appendix B_3). On May 3, 2020, all the stakeholders, including the indigenous communities were asked to provide comment on the draft report. No response was received from the indigenous communities. All the reports and relevant notices were either directly attached in these emails or sent by wetransfer (file sharing site) links attached in these emails.

Agency Consultation

Agencies, such as the Town of Whitby, CLOCA, MECP, MHSTCI, DFO and Aqua Solutions (Peer review) Inc. were asked to review the draft report at different stages of the project and correspondence with these groups have been provided in Appendix B_2. They were contacted after identifying recommended alternative solution in Phase 2 of the EA process. Their valuable comments were considered while selecting the preferred alternative.

Appendix B_2 is sub divided into six different sections each consisting of consultation with different review agencies (Town of Whitby, CLOCA, Aqua Solutions Inc. (Peer Review), MHSTCI, MECP and DFO). All the correspondences are arranged chronologically. These correspondences include technical meeting feedbacks, comments on the draft reports, comments from the regular project update meetings etc.

1.6 Project Team

The Project Team assembled for this study is as follow.

Town of Whitby	
Antony Manoharan, P.Eng. Water Resources Engineer, Project Manager	575 Rossland Road East Whitby, ON L1N 2M8 905.430.4325 x4925 manoharana@whitby.ca
Gautom Singh Team Member	singhg@whitby.ca
Priyan Tharumaratinam Team Member	tharumaratinamp@whitby.ca
Central Lake Ontario Conservation Authority (CLOCA)	
Perry Sisson, P.Eng. Team Member	100 Whiting Avenue Oshawa, Ontario L1H 3T3 Telephone: 905.579.0411x118 Email: psisson@cloca.com
Aqua Solution 5 Inc.	
Judy Sullivan P.Eng Peer Reviewer	15 Woodglen way Markham ON, L3R 3A8 Telephone & Facsimile: 905-604-1295 email: aquasolutions5@rogers.com · www.mjsullivan.ca
AHYDTECH Geomorphic Ltd.	
Dr. Bahar SM, P.Eng., P.Geo. (Ltd), APEGA Consultant Team Lead	22 Zecca Dr. Guelph ON, N1L 1T1 Telephone: 519.400.0264 Email: bahar@ahydtech.ca
Glen Switzer P.Eng Team Member	switzgt@gmail.com

2. Background & Project Requirements

The Town of Whitby, having an area of 147.3 sq. km is situated in the north shore of Lake Ontario. The water level of Lake Ontario was near the 100-year high water mark in 2017, which resulted in severe erosion along the Whitby shoreline. This particular incident initiated for the greater understanding of flood risk, flood hazard and inundation zones, which will assist in flood mitigation, emergency management and future capital planning of the Town. For this purpose, the Town of Whitby was seeking engineering services to complete a Flood Hazard Risk Assessment along the Whitby shoreline. The engineering study followed Phase 1 and 2 of the Municipal Class Environmental Assessment (EA) using Schedule "B" starting from Study Commencement to successful completion of the study report including filings and approvals from the Ministry of Environment, Conservation and Park (MOECP).

2.1 Review of Background Studies

The study area includes roughly 12km of the shoreline of Lake Ontario, which is located between Lakeridge Road and Boundary Road within the Town of Whitby's limits. In order to assess the immediate impacts of the 2017 damages, Town of Whitby retained consultants to perform a Slope Stability analysis and a Bluff Recession Monitoring study.

Lake Ontario Shoreline Management Plan (Sandwell Swan Wooster Inc., 1990) (source: Town of Whitby)

The 1990 study was created to develop a shoreline management plan to be used by the Conservation Authorities. It established a program to prevent flooding and erosion damage, evaluate hazard areas, assess potential damage centers, and provide background information in developing waterfront plans, and erosion management strategies. It reviewed the coastal processes such as water levels, wave climate, sediment transport rates, and shoreline classifications. Beaches Erode and Accrete (Reverse erosion/ deposition) Advanced Nearshore Profile Model (ANPM) which was also used to calculate run up levels (Hawkes method) wave set up at 17 offshore profiles.

By assessing wave climate, the report found substantial fetch lengths from the east through the southwest. Further information was found using wind wave hindcast of Lake Ontario.

Sediment budget analysis involves calculation of sediment removal rate from different types of sources. For example, bluff erosion in the study area shoreline was found to contribute approx. 71,000m^3 of sediment into Lake Ontario per year (erosion monitoring station). The report presents a breakdown of sediment volume input per year from the sources, for each Littoral Cell.

The report highlighted the following areas:

- Thickson's Point acts as partial Littoral Bar, east of point is starved of sediment;
- Lynde Shores -sensitive wetland and wooded area, warm water stream, Migratory bird stop-over, uncommon birds/amphibians/reptiles. only black willow stands in CLOCA, rainbow trout spawning entrance;
- Areas of Whitby Harbor- Pringle Creek, warm water stream fishery, moderate sensitivity, wetlands. Harbor shelters some birds, not significant wildlife area.

Rubble mound structures are recommended instead of Vertical walls. As Vertical walls reflect wave energy rather than absorbing it, this results in wave scour at the toe of the structure. For Medium (3-10m high) bluffs top-down construction may not be an option. In such cases, a haul road to the base of the bluff is necessary. Armor berm protection is also needed for both alternatives. Other recommendations from the study are:

a) Slope mechanically graded to long term stable slope, the graded material is placed between the toe and the bluff and the rock berm.
b) Preservation of top of the bluff, if clean fill can be obtained at little or no cost. High Bluffs (greater than 10m) are susceptible to sloughing, upper face failures, and deep-seated rotational failure. Finer material is carried away from the toe by wave action. Surface drainage is mainly from natural surface features, like gullies and ravines; these are often subject to heavy erosion in large rainfall or snowmelt events. Bluff stabilization would also require gully stabilization works. Armored berm is designed away from toe like the medium bluff, leaving the bluff to natural grading is recommended to get back to a stable slope (1:1.5). With toe erosion halted and drainage installed, the rotational failure risk might be greatly reduced. Drainage textiles on the face of the bluff and swales draining behind the bluff are necessary.

Slope Stability Analysis and Setback Study (2018, GeoPro) (source: Town of Whitby)

GeoPro assessed slope stability from Gordon Richards Park to Ronal C. Deeth Park. Bore holes in-situ tests, and laboratory tests of soil samples provided the geotechnical data. The report outlines the strata and deposition types found in the bore hole investigation. It was noted that, for the "Great Lakes- St. Lawrence River System and large inland lakes: Technical guide for Flooding, Erosion and Dynamic Beaches in Support of Natural Hazards Policies 3.1 of the Provincial Policy statement", a design erosion setback allowance of 30m would be required for the exposed soils which are present at the toe of the slope. GeoPro also noted that erosion setback was beyond the scope of the Geotechnical Investigation.

Bluff Recession Monitoring (2018, Geo Morphix) (source: Town of Whitby)

The report discussed the physiographic features of the bluffs and shoreline. Geo Morphix conducted a drone-based survey to create a DSM model for the shoreline. The study area for baseline monitoring was 2km of bluffs adjacent to the waterfront trail from Kiwanis Heydenshore Park to Thickson Road. The report reviewed the erosion processes of the shoreline, and then created a historical assessment using aerial imaging data from 1954 to 2017. No erosion rate was found due to lack of accurate georeferencing of the aerial image. The shoreline was characterized with respect to the bluffs and beaches, and fluvial processes near the shoreline. Predominant wind direction was classified and broken down by season. The drone collected ortho-photos, which were combined and used to create a Digital Surface model. The model was corrected using control points and manual survey cross-sections (RTK/GPS). High and low water survey was conducted.

Lake Ontario Shoreline Management Plan (LOSMP) (2019-2020), (Zurek Inc)

The LOSMPU study recalculated the 100-year Static Lake Level, the Lake Ontario Storm Surge, and resulting combined 100-year Flood level taking into consideration of the 2017 and 2019 record high water levels. Within the CLOCA boundary, an updated (2019) 100-year Combined Flood Level now is 76.01m (IGLD85'). Reach 1 and 2 from the LOSMPU study are within the Whitby shoreline, and the study has recalculated and presented new recession rates for the reaches. The LOSMPU study looked at 64 years of data (1954-2018) for both the Average Annual Recession Rates, taken from; a) the top of the bluff (TOB) transects (0.15m/year) and b) the Shoreline Change Rates (SCR)(0.23m/year), which were taken from waterline transects. LOSMPU study also determined the revised Flooding and Dynamic Beach hazards using new 100-year water level information.

2.2 Project Requirements

The Whitby shoreline of this project is entirely under the jurisdiction of Central Lake Ontario Conservation Authority (CLOCA). AHYDTECH study proposes an entire plan for the shoreline, which will mitigate flood risks of existing public and private lands, and infrastructures along the Town's waterfront. The expected outcomes of the study will be:

1. Coastal flood hazard inundation limits and flood depths will be quantitatively determined. Background topographic information will be utilized to prepare inundation mapping and risk zones (i.e. 10-year, 25-year, and 100-year).
2. Planning of Inform Emergency Management and supporting future flood mitigation planning.
3. A greater understanding (Risk Assessment) of existing coastal flood hazards at risk property along Town's waterfront has to be established.
4. Identification of existing flood vulnerable public/private infrastructure/property and evaluation of associated risk.
5. Future mitigation projects will be planned to reduce flood risk and/or increase awareness to Canadians.
6. Understanding of existing flood hazards and flood vulnerable infrastructure will be increased in order to minimize financial liabilities through future mitigation planning initiatives.

The study has reviewed the 1990 reach delineations and updated the reaches within the project area. Furthermore, AHYDTECH has undertaken analysis of erosion hazard, evaluation of shoreline structures and estimation of recession rate, updating dynamic beach hazard and determination of slope stability. The requirements also included development of hardening thresholds for nodal areas, recommendation of type of protection for each reach, lake level and wave height warning criteria for emergency response and a complete cost benefit analysis for development of preferred alternatives. All these tasks were performed considering possible environmental and climate change impacts.

3. Collection & Review of Background Data

AHYDTECH has collected relevant data and information related to this project from all available sources, such as Ministry of Environment, Conservation, and Parks (MOECP), Department of Fisheries and Ocean (DFO), Ministry of Natural Resources and Forestry (MNRF), Central Lake Ontario Conservation Authority (CLOCA), Region of Durham (ROD), CN Rail, GO Transit/ Metrolinx, Town of Whitby and any other appropriate sources. AHYDTECH has reviewed all relevant background information, data, documents, maps, existing GIS database and conducted specific desktop studies in their particular areas of expertise. This information was used throughout the Field Assessment to confirm data and to assist in providing information where applicable. The project has reviewed and processed the data and information where available on the following topics:

- Historical Shoreline and shoreline management plan
- Background topographic information
- Background studies and Town's recent study report
- Geographic Information Systems (GIS) data layers and associated database information;
- Wind Climate
- Hindcast Wind-Wave
- Bathymetry
- Photo inventory
- Review of the 1990 reach delineations
- Existing municipal and private infrastructure
- Lake Ontario Water Level
- Lake Ontario Current
- Natural Heritage, Aquatic and Terrestrial Information

LiDAR Data Processing and Creation of Base Map

At the beginning of the project, AHYDTECH was provided with LiDAR topographic information. AHYDTECH has checked and reviewed the provided LiDAR Digital

Elevation/Surface Model (DEM/DSM) and ascertained if any modification or improvement was necessary. Using the processed LiDAR data, base maps were generated. Secondly, a TIN (Triangular Irrigated Networks) surface was generated for the study area.

4. Existing Environment

After performing the collection and review of existing background data, the next key aspect of the study was the field Investigation and site inspection. Mapping information were prepared by AHYDTECH to bring into the field. AHYDTECH has carried out the field investigations by focusing on the coastal conditions, shoreline structures, natural heritage, aquatic and terrestrial environmental components. The following aspects of the field investigations were carried out in order to ultimately conduct the flood hazard risk and erosion hazard assessment. The conditions that were investigated are: evidence of erosion, undercutting, scour, sedimentation, stability of slopes and protection works, conditions of the shore protection work materials, changes in the shoreline characteristics, temporary fence erected on high bluff, existing municipal and private infrastructure, natural heritage features, aquatic and terrestrial vegetation, and habitat features. The field assessment also considered the need for construction and/or rehabilitation/restoration opportunities throughout the site inspection.

AHYDTECH members have conducted fieldwork on April 4, April 10, April 11, April 17, June 3 and June 17, 2019 to document a complete inventory for all the project sites including shoreline characteristics, structure description and type, and georeferenced locations. The fieldwork was divided into two categories. Moreover, AHYDTECH has identified the impacted bluffs and Whitby harbor locations by consulting with staff from Public Works and Whitby Marina for detailed review.

The first category was a shoreline assessment from the water. The nearshore and offshore assessments were carried out using an aluminum boat and camera to collect photographs from offshore. All of the sites were photographed using a digital camera. The boat was capable of traveling in shallow water and pulling up anywhere along the shoreline. This enabled the team flexibility of access to the shoreline at various locations and the ability to investigate areas of interest or concern.

AHYDTECH has documented onshore and nearshore conditions of each of the project sites through photographs, physical surveys, mapping of the shoreline, structures and other site feature locations. AHYDTECH used RTK unit to collect geo-referenced data for shoreline structures and to make spot measurements of dimension of structures, banks, and depth of scour or erosion at toe of banks and structures where possible.

The second category of the field investigation consisted of a land-based collection of information, data and assessment. All the shoreline sites were walked by coastal engineer with assistance from the other team members as required. The land-based field survey included shoreline characteristics, structure description, structure type (revetment, seawall, armor stone blocks etc.), photographs, notes, and topographic surveying which were used to create spatial information in ArcGIS and AutoCAD for design and analysis purposes. Assessment of toe of the shoreline structures were reviewed at the site, to determine if scouring and undercutting of the structure is of concern.

4.1 Planning Environment - Land Use Planning Objectives

AHYDTECH has identified and quoted the policy guideline relevant to the study and its recommendation in the table below. AHYDTECH has provided references from the following guidelines:

- Provincial Policy Statement (2020)
- Greenbelt Plan (2017)
- Growth Plan for the Greater Golden Horseshoe (2020)

The various evaluation criterions which include compilations with regulations, official policies, secondary policies and bylaw requirements have been summarized in Table 1 of Appendix A after reviewing the policy guidelines.

Table 1: Relevant Policy Guidelines

Area	Provincial Policy Statement (2020)	Greenbelt Plan (2017)	Growth Plan (2020)
Public Spaces, Recreation, Parks, Trails and Open Spaces	A. Planning public streets, spaces and facilities to be safe, meet the needs of pedestrians, foster social interaction and facilitate *active transportation* and community connectivity. B. Providing opportunities for public access to shorelines; and C. Recognizing provincial parks, conservation reserves, and other protected areas, and minimizing negative impacts on these areas	A. Include the following considerations in municipal parks plans and open space strategies: 1. Restricting trail uses that are inappropriate to the reasonable capacity of the site (notwithstanding the ability to continue existing trails/uses); 2. Ensuring the protection of the key natural heritage features and key hydrologic features and functions of the landscape	A. non-governmental organizations, and other interested parties are encouraged to develop a system of publicly accessible parkland, open space, and trails, including in shoreline areas, within the GGH that: 1. clearly demarcates where public access is and is not permitted. 2. is based on a coordinated approach to trail planning and development; and 3. is based on good land stewardship practices for public and private lands B. Municipalities are encouraged to establish an open space system within settlement areas, which may include opportunities for urban agriculture, rooftop gardens, communal courtyards, and public parks.
Natural Heritage	A. Natural features and areas shall be protected for the long term. B. The diversity and connectivity of natural features in an area, and the long-term ecological function and biodiversity of natural heritage systems, should be maintained, restored or, where possible, improved, recognizing linkages between and among	A. Development or site alteration is not permitted in key hydrologic features and key natural heritage features within the Natural Heritage System, including any associated vegetation protection zone, with the exception of: 1. Forest, fish and wildlife management; 2. Conservation and flood or erosion control projects, but only if they have	A. Within the Natural Heritage System, a new development or site alteration will demonstrate that: 1. there are no negative impacts on key natural heritage features or key hydrologic features or their functions; 2. connectivity along the system and between key natural heritage features and key

	natural heritage features and areas, surface water features and groundwater features. C. Natural heritage systems *shall be identified in Ecoregions 6E & 7E*[1], *recognizing that* natural heritage systems *will vary in size and form in* settlement areas, rural areas, *and* prime agricultural areas D. Development and site alteration shall not be permitted in: 1. significant wetlands in Ecoregions 5E, 6E and 7E[1]; and 2. significant coastal wetlands E. Development and site alteration shall not be permitted in: 1. significant wetlands in the Canadian Shield north of Ecoregions 5E, 6E and 7E[1]; 2. significant woodlands in Ecoregions 6E and 7E (excluding islands in Lake Huron and the St. Marys River)[1]; 3. significant valley lands in Ecoregions 6E and 7E (excluding islands in Lake Huron and the St. Marys River)[1] 4. significant wildlife habitat; 5. significant areas of natural and scientific interest; and 6. coastal wetlands in Ecoregions 5E, 6E and 7E[1] that are not subject to policy 2.1.4 (b): F. Development and site alteration shall not be permitted in fish habitat except in accordance with	been demonstrated to be necessary in the public interest and after all alternatives have been considered; or 3. Infrastructure, aggregate, recreational, shoreline and existing uses, as described by and subject to the policies of Section 4 of the document (General Policies for the Protected Countryside) B. In the case of wetlands, seepage areas and springs, fish habitat, permanent and intermittent streams, lakes and significant woodlands, the minimum vegetation protection zone shall be a minimum of 30 meters measured from the outside boundary of the key natural heritage feature or key hydrologic feature. C. A proposal for new development or site alteration within 120 meters of a key natural heritage feature within the Natural Heritage System or a key hydrologic feature anywhere within the Protected Countryside requires a natural heritage evaluation or a hydrological evaluation which identifies a vegetation protection zone which: 1. Is of sufficient width to protect the key natural heritage feature or key hydrologic feature and its functions from the impacts of the proposed change and associated activities that may occur before, during and after construction and, where possible, restore or enhance the feature and/or its function; and 2. Is established to achieve and be maintained as natural self-sustaining vegetation.	hydrologic features located within 240 meters of each other will be maintained or, where possible, enhanced for the movement of native plants and animals across the landscape. 3. the removal of other natural features not identified as key natural heritage features and key hydrologic features is avoided, where possible. Such features should be incorporated into the planning and design of the proposed use wherever possible. 4. except for uses described in and governed by the policies in subsection 4.2.8, the disturbed area, including any buildings and structures, will not exceed 25 per cent of the total developable area, and the impervious surface will not exceed 10 per cent of the total developable area; 5. at least 30 per cent of the total developable area will remain or be returned to natural self-sustaining vegetation, except where specified in accordance with the policies in subsection 4.2.8; and B. The natural heritage systems identified in official plans that are approved and in effect as of July 1, 2017 will continue to be protected in accordance with the relevant official plan until the Natural Heritage System has been issued.

	provincial and federal requirements. G. Development and site alteration shall not be permitted in habitat of endangered species and threatened species, except in accordance with provincial and federal requirements. H. Development and site alteration shall not be permitted on adjacent lands to the natural heritage features and areas identified in policies 2.1.4, 2.1.5, and 2.1.6 unless the ecological function of the adjacent lands has been evaluated and it has been demonstrated that there will be no negative impacts on the natural features or on their ecological functions [1]Ecoregions 5E, 6E and 7E are shown on Figure 1 of Provincial Policy Statement	D. A proposal for new *development* or *site alteration* within the Natural Heritage System is not subject to section 3.2.5.5 where the only *key natural heritage feature* is the *habitat of endangered species and threatened species*	C. Beyond the Natural Heritage System, including within settlement areas, the municipality: 1. will continue to protect any other natural heritage features in a manner that is consistent with the PPS; and 2. may continue to protect any other natural heritage system or identify new systems in a manner that is consistent with the PPS
Cultural Heritage and Archaeology	A. Significant built heritage resources and significant cultural heritage landscapes shall be conserved. B. Development and site alteration shall not be permitted on lands containing archaeological resources or areas of archaeological potential unless significant archaeological resources have been conserved. *C.* Planning authorities shall not permit *development* and *site alteration* on *adjacent lands* to *protected heritage property* except where the proposed	A. Cultural heritage resources shall be conserved in order to foster a sense of place and benefit communities B. Municipalities shall work with stakeholders, as well as First Nations and Métis communities, in developing and implementing official plan policies and strategies for the identification, wise use and management of cultural heritage resources C. Municipalities are encouraged to consider the Greenbelt's vision and goals in preparing archaeological management plans and municipal cultural plans and consider them in their decision-making	A. Cultural heritage resources shall be conserved in order to foster a sense of place and benefit communities B. Municipalities shall work with stakeholders, as well as First Nations and Métis communities, in developing and implementing official plan policies and strategies for the identification, wise use and management of cultural heritage resources C. Municipalities are encouraged to consider the Greenbelt's vision and goals in preparing archaeological management plans and municipal

	development and *site alteration* has been evaluated and it has been demonstrated that the *heritage attributes* of the *protected heritage property* will be *conserved* D. Planning authorities should consider and promote archaeological management plans and cultural plans in conserving cultural heritage and archaeological resources E. Planning authorities shall engage with Indigenous communities and consider their interests when identifying, protecting and managing cultural heritage and archaeological resources		cultural plans and consider them in their decision-making
Natural and Man-Made Hazards	**Natural Hazards** A. Development shall generally be directed, in accordance with guidance developed by the Province (as amended from time to time), to areas outside of: 1. hazardous lands adjacent to the shorelines of the Great Lakes - St. Lawrence River System and large inland lakes which are impacted by flooding hazards, erosion hazards and/or dynamic beach hazards 2. hazardous lands adjacent to river, stream and small inland lake systems which are impacted by flooding hazards and/or erosion hazards; and 3. hazardous sites		

	B. Development and site alteration shall not be permitted within: 1. the *dynamic beach hazard*; 2. defined portions of the flooding hazard along connecting channels (the St. Marys, St. Clair, Detroit, Niagara and St. Lawrence Rivers); 3. areas that would be rendered inaccessible to people and vehicles during times of *flooding hazards*, *erosion hazards* and/or *dynamic beach hazards*, unless it has been demonstrated that the site has safe access appropriate for the nature of the *development* and the natural hazard; and 4. a floodway regardless of whether the area of inundation contains high points of land not subject to flooding. C. Development *shall not be permitted to locate in* hazardous lands *and* hazardous sites *where the use is:* 1. an *institutional use* including hospitals, long-term care homes, retirement homes, pre-schools, school nurseries, day cares and schools 2. an *essential emergency service* such as that provided by fire, police and ambulance stations and electrical substations; or 3. uses associated with the disposal, manufacture,		

	treatment or storage of *hazardous substances*. D. Further to policy 3.1.6, and except as prohibited in policies 3.1.4 and 3.1.5, *development* and *site alteration* may be permitted in those portions of *hazardous lands* and *hazardous sites* where the effects and risk to public safety are minor, could be mitigated in accordance with provincial standards, and where all of the following are demonstrated and achieved: 1. development and site alteration is carried out in accordance with floodproofing standards, protection works standards, and access standards; 2. vehicles and people have a way of safely entering and exiting the area during times of flooding, erosion and other emergencies 3. new hazards are not created and existing hazards are not aggravated; and 4. no adverse environmental impacts will result. E. Development shall generally be directed to areas outside of lands that are unsafe for development due to the presence of hazardous forest types for wildland fire. Development may however be permitted in lands with hazardous forest types for wildland fire where the risk is mitigated in accordance with wildland fire		

	assessment and mitigation standards. **Man Made Hazards** A. Sites with contaminants in land or water shall be assessed and remediated as necessary prior to any activity on the site associated with the proposed use such that there will be no adverse effects. B. Planning authorities should support, where feasible, on-site and local re-use of excess soil through planning and development approvals while protecting human health and the environment.		
Climate Change	A. Land use patterns within settlement areas shall be based on densities and a mix of land uses which 1. minimize negative impacts to climate change, and promote energy efficiency; 2. prepare for the *impacts of a changing climate*;	A. Integrating climate change considerations into planning and managing the Agricultural System, Natural Heritage System and Water Resource System to improve resilience and protect carbon sequestration potential, recognizing that the natural Heritage System is also a component of green infrastructure; and B. Integrating climate change considerations into planning and managing growth that includes incorporating techniques to reduce greenhouse gas emissions, and increasing the resilience of settlement areas and infrastructure within the Greenbelt.	A. Upper- and single-tier municipalities will develop policies in their official plans to identify actions that will reduce greenhouse gas emissions and address climate change adaptation goals, aligned with the Ontario Climate Change Strategy, 2015 and the Climate Change Action Plan, 2016 that will include: 1. assessing infrastructure risks and vulnerabilities and identifying actions and investments to address these challenges. 2. undertaking stormwater management planning in a manner that assesses the impacts of extreme weather events and incorporates appropriate green

			infrastructure and low impact development; 3. protecting the Natural Heritage System and water resource systems;
Water Resources System		A. All planning authorities shall provide for a comprehensive, integrated and long-term approach for the protection, improvement or restoration of the quality and quantity of water. Such an approach shall consider all	

In addition, AHYDTECH has complied with the following guidelines and regulations:

- **Environment Protection Act – Ontario Regulation 153/04**.
- **Town of Whitby's Official Plan**
- **MNR Great Lakes Guidelines (MNR 2001)**
- **Ontario Heritage Act**
- **Municipal Class EA Process**

4.2 Topographic/Bathymetric Survey

A topographic/bathymetry survey was conducted by AHYDTECH's Professional Engineer (P.Eng.) using standard engineering RTK/GPS and ECO sounder (Sonar) survey techniques. The study area includes roughly 12km of the shoreline of Lake Ontario, which is located between Lakeridge Road and Boundary Road within the Town of Whitby's limits. AHYDTECH collected cross-section data of the sites in the study area where there were erosion and flooding issues. The cross-section data had 50m-100m interval, which were applied for erosion and flood hazard analysis. AHYDTECH also conducted the survey along and near the shoreline in the study area. The shoreline topographic survey data were applied for the coastal wave uprush and flooding hazard analysis.

A bathymetric survey was also conducted on April 4, April 10, April 11, April 17, June 3 and June 17, 2019 to acquire cross-shore profiles data of the lake and near the shoreline of the 12km long shoreline. The cross-shore profiles had 50m-100m interval. The survey data were taken in the lake from approximately 1m depth to 5m depth using a boat and a bathymetric survey unit. AHYDTECH has an aluminum boat which is 12ft long with a small motor. AHYDTECH has HY1500 Digital Echo Sounder and Lowrance Elite-4 CHIRP bathymetric survey units. AHYDTECH used both the survey units which were capable of recording sonar to measure depth and RTK/GPS to provide geo-referenced coordinates for bathymetric sounding conduction. The bathymetric survey unit has capabilities to

Figure 3: Bathymetry survey of Whitby near shoreline

determine point position, water depth and lakebed elevation. The sonar depth-sounder was attached to the transom of the boat close to the bottom and the mapping CHIRP was attached to the seat of the boat, which allowed the field crew to see the sonar image in lake while operating the boat. The bathymetric soundings had very refined intervals to capture variations of the lakebed and bed near shoreline. The collected data used the Zone 17, NAD83 horizontal datum projection format for surface and contour generation and site layout.

4.3 Shoreline Characterization

AHYDTECH performed site visit and field investigation to characterize the shoreline in the project area. AHYDTECH has filled shoreline characterization forms during the site visit to identify the controlling structure of each of the properties in the project study area. Coastal landforms in the area are mixture of natural and artificial shoreline. The natural coastline exists as beaches, bluffs, and wetlands, while the artificial shoreline includes the Whitby

Figure 4: Reach Delineation of the Whitby Study area

Harbor, concrete walls, armor stone revetments, concrete block walls, and sheet piling. Previous study has done bluff erosion monitoring in parts of the project study area. There are existing high-risk residential neighborhoods along the Whitby waterfront including Whitby Harbor, Eastbourne Beach and Crystal Beach. The shoreline characterization helped in the risk assessment of existing public and private lands and infrastructure along the Town's waterfront to help with mitigation planning and related prioritization. Details of the shoreline characterization were documented in the field assessment forms (Appendix C).

The reaches were categorized as low erosion concern, medium erosion concern, and high erosion concern depending on nearby residential infrastructure, evidence of erosion and structural effectiveness (if any). Reaches were assigned to specific erosion concern. Observed from the field visit, that shoreline of the study area can be categorized as natural and artificial shoreline with concrete retaining wall, sheet pile or revetment structure.

Reach 01 can be categorized as a natural shoreline. It is characterized as a dynamic beach, backed by a 1.5-4.0m high bluff. Silt and coarse sand/cobble are found at the bottom of the bluff which resist erosion. Land parcels in Reach 01 are owned by CLOCA.

Reach 02 shoreline has a privately owned land. It has a vertical seawall with concrete blocks, which is roughly 150m in length, and is about 2.5m tall. The stacked concrete blocks are tilted towards the lake, and multiple blocks have fallen into the Lake. The concrete blocks are stacked in three layers above the waterline. There is a private house roughly 25m away from the seawall. The toe protection of the seawall has displaced and dislodged in many places, which resulted into sliding of the wall towards the lake.

Reach 03 shoreline is located land parcel owned by CLOCA. It is primarily a natural shoreline with fallen trees and a small sheet pile structure in the middle. Though the small structure is potentially able to regulate the water level on the cranberry marsh, it is currently in a limited functional condition. There is a marsh/wetland, which is narrowly separated from Lake Ontario by a barrier beach with fallen trees. Between the lake and marsh, there exists a barrier beach, which has experienced natural processes and has built up sand and gravel. The barrier beach materials limit and slow down drainage discharge from the marsh. Slower discharge means that the marsh is more likely to retain higher levels in the summer and fall, when lake levels are lower. It can partially protect the barrier beach, but water was photographed pooling in the marsh side of the structure.

Reach 04 has been characterized as a natural beach, which has bank height of 2.5m in the west and gradually lowering down to the east. It is approximately 490 m long and extends from the shore trail to the Lynde Creek outlet. The land in this reach is owned by CLOCA. The shoreline is covered with sand and gravel with a bank (1-2m) of clay topsoil.

Reach 04a is about 200mlong, where sand and gravel beach create a nearly closed bay formation with a small outlet passing creek flow. This is a natural beach with dynamic beach barrier, limited access to public and owned by CLOCA.

Reach 05 has vertical retaining wall with large concrete blocks and armor stones. Lower part of the wall has concrete blocks. The retaining wall in Reach 05 has a length of approximately 340m and height of about 3m. It protects a park and stormwater management pond behind the Ontario Shores Mental Health Center. Part of Reach 05 is owned by Town of Whitby and part of it is owned by the Province of Ontario. Concrete blocks at toe of the structure are in poor condition due to erosion/spalling. Besides, due to shifting, visible gaps were observed between consecutive armor stones. No geotextile was secured beneath the structure, due to which soil beneath the armor stone gaps are being washed out.

Reach 06 has cobble beach and bluff of 5-7m high. This reach is about 260m long, and it is owned by the Province of Ontario. The bluff is mostly vegetated with natural features, grass and plants making it a natural shoreline, which is projecting headland in front of Whitby Shores Health Center. The reach is characterized as a non-dynamic beach, backed up by a 5-7m high bluff. The west side of the bluff has been strengthened with vegetation, showing no signs of slumping. However, there is lack of vegetation along the east side and some slumping has been observed there which might be caused by steeper slope. Moreover, large cobbles and stones at the toe of the bluff provides natural toe protection.

Reach 07 is a Province of Ontario owned shoreline with artificial characteristic. There is a retaining wall structure comprised of armor stones, having a length of approximately 300m and height of about 3m. There is a 3-4m high earthen berm 10m away from the structure. The structure is in poor condition due to erosion and dislodgement of armor stones. Due to shifting by wave actions, visible gaps were observed between consecutive armor stones. No geotextile was secured beneath the structure, due to which soil beneath the armor stone gaps are being washed out. Soil over the structure shows erosion which indicates waves are overtopping the armor stone wall.

One of the longest sand beaches in the Whitby shoreline is **Reach 08.** This reach is a natural beach, around 370m in length. The reach is a dynamic beach with fines sorted to the dunes and larger gravel along shoreline. There are some dune grasses and vegetation 10-30m from the shoreline. There is an informal trail and mixed forest behind the shoreline. This reach is owned by the Town of Whitby.

Reach 09 is an artificial shoreline with sheet pile that extends from the Yacht Club along the Bay/Harbor mouth to the Whitby Harbor entrance; the harbor side of the sheet pile is exposed to water. The Lake Ontario side progresses from the dynamic Iroquois Beach sand to a rock/rip-rap beach. The sheet pile has been reinforced with I beams. The steel under water is vulnerable to corrosion and some surface corrosion was also observed. Besides, there are areas on the Lake Ontario side where the stone and cobble eroded out from the toe of the structure. The material near the Iroquois Beach experienced the most toe erosion. Part of Reach 9 is owned by the Town of Whitby and the rest is owned by Fisheries and Oceans Canada and Public Works Canada.

The mouth of the Whitby Harbor is delineated as **Reach 09a**, which is an artificial structure owned by Fisheries and Oceans Canada. The structure has a seawall protecting the entrance. This structure is in perpendicular direction to the Whitby shoreline. The concrete cap of the structure is in aging condition with cracks and visible vegetation growth. The sheet pile has been corroded on the surface but is in fair condition. The tilting of the sheet pile might have been caused due to lack of toe support at base of the structure, but it is comparatively small. A groyne made of armor stones is identified as **Reach 09b**. This reach is owned by Transport Canada. This reach has been characterized as an artificial structure with a stone groyne projecting from the harbor mouth entrance with a purpose of protecting the harbor mouth from wind and wave action. A sheet pile has extended from the west side off the harbor mouth.

The east side of the Whitby Harbor entrance mouth has a long structure made of sheet pile filled by concrete. This structure including the Whitby Harbor is delineated as **Reach 10** which is owned by Transport Canada. Both artificial and natural shorelines have been observed inside the Whitby Harbor. Artificial shoreline consists of parks and environmental protection structures. There is low risk of erosion and flooding since most part of the reach is in fair condition. The shoreline within the Yacht Club harbor docks is subjected to undermining, shifting or scouring of the material under the brick. Though the cracks and gaps between few blocks were fixed with concrete, some bricks in the southwest corner of the structure have buckled upwards. Besides, the uneven surface and undulating length of the wall indicate displacement and scouring of material under the structure.

There is a natural beach in **Reach 11**. This reach is characterized as a low plain dynamic beach consisting of sand and gravel. The reach is approximately 530 m long and has a timber waterfront trail and a gravel/sand dune. Two concrete culverts were observed over the beach to the east side of the ROD building. A large portion of Reach 11 is owned by the Town of Whitby rather than that it is owned by Regional Municipality of Durham (Figure 05).

In the Whitby shoreline, **reach 12** exhibits the most erosion and recession concern. It is a natural shoreline approximately 2.25km long. Several bluffs, with height ranging from 3-7m were observed at different portion of the reach. An observation lookout point was also spotted within 25m from the shoreline. Besides, a waterfront trail is located between 30m to 50m from the shoreline. Most of the Reach 12 is privately owned but a portion towards Reach 13 is owned by the Town. Severe erosion was observed from the creek and culvert drain over the bluff. Moreover, erosion from wave action was also observed, part of the informal trail and vegetation have slumped into the beach.

Three properties at the west of Thickson Road are located within 30m from a medium bluff of **Reach 13**. Reach 13 consist of both natural and artificial shoreline. Although a small portion of this reach is owned by Thickson's Woods Heritage Foundation, it is mostly privately owned. This reach privately owned. The east and west properties are not protected with a seawall; however, there is an abandoned dock at the east property and some broken gabion baskets at toe of the bluff. Besides, rubble and broken concrete were observed at toe of the bluff at Thickson Road dead end. The center property has a wooden board seawall with gabion basket protection at the toe. Although the wooden plank wall has a good alignment, it can’t be considered as an ideal protection structure for the property since wooden materials have such short lifespan.

Reach 14, the Crystal Beach Boulevard, is roughly protected with an armor stone revetment, which is not in a fair condition. The gravel private road falls within 1-5m from the shoreline revetment. Besides, multiple residential buildings are located within 30m from the shore. Though the revetment has been recently constructed and the armor stones are new, several stones were displaced. One of the reasons might be the stone size of the revetment is not large enough to provide protection against the wind and wave action. Most of the armor stones were found to be smaller than required for stable revetment. The displacement of the armor stones can result in failure of the revetment and can cause severe erosion to the reach. Moreover, the soil behind the revetment was washed out to some extent and might continue to be eroded, since no geotextile material was used to retain the soil. Reach 14 is owned by Thickson's Woods Heritage Foundation.

Starting from the Crystal Beach revetment to the Whitby Town limit the shoreline is delineated as **Reach 15**. This reach is a natural shoreline with about 960 m long gravel/cobble beach and owned by Town of Whitby. The outlet of Corbett Creek is partly blocked by the gravel beach. As a result, wetland drainage is reduced, and potential risk of riverine flooding has been increased for the houses of Crystal Beach Boulevard.

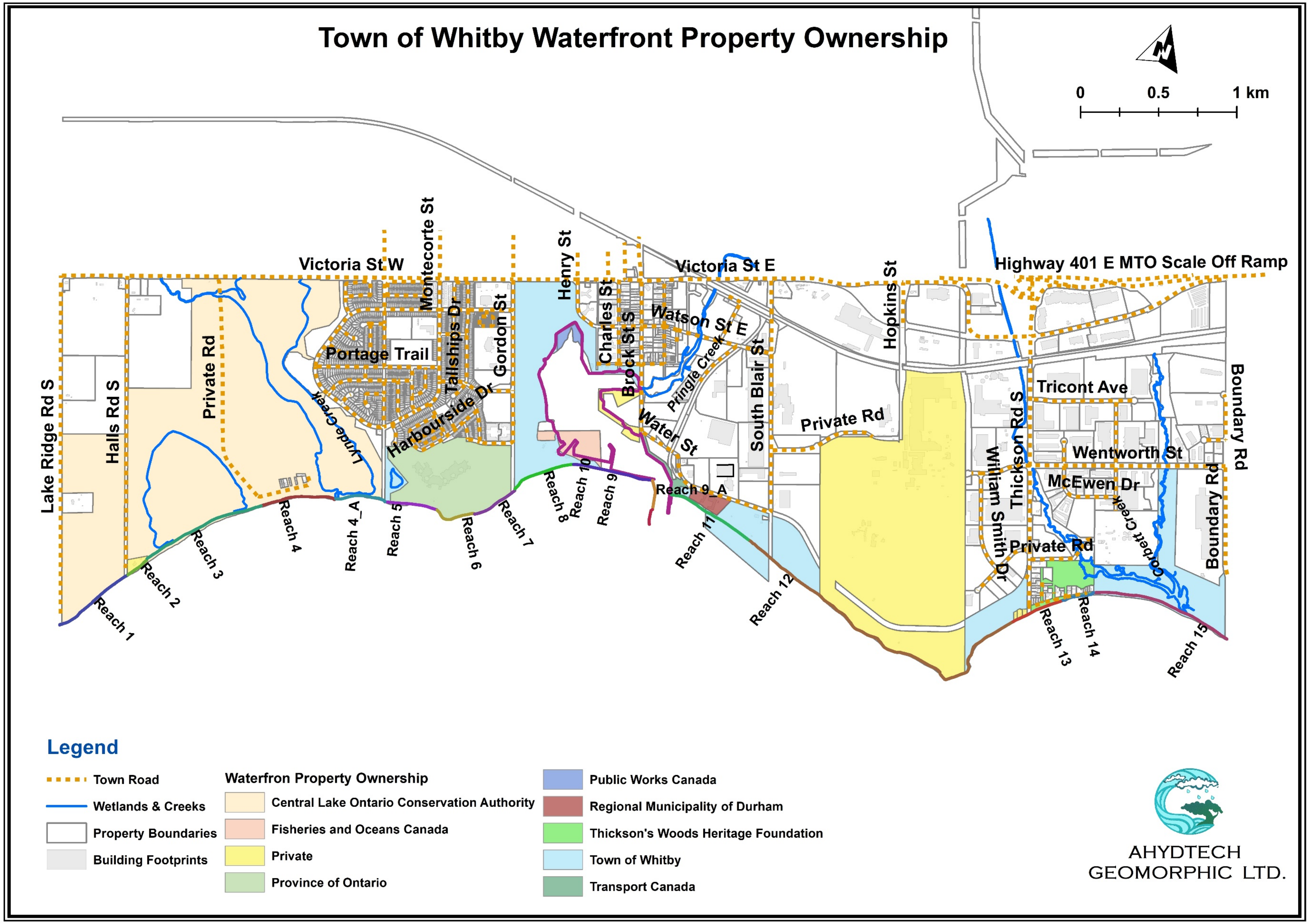


Figure 5: Property map of the Study Area

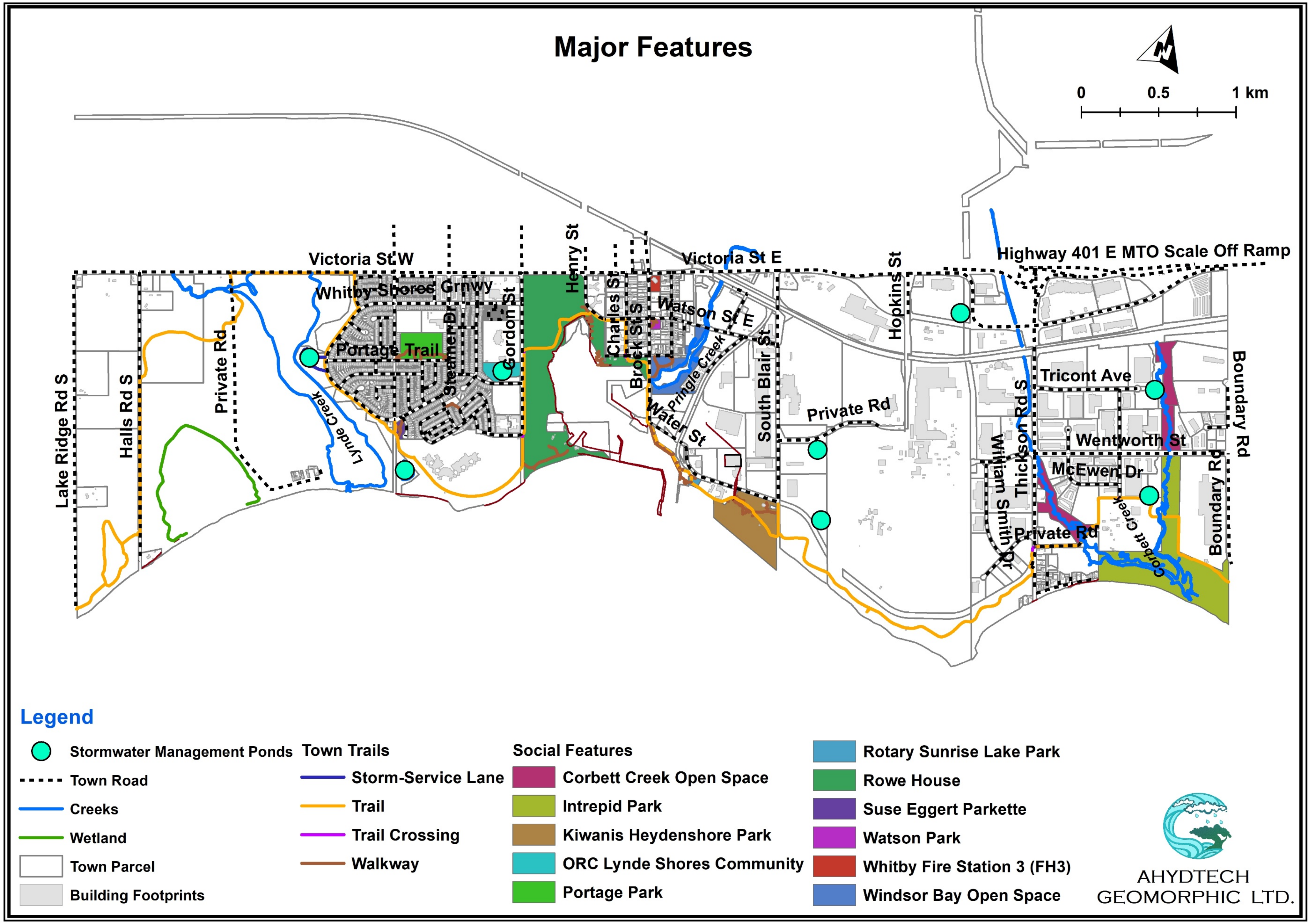


Figure 6: Map of the major features of the study area

4.4 Natural Heritage Assessment

- **Natural Heritage Characterization of the Shoreline Reaches:**

A high-level natural heritage assessment of the shoreline was conducted on July 28, 2019 by viewing accessible portions of each reach on the top of slope and/or lakeshore. Additionally, background material, aerial photographs, and photographs taken during other site visits, including during boat reconnaissance, were reviewed. Following is a high-level characterization of each reach.

Reach 1: Near vertical bluff with natural area above and sand/cobble beach below. The natural area near the shoreline, part of the Lynde Shores Conservation Area, is dominated by cultural meadow with an area dominated by trees and shrubs in the west that has been identified as a small woodland containing a small wetland on provincial mapping. Hedgerows extend back from the top of slope on either end of the reach. The Waterfront Trail extends along the reach in a general east-west direction. A drainage feature through the cultural meadow is present mid-reach originating from a small culvert under the Waterfront Trail that appears to be draining a small woodland located north of the trail. A small ravine is present where the drainage feature flows over the top of bank. Several trees have fallen down the slope in areas including at the ravine. A bank swallow (Riparia riparia) nesting colony is present in the bluff near the east limit of the reach. Bank swallows, a Threatened species in Ontario protected under the Endangered Species Act, were observed foraging over the lake and cultural meadow during the July site visit. Monarch butterfly, a Special Concern species in Ontario, and Common Milkweed, one of its host plants were observed in the cultural meadow. Dog strangling vine, an invasive species in Ontario capable of transforming natural areas, was observed near the shoreline at the end of Halls Road in proximity to the bank swallow colony.
Aquatic habitat features in the lake appear limited to in-water cover provided by scattered boulders and woody debris.

Reach 2: Concrete seawall protecting a property with a single-detached dwelling. The seawall is in disrepair in areas with blocks falling into the lake. A small beach comprised of sand, gravel, cobble and a few boulders is present behind the wall. Debris including broken concrete and erosion control materials are scattered on the beach. A short, vegetated slope comprised mainly of herbaceous plants (including the invasive Common Reed (Phragmites australis)) and some small shrubs separates the beach and seawall from manicured area associated with the dwelling. Armor stone has been set into the top of slope in areas. A small, short, unprotected bluff is present in the extreme east as the shoreline transitions into Reach 3.
Aquatic habitat features in the lake appear limited to in-water cover provided by scattered boulders and woody debris and abundant broken concrete.

Reach 3: Sand beach with trees in west transitioning to a sand and cobble barrier beach that protects the Cranberry Marsh Provincially Significant Wetland. Trees and shrubs are present along most of the barrier beach; however, many trees have been knocked down resulting in considerable woody debris. A relatively short (length and height) sheet pile and

stop-log control structure is present in the middle of the barrier beach. This structure was likely installed by CLOCA to regulate water levels in conjunction with their Cranberry Marsh Management Zone Strategy (1999). Lake levels had overtopped the barrier beach during the July 2019 site visit. The barrier beach transitions to a small sand beach with a short bluff in the east. The top of the bluff is vegetated with trees and shrubs. The Lynde Shores Coastal Wetlands Life Science ANSI is present along the entire reach.
Aquatic habitat features in the lake appear limited to in-water cover provided by the woody debris.

Reach 4: Small sand and gravel beach with a small bluff that is higher in the west and gradually lowers to the east. Thicket with some trees, manicured lawn, and woodland cover is present above the bluff in the west, central, and east portions of the reach respectively. The west portion of the reach is included within the Lynde Shores Coastal Wetlands Life Science ANSI. The east portion of the reach is included within the Lynde Shores Coastal Wetlands Candidate Life Science ANSI and separates the Lynde Creek Marsh Provincially Significant Wetland from the lake. Eastern Pondmussel, a Special Concern species in Ontario, is found in Lynde Creek. Scattered trees are present in the manicured portion starting about 1 m back from the top of the bluff.
Aquatic habitat features in the lake appear absent.

Reach 4a: Sand and gravel barrier beach with the Lynde Creek outlet flowing through it. Behind the barrier beach the creek is embayed with marsh on both banks. The natural area surrounding the embayment, including the barrier beach, forms part of the Lynde Creek Marsh Provincially Significant Wetland and the Lynde Shores Coastal Wetlands Candidate Life Science ANSI. The barrier beach is dominated by trees and shrubs. Eastern Pondmussel, a Special Concern species in Ontario, is found in Lynde Creek.
Aquatic habitat features in the lake appear limited to in-water cover provided by abundant downed trees and limbs.

Reach 5: Reach 5 is one of three reaches present along the lake front of the Ontario Shores Mental Health Centre. The reach is comprised of an armor stone wall with a concrete block toe. A stormwater pond outlet channel flows over the concrete blocks through a break in the armor stone near the westernmost limit of the reach. A very small gravel beach is present in a break in the armor stone wall and concrete blocks a little further east. Relatively flat ground behind the seawall in the west transitions to a small slope that becomes a few meters high in the east. Trees and shrubs dominate the immediate area behind the wall, including the slope, with manicured area further back along most of the reach.
Aquatic habitat features in the lake appear limited to boulders present on the lake bottom in the relatively deep water that abuts the seawall.

Reach 6: Small cobble and boulder beach with a relatively tall natural bluff. The bluff is dominated by herbaceous vegetation with scattered shrubs in the west and central portions while the eastern portion is relatively devoid of vegetation due to slumping. Scattered small trees and shrubs are also present in the beach. Scattered trees are present in manicured area on the tableland. The manicured area extends to the top of the bluff.

Aquatic habitat features in the lake appear limited to in-water cover provided by abundant boulders.

Reach 7: Armor stone seawall with natural area dominated by trees and shrubs behind it. A relatively flat area with a trail in it is present immediately behind the wall with a short slope further back. Manicured area with scattered trees is present on the tableland. The manicured area extends to the top of slope for most of the reach but extends down a gentle slope to the seawall near the eastern limit of the reach. Abundant Dog-strangling vine was observed in the natural area along this reach.
Aquatic habitat features in the lake appear limited to in-water cover provided by abundant boulders and a little woody debris.

Reach 8: Sand and cobble beach with natural area behind dominated by trees and shrubs. A portion of the Whitby-Oshawa Iroquois Beach Provincially Significant Wetland Complex makes up a large part of the natural area.
Aquatic habitat features in the lake appeared absent.

Reach 9, 9a, 9b: Sheet pile wall protecting a marina and harbour. The harbour forms the outlet for Pringle Creek. In the west, a row of planted trees is present behind the wall with a parking lot and buildings further back. The eastern portion of the wall shelters the harbour. Several trees are also present along this portion of the wall. The sheet pile turns perpendicular to the shoreline transitioning into a concrete capped seawall as Reach 9a. Reach 9b is an armor stone groyne that extends from the seawall.
Aquatic habitat features in the lake appear limited to in-water cover provided by boulders and riprap at the toe of the sheet pile wall.

Reach 10: The inner harbour shoreline is comprised of two marinas, natural areas, a boat launch in parkland, developed land, a road crossing of Pringle Creek, and a sheet pile and concrete walkway that extends out into the lake forming a pier that forms the eastern portion of the harbour mouth. The shoreline of the Yacht Club marina is variously comprised of a rock groyne, boat slips with cabled cement, and a pier comprised of sheet pile with gravel and concrete in the middle. Some shrubs are present on the rock groyne. Natural area dominated by trees and shrubs is present north of the Yacht Club. The southern portion of this natural area is part of the Whitby-Oshawa Iroquois Beach Provincially Significant Wetland that extends south to Reach 8.
The shoreline of the parkland is also comprised of a relatively narrow band of trees and shrubs with a trail and manicured lawn further back. The shoreline of the Port Whitby Marina is comprised of riprap with a timber wall supported by I beams protecting the marina building. An abandoned property with shrubs on the eastern shoreline of the harbour is protected by sheet pile.
Aquatic habitat features in the harbour are limited to in-water cover provided by interstitial space in the groyne and rip-rap areas and overhanging cover provided by trees and shrubs in the natural area and parkland.

Reach 11: Gravel and sand beach with occasional trees, shrubs, and herbaceous cover. A small drainage feature outlet at the western limit of the reach beside the harbour pier. Parkland extends away from the beach with some buildings and a wood boardwalk trail close to the beach in the central portion of the reach. Three culverts outlet onto the beach close to the buildings with a row of gabion baskets where they discharge. Aquatic habitat features in the lake appeared absent.

Reach 12: Long stretch of natural shoreline comprised of a small cobble beach and a relatively tall, steep bluff. A short stretch of the bluff is relatively well vegetated with shrubs and herbs in the west while the remainder is largely bear with scattered trees and shrubs. Trees and shrubs are present on the tableland in the west while meadow dominates the remainder. A trail meanders through the meadow parallel to the shoreline coming relatively close to the bluff including a look-out area. Drainage over the bluff has caused significant gullying in two areas and a relatively large concrete culvert outlet is present near the eastern limit of the reach. Aquatic habitat features in the lake appear limited to in-water cover provided by relatively abundant boulders.

Reach 13: Sand and cobble beach with bluff. Homes are present relatively close to the bluff in the western portion of the reach resulting in various forms of protection along the shoreline including gabion baskets, concrete rubble, and a wooden seawall. Manicured area with scattered trees is present on the tableland in the eastern portion of the reach. The bluff itself is relatively well vegetated along the entire reach; however bare patches are present. Herbaceous vegetation is dominant on the bluff with scattered trees and shrubs. The Corbett Creek Coastal Marsh Candidate Life Science ANSI and the Corbett Creek Provincially Significant Wetland are located well inland from the reach behind the houses present on the eastern portion of Crystal Beach Blvd.
Aquatic habitat features in the lake appear limited to in-water cover provided by scattered boulders and some downed woody debris.

Reach 14: Stone revetment with Crystal Beach Boulevard in proximity. The revetment is comprised of large boulders in the east and armor stone in the west. Willow shrubs with occasional trees are present along the revetment. Relatively new live stake geoengineering was observed along the top of the revetment. The Corbett Creek Coastal Marsh Candidate Life Science ANSI and the Corbett Creek Provincially Significant Wetland are located inland from the reach behind the houses present on the eastern portion of Crystal Beach Blvd. However, those features also extend to the shoreline at the eastern limit of the reach just east of the end of Crystal Beach Blvd.
Aquatic habitat in the lake appears limited to the in-water cover provided by the stone revetment.

Reach 15: Cobble beach with woody natural area in the east dominated by Eastern White Cedar and Balsam Poplar. The natural area forms a relatively wide barrier beach between the lake and the Corbett Creek Provincially Significant Wetland. The creek outlets into the lake at the eastern end of the barrier beach. The cobble beach extends east of the creek with a vegetated slope behind. The slope is a mixture of trees, shrubs, and herbs. Meadow and scattered trees are present on the tableland behind the slope. A drainage channel present in the meadow flows over the slope through a degraded gabion basket spillway near the eastern limit of the reach. All but the eastern portion of the reach is included in the Corbett Creek Coastal Marsh Candidate Life Science ANSI.

Aquatic habitat features in the lake appear limited to in-water cover provided by scattered boulders and downed woody debris.

- **Potential Natural Heritage Impacts and Recommended Mitigation Measures and Opportunities Associated with the Identified Preferred Alternative for the Shoreline Reaches**

The high-level natural heritage characterization was used to assess the identified Preliminary Preferred Alternatives for each reach in order to recommend impact mitigation, restoration, and enhancement items for incorporation during design and implementation.

Reach 1 Preliminary Preferred Alternative: Modification & Improvement to natural features

Bank swallow, a Threatened species in Ontario is a constraint as the species and its habitat is protected under the Endangered Species Act. The protected habitat includes the breeding colony (burrows and substrate around them), 50 m in front of the bank space to allow the birds to enter and exit the burrows, and suitable foraging habitat within 500 m of the colony. The Ministry of the Environment Conservation and Parks (MECP) should be consulted for any proposed activities in this reach and a permit under the ESA may be required. Considerations in this regard include but are not limited to:

- avoid planting any vegetation on or in front of the bank face in proximity to the colony
- avoid planting trees or large shrubs at the top of the bank as their roots could interfere with burrow establishment
- avoid the prevention of erosion in proximity to the colony as it maintains suitable nesting habitat by keeping the bank face at or near vertical and preventing the establishment of vegetation on the face

While mitigation details to avoid impacts the breeding colony should be determined in consultation with the MECP (e.g., the exact distance from the colony to be maintained in its current state), it is generally recommended that all modifications and improvements to natural features only occur on the western portion of the reach up to the eastern limit of the small woodland located north of the trail in the central portion of the reach. This would keep all works approximately 100 m away from the bank swallow colony thereby allowing natural erosion of the bluff to occur where the colony is located and maintaining a large portion of the existing meadow foraging habitat.

Habitat for monarch, a Special Concern species in Ontario, is present in the reach as milkweed, its host breeding plant, was observed occasionally in the meadow. Maintaining a large portion of the existing meadow foraging habitat for bank swallow will also ensure that Monarch habitat is maintained.

Limiting all modifications to natural features to the western portion of the reach as described above will allow the two areas where the trail is in closest proximity to the bluff and the

ravine where the drainage feature flows over the top of bank to be addressed while mitigating potential impacts to bank swallow and monarch habitat.
Shoreline alterations have the potential to impact the small woodland and wetland present in the western portion of the reach through the loss of woody cover and altered hydrology. While woody plantings along the shoreline could mitigate the loss of woodland vegetation, the wetland is not easily replaced. As such, maintaining shoreline modifications away from this feature is recommended. Loss of woody cover in the hedgerow at the western limit of the reach due to shoreline modifications should be mitigated through woody plantings.

Reach 2 Preliminary Preferred Alternative: Repair & Replacement of existing shoreline structure

Generally, repair of the existing shoreline structure represents a neutral outcome from a natural heritage perspective. However, it is recommended that existing impacts are removed and opportunities to improve habitat are incorporated into the design. Considerations in this regard include:

- Addition of natural boulders either in front of the seawall or through a change to a revetment design that extends well below water to provide habitat heterogeneity, cover, and lower velocity zones for fish
- Use of natural stone instead of concrete
- Removal of all existing broken concrete and erosion control materials in front of and behind the wall
- Removal (including root systems) of the invasive Common Reed on the shoreline and re-planting with native species

Reach 3 Preliminary Preferred Alternative: Do Nothing or Modification & Improvement to natural features

The hydrology of the Cranberry Marsh Provincially Significant Wetland is the primary natural heritage concern relating to any modifications in this reach. To avoid impacts to wetland hydrology, the existing top elevations of the shoreline banks, barrier beach, and control structure should not be artificially altered. Beach nourishment (e.g. cobbles) could help preserve the existing vegetation and associated shoreline habitat on either side of the barrier beach. Beach nourishment along the barrier beach could help the barrier beach naturally adjust to changing conditions by providing the natural building blocks for natural shoreline dynamics. Plantings to replace the significant amount of tree loss on the barrier beach could be considered; however, their chance of survival may be limited if high lake levels and associated wave action are experienced. Further, if conditions that will support trees and/or shrubs are present in the future it is likely that they will naturally re-colonize the barrier beach relatively quickly. Beach nourishment is consistent with CLOCA's Cranberry Marsh Management Zone Strategy (1999), which is aimed at protecting the physical integrity of the treed beach area but avoiding any 'hard' or 'soft' engineered erosion control structures along the beach or offshore (except for the control structure). Provided the outlined approach is implemented, impacts to the Cranberry Marsh Provincially Significant Wetland and the Lynde Shores Coastal Wetlands Life Science ANSI are not anticipated.

Reaches 4 and 4a Preliminary Preferred Alternative: Do Nothing

Due to fluctuating lake levels and associated wave action, some erosion is expected along these reaches. However, this represents natural dynamic shoreline processes that would not be considered a negative impact. The Do-Nothing approach is consistent with CLOCA's Cranberry Marsh Management Zone Strategy (1999), as outlined above, and Lynde Creek Management Zone Strategy (2000), which recommends no active management along the barrier beach protecting the Lynde Creek Marsh Provincially Significant Wetland. No impacts are anticipated to the Lynde Creek Marsh Provincially Significant Wetland, the Lynde Shores Coastal Wetland Candidate Life Science ANSI, or the Eastern Pondmussel habitat in Lynde Creek due to the preferred alternative.

Reach 5 Preliminary Preferred Alternative: Repair & Replacement of existing shoreline structure

The existing seawall forms an unnatural hardened vertical surface thereby limiting the potential for fish habitat. Through detailed design, habitat could be improved by providing additional natural boulders in front of the seawall or through a change to a natural stone revetment design that extends well below water to provide habitat heterogeneity, cover, and lower velocity zones for fish. Consideration could also be given to replace the concrete toe with natural stone. Tree and/or shrub plantings in the areas of the slope behind the seawall that are currently devoid of woody vegetation would improve the shoreline habitat along the reach. Similarly, plantings within the manicured area to extend the naturalized area further back from the shoreline represent an opportunity to enhance natural habitat. At minimum, areas that are disturbed due to construction should be re-vegetated with a native seed mix and woody plantings.

Reach 6 Preliminary Preferred Alternative: Modification and Improvement to natural features

Increasing native shrub cover on the slope would increase stability; however, it would be difficult to plant on the steeper sections of the bluff and the survivorship would likely be low in those areas. A reduction in slope and increased shrub cover could be realized using layers of brush mattress bioengineering in those areas. The manicured area associated with this reach extends to or close to the top of slope which may be contributing to slope instability due to lack of root structure in the upper portion of the slope. Tree and shrub plantings at the top of slope would help in this regard. Increased toe protection through the placement of large boulders would add habitat heterogeneity along the beach. An increase in native vegetative cover along the reach would be an improvement over existing condition.

Reach 7 Preliminary Preferred Alternative: Repair & Replacement of existing shoreline structure

The existing seawall forms an unnatural hardened vertical surface thereby limiting the potential for fish habitat. Through detailed design, habitat could be improved by providing additional natural boulders in front of the seawall or through a change to a natural stone revetment design that extends well below water to provide habitat heterogeneity, cover, and lower velocity zones for fish. Consideration could also be given to replace the concrete toe with natural stone. Tree and/or shrub plantings at the top of slope would improve the shoreline habitat along the reach. At minimum, areas that are disturbed due to construction should be re-vegetated with a native seed mix and woody plantings. Removal of the invasive Dog-strangling vine as part of, or in addition to, the shoreline structure works should be considered as this species can transform and negatively impact natural areas. At minimum, care should be taken when working in this area to prevent spreading the plant to new locations through adoption of best management practices throughout construction. The Ontario Invasive Plant Council's 2012 Best Management Practices guide is useful in this regard.

Reach 8 Preliminary Preferred Alternative: Do Nothing

The relatively wide beach offers natural protection from shoreline processes to the treed natural area, including the portion of the Whitby-Oshawa Iroquois Beach Provincially Significant Wetland Complex that is present. As such, negative impacts to natural features due to the Do Nothing alternative are not anticipated.

Reaches 9, 9a, and 9b Preliminary Preferred Alternative: Repair & Replacement of existing shoreline structures

The existing seawalls in Reaches 9 and 9a form an unnatural hardened vertical surface thereby limiting the potential for fish habitat. Habitat could be improved by providing additional natural boulders in front of the seawall or through a change to a natural stone breakwater to provide habitat heterogeneity, cover, and lower velocity zones for fish. Similarly, a stone breakwater should be maintained in Reach 9b. The existing trees along the seawall should be protected to the extent feasible or replaced.

Reach 10 Preliminary Preferred Alternative: Repair & Replacement of existing shoreline structures

The existing Yacht Club shoreline offers limited habitat due to the existing cabled concrete block protection. Consideration should be given to replace the concrete blocks to rip-rap similar to the Port Whitby Marina as this would provide some habitat heterogeneity, cover, and lower velocity zones for fish.

If the sheet pile seawall (structure 14) is to be replaced due to poor condition, consideration should be given to replacing with a natural stone revetment to provide habitat heterogeneity, cover, and lower velocity zones for fish.

Replacement of the shoreline structures would not have a negative impact on the natural shoreline areas including the Whitby-Oshawa Iroquois Beach Provincially Significant Wetland.

Reach 11 Preliminary Preferred Alternative: Modification and Improvement to natural features

The proximity of the trail and park land constrain opportunities to improve natural features. Shrub plantings on the lake side of the trail where it is closest to the lake may provide some benefit, but the eastern portion of the reach likely presents the best opportunity. Space is available for tree and shrub plantings on the slope on the lake side of the fence demarcating the park. If desired, tree plantings along the beachfront in the central portion of the park would also offer benefits. If sufficient numbers of trees and shrubs are planted along this reach it would improve the area in terms of migratory bird stopover habitat.

Reach 12 Preliminary Preferred Alternative: Modification and Improvement to natural features

Increasing native shrub cover on the slope would increase stability; however, it would be difficult to plant on the steeper sections of the bluff and the survivorship would likely be low in those areas. A reduction in slope and increased shrub cover could be realized through the use of layers of brush mattress bioengineering in those areas. The tableland meadow area associated with this reach extends to the top of slope which may be contributing to slope instability due to lack of root structure in the upper portion of the slope. Tree and shrub plantings at the top of slope would help in this regard and would provide a seed source for natural colonization of the slope. Similarly, shrub plantings associated with any slope works in the two areas of gullying would help with stability while improving habitat. Increased toe protection through the placement of large boulders would add habitat heterogeneity along the beach. The large expanse of meadow habitat provides an opportunity to significantly improve migratory bird stopover habitat in the reach through extensive tree and shrub plantings across the tableland. However, the area should be studied to ensure that potential grassland/open country bird and/or migratory butterfly stopover habitat would not be compromised. Removal of Common Reed, an invasive grass species observed on the tableland along the reach, in combination with native plantings would help to enhance the biodiversity along the reach. At minimum, care should be taken when working in this area to prevent spreading the plant to new locations through adoption of best management practices throughout construction. The Ontario Invasive Plant Council's 2020 Best Management Practices guide is useful in this regard.

Reach 13 Preliminary Preferred Alternative: Installation of new shoreline structures

In general, shoreline structures reduce aquatic and terrestrial habitat. A new structure would not represent a large reduction in habitat in the area of the existing ad hoc structures; however, extending a new structure along the reach represents an impact. As such, the new structure should be limited in length/locations only to that which is necessary for hazard protection. Additionally, the new shoreline structure should be designed to limit impacts and aim to incorporate aquatic habitat and vegetation to the extent feasible. A natural stone groyne, breakwater, or revetment would provide some habitat heterogeneity, cover, and lower velocity zones for fish. A hardened vertical face should be avoided if possible. All areas disturbed during construction should be re-vegetated with a native seed mix and native woody plantings. Removal of Common Reed, an invasive grass species observed at the toe of the bluff along the reach, in combination with native plantings would help to enhance the biodiversity along the reach. At minimum, care should be taken when working in this area to prevent spreading the plant to new locations through adoption of best management practices throughout construction. The Ontario Invasive Plant Council's 2020 Best Management Practices guide is useful in this regard. The Corbett Creek Coastal Marsh Candidate Life Science ANSI and the Corbett Creek Provincially Significant Wetland are not associated with the shoreline in the reach so they will not be impacted by the preferred alternative.

Reach 14 Preliminary Preferred Alternative: Repair & Replacement of existing shoreline structure

The existing revetment provides some habitat heterogeneity, cover, and lower velocity zones for fish that should be maintained through the repair or replacement. Consideration could be given to adding some soil to the rear of the revetment and stabilizing it through the use of live stakes. As long as the structure does not encroach on the natural beach that begins in Reach 15, no impacts to the Corbett Creek Coastal Marsh Candidate Life Science ANSI and the Corbett Creek Provincially Significant Wetland are anticipated due to the preferred alternative.

Reach 15 Preliminary Preferred Alternative: Modification and Improvement to natural features:

The hydrology of the wetland is the primary concern relating to any possible activities in this reach. Changes to the creek outlet to reduce the risk of riverine flooding have the potential to significantly alter the hydrology of the wetland resulting in a change to vegetation community structure and loss of existing wetland habitat, flora, and fauna. Any proposed modification to natural features would need to be studied carefully to prevent negative impacts to the Corbett Creek Provincially Significant Wetland and the Corbett Creek Coastal Marsh Candidate Life Science ANSI. CLOCA regulates interference to wetlands and must be consulted on any proposed changes.

4.5 Cultural Heritage Assessment

The EA act defines the environment broadly with various components that influence the life of humans or community. One of these components include cultural conditions. As cultural heritage is an integral part of the environment, it is important that any environmental assessment makes a considerable effort in identifying various cultural heritage sites within the study area and potential impact of the proposed alternatives on these features. The Provincial Policy Statement provides the following definition for various aspects of cultural heritage:

Cultural Heritage Landscape: A defined geographical area that may have been modified by human activity and is identified as having cultural heritage value or interest by a community, including an Indigenous community. The area may include features such as buildings, structures, spaces, views, archaeological sites or natural elements that are valued together for their interrelationship, meaning or association. Cultural heritage landscapes may be properties that have been determined to have cultural heritage value or interest under the Ontario Heritage Act, or have been included on federal and/or international registers, and/or protected through official plan, zoning by-law, or other land use planning mechanisms.

Archaeological Resources: Includes artifacts, archaeological sites, marine archaeological sites, as defined under the Ontario Heritage Act. The identification and evaluation of such resources are based upon archaeological fieldwork undertaken in accordance with the Ontario Heritage Act.

Built Heritage Resource: means a building, structure, monument, installation or any manufactured or constructed part or remnant that contributes to a property's cultural heritage value or interest as identified by a community, including an Indigenous community. Built heritage resources are located on property that may be designated under Parts IV or V of the Ontario Heritage Act, or that may be included on local, provincial, federal and/or international registers.

AHYDTECH was provided with the Municipal Heritage Register (2020) for Town of Whitby and associated shapefiles. Based on the information provided, we have been able to identify a total of 4 cultural heritage sites near to the shoreline part of the study. These are listed in the table below. The heritage sites have been classified as either being listed on the register only or being designated in the Ontario Heritage Act.

Table 2: The various heritage sites located near the study area

Address	Year Built	Building Name	Reach No.	Listed or Designated
220 Crystal Beach Blvd(P)	1924	Fair View Villa	13	Listed in Register
299 Front St W	c. 1856	Captain James Rowe House	8, 9 and 10	Designated - Part IV
269 Water Street	1904	Waterworks Pump House	11	Listed in Register
700 Gordon Street	1912-1914	Ontario Shores Centre for Mental Health Sciences	5, 6 and 7	Listed in Register

Site 1: The Fair View Villa (220 Crystal Beach Blvd(P)

The Fair View villa lies 25 meters to the north of the shoreline on Reach 13. For this reach, we had recommended Alternative 4. We do not anticipate any major impact on the heritage site due to the proposed works. The potential impacts of the proposed intervention will only be during the construction phase as listed below:

- Noise Pollution
- Dust
- Disruption of traffic along Crystal Beach Boulevard

Site 2: Captain James Rowe House (299 Front St W)

This built heritage site has been designated in the Ontario Heritage Act (Bylaw 6989-15). This site has been officially named as the Captain James Rowe House with street address being provided as 299 Front St W. However, the heritage site encompasses a large section of the coast adjacent to Reach no. 8, 9 and 10 as shown in figure below. The length of the shoreline along the heritage site accumulates to approximately 2.8 Kilometers and consists of the Yacht Club and Whitby Harbor. AHYDTECH has recommended Alternative 4 for the shoreline adjacent to the Whitby Yacht Club. The shoreline around the Yacht Club is expected to undergo repairs and replacement based on the recommendations. Based on the Bylaw, the Captain James Rowe house, located adjacent to the intersection of Front Street West and Charles Street.

Site 3: Waterworks Pump House

This site is located approximately 30 meters north of the existing shoreline in Reach no. 11. It lies to the east of the Rotary Sunrise Lake Park. For this site, AHYDTECH has proposed alternative 6. Due to the nature of this alternative, no impact is anticipated for this heritage site.

Site 4: Ontario Shores Centre for Mental Health Sciences

This site spans across reach 5, 6 and 7, and has a total area of approximately 300,000 square meters consisting of a building, its parking spot and free spaces most of which is adjacent to the shoreline. This property site has been listed as the Ontario Shores Centre for Mental Health Services, with the building itself being at least 120 meters from the shoreline. Due to the proximity of the property site from the shoreline and the nature of the interventions recommended, no adverse impact is to be expected.

Figure 7: Map of the cultural heritage sites within the study area

Archaeological Potential

The study area has three main features of archaeological potential as explained below:

1. Registered archaeological sites within the study area and even more within a 300-metre radius.
2. The study area is entirely within 300-metres of water (Lake Ontario and several creeks).
3. The features of early historic settlement and early historic transportation routes as mapped on nineteenth- century mapping.

We recommend that a Stage 1 archaeological assessment will be required during detailed design of the reaches in the study area. The additional research from a Stage 1 assessment may be able to eliminate some portions of the study area due to intensive and extensive disturbance, but the preliminary indication is that the entire study area has high potential for archaeological sites.

4.6 Socio-Economic Environment

Reach 1 – The area landward of this reach consists of often spaces with several trees, many of which are distributed sporadically. A section of the Waterfront Trail lies near the shoreline, with the lowest proximity being 20 meters.

Reach 2 – Reach 2 consist if a residential property shoreward of which consist an existing seawall which has been deemed to be in a poor state.

Reach 3 – Reach consists primarily of marshland, the Cranberry Marsh, with a sand and cobble barrier beach and a small sheet pile structure.

Reach 4 – The shoreline at the area consists of a narrow sandy beach backed by a bluff. The area at the top of the bluff consists of primarily trees and shrubs. The nearest man-made property is the Eastbourne Beach Road, north of which lies a few residential buildings, at the western side of the reach.

Reach 4a – Reach 4a consists of a baymouth bar at the outlet of the Lynde Creek. Along the bar consists of a few trees and shrubs.

Reach 5 – The area landward of the shoreline consists of wide-open spaces, trees and the Waterfront Trail. At its closest proximity, the waterfront trail is approximately 45 meters from the shoreline. The area immediately landward consists of trees.

Reach 6 – Reach 6 consists of a non-dynamic beach backed by a high bluff. Vegetation in the form of trees and shrubs are observed landward of the bluff. Further landward of the bluff are open spaces and the Gordon Street approximately 50-70 meters from the shoreline.

Reach 7 – Reach 7 is identical to Reach 5, with a shoreline protection structure and dense vegetation immediately landward of the shoreline. A trail has been observed near the shoreline.

Reach 8 – Reach 8 consists of a dynamic beach that is open to public for recreation purposes.

Reach 9 – On Reach 9, we can observe a sheet pile that extends from the Yacht club to the mouth of the harbour. To the west of reach 1, the area landward of the study area consists of the parking area for the Yacht club. Immediately shoreward of the study area, irregular armour stones are visible.

Reach 9a – This reach consists of a jetty made up of concrete and surrounded with sheetpile. The structure is approximately 12 meters wide throughout its length. This structure plays a role in reducing wave activity on the Whitby harbor and is thus of high value.

Reach 9b – This reach consists of a sole armourstone groyne that serves as a breakwater

Reach 10 – Reach 10 consists of the entire Whitby Harbor. Reach 10 consists of both artificial and natural shorelines. Artificial shoreline is prevalent in this reach and consists of the Whiby Yacht Club and Whitby Marina. Whitby Harbour has several contaminated sites and is currently being managed by Fisheries and Ocean Canada.

Reach 11 – Western part of Reach 11 consists of a cobble beach landward of which lies the Rotary Sunrise Park, Waterfront Trail and commercial buildings that are at close proximity to the beach. On the eastern side of the reach there is a dynamic beach landward of which lies the Kiwanis Heydenshore Park.

Reach 12 – Reach 12 consists of a beach backed by a steep bluff of 3 to 7 meters in height. Landward of the bluff lies the Gordon Richards Park and the Waterfront trail.

Reach 13 – Reach 13 has a shoreline landward of which lies residential buildings. The shoreline appears to have undergone significant scouring and there is a gabion basket at a particular location on the reach, but its long-term stability is questionable.

Reach 14 – Reach 14 has a shoreline landward of which lies the Crystal Beach Road and several residential buildings. This area is a cause for concern as the road is not too far from the existing shoreline although there appears to be shoreline protection works in the form of armour stones. Many of the armour stones have been dislodged and displaced.

Reach 15 – Reach 15 is a natural beach backed by bluff landward.

4.7 Source Water Protection

The Whitby study area is within the Central Lake Ontario Source Protection Area (CLOSPA), which is part of the CTC Source Protection Region. The CTC Source Protection Committee (SPC) is a multi-stakeholder committee represented by municipal, economic, and public interests. The Town of Whitby and Central Lake Ontario Conservation Authority (CLOCA) are part of the SPC. The SPC has legislated responsibilities to protect drinking water sources across the CTC Source Protection Region. The Ministry of the Environment approved the Source Water Protection (SWP) Assessment Report: Central Lake Ontario Source Protection Area in 2012.

This Assessment Report has identified the location and nature of threats to sources of municipal drinking water supplies. Any activities that are impacting, or could adversely impact, drinking water quality or quantity from groundwater and/or surface water sources are considered as threats. As part of the report, watershed characterization, water budget analysis (Tier 1, Tier 2 & Tier 3), water quantity and quality stress assessment, intake protection zone (IPZ1 & IPZ2), drinking water source vulnerability and drinking water threats assessment were completed. In the CLOSPA, there are three surface water intakes. One of the intakes is for Whitby Water Treatment Plant (WTP). IPZ1 of the Whitby WTP represents the area of 1km radius the intake point. This IPZ1 is generally considered the most vulnerable zone. IPZ2 is the area, both on land and in water, where a spill of a contaminant might reach the intake in 2-hours travel time. Based on the Assessment Report, the Whitby Class EA study area falls within the IPZ2. Even though, the Whitby IPZ1 and IPZ2 have high Vulnerability Scoring of 8, but after applying Vulnerability Factor of 0.5, both the zones have a low level of vulnerability. All the reaches of the Whitby Class EA study are in the IPZ2. However, because of the low level of vulnerability, any of the alternative options selected for the reaches will not be concern during their construction and implementation if proper erosion and sediment control measures are in-place. In addition to the IPZs, Whitby's coastline also contains areas designated as Highly Vulnerable Aquifers, score 6 (most reaches) and Events Based Areas for Pipeline Fuel/Oil spill (reach 4 and 4a). During detailed design, the Town will engage the local source protection authority to confirm that there are no source protection policies that apply to the activities of the project.

4.8 Groundwater/Hydrogeological Conditions

The Whitby Class EA study area covers three watersheds: Lynde Creek, Pringle Creek and Corbett Creek. The reaches in this study area are in the most downstream of the watersheds. According to the SWP Assessment Report, the study area reaches have mostly carbonate-derived silty to sandy till, interbedded flow till, silt and clay surficial geology. In the eastern section of the Whitby shoreline has Simcoe Group bedrock geology, and the western area of the shoreline has Blue Mountain formation. The study area physiography is consisting of the Iroquois Plan. According to Chapman and Putnam (1984), the Iroquois Plain in vicinity of the shoreline is characterized as a mosaic of drumlins to the north, and areas of silty lacustrine deposits. In the Whitby shoreline area, groundwater table depth (Scarborough aquifer) is very shallow (70m) compared to in other areas of the watersheds. Potential groundwater discharge areas are mostly located along the creeks and in the shoreline of Whitby Marine. The alternative options in this study will not obstruct groundwater flow in the shoreline as none of the options will require digging below 70m.

4.9 Excess and Contaminant Soil Management

During implementation of some of the alternative options of this study may require soil excavation. If the excavated soil, mainly during construction, may not be able to reuse at the construction site. That excavated soil will be considered as "excess soil". It might be possible temporarily store excess soil at another location and bring it back at the site where the soil was originally excavated. If excess soil cannot be reused at the site, it must be managed to maintain a healthy economy while protecting the environment. During construction, management and discharge of excess soil should follow the Environmental Protection Act, R.S.O 1990, c. E.19 (EPA), O. Reg. 406/19 and the MECP's guidance document "Management of Excess Soil – A Guide for Best Management Practices" (2014).

It is recommended that detailed design must prepare a plan for proper management of excess soil, which will ensure that the management does not result in the discharge of a contaminant soil into the natural environment that causes or may cause an adverse effect on the environment. If any the contaminated soil is found during construction, a comprehensive monitoring, maintenance, and mitigation plan will be developed to prevent any undesirable impacts and it will be in accordance with the provisions of the EPA and Ontario Regulation 153/04.

5. Task: Coastal Analysis: Analysis of Wind-Wave Environment

The Wave Information Studies (WIS) data collected by the United States Army Corps of Engineers (USACE) were used for the wind and wave frequency analysis at the project site. The site is closest to Lake Ontario WIS stations 91171 and 91172. Therefore, the data recorded between 1978 and 2014 at these two stations were used for this project. The shoreline at the project site is facing southeast. The majority of winds with higher wind speed is coming from the west, southwest, and northwest directions. Any wind-wave coming from the southwest direction will have the greatest influence on the property shoreline.

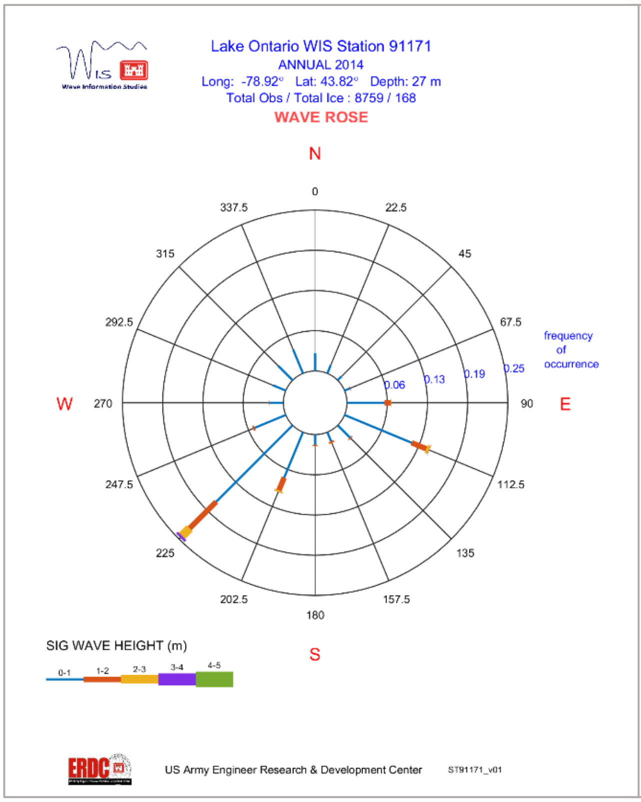


Figure 8: Wave Rose Graph for Significant Wave Height (USACE, 2017) for WIS 91171

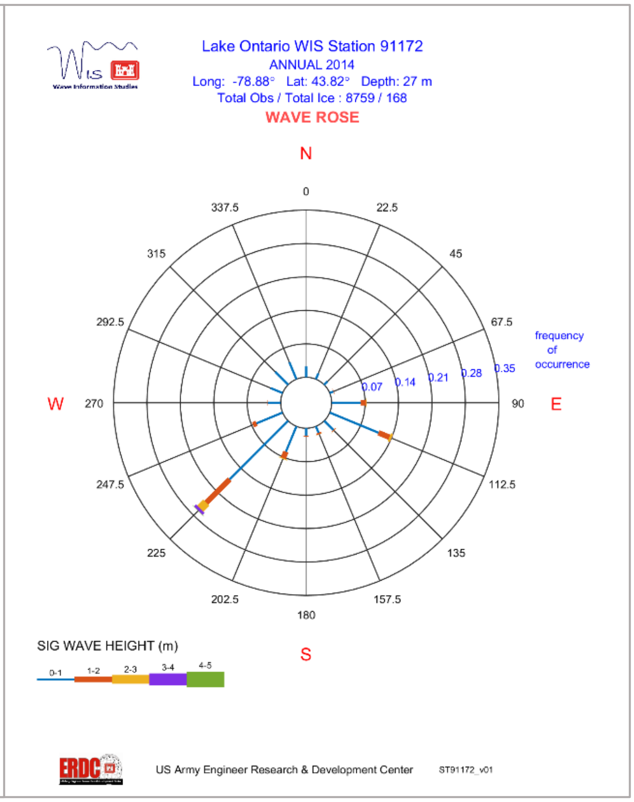


Figure 9: Wave Rose Graph for Significant Wave Height (USACE, 2017) for WIS 91172

Figure 8 illustrates the wave rose graph for WIS 91171 generated by the USACE WIS for the significant wave height from all directions. It is observed from Figure 8 that most of the waves are coming from the southwest and southeast directions, and a minority of waves come from all the other directions. For WIS 91172, it is observed from Figure 9 that most of the waves are coming from the southwest and southeast directions, and a minority of waves come from all the other directions. As mentioned earlier, the shoreline at the project site is facing southeast. Figure 10 and Figure 11 represent the wind rose graphs at the WIS stations 91171 and 91172 respectively. Most of winds with higher wind speed are coming

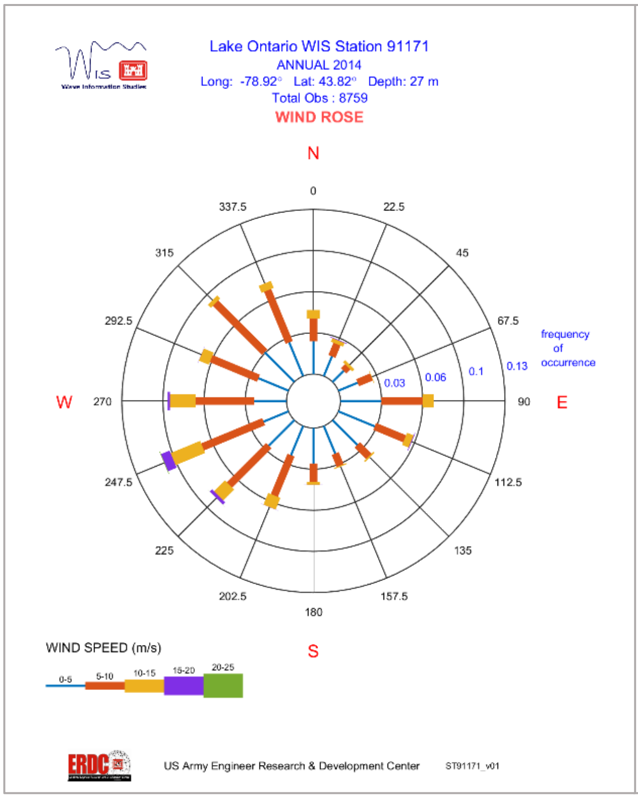


Figure 10: Wind Rose Graph for Wind Speed (USACE, 2017) for WIS 91171

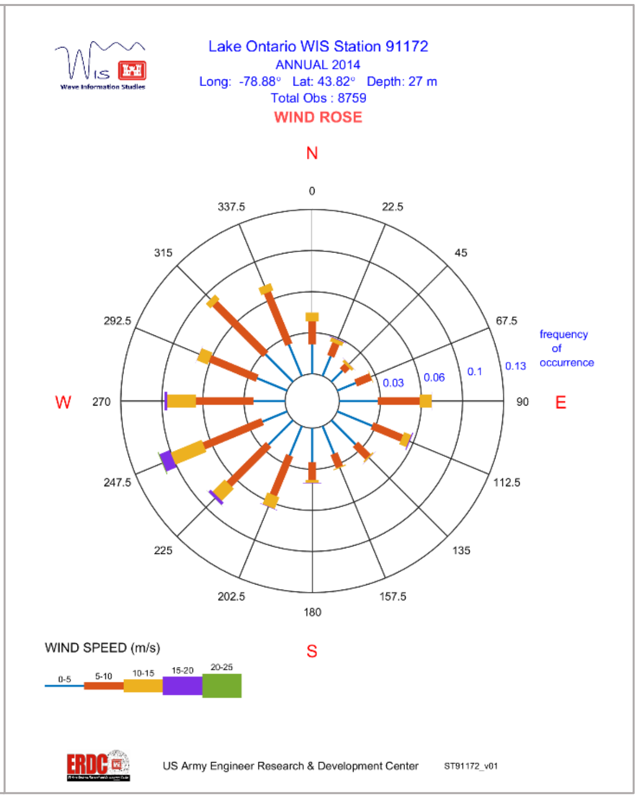


Figure 11: Wind Rose Graph for Wind Speed (USACE, 2017) for WIS 91172

from the west, southwest, and northwest directions. Any wind-wave coming from the southeast direction will have the greatest influence on the study area shoreline.

AHYDTECH performed frequency analysis on 37 years of wind-wave data collected from Lake Ontario WIS stations 91171 and 91172. From the frequency analysis, wind speed and significant wave height for return periods 10, 20 and 25 years were obtained. It can be seen from Table 3 and Table 4 that there are 9 direction categories including a single category representing the wind-wave characteristics from all directions and eight (8) individual direction categories. The raw data from WIS has specific degree angles measured from true north rather than just stating the direction range. However, for the analysis in this study, eight (8) direction categories were adopted. The direction categories were formed by dividing the 360-degree angle into eight equal angles by eight lines from the center, starting from the true north. Then the degree angles within the ±22.5 degree range from the true north were considered to be the north direction. All other directions were categorized in a similar way. The maximum annual wind and wave data were categorized in eight different directions and all directions were obtained by inputting the raw data into a programming code. There are 37 years of data available. Each of the processed data sets for all direction categories were ranked from smallest to largest and further distributed to 100 years with a frequency analysis tool. Finally, wind speed and significant wave height for 50- and 100-year return periods were calculated.

Table 3: Wind Speed Frequency Analysis-WIS 91171

Wind Speed Frequency Analysis			
Wind Speed (m/s)			
Return Period	10	20	25
All Directions	18.91	20.16	20.57
N	13.61	15.25	15.78
NE	13.93	15.51	16.01
E	16.12	17.52	17.97
SE	13.66	15.14	15.62
S	13.63	14.66	15
SW	17.73	19.25	19.74
W	17.37	18.58	18.97
NW	16.11	17.26	17.62

Table 4: Significant Wave Height Frequency Analysis-WIS 91171

Significant Wave Height Frequency Analysis						
Return Period	10		20		25	
	HMO(m)	TP(s)	HMO(m)	TP(s)	HMO(m)	TP(s)
All Directions	3.62	8.33	4.05	8.91	4.19	8.34
N	0.86	3.18	1.03	3.16	1.09	3.37
NE	0.84	4.61	1.06	4.98	1.14	6.1
E	3.16	7.59	3.63	7.86	3.79	8.17
SE	1.93	5.25	2.22	5.42	2.32	6.89
S	2.37	5.09	2.6	5.45	2.67	6.8
SW	3.3	7.65	3.74	8.03	3.88	8.3
W	1.45	5.75	1.6	5.14	1.65	4.03
NW	1.04	3.3	1.17	3.44	1.21	3.57

Table 5: Wind Speed Frequency Analysis-WIS 91172

Wind Speed Frequency Analysis			
Wind Speed (m/s)			
Return Period	10	20	25
All Directions	19.18	20.46	20.87
N	13.76	15.4	15.93
NE	14.16	15.75	16.27
E	16.37	17.77	18.23
SE	13.87	15.37	15.85
S	13.76	14.79	15.12
SW	18.04	19.55	20.03
W	17.66	18.87	19.26
NW	16.34	17.48	17.85

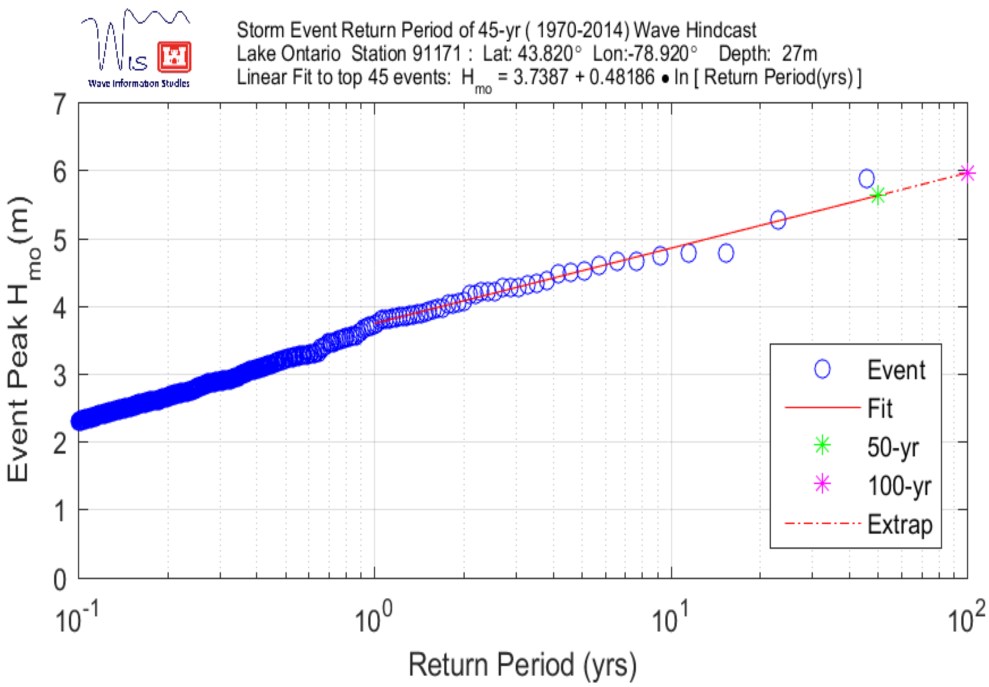
Table 6: Significant Wave Height Frequency Analysis-WIS 91172

Significant Wave Height Frequency Analysis						
Return Period	10		20		25	
	HMO(m)	TP(s)	HMO(m)	TP(s)	HMO(m)	TP(s)
All Directions	3.75	8.13	4.2	8.3	4.34	8.61
N	0.9	3.14	1.08	3.26	1.14	3.34
NE	0.89	4.26	1.13	5.42	1.21	4.76
E	3.22	7.57	3.69	7.52	3.84	8.13
SE	1.99	5.25	2.3	5.43	2.4	5.92
S	2.38	6.14	2.59	6.25	2.66	5.65
SW	3.48	7.66	3.94	8.11	4.08	8.16
W	1.66	6.06	1.83	5.85	1.89	5.92
NW	1.12	3.47	1.28	3.66	1.33	3.73

Generalized extreme value distribution (Table 7) exhibits values that were very close to the values predicted by USACE for WIS 91171. Figure 12 illustrates Frequency Analysis of Wave Hindcast (WIS 91171).

Table 7: Generalized Extreme Value Distribution for WIS 91171

Distribution	2-yr	5-yr	10-yr	20-yr	50-yr	100-yr
Generalized Extreme Value	4.36	4.67	4.93	5.23	5.71	6.16



Top 10 events based on Peak H_{mo}

Event	Date/Time(UTC)	H_{mo}	T_p	θ_{mean}	Event	Date/Time(UTC)	H_{mo}	T_p	θ_{mean}
1	1978/01/26 23:00	5.88	9.52	217.0	6	1990/12/03 19:00	4.65	8.76	107.0
2	2012/03/03 12:00	5.26	9.24	214.0	7	1972/01/17 17:00	4.65	8.39	213.0
3	1977/12/06 04:00	4.77	9.17	107.0	8	1982/01/11 09:00	4.60	8.84	219.0
4	1977/12/06 04:00	4.77	9.17	107.0	9	1987/12/15 16:00	4.52	8.25	110.0
5	1972/01/25 16:00	4.74	8.50	220.0	10	1982/01/05 03:00	4.50	8.60	219.0

An event is defined as any period when $H_{mo} > 2.00$m θ_{mean} is direction that waves are arriving from

ERDC US Army Engineer Research & Development Center ST91171_v01

Figure 12: Frequency Analysis of Wave Hindcast (WIS 91171)

6. Task: Wave Uprush and Flood Frequency Analysis

In order to define safe or acceptable design height for coastal structures, traditional theories and methods are applied for estimating wave run-up and overtopping a slope. The information about wave uprush for a structure near coastal shoreline is important in order to provide a safe setback and clearance distance from the shoreline. Most of the theories have been applied for natural beach slope, which use offshore deep-water wind-wave conditions. A wave uprush computation applies deep water wave parameters, significant wave height and wave period, and local shoreline geometry. Shoaling of deep-water waves have destructive force because of wave breaking and energy dissipation on the shoreline structures.

The primary controlling factors for the wave uprush are still water level (SWL), incident wave climate (wave height, H, and wave period, T); slope of beach or protection work (tan α); slope of lake bottom (tan α); water depth at toe of the protection work or beach (d);

surface roughness (r), and protection work permeability (P). Other factors that may also impact the magnitude of the wave uprush includes bathymetry (e.g., offshore bars and composite slopes), berms in front of protection works, and oblique wave attack. The wave uprush can also be affected by the ice cover of the shore. The ice covers turn the rough permeable slope into a smooth impermeable slope, which limits the depth of water, hence limiting the wave action.

AHYDTECH has followed the MNR Technical Guidelines (2001) and available coastal engineering practices for the wave uprush analysis. AHYDTECH has analyzed several wave uprush computation methods, which are applicable in Crystal Beach, Whitby Harbor, Eastbourne bluffs, beach and any existing public/private lands and infrastructure along the Town's waterfront. These methods are U.S. Army Corps of Engineers (1990), Upper Limit Method (MNR, 2001), Ahrens and Heimbaugh (1988a) and Cox and Machemehl (1986). Most of these methods were presented and discussed in the MNR Technical Guidelines (2001).

The artificial shoreline in the study area has concrete walls, armor stone revetments, concrete block walls, and sheet piling including the Whitby harbor. As suggested by the MNR Technical Guidelines (2001), this study has applied U.S. Army Corps of Engineers (ACES, 1990) and Upper Limit Method (MNR, 2001) methods to estimate wave uprush for the shoreline structures in the study area. The U.S. Army Corps of Engineers (ACES, 1990) method has been widely used to predict the wave uprush. The Coastal Engineering Research Center (U.S. Army Corps of Engineers 1990) developed the software package Automated Coastal Engineering System (ACES).

For four different cross shore profiles, AHYDTECH has computed wave uprush for 10- and 20-year return period. The wave uprush calculation has used IGLD85 as a vertical datum. This study has applied three types of shoreline structures for wave uprush calculation:

I) Natural Shoreline

II) Vertical Wall

III) Slope Revetment

In Table 8-11 present wave uprush results of the four profiles and three shoreline structures.

Table 8: 10 Year Wave Uprush of Natural Shoreline (Reach 04)

10 YEAR WAVE UPRUSH

10 YEAR WAVE UPRUSH

METHOD	PROFILE # 1	PROFILE # 2
Hunt (1959)	0.53	0.56
Battjes (1974) & Lorang (2000)	0.28	0.29
Maximum Wave Uprush (m)	0.53	0.56
Maximum Wave Uprush Elevation (m)	76.53	76.56

Table 9: 20 Year Wave Uprush of Natural Shoreline (Reach 04)

20 YEAR WAVE UPRUSH

20 YEAR WAVE UPRUSH

METHOD	PROFILE # 1	PROFILE # 2
Hunt (1959)	0.59	0.61
Battjes (1974) & Lorang (2000)	0.31	0.32
Maximum Wave Uprush (m)	0.59	0.61
Maximum Wave Uprush Elevation (m)	76.59	76.61

Table 10: Wave Uprush of Vertical Wall (Reach 09)

	Wave Uprush (m)		
METHOD	10 Year	20 Year	MEAN
ACES (USACE 1990) & Goda (1985)	2.45	2.78	2.62
Upper Limit Method (MNR, 2001)	2.46	2.56	2.51
AVERAGE WAVE UPRUSH (m)	2.46	2.67	2.56

Table 11: Wave Uprush of Slope Revetment (Reach 14)

	PROFILE # 1 WAVE UPRUSH (m)			PROFILE #2 WAVE UPRUSH (m)		
METHOD	10 Year	20 Year	MEAN	10 Year	20 Year	MEAN
Ahrens and Heimbaugh (1988a) & Goda (1985)	2.01	2.3	2.16	2.58	2.56	2.57
AVERAGE WAVE UPRUSH (m)	2.01	2.3	2.16	2.58	2.56	2.57

It can be observed that Reach 04 has average ground elevation is approximately 77m above the datum, but the maximum wave uprush height in this reach is 76.61m. This reach has comparatively less risk of flooding due to wave uprush. For Reach 09 design height of wave uprush is 2.56m which is the average of 2.46m and 2.67m. Again, for Reach 14 design wave uprush height is 2.57m which is the average of 2.58m and 2.56m. Coastal flooding height is determined by adding 100 year lake water level with 20 year wave uprush .For example in Reach 09 (Vertical wall) coastal flood height is 78.56m (100 year lake water level 76.0m plus 20 year wave uprush 2.56m).In Reach 14 coastal flood height is about 2.57m.

7. Task: Shoreline Recession & Erosion Hazard

AHYDTECH reviewed the technical assumptions, such as average annual shoreline recession rates, modelling parameters from the 1990 study to determine whether they are still appropriate for use today.

The hazard limit of the Great Lakes - St. Lawrence River system is defined by the combination of flooding, erosion, and dynamic beach hazards along a shoreline. The erosion hazard is determined from both shoreline erosion and slope stability analyses. The predicted long-term stable slope projected from the existing stable toe of the slope or from the predicted location of the toe of the slope as that location may have shifted as a result of shoreline erosion over a 100-year period.

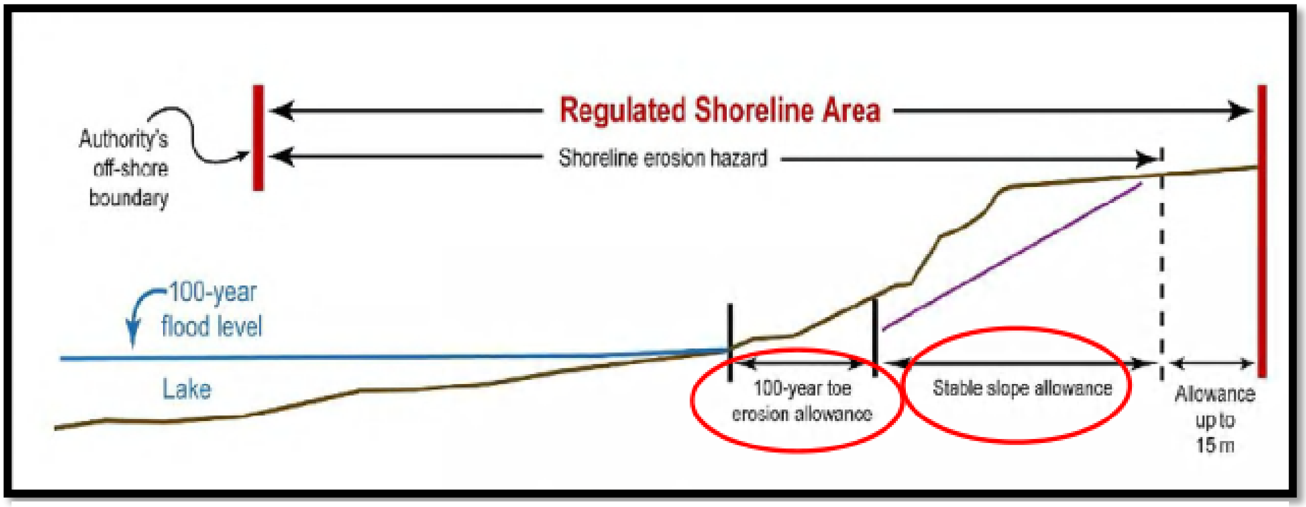


Figure 13: Erosion Hazard limit for Great Lakes (LOSMPU 2019 PPT)

AHYDTECH has performed field investigation as well as desktop analysis following both the MNR and CLOCA guidelines and regulations. According to the “Understanding Natural Hazards Great Lakes – St. Lawrence River System and Large Inland Lakes, River and Stream Systems Hazardous Sites” introductory guideline (MNR, 2001), the erosion hazard is determined by the stable slope allowance plus the erosion allowance. AHYDTECH staff have visited sites for coastal data collection and shoreline assessment. Visual and aerial shoreline characteristics assessment were performed during the site visits. AHYDTECH has performed coastal engineering analysis to determine the flooding and erosion hazard limits. This study has applied the following guidelines and reports to determine the hazard limits:

1) The MNR Great Lakes-St. Lawrence River System and Large Inland Lakes Technical Guideline (2001);
2) Provincial Policy Statement (i.e., the Natural Hazard Policy 3.1);
3) Regulatory Flood Levels – North Shore of Hamilton Harbour, Hamilton Region Conservation Authority, prepared by Beak Consultants Ltd. (1993);
4) Policies and Guidelines for the Administration of Ontario Regulation 162/06 and Land Use Planning Policy Document, Conservation Halton (2006);
5) Living on the Lake - Lake Ontario Erosion Hazards in relation to Ontario Regulation 162/06.

The Technical Guide for Great Lakes – St. Lawrence River Shoreline recommends measuring and surveying a representative cross-profile, and to estimate the amount and rate of erosion measurement in linear and volumetric terms.

This study sought to find the trend of shoreline changes, and the factors attributed to the changes. Aerial photographs and satellite images of 2005, 2009, 2013, 2016, and 2018 were used to digitize the shoreline. The Digital Shoreline Analysis System (DSAS) in ArcGIS environment was used to create transects and perform statistical analyses for the shoreline. The Digital Shoreline Analysis System (DSAS) computes rate-of-change statistics from multiple historic shoreline positions existing in a GIS database.

A geo-database was created in ArcGIS for the digitized shoreline positions with attribute tables for all shorelines which contained- year, ID, shape and uncertainty. The historical change in shoreline was analyzed using DSAS. The 13.5 km long shoreline (Figure 16) was divided in-to 536 transects with 25-meter spacing in order to calculate the change rates. Three statistical methods were used to calculate the change in rates of shoreline from 2005-2018.

The methods were **End Point Rate (EPR) (Figure 14), Weighted Linear Regression (LRR) (Figure 15), and Linear Weighted Regression (WLR) (Figure 16)**. In DSAS work flow the EPR is calculated by dividing the distance of shoreline movement by the time elapsed between the oldest and the most recent shoreline.

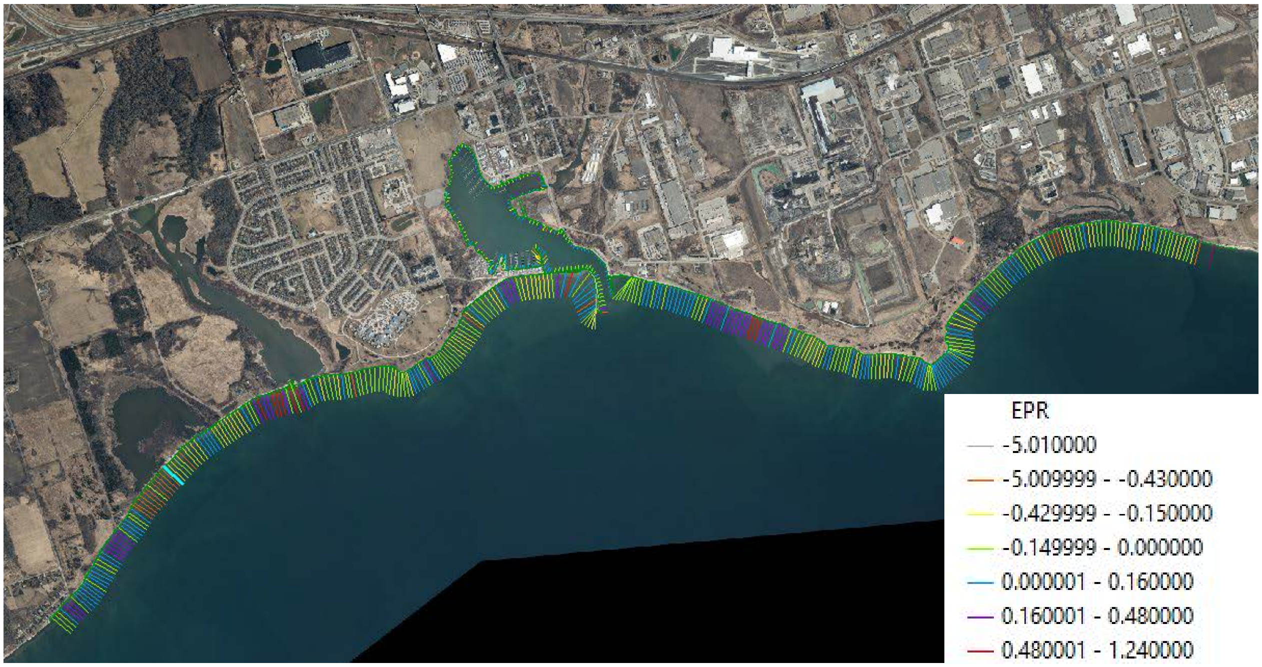


Figure 14: Rate of shoreline change (EPR m/year) along the shore from 2005-2018 (all negative signs show erosion, whereas the positive shows accretion)

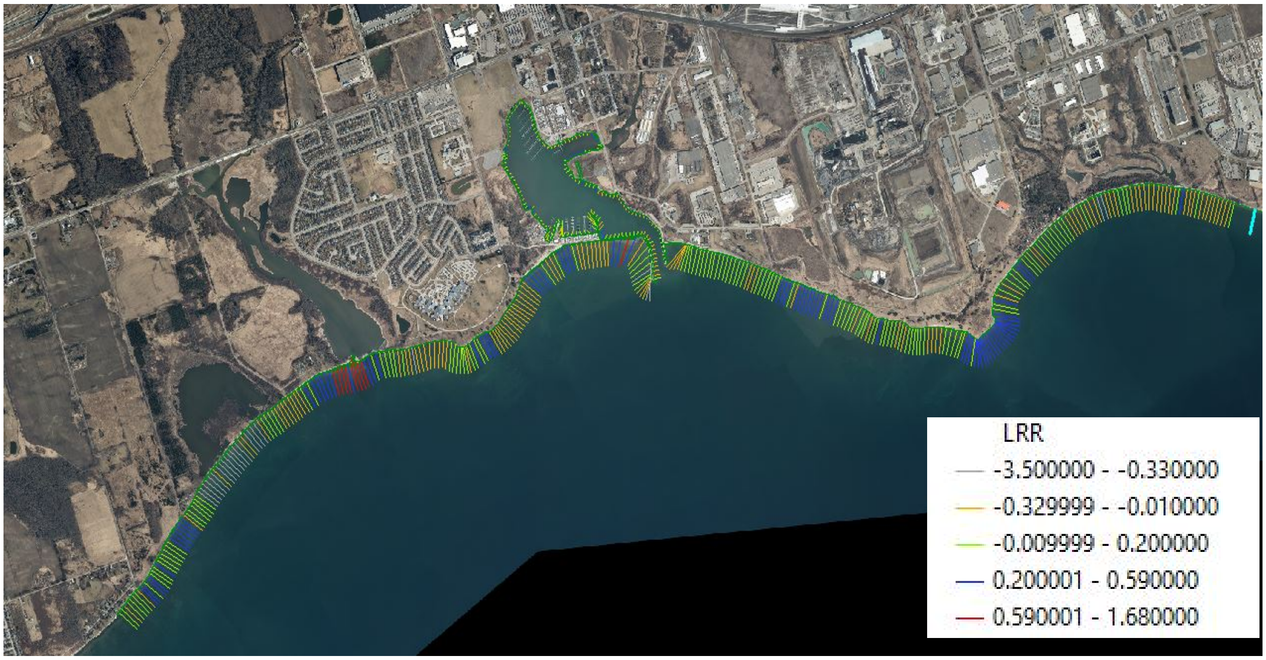


Figure 15: Rate of shoreline change (LRR m/year) along the shore from 2005-2018 (all negative signs show erosion, whereas the positive shows accretion)

Figure 16: Rate of shoreline change (WLR m/year) along the shore from 2005-2018(all negative signs show erosion, whereas the positive shows accretion)

The uncertainty field of the shoreline feature Class is used to calculate a weight. In conjunction with weighted linear regression rate, standard error of the estimate (WSE), standard error of slope with user selected confidence interval (WCI), and R-squared value (WR2) are obtained. The error or uncertainty that comes from different sources of data were calculated based on several studies. Three main sources of errors Identified were; image resolution error (R), geo-referencing error (G), and a physical component of the error or shoreline proxy (D). Fletcher et al (2012), suggested the inclusion of digitization error, hence this variable was included in the following formula:

$$Ep=\sqrt{(G^{2+}R^{2+}D^{2+}Ed^{2})}$$

Where

Ep=Uncertainty
G= Geo-referencing error,
R= Image resolution error,
D= Shoreline proxy error,
Ed= Digitization error

Using the above formula, the uncertainty corresponding to each individual image was ±1.5 m and ±1.5 m for the aerial photographs and satellite image respectively. The shoreline analysis for the period 2005-2018 revealed that most of the beach front underwent erosion with accretion observed in small patches. The WLR shoreline analysis for the beachfront showed a mean of -0.35 m/year where 37.3 percent of transects fall under erosion and 62.7

percent fall under accretion. Table 12 illustrates recession rates for different reaches in the study area.

Table 12: Recession Rate (m/Year)

REACH NO	RECESSION RATE(m/Year)					Average
	Transect ID	2005-2009	2009-2013	2013-2015	2015-2018	2005-2018
1	1-30	0.14	0.37	0.39	-1.28	-0.04
2	31-36	-0.28	0.59	-0.69	-0.25	-0.05
3	37-67	0.04	-0.07	-0.48	-1.37	-0.40
4	68-85	0.29	1.05	1.84	-3.48	-0.16
4A	86-97	-0.03	1.28	1.14	-3.73	-0.34
5	98-109	-0.31	0.03	-0.11	-0.50	-0.22
6	110-123	-0.32	0.62	0.24	-1.57	-0.24
7	124-139	-0.18	0.28	-0.60	-0.73	-0.22
8	140-151	-0.20	0.39	1.00	-2.25	-0.34
9	152-190	-0.08	0.54	0.36	-1.51	-0.16
9A		-0.05	0.10	-0.32	0.46	0.09
9B		-0.25	-0.52	-0.53	-0.31	-0.38
10	191-354	0.07	0.18	-0.20	-0.64	-0.06
11	355-376	-0.32	0.49	0.02	-1.61	-0.30
12	377-470	-0.12	0.72	0.27	-1.46	-0.22
13	471-484	-0.42	0.62	0.56	-1.68	-0.22
14	485-490	-0.51	0.15	0.07	-0.13	-0.23
15	491-523	-0.31	0.28	-0.98	-1.41	-0.40
	AVERAGE	-0.16	0.40	0.11	-1.30	-0.22

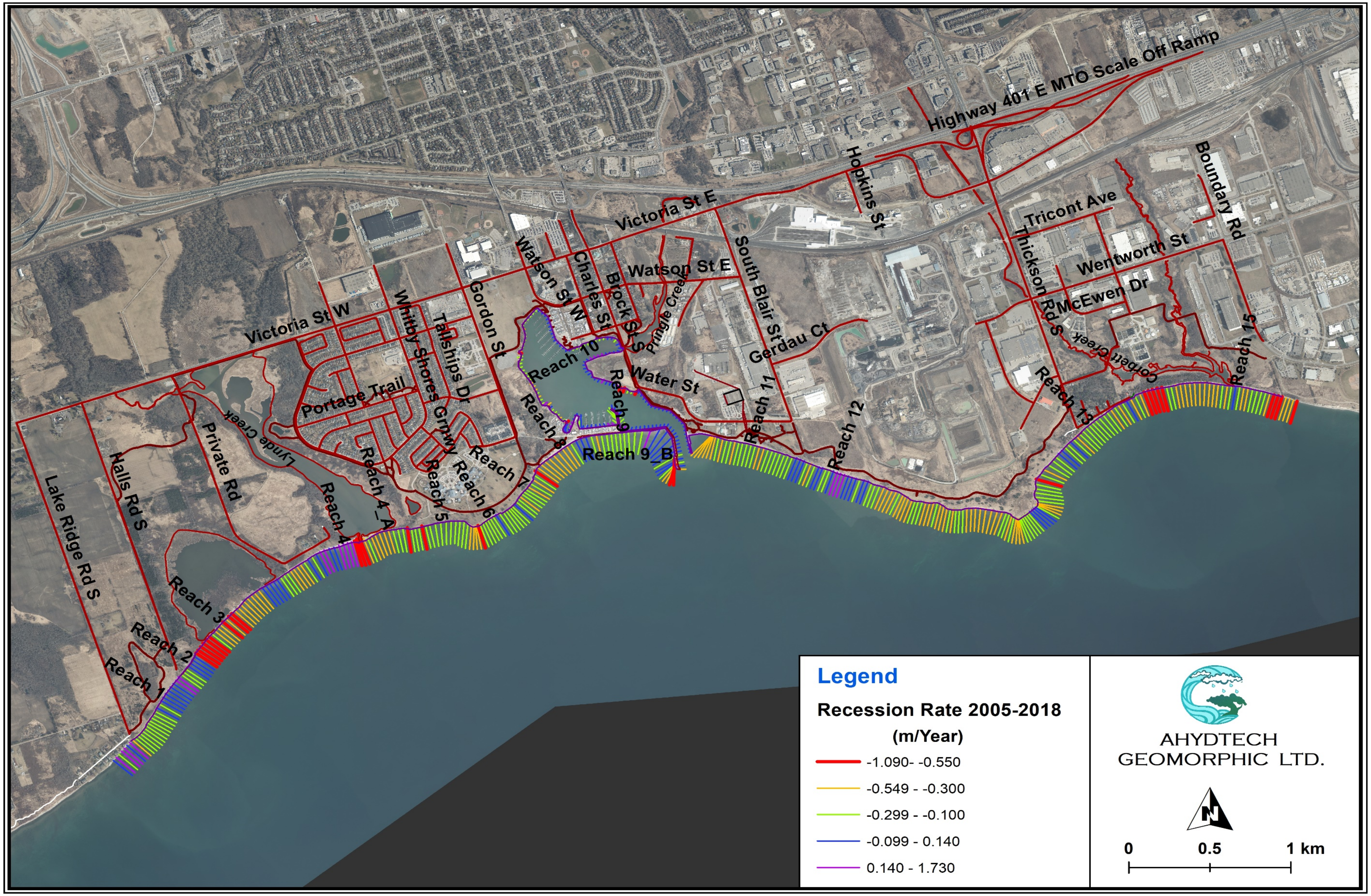


Figure 17: Recession Rate at different Reaches

According to the Lake Ontario Integrated Shoreline Strategy (LOISS) Background review and data gap analysis, the conventional Shoreline Recession Rates for Lake Ontario ranges between 0.1 m/year and 0.3 m/year. A rate of 0.3 m/year is the provincial default for all the Great Lakes. The obtained results fall in this range.

8. Task: Coastal 2D Wind-Wave Model

AHYDTECH has developed a 2D hydrodynamic and circulation model using SMS and ADCIRC software for the shoreline of Lake Ontario along the Town of Whitby. The current output from this circulation model was then used as input dataset for the 2D wave spectral model STWAVE. A diagram showing the 2D modeling approach for this study has been shown in Figure 18. Both the models used wind driven climate force to simulate wave refraction, diffraction, circulation, flow field and wave parameters. AHYDTECH has developed the models for the study area using the shoreline characterization, topography, and bathymetry and shoreline structure data collected in the previous tasks. This study has used wind and wave data from Lake Ontario WIS Station 91172 and 91171.

The models computed flow fields and wave parameters were used to analyze the alternative options to solve the erosion and flooding issues and to do risk and vulnerable assessment of the preferred alternative/alternatives. AHYDTECH has used 10, 25, 50 and 100-year instantaneous flood levels including wave setup and wave uprush to determine flooding and overtopping. The mouths of Pringle and Lynde creeks were included in the 2D models to determine extent of the flooding areas at the mouths.

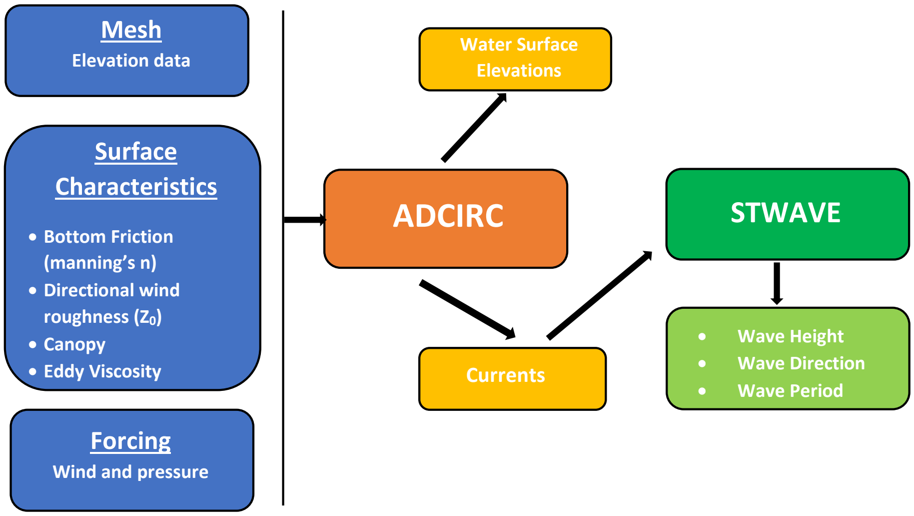


Figure 18: Modeling Schematic for ADCIRC and STWAVE

8.1 Introduction to ADCIRC Modeling

The SMS is a pre- and postprocessor developed for operating various numerical hydrodynamic models. ADCIRC is an extensively validated and commonly used wind-wave circulation model which solves shallow water equations on unstructured, linear and triangular elements. This regional two-dimensional (2-D) depth-integrated, finite-element hydrodynamic circulation model, was applied in this study to provide water level and depth averaged current (circulation) information for Town of Whitby. The depth-integrated implementation is used, where the water level and depth-averaged velocity are solved for at each triangle vertex, referred to as nodes (ARCADIS U.S., Inc., 2013).

8.2 Input files for ADCIRC Modeling

In order to describe the region of interest and its characteristics, boundary conditions and forcing mechanisms (e.g., wind fields), input files are required. The critical inputs used for this study are the computational mesh, surface characteristics file, and meteorological forcing file (wind and pressure fields). The required input files for running the ADCIRC model are explained below:

1. **ADCIRC Grid and Boundary Information File (fort.14)** - An ADCIRC model grid was developed in the course of this modeling initiative. The grid was a large semi-circular grid centered on the Whitby region and exerted from the central point approximately 11 km to both left and right. The grid was extended 10 km towards offshore from the center. The nearshore grid size was selected to be 10 m and the size increased with the distance from the shore. The ADCIRC mesh shown in Figure 19 contains 32492 conceptual nodes with 62517 elements. The ADCIRC model solves the shallow water equations at those conceptual nodes which communicate with each other via linear triangular finite elements.
   An elevation dataset was prepared by merging the data collected by bathymetric surveying of the Whitby shoreline, DTM data set and bathymetry data (x,y,z) of the Western Lake Ontario. The Zone 17, NAD83 horizontal datum projection format was used to prepare this elevation data set. Considering the 100-year lake water level to be 76 m, this value was subtracted from the elevation data set to create the water depth data set. Later, the water depth data set was interpolated to the ADCIRC mesh.

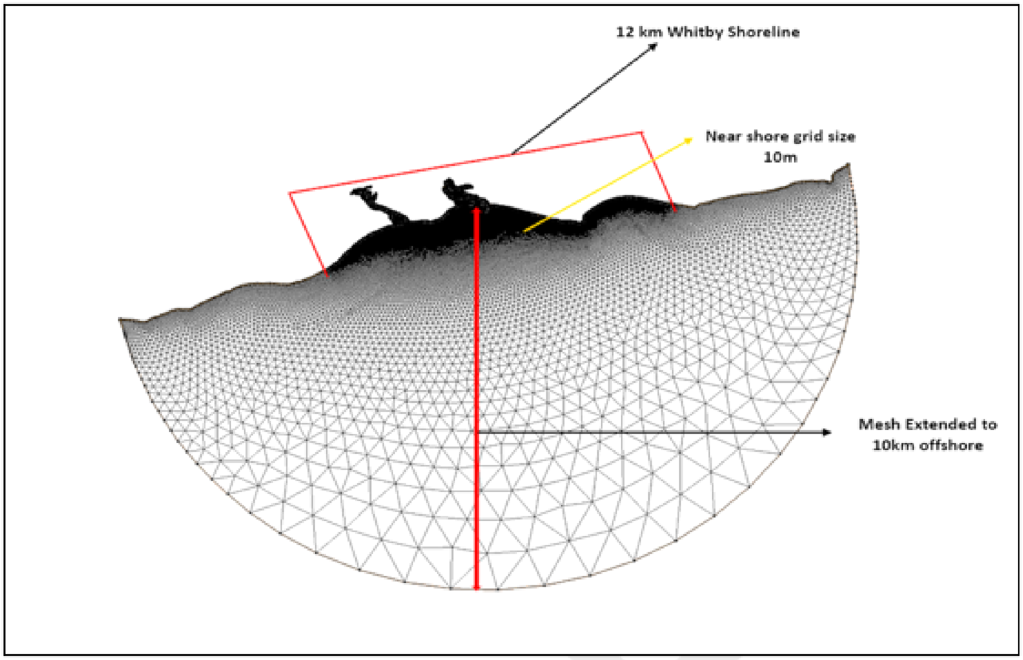


Figure 19: Mesh for 2D Hydrodynamic Wind-Wave Model ADCIRC

2. **Model Parameter and Periodic Boundary Condition File (fort.15)** - Considering no tidal effect in Western Lake Ontario, a closed boundary was assigned surrounding the model domain as shown in Figure 19.

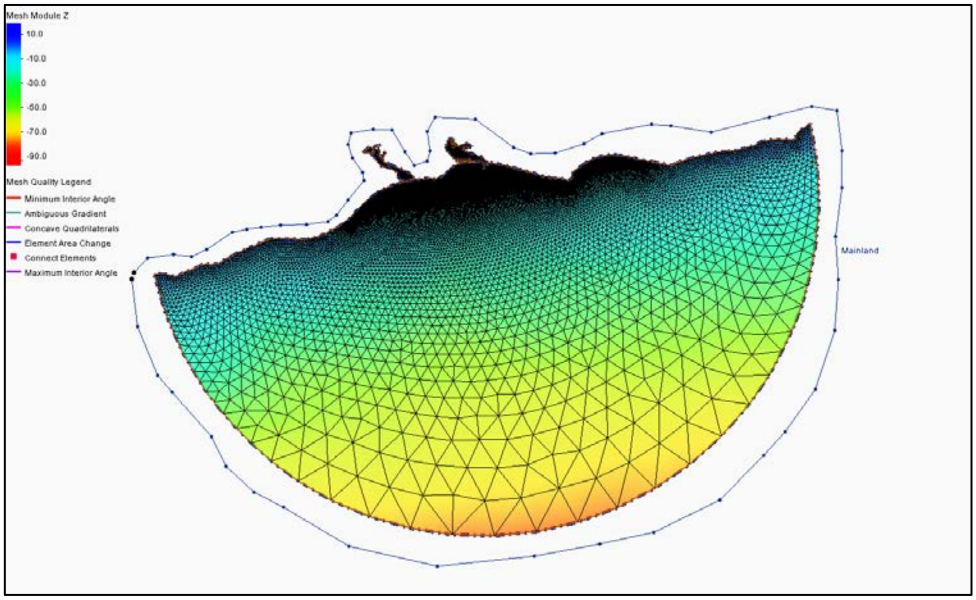


Figure 20: Assigning model Boundary condition

In order to run the ADCIRC model, certain parameters were used as shown in Table 13-

Table 13:Model Control Parameters of ADCIRC

Name of Parameter	Value
Quadratic Bottom friction- CF	0.0025
Minimum angle for tangential flow	110
Finite amplitude terms	With wetting/ drying
Minimum depth (m)	0.05
Minimum Velocity (m/s)	0.05
Weighting factor- TAU0	0.005
Time weighing factor, k+1	0.35
Time weighing factor, k	0.3
Time weighing factor, k-1	0.35
Time step (seconds)	1
Length of run (days)	1
General Ramp (days)	0.5
Node Wind Stress (NWS) value	5- Velocity/ Pressure- every node/time interval

The NWS Parameter controls whether wind velocity or stress, wave radiation stress and atmospheric pressure are used to force ADCIRC. When the NWS parameter is set to 5, wind velocity and atmospheric pressure are read in at all grid nodes from the Single File Meteorological Forcing Input File. Garret's formula is used to compute wind stress from wind velocity.

3. **Meteorological Forcing Data (fort.22)** - A single meteorological input file (wind velocity and atmospheric pressure) is read when meteorological forcing has been indicated by the NWS parameter in the fort.15 file.

The ADCIRC model for the Town of Whitby shoreline was intended to run for steady state wind speed condition. For this purpose, a vector data set for wind speed and a data set for constant atmospheric pressure were created using the Scatter Module in SMS. The Wave Information Studies (WIS) data collected by the United States Army Corps of Engineers (USACE) were used for the wind speed frequency analysis at the project site. The site is closest to Lake Ontario WIS station 91172 and 91171. Therefore, the data recorded between 1979 and 2014 at this station were used for this project. The shoreline at the project site is facing southeast. The majority of winds and higher wind speed are coming from the west, southwest, and northwest directions. Any wind-wave coming from the southwest direction will have the greatest influence on the property shoreline.

A frequency analysis for the wind speed was conducted and analyzed using the WIS data. There are 44 years of data available. This data was used to determine the 10, 25, 50- and 100-year return period of wind speed for both stations. However, higher values (station 91172) were used to run the model as shown in Table 14.

Table 14: Wind speed frequency analysis results for WIS station 91172 (south-west)

Return Period (years)	Wind speed Magnitude (m/s)	Wind speed Direction (degree)
10	18.04	225
25	20.03	225
50	23.7	225
100	24.2	225

The wind speed and direction data set were interpolated to the ADCIRC mesh and converted into wind speed vector data set (Figure 20). A constant atmospheric pressure data set was created using the value 10.3325 (1 atmosphere in meters of H2O) and interpolated to the ADCIRC mesh. Both the wind and pressure data sets were converted to transient data that span 1 day having 5 identical time steps (each time step is 6 hours apart) before being interpolated to the mesh.

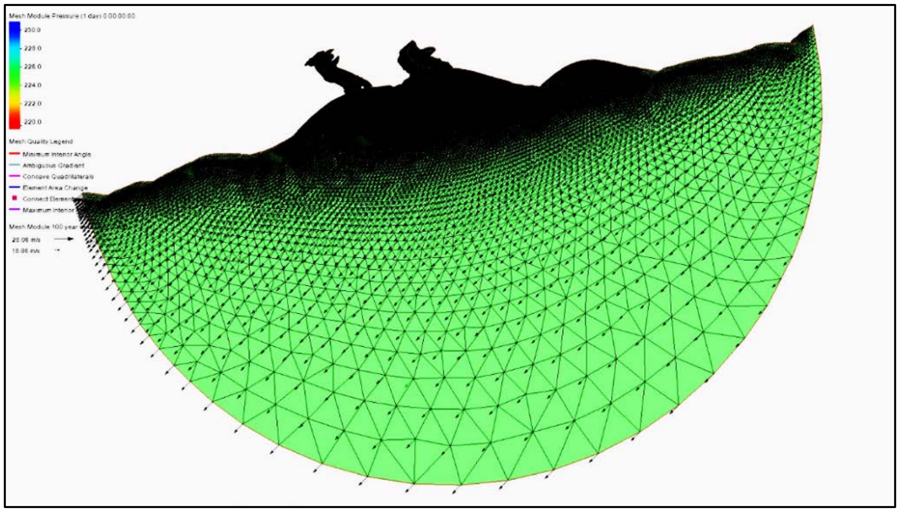


Figure 21: Wind Velocity vector interpolated at every node of ADCIRC mesh

8.3 Output Files for ADCIRC Modeling

ADCIRC model was run for 10, 25, 50 and 100-year return period wind, and the following outputs were generated:

1. **General Diagnostic Output (fort.16):** This file echo prints information from the Grid and Boundary Information File, the Model Parameter and Periodic Boundary Condition File, provides some processed information and prints out error messages from ADCIRC.

2. **Iterative solver ITPACKV 2D diagnostic output file (fort.33):** Diagnostic output from the ITPACKV 2D solver is written to this file if the solver encounters difficulty converging.

3. **Elevation Time Series at All Nodes in the Model Grid (fort.63):** This file includes elevation time series output at all nodes in the model grid as specified in the Model Parameter and Periodic Boundary Condition File.

4. **Depth-averaged Velocity Time Series at All Nodes in the Model Grid (fort.64):** This file contains depth-averaged velocity time series output at all nodes in the model grid as specified in the Model Parameter and Periodic Boundary Condition File.

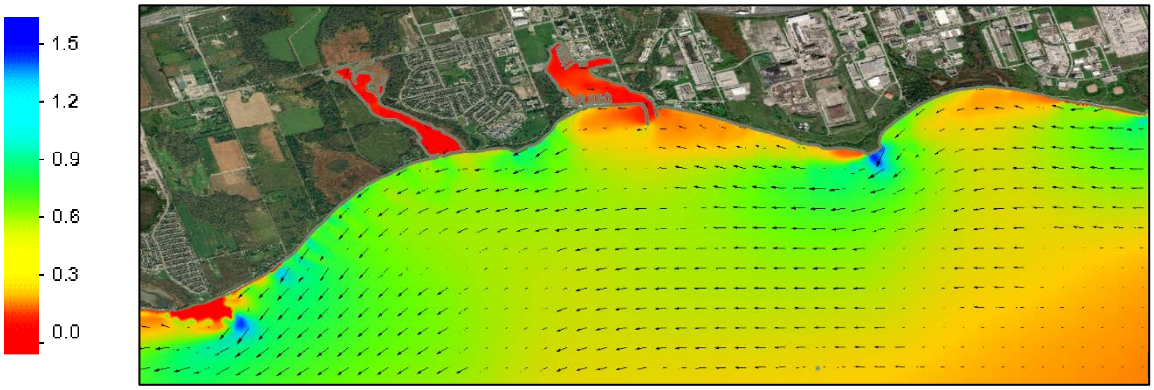


Figure 22: Current near the Whitby Shoreline for 100-Year Return Period of Wind

Figure 22 represents the scenario of current near the shoreline of Whitby. It is observed that current near Reach 12 is much higher than that of other reaches. It is also observed that current inside the Whitby Harbor is almost negligible.

5. **Hot Start Files (fort.67, fort.68)**: One of these files is used to restart the model. Restart output is written to fort.67 and fort.68 on an alternating basis so that if the computer crashes in the process of writing one of these files, the other will be unaffected and can be used to restart the model.

6. **Global Maximum and Minimum files for the Model Run (maxele.63, maxvel.63, maxwvel.63, minpr.63):** These input/output files were developed to resolve issues where only the most extreme values at each node in the domain were required, e.g., peak water levels throughout the domain.

8.4 Summary of ADCIRC Modeling

In order to get accurate results of wave height and peak periods in each individual reach, value of wave velocity in each node of the STWAVE grid is required. From the ADCIRC modeling, wind generated wave current was obtained in the model domain. It was observed from the results that current near Reach 12 is the highest compared to other the reaches, and current inside the Whitby Harbor is almost negligible. Maximum velocity in the model domain is approximately 1.5m/s.

9. Steady-state spectral wave model

Wave parameters such as wave height and peak period were generated using steady-state spectral wave model. AHYDTECH has used STWAVE software for this task. The model used the current values generated from the ADCIRC model described in the previous section. AHYDTECH has used 10, 25, 50 and 100-year return period flood level, offshore wave height and wave period to generate the near-shore wave parameters along the Whitby shoreline.

9.1 Introduction to STWAVE Modeling

STWAVE simulates depth-induced wave refraction and shoaling, current induced refraction and shoaling, depth and steepness-induced wave breaking, diffraction, wave growth because of wind input, and wave-wave interaction and white capping that redistribute and dissipate energy in a growing wave field. STWAVE is a halfplane model, meaning that wave energy can propagate only from the offshore toward the nearshore (±87.5 deg from the x axis of the grid, which is typically the approximate shore-normal direction). The input spectrum in STWAVE is constant along the offshore boundary. For wave generation, the steady-state assumption means that the winds have remained steady sufficiently long for the waves to attain fetch-limited or fully developed conditions (waves are not limited by the duration of the winds). Bottom friction is neglected in STWAVE.

STWAVE input and output are illustrated in Figure 22. All STWAVE input files has been generated using SMS for the shoreline of Lake Ontario covering the Town of Whitby study area.

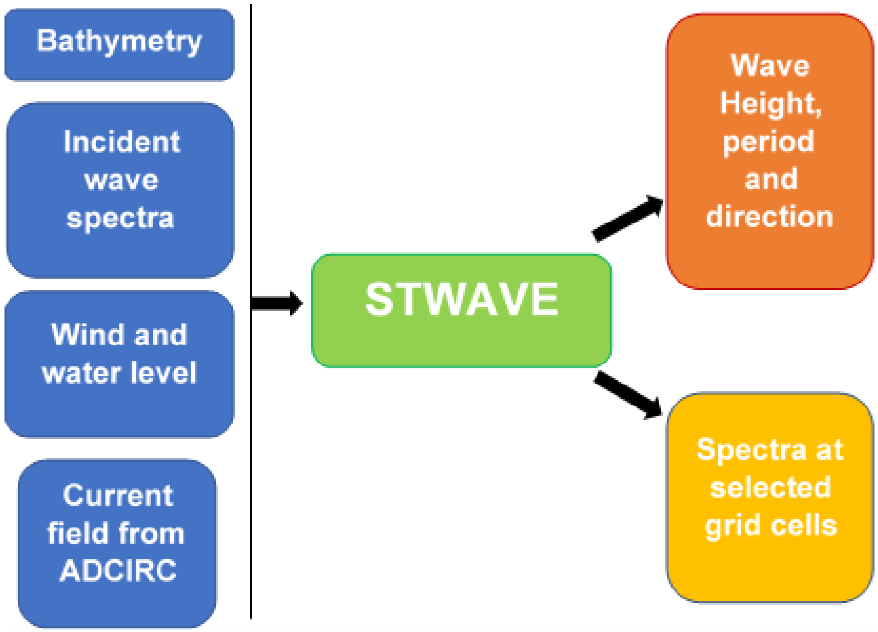


Figure 23: STWAVE Model Schematic

9.2 Input Files for STWAVE Modeling

STWAVES applies several model parameters for simulation and model output. The input options are wind input (for local wave growth) and wave current interaction. Figure 23 shows the STWAVE modeling domain selected for the study area. The offshore boundary location is selected at an approximate depth of 30 m and at a distance of approximately 4.5 km from the shoreline. This depth is chosen because the bottom contours are fairly straight and parallel at this depth and because the concerned WIS station 91172 (with extreme values of wind speed and wave height) was located near this contour to provide the input wave conditions. The lateral boundaries of the domain are positioned away from the influence of the inlet to areas of fairly straight and parallel depth contours. A 10m grid cell spacing is selected to resolve the ebb shoal and inlet bathymetry. To cover the domain with 10m resolution requires 531 cells across the shore (NI) and 801 cells alongshore (NJ).

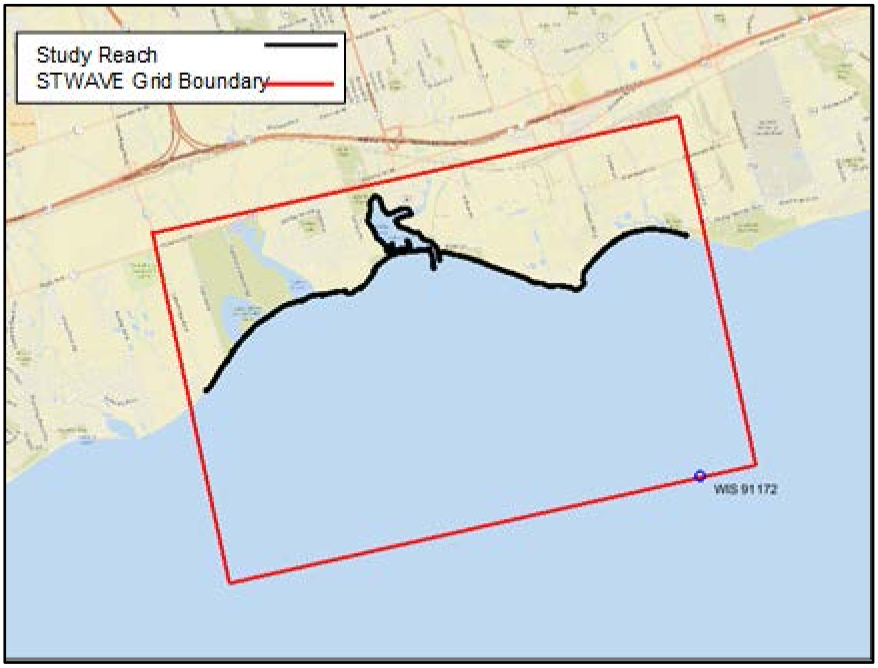


Figure 24: **Domain of STWAVE Model**

1. **Bathymetry**. The elevation dataset was prepared by merging the data collected by bathymetric surveying of the Whitby shoreline, DTM data set and bathymetry data (x,y,z) of the Western Lake Ontario. The Zone 17, NAD83 horizontal datum projection format was used to prepare this elevation data set. Considering the 100-year lake water level to be 76m, this value was subtracted from the elevation data set to create the water depth data set. Later, the water depth data set was interpolated to the STWAVE Grid. The grid was developed using a grid generator, which accepts random x, y, and depth triplets and interpolates them onto a Cartesian grid with a given origin, orientation, and resolution. In this model, water cells are denoted with positive depths and land cells with negative depths. Water boundaries are open and allow wave energy, consistent with neighboring cells to propagate into or out of the domain (zero-gradient type boundary condition). On the other hand, land boundaries allow no energy to propagate in or out of the domain.

2. **Incident wave spectra.** Wave spectrum are defined as the input waves on the offshore grid boundary. The STWAVE model for this study was run individually for 10, 25, 50 and 100-year wind and wave conditions. Typical wave periods for this site are 10 to 5 sec (0.1 to 0.2 Hz). To resolve this range, 30 frequency bins were used with an initial frequency of 0.07 Hz and a frequency increment of 0.007 Hz (range of frequencies is 0.07 to 0.273 Hz). Three monitoring stations were assigned at locations near Reach 8, Reach 11 and Reach 14. The incident wave spectrum was generated using a TMA spectral shape (with a spectral peakedness parameter 3.3), directional distribution (with nn = 4). For 4 different return periods, 4 spectra were

generated. The values of the wave spectrum for different return periods are shown in Table 15.

Table 15: Incident Wave Spectrum Parameters

Return Period (years)	Time offset (hours)	Angle (Meteorological)	H_{mo} (m)	T_p (s)	Gamma	nn
10	1	225	3.48	7.66	3.3	4
25	1	225	4.08	8.11	3.3	4
50	1	225	5.71	8.16	3.3	4
100	1	225	6.16	9.3	3.3	4

3. **Wind and Water Level:** Additional parameters of wind speed, wind direction, and water level are required for each input spectrum specified. In half-plane model winds blowing offshore are neglected. Tide information was specified relative to the bathymetry datum used to generate the model grid. For this study constant values of wind speed and direction along with water level were provided. The values are shown for different return periods in Table 16.

Table 16:Wind and Water Level Input

Return Period (years)	Time	Wind Speed (m/s)	Wind Direction (Meteorological)	Water Level (m)
10	2019-11-18 12:00:00 pm	18.04	225	0
25	2019-11-18 12:00:00 pm	20.03	225	0.12
50	2019-11-18 12:00:00 pm	23.70	225	0.28
100	2019-11-18 12:00:00 pm	24.2	225	0.4

4. **Current fields**. In order to add current field as an input, the wave-current interaction option was selected. The maximum velocity field from the ADCIRC model for different return periods as described in Section 8.3 was exported as scatter data sets to the STWAVE model. These scatter datasets were later interpolated to the cartesian grid and were used for the input spectrum.

9.3 Output Files for STWAVE Modeling

The output options in STWAVE include specifying regions of wave breaking, calculating radiation stresses, and saving wave spectra at selected output locations. Two-dimensional fields of significant wave height, peak period, and mean direction were also saved over the entire model domain. The generated outputs for this study are discussed below:

1. **Fields of wave height and wave period**. For the input spectrum, STWAVE outputs fields of significant wave height (defined as the zeroth moment of the spectrum), peak period, and mean direction were generated. The parameters were provided for all grid cells. The purpose of applying nearshore wave model in this study was to quantitatively describe the wave parameters (especially wave height) in the nearshore arena. Therefore, the wave heights from the STWAVE model result were analyzed for all the reaches (1-15). Graphs showing variation of wave heights against distance for different return periods are provided for individual reaches in Appendix F. The summary of maximum wave height at each reach is shown in Figure 25.

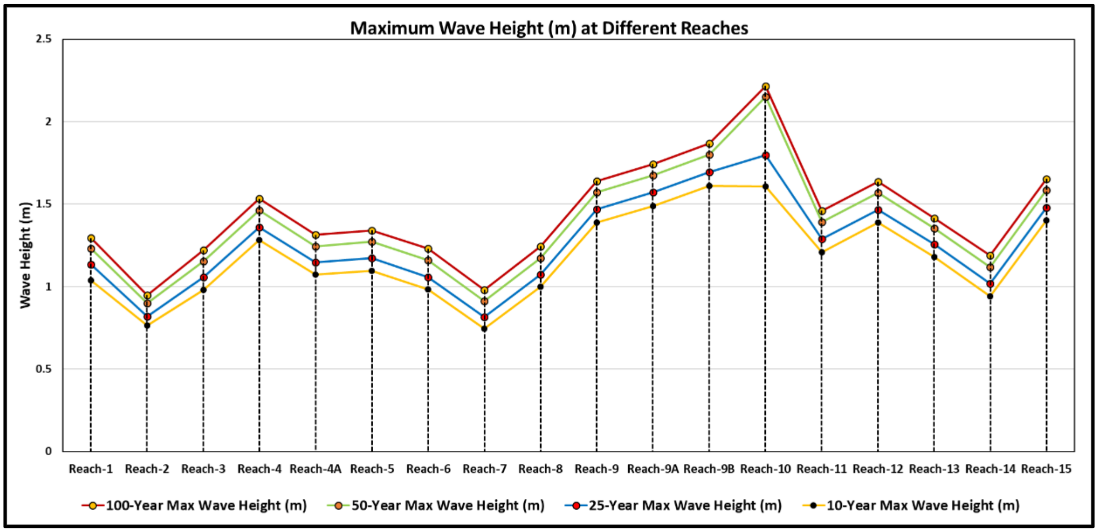


Figure 25: Maximum Wave Height VS Distance for Different Reaches

From the summary, it is evident that the maximum wave height at different reaches for 100-year wind-wave condition ranges from 0.95-2.2m. For all return periods of wind-wave, Reach 10 happens to have the highest wave height among all the reaches. Reach 10 includes a long structure made of sheet pile along with Whitby Harbour entrance. Although wave height in this region is the highest, the reach is at low risk of flooding since most part of the reach is in fair condition as mentioned in Section 4.2. From STWAVE analysis, the highest wave-height along the Whitby Shoreline was found to be 2.216m. However, from the wave-uprush analysis, average wave-height along the study reach was estimated to be 2.64m. Therefore, the results of wave-uprush analysis are much more conservative than that of the STWAVE analysis.

Typical wave period for the study area was found within 8-10s which is represented in Figure 26. Values of wave period for the entire study area in different return period cases are provided in Appendix F.

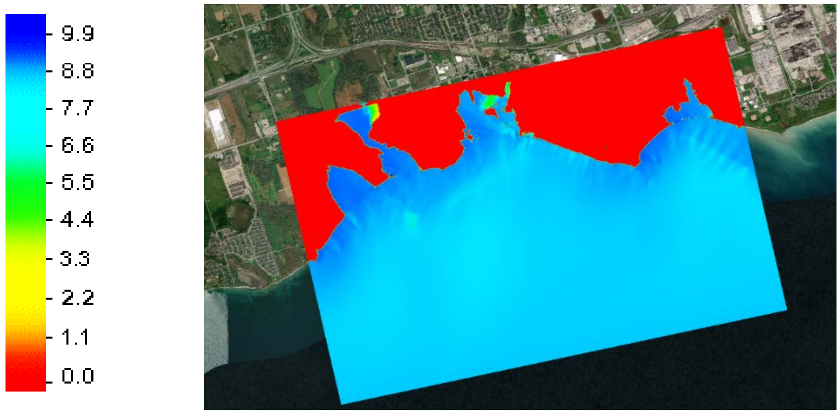


Figure 26: Wave Period in the model domain for 100-Year Return Period Condition

2. **Spectra at selected grid cells.** Full two-dimensional (frequency-direction) spectrum were generated for selected monitoring cells. For this study, the monitoring cells were selected at Reach 8, 11 and 14. Reach 8 represents the Iroquois Beach which is one of the long sandy beaches in the Whitby shoreline. Reach 11 is 530m long low plain dynamic beach consisting of sand and gravel. Finally, Reach 14 represents the Crystal Beach Boulevard and is roughly protected with an armour stone revetment, which is not in a fair condition. Considering the importance of these three reaches, monitoring cells for STWAVE modeling were placed in these regions. The wave parameters (wave height, peak period, and mean direction) for the three monitoring positions were generated in the 'selhts.out' file. The results for 100-year return period are shown on Table 5 of Appendix F. Energy VS Frequency curves for the selected grid cells for 25 and 100-year return period can be found in Appendix F. The output can be used for validation or as input to other engineering calculations.

Table 17: Output in Monitoring Cells for 100-Year Return Period Condition

Reach No	Date	I	J	H_{mo}	T_p	Θ_m
8	201911181200	415	483	0.568	8.717	27.6
11	201911181200	408	379	1.094	8.037	-27.534
14	201911181200	375	126	1.085	8.684	9.383

In this table, 'I' denotes the number of partitions in the I-direction (perpendicular to the shoreline) and 'J' denotes the number of partitions in the J-direction (along the shoreline). H_{mo}, T_p and Θ_m represent wave height at zero moment, peak period and mean direction of waves respectively.

9.4 Summary of STWAVE Modeling

The near-shore wave parameters are important to determine the flood hazard limit. From the STWAVE analysis, the maximum wave-height along the Whitby shoreline was estimated to be 2.216m. However, from the wave-uprush analysis described in Section 6 , the maximum wave-height was found to be 2.64m in the study area. To stay in the conservative side, AHYDTECH has used the wave-height values obtained from the wave-uprush analysis to analyze the alternative options and to do risk and vulnerable assessment of the preferred alternative/alternatives.

10. Task: Dynamic Beach Analysis

AHYDTECH has used SBEACH (**S**torm-induced **BEA**ch **CH**ange model) in order to perform Dynamic Beach Analysis along Whitby shoreline. SBEACH is a numerical 2D model developed by US Army Corps of Engineers (USACE) designed to perform cross-shore sediment transport analysis. SBEACH eliminates much of the complexities observed in other sediment evolution models and thus proves convenient for this study. Initial assessment suggested that dynamic beach analysis is needed to be done only for a few segments along the study area. Cross-shore profiles along Reach 4, Reach 8 and Reach 11 (2 distinct cross-shores) were taken for the analysis.

The Lake Ontario Shoreline Management Plan (1990) by Sandwell Wooster Inc. also suggested that Reach 8 and Reach 11 are dynamic beaches. A cross-shore profile on the eastern segment of Reach 4 was also used for analysis purposes. Other reaches were not considered for dynamic beach analysis at least one of the following reasons:

1) Presence of Seawall or other artificial features along the shoreline.
2) Large boulders or broken seawall along the shoreline.
3) Short Dynamic Beaches backed by high bluff.

10.1 Model Data

Cross-shore profiles were developed using the topographic and bathymetric data collected during the field survey. Offshore buoy data from US Army Wave Information Studies (WIS) were used to prepare time series of significant wave height, wave period and wind speed. Hourly time series data were available and used in the model. AHYDTECH used Lake Ontario WIS station no. 91171 for the analysis as it was at close proximity to the reaches analyzed. We used the storm data representing the most significant storm within period 1970 to 2014 (**H45 storm**). A model was simulated using storm data for the period 24/01/1978 12:00am to 28/01/1978 12:00am (4-day long period). For each design storm, AHYDTECH performed the analysis using each of the following water levels: 75m, 75.2m, 75.4m, 75.6m, 75.8m and 76m above 1985 IGLD datum, with the water level being constant throughout the simulation. Worst case scenarios were assumed in the analysis. More details about model data are provided in Section G.4 of Appendix G.

Reach configuration data were required as input in the model. The parameters included Effective Grain Size (D_{50}), Transport Rate Coefficient, Slope Dependent Term, Overwash Transport Coefficient, Water Temperature and Surf Zone Depth. While parameters such as effective grain size and water temperature can be determined, the other parameters are calibration parameters with a wide range of recommended values. Initially, AHYDTECH performed sensitivity analysis tests in order to determine the extent of variability of the model results with changes to values of each of these parameters.

During sensitivity analysis, AHYDTECH initially performed a base simulation, and compared the results of that base simulation with subsequent simulations. Each subsequent simulation had only a single parameter adjusted with respect to the initial or base simulation. The final bed profile observed for the simulations would indicate whether the model is sensitive to changes in values of a particular parameter. From sensitivity analysis trials, the model showed sufficient sensitivity for two parameters: a) Effective Grain Size and b) Transport Rate Decay Coefficient. Transport Rate Decay Coefficient parameters and all other parameters were given values which modelled worst case scenarios. As it was difficult to select a suitable value of effective grain size, each storm simulation was run for a range of values of this parameter. Grain sizes used included 0.3mm, 0.5mm, 0.6mm, 0.8mm and 1mm. Sensitivity analysis results has been discussed greater in Section G.3 of Appendix G.

10.2 Measuring Recession

While SBEACH simulates the cross-shore profile bed after the storm event, which can be compared to the pre-storm profile. The software also provides an output of recession of each of the contours on a particular cross-shore. Recession was measured for 3 to 6 contours for each cross-shore profile. For example, recession was determined for the contours of 75m, 75.25m, 75.5m, 75.75m, 76m and 76.5m at Reach 8. In the image below, a demonstration of a model result has been provided. The model provides us the final cross-shore bed as well as the recession of the contours. Figure 27 shows extent of the 76.5m, 76.0m and 75.5m contour line recessions. The contour recessions help to determine the landward limit of dynamic beach hazard.

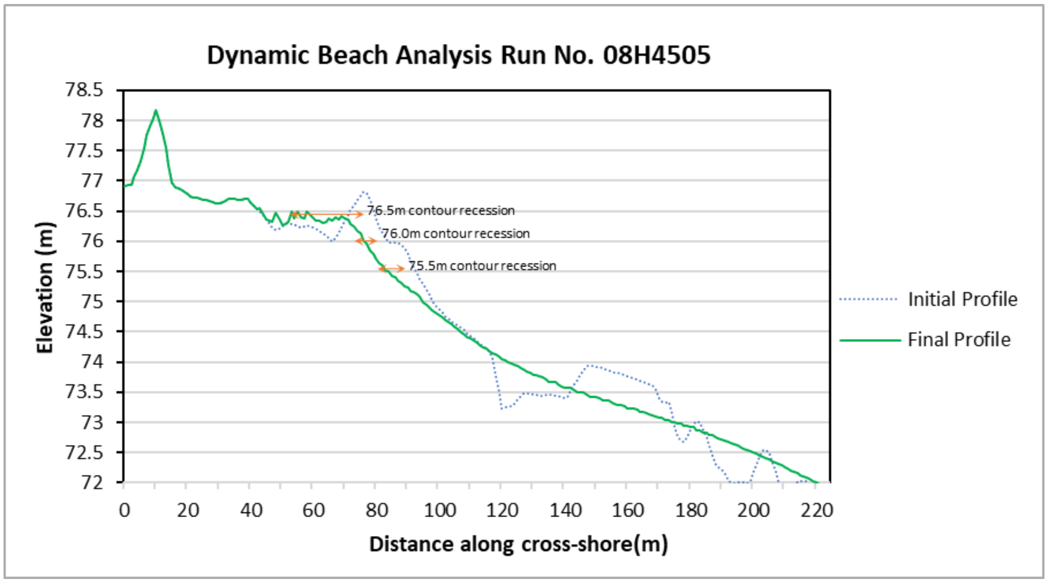


Figure 27: Diagrammatic representation of contour recession

10.3 Model Result

Figure 28 to Figure 30 shows the final cross-shore profile for different reaches:

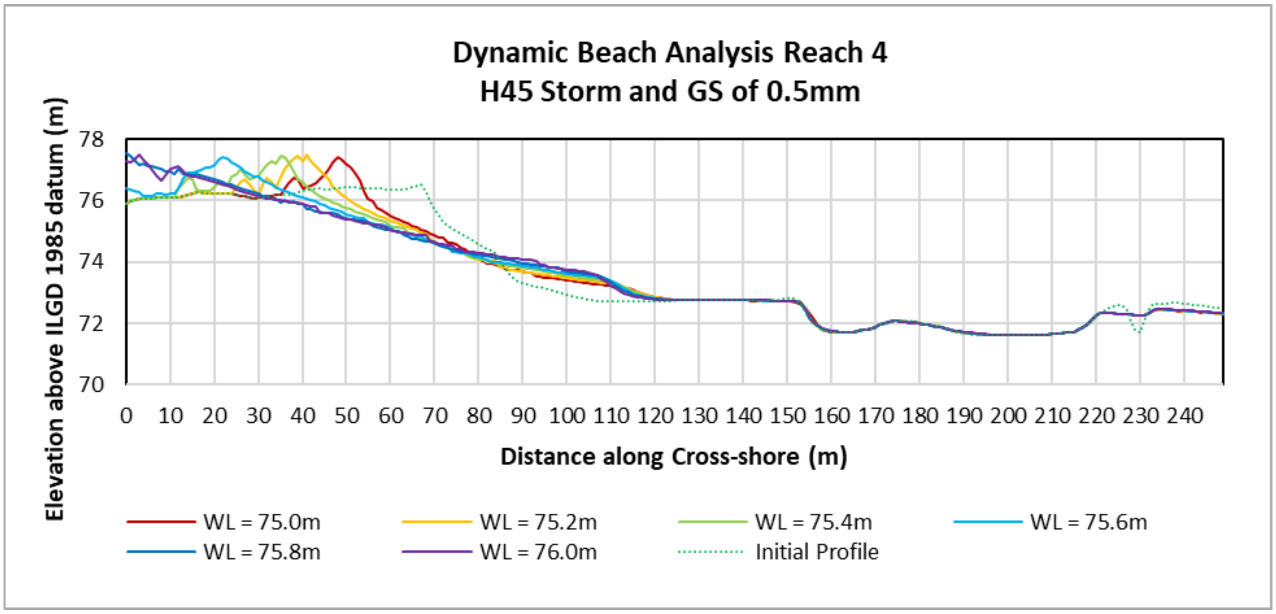


Figure 28: Final bed profile elevation post H45 storm for D50 of 0.5mm and varying water levels for Reach 4

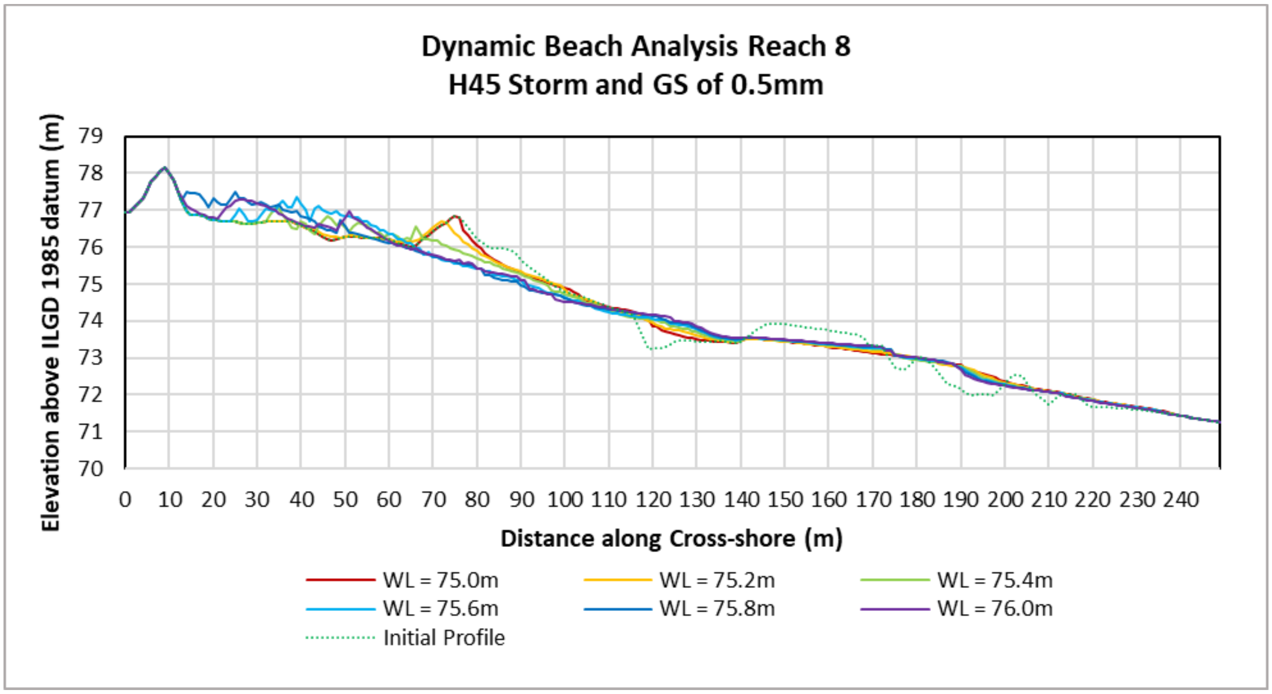


Figure 29: Final bed profile elevation post H45 storm for D50 of 0. 5mm and varying water levels for Reach 8

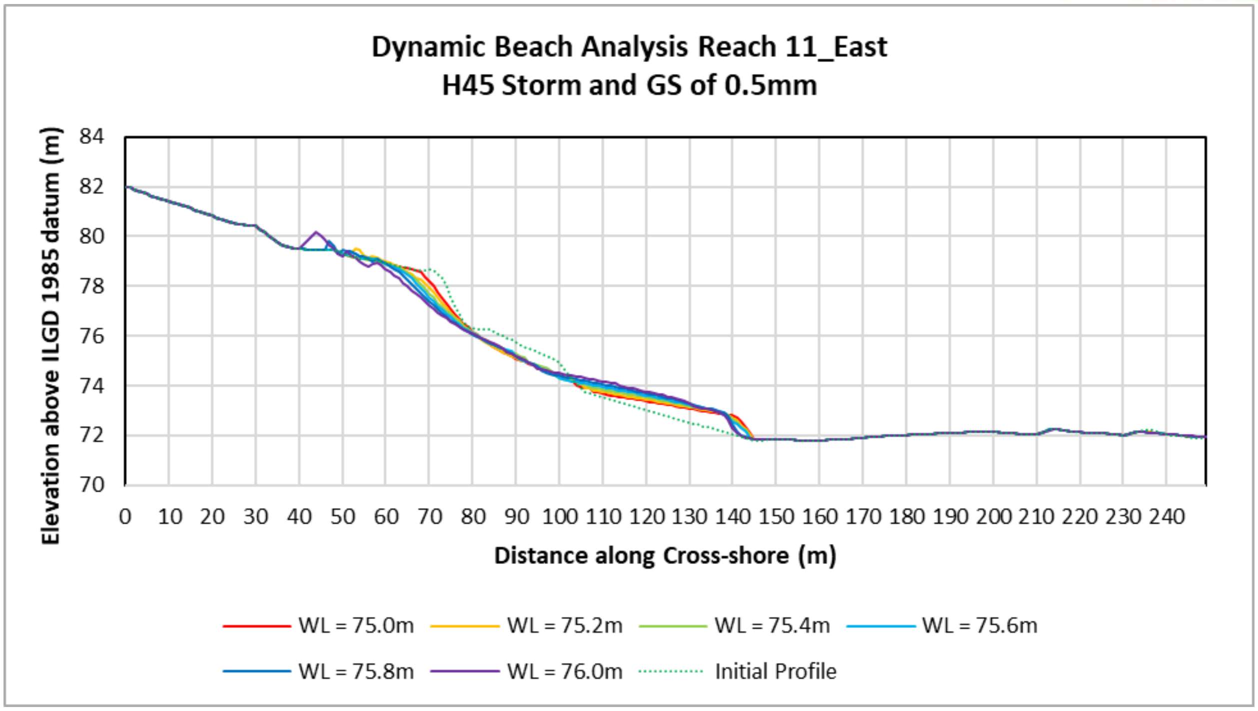


Figure 30: Final bed profile elevation post H45 storm for D50 of 0.5mm and varying water levels for Eastern part of Reach 11

The figures below (Figure 31 and 32) show contour recessions for varying water levels. In Reach 11, the maximum recession of about 9m occurs for the 78.0m contour during the 100-year water level. The 76.0m contours of this reach exhibits a constant recession of 6.0m for all lake water levels (75m to 76m). The maximum recession in Reach 8 is 20m for the 75.75m contour during 75.6m lake water level.

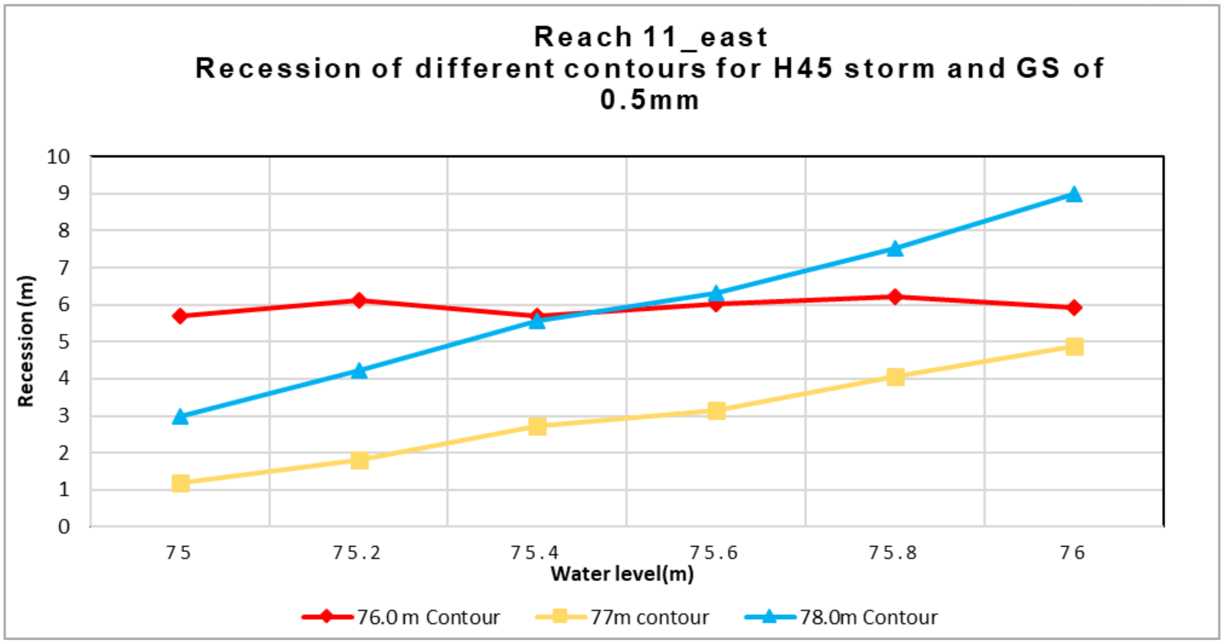


Figure 31: Recession of different Contours for H45 storm and Grain Size of 0.5mm for varying water levels for eastern part of reach 11

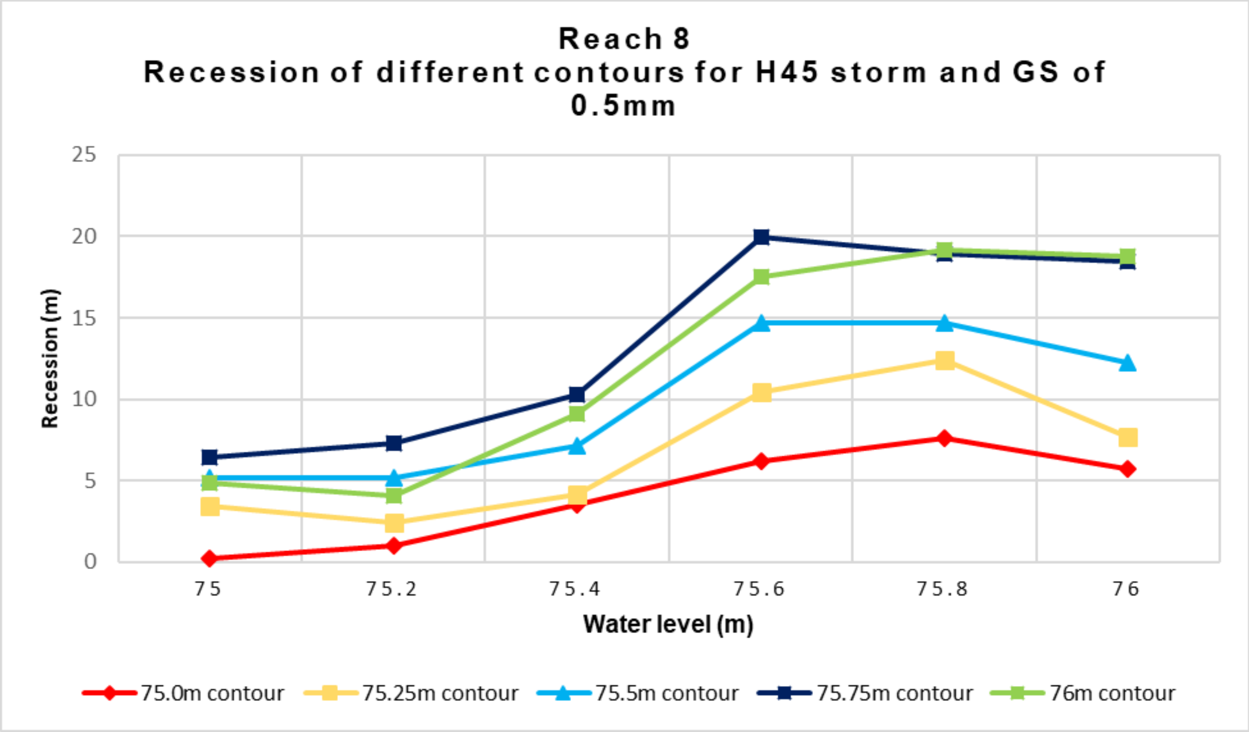


Figure 32: Recession of different Contours for H45 storm and Grain Size of 0.5mm for varying water levels for reach 8

11. Task: Flooding & Erosion Hazard Limits

The aim of the flood and erosion hazard assessment is to estimate hazard limits in the study area for supporting the Town's risk management activities. To carry out this assessment, the project team members performed extensive flooding and erosion analysis of the study area.

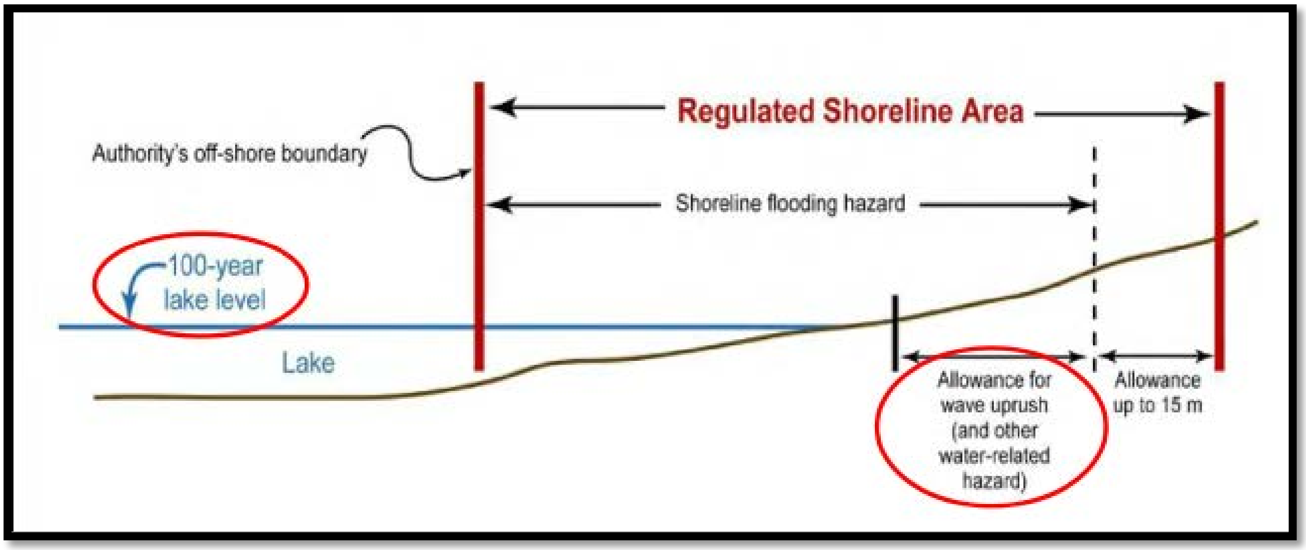


Figure 33: Flooding hazard limit (LOSMPU 2019 PPT)

The flooding hazard limit in Whitby shoreline area is determined based on the combination of the 100-year static flood level, the maximum wave uprush, and other water-related hazards. For example, in Reach 02, wave uprush height is about 2.64 m. Combining this wave uprush value with 100-year static flood level, the flooding hazard limit is adopted as 78.6 m for Reach 02. Top elevation of the existing shoreline protection structure is 78.8 m, which is higher than the flooding hazard elevation. Therefore, the property is under minimal risk of flooding. Possibility of flooding in Reach 5, 6 and 7 is comparatively low because of the presence of moderate to high bluff immediately landward of the shoreline. Average top elevation of the shoreline in these reaches is about 81 m or above. For Reach 14, average wave uprush is calculated to be 2.57 m. Therefore, combining the wave uprush with the static 100-year flood level, the flood hazard limit is obtained to be 78.57 m. Top elevation of the existing shoreline protection structure is 77.5 m, which is less than the flooding hazard elevation. Thus, it can be concluded that the property adjacent to the shoreline is in a great risk of flooding. For Reach 11 Obtained flood hazard limit is 76.50. Maximum flood level In Reach 12 and Reach 13 is about 76.34 m and 78.57 m respectively. Average top elevation of the existing bluff in these reaches (Reach 12 & Reach 13) is about 83 m. which is greater than the flooding hazard elevation. Thus, it can be concluded that the property adjacent to the shoreline is protected from flooding hazard.

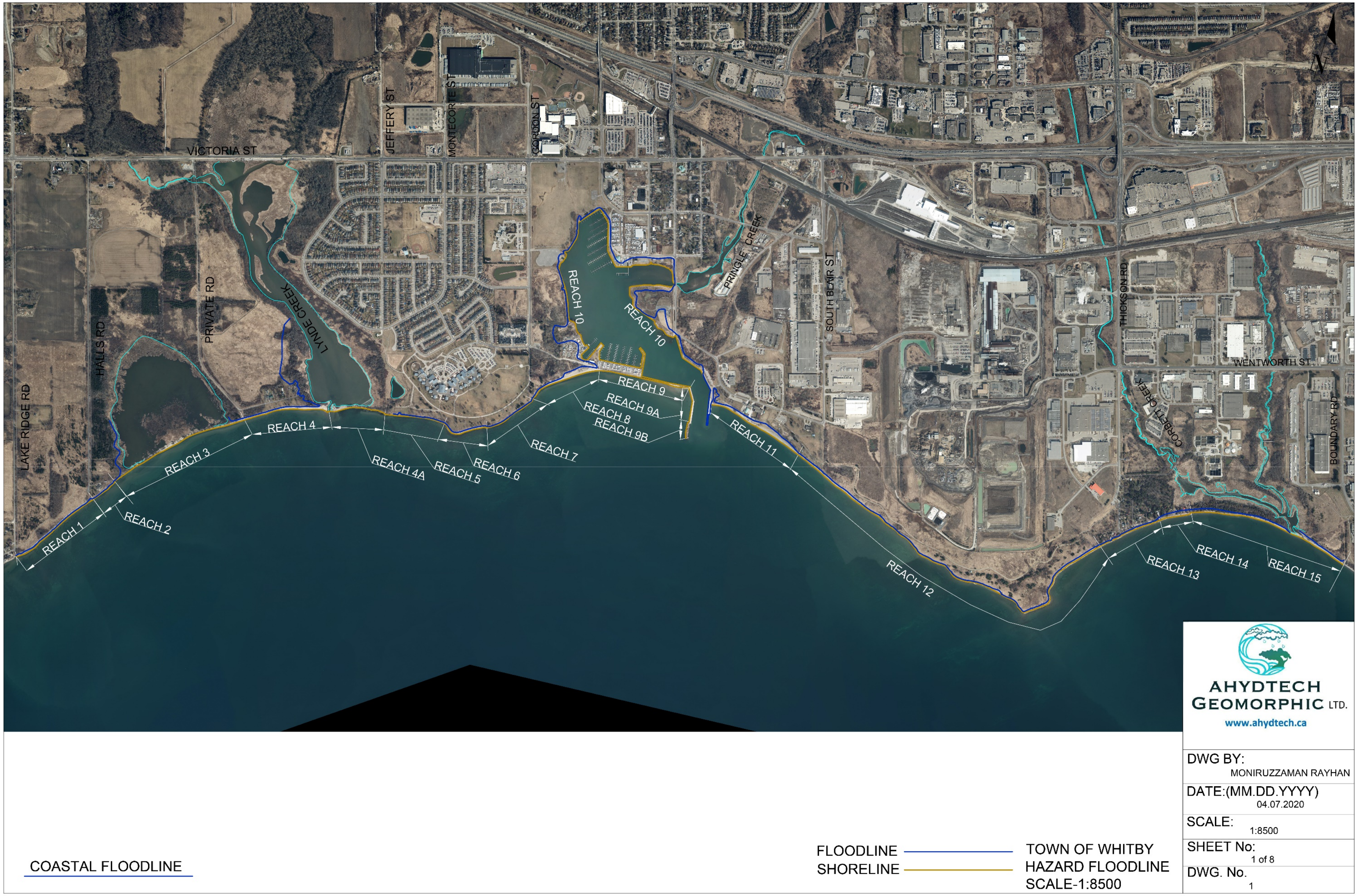


Figure 34: Flooding Hazard Limit delineated by AHYDTECH

The hazard limit of the Great Lakes - St. Lawrence River system is defined by the combination of flooding hazard limit, erosion hazard limit, and dynamic beach hazard limit along a shoreline. In selective reaches, no artificial shoreline protection structures rather than natural shorelines exist. These reaches are susceptible to dynamic beach hazard, and as a result, assessment of dynamic beach hazard was performed. For Reach 04, the dynamic beach hazard is not substantial as the nearest structure being Eastbourne Beach Road, which is about 50-60m landward of the shoreline. There is a low-bluff near the existing shoreline, which would limit extent of the hazard to the bluff toe. Furthermore, the Lake Ontario Shoreline Management Plan, prepared by Sandwell Swan Wooster Inc.(Sandwell, 1990), suggested a setback of 30 meters which remains sufficient under current conditions. Reach 8 has a dynamic beach, and the model results stated that a maximum recession of 20 meters for a few distinct contour elevations. A setback of 40 m was suggested for Reach 08 in the Lake Ontario Shoreline Management Plan. There is no protected structure within 40 meters of the shoreline. The Lake Ontario Shoreline Management Plan has classified Reach 11 as a dynamic beach with a setback of 40 meters. The dynamic beach model depicts the most conservative recession. In the western part of Reach 11, the maximum recession is 30m. In reality, recession in this reach is expected to be significantly lower than 30m, as the shoreline beach is dominated by cobbles. The eastern segment of Reach 11 was more appropriate for dynamic beach analysis because of its sandy beach characteristics. But the model results show that the maximum recession is less than 10 meters for all contour elevations in this reach.

The erosion hazard analysis performed by AHYDTECH is presented in the following sections.

AHYDTECH performed a desktop analysis following the MNRF Great Lakes Guidelines. The erosion allowance was calculated as product of the average annual recession rate times the 100-year time span or simply 30m as the erosion allowance if the average annual recession rate was not available. AHYDTECH followed the erosion threatened area calculation method stated in the MNR guidelines (MNR, 2001). The Policy and Procedural Document of CLOCA stated that the adopted hazard limit should be the furthest landward extent among flooding hazard, erosion hazards, and dynamic beach hazard, plus another 15m inland allowance. The details of erosion hazard determination are presented below.

Table 18: Coastal flood water level for different reaches.

Reach No	Reach Type	100-year static water level (IGLD)	20-year wave uprush	Costal flood level
1	Natural	76.00	0.44	76.44
2	Artificial	76.00	2.64	78.64
3	Natural	76.00	0.44	76.44
4	Natural	76.00	0.44	76.44
4a	Natural	76.00	0.44	76.44
5	Artificial	76.00	2.57	78.57
6	Natural	76.00	0.34	76.34
7	Artificial	76.00	2.57	78.57
8	Natural	76.00	0.34	76.34
9	Artificial	76.00	2.57	78.57
9a	Artificial	76.00	2.57	78.57
9b	Artificial	76.00	2.57	78.57
10	Mixed (Natural & artificial)	76.00	0.34	76.34
11	Natural	76.00	0.50	76.50
12	Natural	76.00	0.34	76.34
13	Mixed (Natural & artificial)	76.00	2.57	78.57
14	Artificial	76.00	2.57	78.57
15	Natural	76.00	0.34	76.34

Average Annual Recession and Erosion Allowance

AHYDTECH performed a desktop analysis using Digital Shoreline Analysis System (DSAS) in ArcGIS to determine the shoreline recession rate. The historical change in shoreline was analyzed using a Digital Shoreline Analysis System (DSAS 5) computer software which is an extension of ArcGIS. The DSAS computes rate-of-change statistics from multiple historic shoreline positions residing in a GIS. Three statistical methods were used to calculate the change in rates of shoreline from 2005 to2019. The Methods are **End Point Rate (EPR), Weighted Linear Regression (WLR), and Linear Weighted Regression (WLR)**. In DSAS work flow, the EPR is calculated by dividing the distance of shoreline movement by the time elapsed between the oldest and the most recent shoreline available.

Table 19: 100-year Erosion Allowance for reaches

	Recession Rates (m/year)	100 Year Erosion allowance for Reaches (m)
Reaches	Year-2005-2018	
1	-0.03633	3.633
2	-0.04833	4.833
3	-0.40065	40.065
4	-0.01617	1.617
4a	-0.3375	33.75
5	-0.21917	21.917
6	-0.24143	24.143
7	-0.21813	21.813
8	-0.34083	34.083
9	-0.1586	15.86
9a	0.09	9
9b	-0.38375	38.375
10	-0.05634	5.634
11	-0.29636	29.636
12	-0.22319	22.319
13	-0.21786	21.786
14	-0.23	23
15	-0.03964	3.964
Average	-0.21536	21.536

The long-term annual average shoreline recession rate computed is 0.21 meters per year, which is a moderate erosion rate as defined by the Ministry of Natural Resources (MNR) standards for the Great Lakes - St. Lawrence River system (MNR, 2001). Therefore, average erosion hazard limit of 21 m will be applied in the study area. However, As the recession rate varies from reach to reach, 100-year erosion setback will be different at different reaches (Table 19).

Stable Slope Allowance

According to the Provincial Standard, the 3 (Horizontal): 1 (vertical) slope method was used to determine the stable slope allowance, if no geotechnical report on slope stability was found. In that case, stable slope profile was projected from toe of the shoreline. However, if the property had a stable bank with supporting geotechnical analysis, slope setbacks of 2H:1V may be acceptable. But for the section of shoreline from Gordon Richards Park to Ronal C. Deeth Park, there is a detailed geotechnical study by GeoPro Consulting Ltd. This study can be used for determining stable slope allowance for this section of shoreline only.

Figure 35:100-year erosion allowance obtained from slope stability analysis and recession analysis

12. Task: Climate Change

Based on research of the Great Lakes, climate change has potential impact on water level, ice cover, temperature, rainfall intensity, wind-wave condition, and water quality (Lam, D. C. L., & Schertzer, W. M., 1999).

From the study of Durham Region's Future Climate (2040-2049), the climate in Whitby in the 2040 to 2049 period can be described as:

- Considerably warmer with higher humidity
- Less snow, more rain in winter
- More frequent and intense summer rain events
- Lower winds generally
- More extreme weather events with high winds and heavy rain

Since climate change will increase the intensity of rainfall and extreme storm events, it will increase risk of higher wind-wave and coastal flooding. This will result in accelerated beach, shore, and bluff erosion along with increased shoreline structure vulnerability. Moreover, the ice season could be shortened, and the extent of ice cover could be reduced due to global warming. Ice cover protects the shoreline from winter storm and wave erosion (Mortsch et al., 2003). Climate change will result in seasonal alterations in coastal wave power and direction, altered littoral sediment transport rates and processes, increased shoreline erosion, reduced nearshore water quality, and reduced marina/harbor/port access (increased dredging activity). Therefore, the physical characteristics and structure of the shoreline are vulnerable to climate change. At the same time, coastal habitats, biological communities, and ecosystems that rely on those shorelines will be vulnerable to climate change.

Even though Great Lakes water levels do respond to climate variability, there are no long-term changes of the water level (Mortsch et al., 2003). The Mortsch et al., 2000 study based on the Global Climate Models (GCM) climate change scenario indicated that Lake Ontario mean annual water level will decrease by 1.3m. However, UK HadCM2 climate model indicates an increase of the lake water level by 0.01m (Taylor et al, 2014).

For the proposed study for coastal flood hazard analysis, AHYDTECH assessed structural vulnerability to climate change using the following criteria:

- Lake Water Level
- Reduced Seasonal Ice Cover
- Frequency and Magnitude of Extreme Precipitation
- Extreme Wind-Wave
- Littoral Sediment Transport Rates and

- Coastal Flooding

AHYDTECH has collected and reviewed available studies and reports related to the criteria above and discussed with the Town to define the criteria. The effectiveness and resilience of shoreline protection structure with respect to climate change were assessed by AHYDTECH using the above criteria.

13. Task: Review Shoreline Structures

In order to review the Whitby Shoreline Structures, which is an essential part of this study, the team carried out the following services:

- Preparation of an inventory of shoreline and shoreline protection structures at each site including description, georeferenced location, structure type, dimensions, photographic documentation, etc.;
- Assessment of shoreline at each site including shoreline structure condition, remaining lifespan, effectiveness of the structure to shoreline protection, structure resilience with respect to water level and climate variability, maintenance recommendations, risk management options and costing, and assessment of aquatic natural heritage habitats;
- Documentation of onshore and offshore conditions including photographs, geomorphic and topographic surveys, mapping of site features, shorelines, and engineering structures in ArcGIS and/or AutoCAD software;
- Recommendation of replacement, conversion, or rehabilitation options for shoreline structures with the goal of not only protecting but also naturalizing the shoreline at the same time, including cost and maintenance recommendations;
- Assessment of the shoreline protection structures based on the following Evaluation Criteria:

  i. Risk of Damage and Structure Failure
  ii. Personal Safety
  iii. Material Condition
  iv. Structures Effectiveness and Performance
  v. Environmental Factors and Impacts (e.g. natural heritage, terrestrial and aquatic habitat)
  vi. Structural Vulnerability to Climate Change

R2-ST1=Conc. Block Wall
R3-ST2=Steel Sheet Pile Stoplog Dam
R5-ST3=Conc. Block toe,Armour Stone Wall
R7-ST4=Conc. Block toe,Armour Stone Wall
R9-ST5=Steel Sheet pile,I Beam Reinforcement
R9a-ST6=Concrete Capped Sheet Pile
R9b-ST7=Large Armour Stone Stacked Groyne
R10-ST8=Armour Stone Groyne and shore protection
R10-ST9=Cinder block with cable tension

R10-ST10=Steel sheet pile with Anchor bolts and concrete cap
R10-ST11=Steel Sheet pile
R10-ST12=Rip rap lined shoreline
R10-ST13=Timber and steel beams
R10-ST14=Steel Sheet pile
R10-ST15=Concrete Capped Sheet Pile
R13-ST16=Board wall and gabion basket toe
R14-ST17=Armor stone revetment, stones less than 1 ton

TOWN OF WHITBY
STRUCTURAL ASSESSMENT
SCALE-1:8500

AHYDTECH GEOMORPHIC LTD.
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DWG BY:	MONIRUZZAMAN RAYHAN
DATE:(MM.DD.YYYY)	04.07.2020
SCALE:	1:8500
SHEET No:	1 of 2
DWG. No.	2

Figure 36: Identification and breakdown of reaches based on structure type

- Ranking shoreline structures based on each Evaluation Areas and combining them to produce overall condition assessment for each site and structure, which resulted in a priority list for replacement or rehabilitation;
- Documentation and analysis of all collected data in excel tables and preparation of an ArcGIS package (ArcReader) with shoreline spatial information in submission to the Town and CLOCA;
- Integration of the data and collected photography into Excel tables, ArcReader package, geodatabase, shapefiles, etc.;

After conducting the field investigation and shoreline characterization, AHYDTECH performed desktop analysis in order to prepare data, update and create environmental ranking system and structure condition.

Breakdown of main sites into sub-sections

Once the field investigations were completed, all the project sites had been broken down classified into different sub-sections where the various shoreline characteristics, types of structures, analysis of photographs and site information would dictate these subsections. There was a ranking criterion developed for the Environmental Factors and Impacts (e.g. natural heritage, terrestrial and aquatic habitat).

Structure Condition Assessment:

We have conducted detailed assessment of each site including the natural shoreline and the shoreline protection structures; the assessment included shoreline structure conditions, remaining lifespan, associated risk of damage and structure failure. The field visit information and data were used to focus on the coastal and protection structure conditions, short-term and long-term shoreline stability, dynamic beach, flooding and erosion hazards. Existing natural heritage, aquatic and terrestrial habitats were also assessed for any potential impacts at each project site.

Structure Effectiveness Assessment:

The effectiveness of the shoreline structures was based on assessment and observation of a combination of numerous factors such as; shoreline dynamic beach, erosion and flooding hazards, composition of the materials, scour, undercutting, looseness or missing materials, deterioration of materials, drainage issues, bank slopes, active across-shore and alongshore processes along the Whitby shoreline. The structure effectiveness was also based on the collected or calculated erosion/recession rate for unprotected or informally protected areas and available wave hindcast data. The assessments also included an evaluation of whether the structure is necessary and considered any improvement opportunities in the process.

Estimated structure life span based on results of the field assessment and data analysis were included in the structure effectiveness assessment and provided in the excel summary. The effectiveness and resilience of shoreline protection structure with respect to climate change and varying water levels were assessed by AHYDTECH and results were incorporated into this aspect of the assessment process. Discussions were made with the project team to determine the scenario of climate including increasing temperature, changing precipitation and wind patterns, and a potential increase in the frequency of severe events such as windstorms and ice storms.

Completion of Ranking:

All the resulting data were entered into excel tables for the preparation of the ranking process. Shoreline ranking was assigned to each of the following areas;

- Risk of Damage and Structure Failure;
- Personal Safety;
- Material Condition;
- Structures Effectiveness and Performance;
- The Structural vulnerability to climate change will be incorporated into an existing appropriate category or a new category will be developed if necessary;
- Environmental Factors and Impacts (e.g. natural heritage, terrestrial and aquatic habitat)

AHYDTECH has carried out the ranking for all the sites. Each of the category scores were ranked and combined to produce an overall assessment ranking for each of the individual structures. All of the sites and their subsections were ranked in priority for both their hazard assessment and environmental considerations.

Table 20: Summary and Ranking of Structural Assessment

Structure number	Site name	Structure type	Length (m)	A- Risk of Damage	B- Personal Safety	C- Material Condition	D-Structure Effectiveness/ Performance	Overall ranking (sum)	Sum Ranking
R2_ST1	Halls Rd	Conc. Block wall	150	4-Poor	3-Fair	4-Poor	4-Poor	15	Poor
R3_ST2	Cranberry Marsh	Steel Sheetpile and stoplog structure	30	1-Best	4-Poor	4-Poor	3-Fair	12	Fair
R5_ST3	Health Center west	Concrete block toe, armor stone wall	340	2-Good	4-Poor	3-Fair	2-Good	11	Fair
R7_ST4	Health Center east	Concrete block toe, armor stone wall	300	1-Best	3-Fair	3-Fair	3-Fair	10	Fair
R9_ST5	Harbour Mouth Wall	Steel Sheet Pile, I beam reinforcement	270	2-Good	3-Fair	3-Fair	3-Fair	11	Fair
R9a-ST6	Harbour Mouth Wall	Concrete Capped Sheet pile	210	2-Good	2-Good	3-Fair	3-Fair	10	Fair
R9b-ST7	Harbour Mouth Stone Groyne	Large Armorstone stacked Groyne	95	2-Good	2-Good	2-Good	2-good	8	Good
R10_ST8	Yacht Club East	Armor stone groyne and shore protection	160	2-Good	2-Good	2-Good	2-Good	8	Good
R10_ST9	Yacht Club harbour	Cinder block with cable tension	470	3-Fair	2-Good	2-Good	4-Poor	11	Fair
R10_ST10	Yacht Club Pier	Steel Sheet Pile, with bolt anchors and concrete cap	130	2-Good	2-Good	2-Good	2-Good	8	Good
R10_ST11	Public Boat Launch	Steel Sheet pile	30	1-Best	2-Good	2-Good	3-Fair	8	Good
R10_ST12	Marina Riprap	Rip rap lined shoreline	310	3-Fair	2-Good	2-Good	2-Good	9	Good
R10_ST13	Marina Seawall	Timber and Steel beams	90	3-Fair	2-Good	2-Good	2-Good	9	Good
R10_ST14	Disused Shoreline	Steel sheet pile	100	1-Best	4-Poor	4-Poor	4-Poor	13	Poor
R10_ST15	Lions Promanade	Concrete Capped Sheet pile	560	2-Good	2-Good	1-Best	1-Best	6	Good
R13_ST16	Crystal Beach West	Board wall and gabion basket toe	15	4-Poor	3-Fair	2-Good	3-Fair	12	Fair
R14_ST17	Crystal Beach Revetment	Armor stone revetment, stones less than 1 ton	180	4-Poor	3-Fair	3-Fair	4-Poor	14	Poor

Environmental Factors and Impacts:

Providing restoration and enhancement within the littoral zones is of greater value and benefit to the shoreline ecosystems, which in turn lead to greater sustainability. Various natural heritage components at the site level were applied as additional sets of indicators to the existing background information to determine how shoreline structure integrity and sustainability can be enhanced.

Approach to Aquatic and Terrestrial Assessments of Shoreline Structures:

As growing awareness of stewardship and watershed health becomes increasingly prevalent, AHYDTECH recognizes that greater opportunities for collaboration among watershed stakeholders exist with the emergence of GIS based data sharing within government agencies, researchers, and municipalities.

Examination of the shoreline interface, in relation to the habitat quality and linkage potential provide an opportunity to determine at the site level what possibilities exist for restoration and enhancement. This was accomplished by examination of high-resolution aerial mapping along with site visits by the team of AHYDTECH to determine the likelihood and feasibility of restoration. Attributes which were measured at the site level include:

- Accessibility and slopes within the shoreline interface;
- Substrates and remnant vegetation cover along the shoreline;
- Macrophyte cover and diversity of wetland/upland vegetation;
- Presence of underwater structures such as logs, cobbles, rip rap or boulders, undercuts in addition to shoreline features such as exposed sands, basking logs, woody debris, and animal borrows; and,
- Exposure to wind and wave action.

Replacement or Conversion Recommendations:

Once the site inspection, assessment and ranking work for the shoreline structures, existing natural heritage, aquatic and terrestrial habitat were completed, we discussed these assessments and provided input with respect to what sites to consider for construction and/or rehabilitation/restoration opportunities along the specific site locations. Restoration or conversion recommendations for shoreline naturalization (without negatively affecting flooding and erosion protection) were provided for all the sites.

Once the results for the ranking were completed, the top priority sites were considered as to what possible shoreline replacement, repairs, restoration or conversion recommendations could be considered depending on the site characteristics, natural and physical processes restrictions and the accompanying environmental conditions. Consideration were given not only to address the hazards but also for shoreline naturalization (without negatively affecting flooding and erosion protection), cultural priorities and values when making.

14. Task: Class EA Study

The Town of Whitby is located in Durham region, which is in Southern Ontario. East of the town is Ajax and Oshawa is in the west. For the Town of Whitby, initially the problem situations identified were Shoreline Erosion and Shoreline Flooding. In case of shoreline flooding, wave action was considered in addition to increase in water levels. The still water level plus the wave action (wave uprush/runup, overtopping, and ice accumulation) result in a final flood elevation. To protect an area from shoreline flooding alternative measures include preventing entry of floodwaters at a particular site or reducing the wave uprush elevations by reducing wave energy at offshore. Shoreline erosion is caused by waves, currents, shore geomorphology, ice and changes in water levels. As a result, shoreline erosion is different from erosion in a river system. Deterioration of bluffs/banks, dunes, berms and beaches can occur as a result of shoreline erosion. In order to stop erosion of the backshore and coast area, protection of natural features such as beaches, berms and dunes are necessary. Alternative remedial measures suitable to address shoreline erosion include reducing wave energy and enhancing natural processes, protecting from wave energy, stabilizing the slope through drainage, or grading improvements.

14.1 List of Alternatives and Evaluation Category

The project team analyzed and identified alternative solutions to the existing problems in the project area. Below are the tentative alternative solutions for consideration in addressing the problems and opportunities, which will be updated and refined through consultation with the Town and other stakeholders:

Alternative 1: Do Nothing: Maintain the existing infrastructure, bluff, natural features, shoreline structures and water course outlets. This alternative does not solve the problem.

Alternative 2: Modification & Improvement of the existing municipal infrastructure.

Alternative 3: Modification & Improvement to bluff.

Alternative 4: Repair & Replacement of existing shoreline structures, such as seawall, revetment, sheet pile, groyne & marina structures.

Alternative 5: Installation of new shoreline structures, such as seawall, revetment, sheet pile, groyne & marina structures.

Alternative 6: Modification & Improvement to natural features, such as natural shoreline, wetlands, aquatic habitat and water course/creek outlets.

Alternative 7: Combination of Alternative 2 to 6.

We have identified and evaluated the potential alternative solutions in order to assist the Town in the selection of a preferred alternative solution.

The alternative methods are evaluated considering the following evaluation categories-

- **Physical/ Natural Environment:** Hydrology, Hydraulic & Flooding, Coastal Process, Acquisition of Private Property, Integration with Existing Environment, Integration with Existing Infrastructure, Groundwater/ Hydrogeological, Natural Heritage, Wildlife and Vegetation, Aquatic Species, Habitat.
- **Social/Cultural Environment:** Landowner acceptance, Public Health & Safety, Utility Lines.
- **Technical/Engineering Factors:** Ease of Implementation and Construction, Agency Acceptance, Official Policy, Secondary Policies and Bylaw Requirements, & Technical Feasibility.
- **Economic Environment:** Timing Constraints, Operation & Maintenance, Capital Cost & Lifecycle Cost.

14.2. Preliminary Preferred alternatives

The alternative Evaluation Table is provided in Table 3 in Appendix A where impacts resulted from undertaking each alternative is evaluated for the mentioned categories. It is checked whether the impacts are positive or negative, if these impacts are significant and if these impacts can be fully or partially mitigated.

Reach 01: Reach 01 is characterized as a dynamic beach, backed by a 1.5-4.0m high bluff. Silt and coarse sand/cobble are found at the bottom of the bluff which resist erosion. However, the waterfront trail is susceptible to erosion as it lies within 30m from the shore. Reach 01 is predominant for passive use, there is no residential building near the slope, and the area is mostly covered by natural features and park. Therefore, erosion hazard is comparatively less in this reach. The erosion can be reduced by modifying and installing the natural features, such as reducing slope or improvement of vegetation cover. These measures will have positive impacts on local hydrology and the shoreline function. Though there might be some negative impacts over shoreline stability and erosion protection of the reach, those impacts can be toned down. Besides, there will be no significant impact on groundwater quality and local hydrogeology due to this alternative. As long as recommended mitigation measures provided in section 4.4 are implemented, there will be no significant impact on natural heritage area, wildlife and vegetation population as well. Most of the construction impacts on aquatic and terrestrial habitat can be alleviated through different measures such as- erosion control measures, working in construction windows etc. **Considering all the impacts and the possibility of mitigating the impacts, Alternative 6 (Modification & Improvement to natural features, such as natural shoreline, wetlands, aquatic habitat and water course/creek outlets) is preliminarily prioritized as the preferred alternative for Reach 01.** The modification should be implemented within 10 years. Detailed design of the project will follow the revisions to schedule B project as per section A.4.1.1. of MCEA.

Reach 02: In Reach 02, there is an old concrete block seawall structure, which is in poor condition. The seawall structure is roughly 150m in length and about 2.5m high. The stacked blocks are tilted towards the lake, and multiple blocks have fallen into the lake. Besides, the toe protection has been displaced in many places which has resulted into sliding of the wall towards the lake. Such type of displacement may cause failure of the structure, if proper measures have not been taken immediately. Since there is a private house only 25m away from the seawall, the extent of potential damage due to erosion is comparatively high for this reach. However, the risk can be mitigated by repairing the existing sea wall, which will ultimately improve shoreline form, bank stability, shoreline function and most importantly short-term and long-term erosion protection. If this alternative is undertaken, construction related impacts like noise, dust and traffic can be fully mitigated, and there will be no significant long-term effects. If the recommended opportunities to remove existing impacts and to improve habitat are implemented, this alternative will provide positive potential long-term effects on the existing environment. There will be no significant impact on natural heritage area, wildlife, and vegetation population due to repairment of the existing structure. Construction impacts on aquatic and terrestrial habitat can be mitigated through different measures such as- erosion control measures, working in construction windows etc. Landowners' suggestions and obligations can also be considered. The anticipated longevity of this alternative is also promising and will reduce overall erosion and flooding hazard. **Considering all the impacts and the possibility of mitigating the impacts, Alternative 4 is prioritized as the preliminary preferred alternative for Reach 02 (Repair & Replacement of existing shoreline structures, such as seawall, revetment, sheet pile, groyne & marina structures).** Repair and replacement should be accompanied by a coastal engineering assessment to ensure appropriately sized material, founding conditions, and drainage considerations are provided to maximize the longevity of the structure.

Reach 03: Sand and cobble barrier beach along with trees and shrubs are major features in this reach. These features also protect the Cranberry Marsh Provincially Significant Wetland. There is a small sheet pile structure, currently in a limited function, in Reach 03 which acts as a breakwater for the marsh. There is no residential building near the shoreline, and the area is mostly covered by natural wetland. Therefore, erosion hazard in this reach is comparatively less. To avoid impacts to wetland hydrology, the existing top elevations of the shoreline banks, barrier beach, and control structure should not be artificially altered. Beach nourishment (e.g., cobbles) could help preserve the existing vegetation and associated shoreline habitat on either side of the barrier beach. Beach nourishment along the barrier beach could help the barrier beach naturally adjust to changing conditions by providing the natural building blocks for natural shoreline dynamics. **Considering all the impacts and the possibility of mitigating the impacts, Alternative 1 (Do Nothing) or Alternative 6 (Modification & Improvement to natural features) is prioritized as the**

preliminary preferred alternative for Reach 03. The modification should be implemented within 10 years. Detailed design of the project will follow the revisions to schedule B project as per section A.4.1.1. of MCEA.

Reach 04: Reach 04 shoreline, covered with gravels and cobbles, extends from the shore trail to the Lynde Creek outlet. The nearest intra-structure in this is Eastbourne Beach Road, which is about 50-60 m away from the shoreline, and houses are situated further away from the reach shoreline. There is comparatively less risk for erosion hazard. However, modification to the natural shoreline can be another option which will improve shoreline form, function and stability, and will provide erosion protection of the road and flooding impact of the residential area. There will be no significant impact on groundwater quality and local hydrogeology. But as different structures and houses are situated far away from the shoreline, **considering all the impacts and the possibility of mitigating the impacts, Alternative 1 (Do Nothing) is prioritized as the preliminary preferred alternative.**

Reach 04a: Reach 04a is about 200m long, where sand and gravel beach create a nearly closed bay formation with a small outlet passing the creek flow. This is a natural beach with dynamic beach barrier, which has limited access to people. There is no residential building or other infrastructure near the bank, and the area is mainly natural. Therefore, risk of erosion hazard is comparatively less here. **Thus, Alternative 1 "Do Nothing" is preliminarily prioritized as the preferred alternative for Reach 04a.**

Reach 05: In Reach 05, there is a shoreline protection structure comprised of armor stones and concrete blocks. It has a length of approximately 340m and height about 3m. It protects the park and stormwater management pond behind the Ontario Shores Mental Health Center. The concrete blocks at the toe of the structure are in poor condition due to erosion/spalling. Besides, visible gaps were observed between armor stones due to wave-actions shifting the stones. No geotextile was secured beneath the structure, due to which soil beneath the armor stone gaps are being washed out. But there is no residential or industrial building near the shoreline. The waterfront trail is about 40m from the bank and a gazebo in the south of waterfront trail is about 45 m away from the bank. Therefore, risk due to erosion hazard is comparatively less here. Furthermore, due to the shoreline structure and the bluff behind it, flood hazard risk is also trivial for this reach. **Considering all the impacts and possibility of mitigating the impacts, Alternative 4 (Repair & Replacement of existing shoreline structures) is preliminarily prioritized as the preferred alternative for Reach 05.** The modification should be implemented within 10 years. Detailed design of the project will follow the revisions to schedule A+ project as per section A.1.2.2. of MCEA.

Reach 06: Reach 06 is around 260 m long, projecting headland in front of Whitby Shores Health Center. The reach is characterized as a non-dynamic beach, backed up by a 5-7m high bluff. The west side of the bluff has been strengthened with vegetation, showing no signs of slumping. However, there is lack of vegetation along the east side and some slumping has been observed there which might be caused by steeper slope. Moreover, large cobbles and stones at the toe of the bluff provides natural toe protection. Like Reach 05, there is no infrastructure within 30m of the shoreline. Thus, there is low risk of erosion hazard and because of the high bluff, possibility of hazard due to flooding is also insignificant**.** The erosion can be tempered by modifying and improving the natural features like growing vegetation cover. **Considering all the impacts and possibility of mitigating the impacts, Alternative 6 (Modification & Improvement to natural features) is preliminarily prioritized as the preferred alternative for Reach 06.** The modification should be implemented within 10 years. Detailed design of the project will follow the revisions to schedule B project as per section A.4.1.1. of MCEA.

Reach 07: In Reach 07, there is a shoreline structure comprised of armor stone and concrete blocks. It has a length of approximately 300m and height about 3m. There is a 3-4m high earthen berm 10m away from the structure. The concrete blocks at the toe of the structure are in poor condition due to erosion/spalling. Besides, due to wave-actions, armor stones are dislodged and visible gaps were observed between armor stones. No geotextile was secured beneath the structure, due to which soil beneath the armor stone gaps are being washed out. However, the waterfront trail is susceptible to erosion as it lies within 30m from the shoreline. Reach 07 is predominant for passive use, the area is mostly covered with vegetation and trees. The failure of the structure would result in the loss of park land and a paved portion of trail. Even though, the hazard risk due to erosion and flooding in this reach is not immediate, however, the reach shoreline structure will require repair and replacement for long-term stability of the shoreline**. Under these circumstances considering all the impacts and possibility of mitigating the impacts, Alternative 4 (Repair & Replacement of existing shoreline structures) is preliminarily preferred for Reach 07.** The modification should be implemented within 10 years. Detailed design of the project will follow the revisions to schedule A+ project as per section A.1.2.2. of MCEA.

Reach 08: Reach 08, around 370m in length, is a dynamic beach with coarse sand sorted to dunes and larger gravel along water-edge. There are some areas with grass and vegetation 10-30m from the shoreline. There is an informal trail and mixed forest behind the shoreline. However, the reach is characterized as low plain dynamic beach, consisting sand and gravel. There is no residential building near the shoreline, and the area is mostly covered by natural forest. Therefore, erosion and flooding hazard is comparatively less in this reach. So, **Alternative 1 (Do-Nothing) is preliminarily preferred for Reach 08, considering all the impacts and the possibility of mitigating the impacts**.

Reach 09: In Reach 09, there are steel sheet piles that extend from the Yacht Club along the Bay/Harbor mouth to the concrete entrance of the harbor; the harbor side of the sheet pile wall is exposed to water. The Lake Ontario side progresses from the dynamic Iroquois Beach sand to a rock/rip-rap beach. The sheet pile wall has been reinforced with I beams. The steel of the wall under water is vulnerable to corrosion, and some surface corrosion was also observed. Besides, there are areas in the Lake Ontario side where the stone and cobble have been eroded out from toe of the structure. The material near the Iroquois Beach experienced the most toe erosion. Alternative 4- "Repairment of the existing infrastructure"- can provide a better result in this situation. Repairment of the existing sea wall will provide bank stability, and most importantly, short-term and long-term erosion protection. If this alternative is undertaken, construction related impacts like noise, dust and traffic can be fully mitigated. Besides, there will be no significant long-term damage to the property and owners won't have to face any problem regarding property acquisition. This alternative will also provide positive potential long-term effects on the existing environment and no significant impact on the existing infrastructure as long as the recommendations at section 4,4 (natural heritage assessment) are implemented. There will be no significant impact on natural heritage area, wildlife and vegetation population due to repairment of the existing structure. Most of the construction impacts on aquatic and terrestrial habitat can be alleviated through different measures such as- erosion control measures, working in construction windows etc. Landowners' suggestions and obligations can also be considered. The anticipated longevity of this alternative is also promising. **Considering all the impacts and possibility of mitigating the impacts, Alternative 4 (Repair & Replacement of existing shoreline structures, such as seawall, revetment, sheet pile, groyne & marina structures) is preliminarily prioritized as the preferred alternative for Reach 09.**

Reach 09a: In Reach 09a, a seawall protects the mouth of the Whitby Harbor, which is roughly 2m high above the lake level. This seawall is in perpendicular direction to the Whitby shoreline. Both sides of the seawall are made of steel sheet piles, and gap between the steel sheet piles has concrete cap. This concrete cap is in aging condition with cracks and visible vegetation growth. The steel sheet piles have shown corrosion and rust on the surface. But the seawall is in fair condition. Besides, the concrete cap has cracks and small to medium vegetation growth. Nevertheless, overall performance and effectiveness of the structure is viable. **Considering these factors Alternative 1 (Do nothing or Alternative 4) is preliminarily prioritized as the preferred alternative for Reach 09a**.

Reach 09b: In Reach 09b, there is an armour stone groyne started from the sheet pile seawall of Reach 09a with a purpose of protecting the harbor mouth from wind and wave actions. As the groyne structure acts as a breakwater, failure of the structure could cause severe exposure of the harbor mouth to wind-waves. Stone size of the structure is large enough and uneven stacking of stones help to attenuate wind-wave actions. Many of the armour stones of the groyne have been dislodged and displaced. At present, the groyne structure is in a fair and viable condition. Displacement of armour stones will be larger and the structure condition will deteriorate with time if repair, replenishment and replacement are not accomplished soon. **Therefore, considering these positive factors regarding the existing condition of the reach, Alternative 4 (Repair, Replenishment & Replacement of existing shoreline structures) is rudimentarily suggested as the preferred alternative for Reach 09b.**

Reach 10: Both artificial and natural shorelines were observed in Reach 10. Artificial shoreline consists of parks and protection structures. There is low risk of erosion and flooding since most part of the reach is in fair condition. But the shoreline within the Yacht Club harbour docks is subjected to undermining, shifting or scouring of the material under the brick. Though the cracks and gaps between few blocks were fixed with concrete, some bricks in the south west corner of the structure have buckled upwards. Besides, the uneven surface and undulating length of the wall indicates displacement and scouring of material under the structure. Additional gravels have been provided to the top of the shoreline along the parking lot. **Considering the above-mentioned condition of the reach, Alternative 4 (Repair & Replacement of existing shoreline structures) has been primarily suggested as the preferred alternative for Reach 10.** This alternative will improve shoreline form, stability, erosion protection to some extent. There will be no significant impact on groundwater quality and local hydrogeology. If this alternative is undertaken, construction related impacts like noise, dust and traffic can be fully mitigated. Most of the construction impacts on aquatic and terrestrial habitat can be alleviated through different measures such as- erosion control measures, working in construction windows etc. A few improvements can be made during replacement as outlined in natural heritage assessment but overall, replacement is considered neutral for natural features/functions.

Reach 11: As the reach is undergoing dynamic process, it is characterized as a low plain dynamic beach consisting of sand and gravel. The reach is approximately 530 m long and has a timber waterfront trail and a gravel dune. Part of the reach will require natural modification of the shoreline by improving vegetation cover. This modification can assuage the effects of erosion hazard. These measures will have positive impacts on local hydrology, shoreline form, shoreline function, natural heritage area, wildlife and vegetation population. Though there might be some negative impacts over shoreline stability and erosion protection of the reach, those impacts can be toned down. Besides, there will be no significant effect on groundwater quality and local hydrogeology from this alternative. **Considering all the impacts and possibility of mitigating the impacts, Alternative 6 (Modification & Improvement to natural features) is preliminarily preferred for Reach 11**.

Reach 12: The length of Reach 12 is around 2.25km. Several bluffs, with height ranging from 3-7m were observed at different portion of the reach. An observation lookout point was also spotted within 25m from the shoreline. A waterfront trail is located between 30m to 50m from the shoreline. Severe erosion was observed from the creek and culvert drain over the bluff. Moreover, erosion from wave actions was also observed, part of the informal trail and vegetation have slumped into the beach. In this case, the erosion can be tempered by modifying and improving the natural features (Alternative 6) like vegetation cover, reducing slope etc. where they are needed. Shrub plantings associated with any slope works in the two areas of gullying would help with stability while improving habitat. This alternative can provide sufficient protection from the significant gullying resulting from drainage over the bluffs by protecting the observation lookout point from erosion hazard; improving shoreline form, stability, and shoreline function; improving local hydrology. **Therefore, considering all the impacts and possibility of mitigating the impacts, Alternative 6 (Modification & Improvement to natural features, such as natural shoreline, wetlands, aquatic habitat and water course/creek outlets) is prioritized as the preliminary preferred alternative for Reach 12. This alternative does not recommend hardening of the slopes or any structural intervention. For this reach, it is recommended that slopes can be reduced by a small margin accompanied by improvement of vegetation cover specially where they are needed (i.e., protecting the trail/look-out where they are close to the shoreline and to rehabilitate the gullying. Leaving the bluffs alone where there are no hazards to structures is good from a natural perspective). This alternative will naturally protect the slopes and reduce the erosion rate.**

For Reach 12, the location of the fence is based on 14.50m stable slope recommended by GeoPro Consulting (2017) and shoreline erosion setback (8.5m) analysis as shown on Figure 37. AHYDTECH calculated recent erosion rate (2015-2018) of the shoreline near the observatory to determine 5-year erosion setback. The "Limit of Temporary Fence" can be extended all along this reach as long as it has a minimum of 23m (Stable slope + 5 Year Erosion setback) distance from shoreline toe. Though it is standard to use 100-year erosion setback (Figure 35) but it is recommended to use 5-year erosion (recent erosion rate) setback here, keeping in mind that the Town should monitor the shoreline erosion every 2 year to determine if the temporary fence needs to relocated based on progression of the shoreline erosion. The chain fencing can be removed after installing wooden temporary fence. Length of the fence would be about 1200 m long and the height of the fence should be about (1.5 -2.0 m)

Figure 37: Erosion hazard limit at Reach 12.

Reach 13: Three properties west of Thickson Road are located within 30m from a medium bluff of Reach 13. The east and west properties are not protected with a seawall; however, there is an abandoned dock at the east property and some broken gabion baskets at the toe of the bluff. Besides, rubble and broken concrete were observed at the toe of the bluff at Thickson Road dead end. The center property has a wooden board seawall with gabion basket protection at the toe. Although the wooden plank wall has a good alignment, it can't be considered as an ideal protection structure for the property since wooden materials have such short lifespan. Moreover, the existence of a residential building within 10m of the wall substantially increases the potential damage due to erosion and structural failure. In this case, installation of new shoreline structure (Alternative 5) can provide protection to the reach by improving shoreline form, stability and shoreline function, reducing road flooding impact and residential flooding impact etc. If this alternative is undertaken, construction related impacts like noise, dust and traffic can be fully mitigated. Landowner acceptance and suggestions can easily be taken in this alternative. A new structure would not represent a large reduction in habitat in the area of the existing ad hoc structures; however, extending a new structure along the reach represents an impact. As such, the new structure should be limited in length/locations only to that which is necessary for hazard protection. Additionally, the new shoreline structure should be designed to limit impacts and aim to incorporate aquatic habitat and vegetation to the extent feasible. There will be no potential traffic risk due to this alternative. Most of the impacts in existing utility lines can be reduced. The anticipated longevity of this alternative is also promising with less frequent maintenance. **Considering all the impacts and possibility of mitigating the impacts, Alternative 5 (Installation of new shoreline structures, such as seawall, revetment, sheet pile, groyne & marina structures) is preliminarily prioritized as the preferred alternative for Reach 13**.

Reach 14: Reach 14, the Crystal Beach Boulevard, is roughly protected with an armor stone revetment, which is not in a fair condition. The gravel private road falls within 1-5m from the shoreline revetment. Besides, multiple residential buildings are located within 30m from the shore. Though the revetment has been recently constructed and the armor stones are new, several stones were displaced and dislodged. One of the reasons might be, the stone size of the revetment is not large enough to provide protection against the wind and wave forces. Most of the stones in this reach were found to be less than 1 Ton. The displacement of the stones can result in the failure of the revetment and can cause severe erosion to the reach. Moreover, the soil behind the revetment was washed out to some extent and might continue to be eroded, since no geotextile material was used to retain the soil. In such event of severe risks, repairing and replacement of existing shoreline structure (Alternative 4) can be effective as it will improve shoreline form, bank stability, shoreline function and most importantly provide short-term and long -term erosion protection. Moreover, if this alternative is undertaken, construction related impacts like noise, dust and traffic can be fully mitigated. There will be no significant long-term effects on property damage or property acquisition and over current and future condition of the reach. Landowner acceptance and suggestions can easily be taken in this alternative. Besides, there will be no potential traffic risk and most of the impacts on existing utility lines can be reduced. The anticipated longevity of this alternative is also promising. **Considering all the impacts and possibility of mitigating the impacts, Alternative 4 (Repair & Replacement of existing shoreline structures, such as seawall, revetment, sheet pile, groyne & marina structures**) **is prioritized as the preliminary preferred alternative for Reach 14.**

Reach 15: Reach 15 is about 960 m long, starting from the Crystal Beach revetment to the Whitby town limit. The outlet of the Corbett Creek is partly blocked by the gravel beach. As a result, wet land drainage is reduced, and potential risk of riverine flooding has been increased for the houses of Crystal Beach Boulevard. In such case, modifying natural features (Alternative 6) with proper environmental analysis, might ameliorate the creek outlet and reduce the risk of flooding. But changes to the creek outlet to reduce the risk of riverine flooding have the potential to significantly alter the hydrology of the wetland resulting in a change to vegetation community structure and loss of existing wetland habitat, flora, and fauna. Any proposed modification to natural features would need to be studied carefully to prevent negative impacts to the Corbett Creek Provincially Significant Wetland and the Corbett Creek Coastal Marsh Candidate Life Science ANSI and that is a part of the detailed design. According to aquatic species at risk map outlined in the DFO website, no species at risk and critical habitats for these species found (or potentially found) within Reach 15. **So, considering all the impacts and the possibility of mitigating the impacts, Alternative 6 (Modification & Improvement to natural features, such as natural shoreline, wetlands, aquatic habitat and water course/creek outlets) is prioritized as the preliminary preferred alternative for Reach 15**. The modification should be implemented within 10 years. Detailed design of the project will follow the revisions to schedule C project as per section A.4.1.1. of MCEA.

As this Master Plan study is following Approach #2, investigation, consultation, and documentation is completed at a project-specific level for each of the Schedule A, A+, B and C projects identified within it. Reach 13 and 15 was identified as a schedule C project and it must fulfil Phases 3 and 4 prior to filing an Environmental Study Report for public review. The Master Plan can be used as a basis for future project specific investigations for the Schedule C projects.

Table 21: Preliminary preferred alternative and initial cost for each reach

Reach Name	Preliminary Preferred alternative	Name of the alternative	Initial cost (millions $)	Prioritization	Schedule Classification
Reach 01	Alternative 6	Modification & Improvement to natural features	1.92	Action required in 10 years	Schedule B
Reach 02	Alternative 4	Repair & Replacement of existing shoreline structures	0.73	Action required in 5 years	Schedule A+
Reach 03	Alternative 1 or Alternative 6	Do Nothing/Modification & Improvement to natural features	2.84	Action required in 10 years	Schedule B
Reach 04	Alternative 1	Do Nothing	0.00	No action required	NA
Reach04_a	Alternative 1	Do Nothing	0.00	No action required	NA
Reach 05	Alternative 4	Repair & Replacement of existing shoreline structures	1.36	Action required in 10 years	Schedule A+
Reach 06	Alternative 6	Modification & Improvement to natural features	0.96	Action required in 10 years	Schedule B
Reach 07	Alternative 4	Repair & Replacement of existing shoreline structures	1.41	Action required in 10 years	Schedule A+
Reach 08	Alternative 1	Do Nothing	0.00	No action required	NA
Reach 09	Alternative 4	Repair & Replacement of existing shoreline structures	2.84	Immediate action required	Schedule A+
Reach09_a	Alternative 1 or Alternative 4	Do Nothing/Repair & Replacement of existing shoreline structures	0.86	Action required in 5 years	Schedule A+
Reach09_b	Alternative 4	Repair & Replacement of existing shoreline structures	0.45	Immediate action required	Schedule A+
Reach 10	Alternative 4	Repair & Replacement of existing shoreline structures	1.38	Action required in 5 years	Schedule A+
Reach 11	Alternative 6	Modification & Improvement to natural features	2.02	Action required in 5 years	Schedule B
Reach 12	Alternative 6	Modification & Improvement to natural features	8.83	Immediate action required	Schedule B
Reach 13	Alternative 5	Installation of new shoreline structures	2.95	Immediate action required	Schedule C
Reach 14	Alternative 4	Repair & Replacement of existing shoreline structures	1.42	Immediate action required	Schedule A+
Reach 15	Alternative 6	Modification & Improvement to natural features	3.24	Action required in 10 years	Schedule C

14.3. Impact Assessment and Mitigation Strategies

Reach 1 – AHYDTECH recommends Alternative 6 (Modification and improvement to natural features) for Reach 1, which can be implemented gradually over a period. No socio-economic impact is anticipated. This area is a host to wide array of both terrestrial and aquatic organisms, and the preferred alternative will have negligible adverse impact on the natural environment.

Reach 2 – Considering the state of Reach 2, we have recommended Alternative 4 (Repair and Replacement of Existing structures) to be implemented in 5 years. This reach is privately owned, and it is imperative that the owner is contacted for permission to conduct repair works and/or engage in additional consultation. As the building at the property site is very close to the shoreline, it would be best to limit construction activities during business hours and to minimize the use of the backyard as construction staging area as much as possible. Other potential impact includes adverse effect on fish habitat, and dust and noise pollution for residents during construction work.

Reach 3 –AHYDTECH recommended Alternative 6 for this reach, with the implementation works to be done within 10 years. Both socio-economic and environmental impact would be negligible.

Reach 4 – AHYDTECH recommends Alternative 1 (Do nothing) for this study area.

Reach 4a – Just as with Reach 4, AHYDTECH recommends Alternative 1 (Do nothing) for this study area.

Reach 5 – AHYDTECH recommends Alternative 4 for this reach which is to be implemented in 10 years. It is anticipated that some of the trees and shrubs adjacent to the shoreline need to be removed (preferably relocated landward) Socio-economic impacts are negligible. However, adverse impact is to be anticipated on both aquatic and terrestrial habitat and species due to replacement of the existing seawall. Reach 5, along with reach 6 and 7, consists of a privately owned property. It is essential that the Town seeks permission from the property owner prior to implementation works.

Reach 6 – As AHYDTECH has recommended Alternative 6, socio-economic and environmental impact is expected to be negligible.

Reach 7 – As with Reach 5, implementation of Alternative 4 has been recommended and its impact on terrestrial and aquatic habitat and species are expected to be similar to that in Reach 5. The trees and shrubs adjacent to the shoreline is expected to be displaced. In addition, the trail to the north will need to be shut off to public during the construction phase.

Reach 8 –Based on assessments, Alternative 1 has been recommended for Reach 8. Thus, there will be no impact on the existing area.

Reach 9 –AHYDTECH recommends Alternative 4, i.e. repair and replacement of the existing sheetpile for this reach. Socio-economic impacts are negligible. However, the construction of the new and improved sheet pile is expected to have impact on the aquatic habitat near the yacht club in particular. Reach 9 is immediately south of the Whitby Harbor which has been identified as a contaminated side.

Reach 9a – AHYDTECH recommends Alternative 1 as the preferred solution for this reach, although Alternative 4 can be considered in the future.

Reach 9b – AHYDTECH has recommended Alternative 4 to be implemented and this would have negative impact on aquatic habitats and species, especially during the construction phase.

Reach 10 – AHYDTECH does not have any recommendations for the natural shoreline. For artificial shoreline, AHYDTECH recommends Alternative 4. While most of the land along this reach is public property, the Yacht Club is privately owned, and this is the site where AHYDTECH recommends interventions. It is anticipated that the repair and replacement of existing structure would mean temporary shutdown of the activity of the Yacht Club. This reach also happens to encompass the Whitby Harbor which has been known as a federal contaminated area managed by Fisheries and Ocean Canada, Permission for access and implementation must be obtained from the owners. Also, construction work can have mild to moderate adverse impact on the aquatic habitat and species.

Reach 11 –AHYDTECH recommends Alternative 6 which will have minimal socio-economic and environmental impact. This reach is at a sufficient distance from the privately owned properties.

Reach 12 –AHYDTECH has recommended Alternative 6 to be implemented which will not have adverse impacts on the socio-economic condition or the natural environment. The western half of this reach and a few sections to the east-most section of this reach is privately owned. Permission needs to be obtained from the property owners accordingly.

Reach 13 – AHYDTECH has recommended Alternative 5 (Installation of new shoreline structures, such as seawalls, sheet pile, groyne and marina structure for Reach 13.

Construction of the shoreline protection works is expected to result in dust and noise pollution. In addition, construction of shoreline protection works may be harmful to aquatic species at risk. This reach consists of privately owned property and the Town must seek permission from the property owners for the access and implementation of protection works along the shoreline. The bluff here appears to be vegetated with herbaceous organisms and a few scattered trees, some of which might need to be removed. The installation of seawall is expected to have adverse impact on aquatic organisms along the shoreline. he Corbett Creek Coastal Marsh Candidate Life Science ANSI and the Corbett Creek Provincially Significant Wetland are located well inland from the reach behind the houses present on the eastern portion of Crystal Beach Blvd, thus no impact on them.

Reach 14 – AHYDTECH recommends implementation of Alternative 4. Replacement of existing structure will result in noise and dust pollutions for nearby residents and at the same time the Crystal Beach Road may have disruption in traffic flow (or total blockage) during construction phase. This reach consists of privately owned property and the Town must seek permission from the property owners for the access and implementation of protection works along the shoreline. The anticipated environmental impact is almost identical to that for reach 14.

Reach 15 – AHYDTECH recommends Alternative 6 which will not result in any adverse impacts.

Generally speaking, in each of the reaches were interventions (particularly alternative 4 and 5) are recommended, there is a potential for accidental spills.

Table 22 summarizes the potential impacts of various shoreline protection works and their respective mitigation strategies. AHYDTECH strongly recommends additional consultation with stakeholders during implementation of the alternatives. During detail design phase, the Town should engage in stakeholder consultation. At the bare minimum, the Town must consult with the property owners at each site, CLOCA and the DFO. The table below summarizes the potential impacts of various shoreline protection works and their respective mitigation strategies.

Table 22: Potential Effects and Mitigation strategies for shoreline improvement works.

Potential Impact of Various Shoreline Improvements	Reaches where impacts are anticipated	Potential Mitigating Strategies
Impact on nearshore aquatic species and habitat	2, 5, 7, 9, 9b, 10, 13. 14	• Timing of in-water construction must be restricted between April 1 and June 30. • Addition of natural boulders either in front of the seawall or through a change to a revetment design that extends well below water to provide habitat heterogeneity, cover, and lower velocity zones for fish • Make use of heavy-duty floating turbidity curtains to minimize sedimentation • Use of natural stone instead of concrete
Dust and noise during construction processes	2, 5, 7, 9, 9b, 10, 13, 14	• Construction work must adhere to Noise by-laws • Make use practices that results in lesser dust pollution to the extent possible • Construction work to be carried out during business hours
Removal of trees and other vegetation from shoreline	5, 7, 13, 14	• During construction, all vegetation and structures on private property, adjacent to the work area, is to be protected or, if removal is required, restored to original condition upon completion of work. • Relocate trees and shrubs slightly landward if possible. • Perform a survey to determine if the trees are habitat of endangered terrestrial species.
Higher traffic volume due to trucks conveying construction materials.	2, 5, 7, 9, 9b, 10, 13, 14	• Deliveries need to be scheduled during business hours.
Disruption of traffic due to construction work	14	• Minimize the duration of construction work as much possible. • Prepare Traffic Management Plan during detailed design
Temporary closure of trails and parks	7,11	• Minimize the duration of construction work as much possible • Fences and signage need to be provided along the trails during construction work
Temporary closure of marina and yacht club	10	• Minimize the length of construction window. • Dedicate alternative parking location(S) for boats and yachts. • Carry out construction work of various sections of the reaches in different time phases instead of all at once.

Accidental spills of oil and sediments	1, 2, 3, 5, 6, 7, 9, 9a, 10, 11, 12, 13, 14, 15	• All activities, including maintenance procedure shall be controlled to prevent the entry of petroleum products, debris, rubble, concrete or other deleterious substances into water. Vehicular maintenance shall be conducted 30 m from the water. • Any sediment spill from the site must be reported to ministry of environment, conservation and parks (call spill action center at 1 800 268 6060.) • Maintain temporary erosion control and pollution control features installed under this contract. Erosion and sediment controls methods are to be continuously evaluated; and upgrades are to be implemented, when necessary
Potential impact on Cultural Heritage site	8, 9 and 10	• Conduct a stage 1 and stage 2 archaeological assessment prior to detailed design.
Impacts to and from Contaminated Sites	9, 10	• Prepare a plan for proper management of excess soil during detailed design • If potential contaminated areas are located within a project's zone of influence, a monitoring, maintenance, and mitigation plan should be developed during detailed design to prevent any undesirable impacts during the implementation of each project from these contaminated areas
Private Property	2, 5, 6, 7, 10, 13, 14	• The Town must obtain permission from the property owners to access the reach and implement the recommended alternatives. • At reaches which are near private buildings, it is important that construction work is performed during business hour. • For sites where shore protections structures are to be repaired or new ones to be installed, the construction staging area must be minimalized as much as possible.

15. Summary and Recommendations

1. A Class EA has been conducted to design preventive measures for the flooding and erosion problems occurring in the Whitby shoreline area. As part of this Class EA project, 7 alternatives were evaluated.

2. If the time period exceeds 10 years before any action is taken for a certain project, after the Notice of Completion was given, Town shall review the planning and design process to ensure that the project and the mitigating measures are still valid given the current context.
   Also, if there are any significant modifications required from the project outlined in this report or if there is any significant environmental change which occurs after the filing of this report, Town shall review it and provide an addendum to this report.
   In either event, the Town shall issue a Revised Notice of Completion to all potentially affected members of the public and review agencies. A period of 30 calendar days shall be provided for review and response by the public. The Notice shall include the public's right to request a Part II Order within the 30-day review period. If no Part II Order request is received by the Minister, the Town will be free to proceed with implementation and construction.

3. Background research, field investigation and data collection were performed, by gathering input from stakeholders and the public. The field investigation included topographic survey, bathymetric survey and shoreline characterization. The Whitby shoreline was delineated into 15 reaches based on the shoreline characteristics.

4. This study developed 2D hydrodynamic, circulation and wind-wave models. The models computed flow fields and wave parameters which were used to analyze the alternative options. In addition, wave setup and wave uprush were used to determine flooding and overtopping to analyze flooding issues and to perform risk and vulnerability assessment of the preferred alternative/alternatives.

5. 2D modelling software, SBEACH, was used for simulating cross-shore beach, berm, and dune erosion produced by storm waves and changes in water levels. Historical aerial photos were also used to determine long-term erosion/recession rate in the study area. Both the dynamic beach erosion and recession rate were applied to estimate 100-year erosion for each of the reaches for determining and mapping erosion hazard limits.

6. Reach 12 of the study area has a trail and observatory. At present, the observatory in the reach is closed for public. A "Temporary Wooden Fence" can be installed replacing the existing chain fence. It is recommended to install the Wooden Fence at a minimum distance of 23m from the existing shoreline. As erosion/recession of

Reach 12 is comparatively very high, the Town should monitor the Reach 12 shoreline erosion every two years.

7. Municipal Class EA processes were applied to assess and evaluate alternative options to address the flooding and erosion issues/concerns each of the 15 reaches. Based on the evaluation and assessment, this study has prepared preliminary preferred alternative and initial cost estimate for each of the reaches to provide the best possible solution to the existing problem/problems.

8. Implementation: Upon completion of the "Whitby Coastal Flood Risk Assessment and Municipal Class EA", detailed engineering design of the shoreline structures will be required. A priority list has been prepared for implementation and construction the preferred alternatives.

9. During the detailed design phase, AHYDTECH recommends the following additional studies to be conducted:

    1) DFO Review – For alternatives that require installation of a shoreline protection structure, DFO review is necessary to assess the hazard on aquatic species.
    2) Archaeological Assessment – AHYDTECH recommends Stage 1 archaeological assessment to be conducted for the reaches that require detailed design, and submitted to the Ministry of Heritage, Sport, Tourism and Culture Industries for review and acceptance onto the Ontario Public Register of Archaeological Reports. The necessity for Stage 2 Archaeological Assessment will be determined based on the findings of Stage 1 assessment. When such works will be carried out, if there are relevant archaeological findings for any comments/concerns to be considered, the Town shall consult with the indigenous communities identified by MECP.
    3) Geotechnical Investigation – For reaches were Alternative 4 and 5 have been recommended, Geotechnical Investigations is highly recommended. Geotechnical study will assess the slope stability conditions accurately.

10. The project team recommended four preliminary preferred alternative solutions to the existing problems in the project area. Below are the preliminary preferred alternative solutions for consideration in addressing the problems and opportunities.

    a. **Do Nothing:** Maintain the existing infrastructure, bluff, natural features, shoreline structures and water course outlets. This alternative does not solve the problem. This alternative is recommended for Reach 04, Reach 04a, and Reach 08. These reaches have natural beach with sand and gravel. There is no erosion and flooding hazards in these reaches. Therefore, "**Do Nothing**" is the preferred alternative for these reaches.

b. **Modification & Improvement to natural features, such as natural shoreline, wetlands, aquatic habitat and water course/creek outlets**. It is recommended that slopes can be reduced by a small margin accompanied by improvement of vegetation cover. This alternative will naturally protect the slopes and reduce the erosion rate. This alternative does not recommend hardening of slopes or any structural intervention. However, cobbles can be provided at toe of bluff where necessary to protect the bluff from toe scour. For example, Reach 12 has very high bluff with steep slope. Severe erosion was observed from the creek and culvert drain over the bluff. Moreover, erosion from wave actions was also observed, part of the informal trail and vegetation have slumped into the beach. In this case the slope can be reduced by a small margin. Also, an improved vegetation cover should be provided along the slope, so that no slumping can occur.in order to protect the toe of the bluff from scouring cobbles can be placed uniformly. In Reach 03, The barrier beach materials limit and slow down drainage discharge from the marsh. Slower discharge means that the marsh is more likely to retain higher levels in the summer and fall, when lake levels are lower. The barrier beach can be improved by artificial beach nourishment (introducing coarser materials).

   The study has recommended this alternative for Reach 01, Reach 03, Reach 06, Reach 11, Reach 12 and Reach 15. Conceptual drawings are provided in Appendix H.

c. **Repair & Replacement of existing shoreline structures, such as seawall, revetment, sheet pile, groin & marina structures**. This recommendation has been made for the shoreline structures in critical condition. As such, for crystal beach it is recommended to replace the existing revetment structure with appropriate design and size of stone. In Reach 02, the vertical wall has been recommended to repair with stalked concrete block. In Reach 09, it is recommended to repair the existing sheet pile wall, having armor stone on the lake side of the wall.

   The study has recommended this alternative for Reach 02, Reach 05, Reach 07, Reach 09, Reach 9a, Reach 9b, Reach 10, and Reach 14. Conceptual drawings are provided in Appendix H.

d. **Installation of new shoreline structures, such as seawall, revetment, sheet pile, groin & marina structures**. It has been recommended for Reach 13. Although, there are some shoreline structures like (broken gabion basket, wooden plank wall, etc.), these are not be considered as ideal protection structure for the reach. Moreover, the existence of a residential building within 10m of the shoreline substantially increases the potential damage due to erosion and structural failure. Therefore, a sloped revetment structure has been recommended preferred alternative for Reach 13. Conceptual drawings are provided in Appendix H.

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