Addendum to CVC's Lake Ontario Shoreline Hazards Report (Shoreplan, 2005)

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The LOSH study includes both hazard delineation, with mapping, and a suggested approach for applying the hazard limits to typical development applications. Since the Lake Ontario Shoreline Hazard (LOSH) study report was prepared, there have been several changes in Federal and Provincial policies along with technical advancements. A peer review was initiated to understand which components of the study, if any, are outdated and therefore, require revision. This addendum provides guidance on shoreline hazard delineation and the application of hazard limits to new development applications based on the recommendations of the Review of CVC's Lake Ontario Shoreline Management Hazards Report (Shoreplan, 2005), and other resources. This document should be read in combination with CVC's Lake Ontario Shoreline Hazard (LOSH) Study.

The 2020 update to the Provincial Policy Statement added item 3.1.3 which states "Planning authorities shall prepare for the *impacts of a changing climate* that may increase the risk associated with natural hazards". Impacts of a changing climate are defined as the present and future consequences from changes in weather patterns at local and regional levels, including extreme weather events and increased climate variability. A considerable amount of research has been done on climate change and its expected effects on the Great Lakes, but while results vary considerably, there is general consensus on several key points. Overall, water levels are expected to fall while severe storm frequency and intensity are both expected to increase. The aspect of climate change most relevant to the LOSH relates to changing water levels, unfortunately there is little confidence in the existing calculations of future water levels in_adequately projecting impacts to a changing climate.

Irrespective of whether they were caused by climate change, the high-water levels that occurred in 2017 and in 2019 have changed how the 100-year lake level is calculated. Additionally, Implementation of IJC's Plan 2014, which guides the current regulation of Lake Ontario's water levels, will also affect future lake levels (Baird, 2019); for instance, the 100-year lake levels used in the LOSH were based on values calculated by MNRF in 1989. Based on extreme value analyses of measured lake levels at Toronto from 1962 to 2019, and accounting for a possible 0.07m increase in mean water levels due to Plan 2014, the 100-year lake levels need to increase. Using lake level data up to 2019 at Toronto gauging station, a recent study by Toronto and Region Conservation Authority (TRCA) estimated that the 100-year lake level will increase by 0.33m, above the MNRF's (1989) estimated values (Baird, 2019). Similarly, another study for Central Lake Ontario Conservation (CLOCA) and neighbouring CAs (at Toronto Gauge station) estimated the increase in 100-year lake levels to be 0.27m above the previously estimated 100-lake level by MNRF in 1989.

Shoreplan completed extreme value analyses for the 58-year (1962-2019) of observed lake level at Toronto gauging station, which suggest 0.33m increase in instantaneous lake levels (Shoreplan, 2020). Consistent to these studies, practitioners are often using 0.30m to 0.40m increased lake levels in lake hazard assessment.

Considering the above-mentioned changes in lake levels and guided by the Provincial Policy Statement's section 3.1.3, it is reasonable for the CVC to increase the 100-year lake level by at least 0.20m, in the interim. Doing so now, will ensure protection of higher value development and infrastructure from lake hazards. It is recommended that practitioners apply professional judgement in determining a 100-year lake level greater than 0.2m above existing, as appropriate. This will be an interim solution until comprehensive research and analyses are conducted in collaboration with neighbouring CAs, Provincial, and Federal agencies. The following table summarizes the 100-year lake levels for two of MNRF reaches, known as O-3 and O-4 within the CVC watershed.

Location	**100-Year Lake Level**	
	(LOSH 2005)	**New (2020)**
East of Clarkson Pier	75.80m CGVD (75.85m IGLD)	76.00m CGVD (76.05m IGLD)
West of Clarkson Pier	75.90m CGVD (75.95m IGLD)	76.10m CGVD (76.15m IGLD)

CGVD= Canadian Geodetic Vertical Datum, also known as Geodetic Survey of Canada (GSC)
IGLD = International Great Lakes Datum

CVC's Lake Ontario Integrated Shoreline Strategy (LOISS) studies have established erosion monitoring stations and completed assessments of shoreline protection structures at twenty sites and CVC has also updated its shoreline topographic mapping using LiDAR data collected in 2015. In terms of shoreline structure assessments as part of any site-specific studies, it is not recommended that the LOISS recession rate data be re-calculated at this time

The digital mapping quality used in the LOSH also does not need to be updated at this time as it currently meets mapping standards. It is recommended that any site-specific wave uprush calculations should use the latest available LiDAR and bathymetric data. To note, the Canadian Hydrographic Service prepared a 2015 field sheet which contains much greater detail than the field sheet used in the wave analysis for the uprush calculations in the LOSH.

In conclusion, by increasing the 100-year lake level by 0.20m in the CVC Watershed, it becomes unnecessary to recalculate the flood hazard limits in the LOSH, particularly when, for the majority of the reaches, it is the erosion hazard versus the flood hazard that is the governing hazard limit. Additionally, once, the 15m regulatory limit is added to the governing hazard limit, this total area sufficiently encompasses any uncalculated increase to flood hazard limits due to the higher water level. A site-specific flood hazard analysis with the elevated lake level will accurately establish local lake hazards.

References

Baird (2019). Toronto Islands Flood Characterization and Risk Assessment Project. Flood Characterization Report. Prepared for Toronto and Region Conservation Authority by W. F. Baird & Associates Coastal Engineers Ltd. Final Report. 12 March 2019.

IJC (2014). Lake Ontario – St. Lawrence River Plan 2014. International Joint Commission. June 2014.

MNRF (2001). Technical Guide for Great Lakes - St. Lawrence River Shorelines. Prepared by Province of Ontario.

Peter (2020). Lake Ontario Shoreline Hazard Management Plan Update, Zuzek Inc., and SJL Engineering Inc. Prepared for Central Lake Ontario (CLOCA), Lower Trent Regional (LTRCA), and Ganaraska Region (GRCA Conservation Authorities).

PPS (2020). Provincial Policy Statement of Planning Act. Ministry of Municipal Affairs.

Shoreplan (2020). Review of CVC's Lake Ontario Shoreline Management Hazards Report.

FINAL REPORT

Lake Ontario Shoreline Hazards

Credit Valley Conservation

prepared by

Shoreplan Engineering Limited

September 2005

Shoreplan Engineering Limited
139 Merton Street, Suite 631
Toronto, Ontario M4S 3G7
T) 416.487.4756 F) 414.487.5129
E) mail@shoreplan.com

SHOREPLAN

September 26, 2005

Mr. Chris Hibberd
Credit Valley Conservation
1225 Old Derry Road
Mississauga, ON
L5N 6R4

Dear Sir

RE: Lake Ontario Shoreline Hazards
Our file 04-756

We are pleased to present our final report and mapping for the Lake Ontario Shoreline Hazards project. The bound report includes reduced scale copies of the shoreline hazard mapping. A set of 1:2,000 scale prints of the mapping is provided under separate cover. The CD bound within the report includes digital copies of the mapping and final report, ESRI Shapefiles and oblique aerial photographs of the shoreline.

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.

Yours truly,

Shoreplan Engineering Limited

Bruce Pinchin, P.Eng. Milo Sturm, P.Eng.

Executive Summary

This report describes a study carried out to define the Lake Ontario Shoreline Hazards within the limits of the Credit Valley Conservation watershed. Shoreline hazard mapping was produced to enable CVC to enact the new Generic Regulation of the Conservation Authorities Act, Section 28.

The shoreline within the study area was divided into a total of 87 reaches as required to ensure that the reach attributes used to calculate the hazard limits were consistent across each reach. Erosion, flood, and dynamic beach hazard limits were calculated for each reach. The hazard limit calculations were consistent with methods described in the Technical Guidelines to the Natural Hazards Policy (3.1) of the Provincial Policy Statement of the Planning Act. These hazard limits were plotted on 1:2,000 scale prints of FDRP map sheets. The map sheets were scanned and the plotted hazard limits were digitized.

The digitized hazard limits were added to 2002 digital contour mapping provided by the City of Mississauga. The limit of the regulated area was determined by creating a limit offset 15 metres from the landward most hazard limit within each reach. Hardcopy plots of the Shore Hazard Maps were produced at a scale of 1:2,000.

Table of Contents

List of Figures

List of Tables

1. Introduction

This report presents the results of a shoreline hazards study carried out for Credit Valley Conservation (CVC) by Shoreplan Engineering Limited. The work carried out during this study followed the methodology outlined in a Shoreplan proposal prepared in response to terms of reference from CVC dated November 10, 2004.

The purpose of the study was to prepare mapping showing the shoreline hazards that occur along the Lake Ontario shoreline within the jurisdiction of the CVC. Hazards considered included erosion hazards, flood hazards including wave-uprush and other water related hazards, and dynamic beach hazards. Methods of identifying and quantifying those hazards were based on procedures described in the Technical Guidelines to the Natural Hazards Policy (3.1) of the Provincial Policy Statement of the Planning Act (Watershed Science Centre and Ontario Ministry of Natural Resources, 2001), which are referred to herein as the Guidelines. The information produced by this study will be used by CVC to aid in preparing new regulation mapping under the Generic Regulation of the Conservation Authorities Act, Section 28.

Representative hazard limits were calculated for a number of shoreline reaches covering the Lake Ontario shoreline within the CVC jurisdiction. Section 2 of this report describes these shoreline reaches. Section 3 describes the methods used to calculate the erosion, flood, and dynamic beach hazard limits, as well as an additional limit applied under the generic regulation. Section 4 of the report describes mapping that presents the results of the hazard limit calculations. Section 5 of the report describes the material delivered to CVC under this study.

For each reach, representative conditions were determined for use over the entire reach when assessing the hazard limits. These conditions included parameters such as typical structure types, structure toe elevations and bluff crest elevations. A full listing of the representative conditions selected and their relevance to the hazard limit calculations are described in the related sections of this report. It is important to realize that because representative conditions were used for each reach, the hazard limits presented in this report were not determined to the level of precision that can be obtained with a site specific analysis. The results of this study are intended to be used as a planning tool not as a detailed engineering analysis. The hazard limits presented on the mapping are not as accurate as can be obtained from a site specific survey.

The approved regulation schedule will identify areas where permission is required from CVC prior to any development. Whether CVC approves or denies a development application should be based on a site specific evaluation of the subject property. That evaluation may be as limited as verifying that the reach wide representative conditions are applicable at the actual site.

1.1. Background Review

A number of reports and other documents were reviewed to obtain background information for this study. Shoreplan staff members also contributed information from personal experience obtained by working on a number of different projects within this area over the last two decades.

Aerial photographs were used to distinguish shoreline types and structure characteristics during the designation of the shoreline reaches. Photographs used included:

- 2002 high resolution orthorectified overhead photographs obtained from the City of Mississauga by CVC,
- 2005 oblique photographs provided compliments of Tarandus Associates Limited
- undated (early 1990s) oblique photographs from the Shoreplan library (originally obtained from the City of Mississauga)

Digital copies of the oblique aerial photographs are supplied on the included CD as Appendix C to serve as a one-time record of the shoreline conditions within the study limits.

A number of unpublished reports in both the CVC library and the Shoreplan library were reviewed to obtain any available information about the physical characteristics of the shoreline within the study area and any design details for existing shore protection structures. Reports found to include useful information included:

- Soil-Eng (1998a)
- Soil-Eng (1998b)
- Soil-Eng (2000)
- City of Mississauga (1993)
- CVCA (1998)
- Atria (1994)
- JSW+ (1993)

Surveyed nearshore profiles were supplemented with offshore bathymetric data originating from the Canadian Hydrographic Service (field sheets 8224, 8305 and 8338). This bathymetric data was used to assess likely changes in wave conditions within the study area and for the wave uprush calculations described later in the report.

1.2. Site Visits

A number of site visits were carried out over the course of the study both to confirm general conditions assumed within a number of reaches and to survey representative profiles for each of the sites initially defined as dynamic beaches. The beach surveys were completed to allow accurate estimates of the wave uprush characteristics along the dynamic beach shorelines. A greater accuracy was desired on the dynamic beaches than on non-beach shorelines because of the more restrictive development policies of the PPS on dynamic beaches. Details of the surveyed beach profiles are discussed in Section 3.2 of the report.

1.3. Geological Setting

Appendix D contains an excerpt of part of the Lake Ontario Shoreline Management Plan prepared by CVC in 1988. This excerpt describes the geological setting of the Lake Ontario shoreline within the CVC watershed.

2. Shoreline Reaches

The Lake Ontario shoreline within the CVC watershed is located mainly in the City of Mississauga and has a total length in the order of 13 kilometers. For this study the shoreline was divided into a total of 22 primary reaches based on coastal processes. Each primary reach was further sub-divided into secondary reaches where required to ensure that relatively consistent hazard conditions existed within each secondary reach and to consider public ownership. There were a total of 87 secondary reaches. Figure 2.1 shows the Lake Ontario shoreline within the CVC jurisdiction and the limits of the primary and secondary reaches.

2.1. Primary Reaches

The CVC shoreline was divided into a total of 22 primary reaches based on coastal processes. New primary reaches were defined where there were either total or near total barriers to the alongshore transport of littoral sediment and for sections of shoreline originally thought to contain dynamic beaches. Not all of the shoreline reaches originally thought to contain dynamic beaches were confirmed to be so, but those initial reach designations were kept. Reaches defined on the basis of littoral cells and the barriers that form the cell boundaries included:

- reach 2 – Lakeview Generating Station breakwater
- reach 3 – Lakefront Promenade Park marina breakwater
- reach 6 – Port Credit marina breakwater
- reach 18 – Petro-Canada Clarkson Refinery pier
- reach 21 – St. Lawrence Cement pier

Reaches originally considered as dynamic beaches included reaches 4, 8, 10, 12, 14, 16, 19 and 22 although reaches 4 and 8 were later determined to not be dynamic beaches. This is discussed in more detail in Section 3.3 of the report.

Reach 7 was defined as a new reach starting on the south side of the Credit River. Reach 6e stops at the north side of the Credit River and the river mouth was left as a discontinuity along the shoreline. The remaining reaches (5, 9, 11, 13, 15, 17 and 20) were defined because they were the next section of shoreline adjacent to the dynamic beach reaches. Reach 1 is the north-eastern most primary reach and reach 22 is the south-western most primary reach.

figure 2.1 (full page insert)

2.2. Secondary Reaches

Each primary reach was subdivided into secondary reaches as required to ensure that the reach attributes used to calculate the hazard limits were consistent across each reach. The criteria used to define the secondary reaches included:

- shore type (geological)
- exposure to the 3 hazards - erosion, flooding and beaches
- "natural" recession rate in absence of protection
- land elevation
- wave exposure
- public verses private ownership
- extent of development / land use
- protection, considering to some extent:
    - amount of protection
    - type of protection
    - structure toe depth
    - structure crest elevation height
    - structure quality and anticipated life

Once the secondary reaches had been designated the hazard limits were calculated for each secondary reach. The reasons for differentiating the primary reaches were not more relevant to the calculation of the hazard limits than the reason for differentiating the secondary reaches, so the designation of primary reach versus secondary reach was not important. The secondary reaches are therefore referred to simply as reaches for the remainder of this report.

2.3. Major Structures

A total of 9 special reaches (reaches 2a, 2c, 3a, 3e, 6a, 6c, 7d, 18a, and 21a) were defined to deal with major marine structures which require a level of review beyond the scope of this project. It was considered inappropriate to include those structures as part of a planning level of analysis. A detailed engineering review of those structures should be carried out before approval to change their existing use is granted. The reaches including those structures are therefore placed within the regulated area without specific analysis of the individual requisite hazards. The limits of these reaches correspond to the approximate limits of the structures along the shoreline.

2.4. Reach Attributes

A set of attributes was used to describe the characteristics of each reach and to calculate the various hazard limits. Appendix B contains a description of the attributes and a listing of the value of each attribute for all of the shoreline reaches, where applicable. The values in Appendix B were obtained from a number of different sources and their accuracy was confirmed only to the level of detail required for this study. Accuracy should be independently confirmed before that data is used for any other purpose.

3. Calculating Hazard Limits

For this study we have mapped hazard limits based on an assessment of the requisite hazards consistent with the Guidelines for Developing Schedules of Regulated Areas (Conservation Ontario, 2003). The requisite hazards considered were erosion hazards, flood hazards and dynamic beach hazards. An additional allowance of 15 metres was added to the landward most requisite hazard limit, as permitted under the generic guidelines. This allowance is referred to as the generic limit. It fulfills the important role of providing a buffer beyond the calculated hazard limits so that any inaccuracies associated with the hazard limit calculations do not exclude shoreline areas that should be within the regulated area. Descriptions of the requisite hazard limits are provided below.

In determining the hazard limits for the various reaches we have applied the "worst-case" conditions within each reach to ensure that our calculations are conservative. This has led, in many instances, to different values being used for a given parameter where that parameter is used in the calculation of more than one hazard limit. As an example, the list of reach attributes for reach 1A (see appendix B) shows that a bluff crest elevation of 77.0m was used in the stable slope portion of the erosion hazard limit calculation but an elevation of 76.0m was used for the wave uprush portion of the flood hazard limit. Using the lower bluff elevation for the erosion calculation or the higher bluff elevation for the flood calculation would not have been conservative.

The values of each of the parameters used for calculating the hazard limits for each reach are shown in the list of reach attributes in Appendix B.

3.1. Erosion Hazard Limits

Erosion hazard limits were calculated as N times the average annual shoreline erosion rate plus a stable slope allowance where N represents the number of years of erosion to be considered. N is always taken to be 100 years except where credit for existing shoreline protection is given. The length of time credited for shoreline protection is based on the estimated life of the structure multiplied by the percentage effectiveness of the structure. Structure life and effectiveness were estimated according to the assumed conditions shown in Tables 1 and 2.

The erosion hazard limit is therefore calculated as

$$H_E = (100 - L \times E) \times R + S \times B$$

where

H_E is the erosion hazard limit in metres
L is the structure life (years) from Table 3.1
E is the structure effectiveness from Table 3.2
R is the average annual recession rate in metres/year
S is the stable slope of the bluff (horizontal: vertical)

B is the height of the bluff in metres

Table 3.1 Protection Structure Life Spans

Life	Description
50 years	Structure has certainly or most likely been professionally engineered, or structure is extremely well protected, such as in a marina
35 years	Structure has probably been professionally engineered
25 years	Origin of structure is unknown but structure looks reasonable (assessed without a detailed review)
0 years	Otherwise

Table 3.2 Protection Structure Effectiveness

Effectiveness	Description
100 %	Report authors are aware that this protection is in excellent shape and is performing properly.
75 %	Structure appears to be in excellent shape and performing properly but the authors are not specifically familiar with the structure
50 %	Structure appears to be in good shape and performing adequately
0 %	Otherwise

The values of each of these variables used in the erosion hazard limit calculations are included in the list of reach attributes presented in Appendix B. Our assessment of the life span and effectiveness of the shoreline structures was based on a review of aerial photographs with a limited number of site visits.

A stable slope of 2.5: 1 (horizontal: vertical) was used for the entire study area. There was a limited amount of geotechnical information available but the information we found all showed that the stable slope was 2:1. This information included slope stability reports for the bluffs in reaches 11A and 11C (Soil-Eng, 1998 and 2000), which are the highest bluffs in the study area, and reference to a slope stability analysis within reaches 21B and 21C (Terraprobe, 1993 cited in CVC file dealing with Westrock Inc. property). It is likely that all of the bluff shoreline within the study area will have a similar stable slope but it was decided that a 2.5:1 slope should be used to be conservative.

Bluff heights were calculated as the bluff crest elevation minus the bluff toe elevation. Bluff crest elevations were generally obtained from the FDRP mapping, although site specific information was used where available. Bluff toe elevations were also determined from site specific information where available. If no specific information was available then default values were assumed based on the nature of the shoreline within the reach. The default toe elevations used are shown in Table 3.3. Based on our site review these are reasonable elevations for the typical conditions found within the study area. The source of the bluff height and toe elevation data for each reach is included in the list of reach attributes in Appendix B.

Table 3.3 Default Toe Elevations

Elevation	Description
72.5 m	Headlands and major fill areas extending well out from shore
73.5 m	Large protection structures (generally built at a modest offset from the original shoreline)
74.0 m	Nearshore protection structures (generally built directly against the existing bank)
74.5 m	Unprotected bluff and beach shorelines

Three different values of the average annual erosion rate were used; 0.1m/yr, 0.2m/yr, and 0.3m/yr. A value of 0.3m/yr, the default value defined in the Guidelines, was used for the large headland areas constructed with moderately compacted landfill. This is probably a high rate as large rubble was used to protect the headlands during construction, but the unknown nature of the landfill dictates its use.

An average annual erosion rate of 0.1m/yr was used for all beach shoreline, including significant beach deposits that were not long enough to be classified as dynamic beaches. This is higher than the erosion rate of 0.08m/yr calculated for the existing beach in Reach 12D as part of the design at Jack Darling Park (JSW+, 1993).

We used an erosion rate of 0.2m/yr for all other shoreline. This is a conservative rate for shoreline where bedrock is the controlling substrate. For such shoreline an average annual erosion rate of 0.1 to 0.15m/yr is typically used.

3.2. Flood Hazard Limits

Flood hazard limits were calculated as the 100-year instantaneous water level plus a wave uprush allowance. The 100-year instantaneous water level was determined by MNR (1989) to be 75.8m GSC east of the Clarkson refinery pier (reach 18a) and 75.9m GSC west of the pier. Wave uprush calculations were carried out for a wave condition with a return period in the order of 10 to 20 years, as specified in the Guidelines. A wave with a deep water significant wave height of 6m and a significant wave period of 9s was used. This wave was selected from the results of an extreme value wave analysis carried out by Shoreplan Engineering Limited for a project in Port Credit.

A series of wave uprush calculations were carried out for typical revetment and wall structures as well as a number of surveyed profiles. Nearshore profiles were surveyed within each reach where it was thought that dynamic beach hazards might apply. The surveyed profiles were extended into deeper water using data surveyed by the Canadian Hydrographic Service. Cross sections of the combined profiles from the Shoreplan surveys and the CHS data are presented in Appendix A.

Typical structures considered in the wave uprush assessment included both vertical and near-vertical walls and sloped revetments. The toe elevations from Table 3.3 were considered, as well as a range of possible crest elevations. For the uprush calculations it was assumed that the shore landward of the structures (or natural bank) was essentially flat. This assumption was made to keep the uprush calculations conservative as the landward extent of flooding from overtopping waves is greater on flatter land than on land that slopes upward. Site specific analyses would be required to accurately consider the actual topography found behind the different structures within the study area.

Table 3.4 shows the calculated uprush elevations and offsets for the typical structures considered. The uprush offset is measured horizontally from the crest of the structure and indicates how far inland overtopping water is to be expected when the structure is overtopped. Both the uprush elevation and offset are products of the in-house model used for the wave uprush calculations. This model calculates an equivalent runup slope by matching calculated uprush levels with the actual structure profile. Wave uprush elevations were calculated using the Hunt runup equation for beaches and the Ahrens and McCartney runup equations for structures. These runup equations are discussed in the appendices to the Guidelines. If the structure is not overtopped then the uprush elevation is reported as below the structure crest.

The uprush elevations presented in Table 3.4 were calculated using an instantaneous water level of 75.85m, which is the average of the two MNR 100-year instantaneous water levels described above. This was done so that the results in Table 3.4 could be applied over the entire study area. This is a reasonable approximation as the accuracy of wave uprush calculations on structures is less than the error introduced by averaging the 100-year instantaneous water levels.

On the list of reach attributes presented in Appendix B, an offset to the crest of the structure/bluff is shown with the flood hazard parameters. That value, when added to

Table 3.4 Uprush Elevations and Offsets for Protection Structures

	Revetments		Walls	
Crest Elevation (m)	**Uprush Elevation (m)**	**Uprush Offset from Front of Structure (m)**	**Uprush Elevation (m)**	**Uprush Offset from Front of Structure (m)**
Toe elevation 72.5m (default for headlands)				
high	78.7	below crest		
78.0	overtops	7		
77.5	overtops	14		
77.0	overtops	19		
76.5	overtops	34		
Toe elevation 73.5m (default for large structures)				
79.0			79.0	at crest
78.0	77.9	below crest	overtops	7
77.5	overtops	5	overtops	11
77.0	overtops	12	overtops	17
76.5	overtops	22	overtops	26
Toe elevation 74.0m (default for nearshore structures)				
79.0			78.3	below crest
78.0			overtops	2
77.5	77.5	at crest	overtops	6
77.0	overtops	7	overtops	11
76.5	overtops	16	overtops	19
Toe elevation 74.5m (default for unprotected shores)				
78.0	77.1	below crest	77.6	below crest
77.5	77.1	below crest	overtops	1
77.0	overtops	2	overtops	5
76.5	overtops	9	overtops	12

the uprush offset, gives the width of the flood hazard limit in a form that it can be directly compared to the width of the erosion hazard limit as both limits are measured from the same point. It is important to note that the crest offset values shown are approximate only and are not actually used in the mapping of the flood hazard limits. Where overtopping applies the wave uprush limit is mapped using the offset from the structure crest. Where the erosion hazard limit is larger than the flood hazard limit the value of the offset to the crest of the structure is not important and is not necessarily the worst case value for the reach.

Wave uprush was not calculated in a limited number of reaches due to a lack of knowledge of the design wave conditions. This occurred in reaches where there was significant sheltering from nearby structures. For most of those reaches we were able to assume a maximum uprush level as we know the structures in those reaches were designed for no overtopping. If we were not able to make such an assessment then the provincial default 15m wave uprush allowance was applied. The flood hazard notes in the list of reach attributes identify the reaches where these assumptions were made.

For the very sheltered shoreline within the Port Credit and Lakefront Promenade Park marinas we applied a flood elevation of 76.3m GSC, referred to as the default marina flood elevation. It was calculated by adding a 0.5m uprush height to the 75.8m 100-year instantaneous water level. This is an appropriate uprush height as the marinas in question have all been designed so that the maximum wave height within the mooring areas is less than 0.3 metres. A wave height less than 0.3m will produce uprush of about 0.5m when it strikes a vertical wall.

Flood hazard limits for each dynamic beach reach were calculated from surveyed typical profiles within those reaches. Cross-sections of the profiles used in those calculations are presented in Appendix A. Due to the nature of the beaches within the study area the flood limits tended to extend beyond the actual limits of the beaches. This is due to the lack of dune or berm formation associated with a general lack of supply of beach material.

3.3. Dynamic Beach Hazard Limits

Each reach with a significant beach deposit was investigated to determine if the beach met the requirements for definition of a dynamic beach as specified in the Guidelines. Where the minimum requirements for classification as a dynamic beach were met, we reviewed the site conditions to determine what dynamic beach allowance should be added to the wave uprush limit to define the dynamic beach limit. The dynamic beach limit and a brief explanation of why that limit was selected are included in the reach attributes in Appendix B.

It is important to remember that this study applied a general planning level of effort for the analysis of the shoreline hazards rather than a site specific detailed engineering level of analysis. To remain conservative we have designated certain shoreline reaches to be dynamic beaches after a limited review of those beaches. Our designation of dynamic beaches is appropriate for this study. It is possible that a detailed scientific or engineering study could conclude that some of these beaches are not dynamic.

The Guidelines recommend that where there is evidence of long-term recession of dynamic beaches that the best estimate of the recession rate be included in the determination of the landward limit of the dynamic beach hazard. As described previously we have used a long-term recession rate of 0.1 metres per year for beach shoreline within the study area. We have therefore added a 10 metre erosion allowance (100 years x 0.1 metres/year) to the otherwise determined limit of each dynamic beach hazard limit. It is possible that a detailed scientific or engineering study could conclude that some of these beaches are not experiencing long-term recession and the additional erosion setback is not required.

Reaches originally considered as dynamic beaches included reaches 4, 8, 10a-c, 12a-d, 14a-b, 16a-b, 19 and 22. The Guidelines specify that the dynamic beach hazard only be applied where the beach deposit is at least 30 metres wide and 100 metres long. Reach 4 is a small sand fillet beach that has formed against the outlet of Cooksville Creek because of the adjacent headland from Lakefront Promenade Park. This was determined to not be a dynamic beach because the portion of the fillet beach that was more than 30 metres wide was less than 100 metres long. A beach profile was still surveyed, however, so that the wave uprush limits could be accurately determined. The surveyed cross-section is included in Appendix A.

Reach 8 contains a cobble beach along the shore of Rhododendron Garden Park. This reach was also determined to not be a dynamic beach because the width of the cobble deposits was less than 30 metres and because a length of armourstone protection divides the cobble deposits into segments less than 100 metres long.

Reaches 10a-c are the shoreline at Richard's Memorial Park and contain three beach cells between armoured groynes. For this study we have considered the groynes to be part of the beach system and have considered this reach to be a dynamic beach. If the groynes were considered to be separate structures dividing three separate beaches then the beaches would not be long enough to be defined as dynamic beaches. There is no indication of current dune formation at the upper end of these beaches and no signs of dynamic processes taking place. The back of the beaches are either restrained by the low bank or meet the low plain backshore within the limit of the design wash uprush. The limit of the dynamic beach hazard was therefore set at the wave uprush limit plus the 10 metre erosion allowance described above.

Reach 12d is at the southern end of Jack Darling Park and contains the only signs of a dune found within the study area. This dune, however, is small and only exists because trees on the beach have trapped the sand. The dune will be overtopped during design conditions with the wave uprush limit extending beyond the limits of the beach onto the sand plain behind the beach. For this reach the limit of the dynamic beach hazard was set at the wave uprush limit plus the 10 metre erosion allowance described above.

Reach 14a is the barrier beach fronting the Rattray Marsh so the limit of the dynamic beach hazard is the toe of the barrier slope on the landward side. This toe is not shown on the available mapping so we applied the full 30 metre default dynamic beach limit specified in the Guidelines. This is most likely an overly conservative estimate of the toe of the barrier slope but is without consequence here as the flood hazard limit extends much further inland because of the marsh. The 30 metre dynamic beach limit was added to the calculated erosion hazard limit to be consistent with the way erosion was considered in all the other dynamic beach reaches.

Sub-reach 16a is a cobble beach on the Petro-Canada Clarkson Refinery property. This beach does not appear to be at all dynamic as the beach crest is heavily vegetated. The crest will be overtopped during design conditions with the uprush extending beyond the limits of the beach cobbles. The dynamic beach hazard limit was set at the limit of the wave uprush plus the 10 metre erosion allowance described above.

The remainder of the dynamic beaches (reaches 12a-c, 14b, 16b, 19, and 22) front banks or bluffs so the toe of the bluffs determine the dynamic beach hazard limits, as specified in the Guidelines. The dynamic beach hazard limits were therefore defined as the bluff toe plus the 10 metre erosion allowance described above.

3.4. Generic Limit

An additional allowance of 15 metres was added to the landward most requisite hazard limit, as permitted under the generic guidelines (Conservation Ontario, 2003). This allowance is referred to as the generic limit. It fulfills the important role of providing a buffer beyond the calculated hazard limits so that any inaccuracies associated with the hazard limit calculations do not exclude shoreline areas that should be within the regulated area.

4. Mapping Hazard Limits

The requisite hazard limits described in Section 3 of this report were plotted on 1:2,000 scale prints of the CVC's FDRP mapping as specified in the terms of reference. The hazard limits were digitized and converted to ESRI Shapefiles for use in the CVC GIS system. These Shapefiles were also combined with digital contour mapping (based on 2002 aerial photography) which became available from the City of Mississauga during the study. The 2002 digital contour mapping was used as a base for the hazard limit mapping produced for this project.

4.1. FDRP Mapping

The hazard limits described previously were manually plotted on 1:2,000 scale prints of maps prepared during the Canada-Ontario Flood Damage Reduction Program (FDRP). These maps were produced from 1989 aerial photographs and cover the Lake Ontario shoreline within the CVC watershed.

The erosion hazard limit should be measured from the toe of the bluff or bank, where the toe is defined by a break in slope. The position of the toe of the bank is not shown on the FDRP mapping or the Mississauga digital mapping so we measured the erosion hazard limit from the lakeward-most contour line. This results in a conservative positioning of the erosion hazard limit line on the mapping.

Where the flood hazard limits were based on elevations (no overtopping) the limits were determined using wave uprush elevations calculated to one decimal place. The FDRP mapping contour interval is 1.0 metres although there are some auxiliary contour lines plotted at 0.5 metre intervals. Spot elevations are also provided throughout the maps. The position of the flood elevation contour was estimated using the FDRP contour lines which introduced a degree of uncertainty because of the spacing of the FDRP contour lines.

Where the structures or bluffs were determined to be overtopped the flood hazard limits were calculated as a horizontal offset from the crest of the structure (see Table 3.4). The hazard limit was plotted as an offset from the FDRP contour line assumed to represent the bluff or structure crest.

The FDRP mapping legend shows entries for a regulatory flood level, a standard wave action offset, a regulatory erosion limit and a regulatory dynamic beach limit. The regulatory flood level line is apparent on the mapping but we did not find instances of the other line types. It is important to note that those limits were determined during the FDRP program and should not be confused with the hazard limits determined during the study described by this report.

Given the FDRP map scale of 1:2,000 a 1mm uncertainty in plotting the hazard limit translates into a 2 metre prototype uncertainty. We recommend that +/- 2 metres be considered the minimum accuracy of the prototype hazard limits. This is particularly important when viewing the hazard limits at a high resolution scale with GIS software and the digital mapping.

4.2. Digital Mapping

The FDRP map sheets with the plotted hazard limit lines were scanned then registered (georeferenced) using the coordinate system on the map sheets (UTM Zone 17N NAD 27). The hazard lines were then digitized on-screen using ArcGIS, producing ESRI shapefiles of the hazard lines. The hazard line segments associated with each reach were recorded as attributes in the ESRI shapefiles. Reach limit position points along the shoreline were also digitized as ESRI shapefiles.

The shapefiles were combined with the 2002 digital mapping from the City of Mississauga to produce the Shoreline Hazard Maps that are the main product of this study. Hardcopy prints of those maps at a scale of 1:2,000 are presented under separate cover as Appendix E. Digital copies of the maps are included on the accompanying CD in Appendix C. The maps were prepared using CVC specifications based on their Floodline Mapping.

The FDRP mapping was based on the NAD27 horizontal datum. The digitized hazard lines were shifted to match the NAD83 horizontal datum used in the 2002 digital mapping. The amount of shift required to covert from NAD27 to NAD83 was determined using the NTv2 computer program from Geodetic Survey Canada. Single values of the north-south shift and the east-west shift were used for all maps.

The 15 metre offset Generic Limit (section 3.4) was produced by first assembling line segments to represent the landward most hazard lines then using ArcGIS to generate an offset line. Vector editing and clean up was required to deal with areas of intersection of the offset lines caused by offsetting non-parallel lines. No other smoothing was performed on the offset lines.

The total regulated area has been represented in the shapefiles as a series of closed polygons. Polygons were generated for contiguous segments of the generic offset line derived from the 15m offset. This line was interrupted by discontinuities in the shoreline (Cooksville Creek and the Credit River) and by the special reaches with major structures (section 2.3). Each major structure reach was also represented by a closed polygon using the sides of the adjacent polygons based on the 15 metre offset lines.

4.2.1. Reach Attributes

The list of reach attributes presented in Appendix B is included in a Microsoft Excel 2002 file on the accompanying CD. The data in the list of reach attributes can be readily linked to existing shapefiles.

5. Typical Application

A typical application of the hazard mapping and supporting report is likely to involve using this material to determine if CVC should give their approval to a development application. If a proposed development includes work within the regulated area (defined from the Generic Limit) then all the shoreline hazards should be reviewed for that site.

It was the intention of this study to be conservative so if the proposed development is within the regulated area but outside the actual hazard limits then only a brief review should be required to confirm that the proposed development is safe from shoreline hazards. CVC should confirm that actual conditions are equal to or better than those assumed in determining the hazard limits. This may include estimating the probable life span and/or effectiveness of an existing protection structure so a certain level of engineering experience could be required.

If the proposed development is within the mapped hazard limits it will be up to CVC to decide if a site specific analysis of the hazard limits are warranted and if that analysis should be done by CVC or the responsibility of the proponent. It is not uncommon for a Conservation Authority to require the proponent retain a qualified professional engineer to assess the actual shoreline hazards. This would be an appropriate action for a proposed development located well within the hazard limits calculated for this study. If, however, the proposed development is only marginally within the hazard limits CVC may wish to carry out their own review to see if overly-conservative assumptions have caused the calculated hazard limit to include the proposed development area.

The first step in evaluating a given site is to determine how the specific conditions at that site compare to the general conditions assumed for the shoreline reach containing the site. If conditions differ then the significance of that difference must be evaluated as the significance of the differences is also site specific. For example, an inaccuracy in the estimated bluff or structure height is much more relevant on a low bluff shore that overtops and the extent of uprush inland defines the flood hazard limit than it is on a high structure that does not overtop and the limit of the flood hazard is on the face of the structure. If the differences are significant and likely to lead to a reduction in the hazard limit then the limits could be re-evaluated with the site specific conditions. If the proposed development is then outside the re-evaluated hazard limits CVC might opt to approve the development without further assessment.

The site specific conditions that would need to be evaluated are included in the list of reach attributes in Appendix B. From that list the controlling substrate, general shore type, surficial substrate and exposure are all related to the long-term average recession rate. The significance of differences in those values will be site specific, as described above.

The toe and bluff elevations in the erosion hazard calculations are used to calculate the bluff height, which in turn is used to determine the stable slope setback. The sensitivity of the erosion hazard limit to the assumed bluff height can be easily determined and the hazard limit position can be adjusted if required.

The probable life span and effectiveness of protection structures can have a significant effect on the calculated erosion hazard limit. We recommend that only qualified professional engineers be used to evaluate protection structures if their existence is important to the calculated hazard limits.

The toe and crest elevations and structure types used in the uprush calculations have a significant effect on the calculated flood hazard limits. If site specific conditions allow different toe and crest elevations or structure types from Table 3.4 to be used then the resulting different flood limits from Table 3.4 may also be used comfortably. If site specific toe and crest elevations or structure type are different from those in table 3.4 but other Table 3.4 values do not apply then new uprush calculations must be carried out by a qualified professional engineer. We do not recommend that CVC do those calculations themselves.

We do not anticipate a need for CVC to re-evaluate the dynamic beach limits. If a proponent believes a dynamic beach as defined in this study is not actually a dynamic beach then a detailed evaluation of the beach should be carried out by a qualified individual as specified in the Guidelines.

6. Deliverables

Material delivered to Credit Valley Conservation as part of this study includes:

- hardcopy prints of this final report
- softcopies of this report in Adobe Acrobat PDF version 6.0 and Microsoft Word 2002 formats
- hardcopy prints of the flood hazard maps at 1:2,000 scale
- AUTOCAD version LD 2004 and Adobe Acrobat PDF version 6.0 softcopies of the flood hazard maps
- ERSI Shapefiles of the hazard limits
- A Microsoft Excel 2002 format softcopy of the reach attributes presented in the report Appendix B

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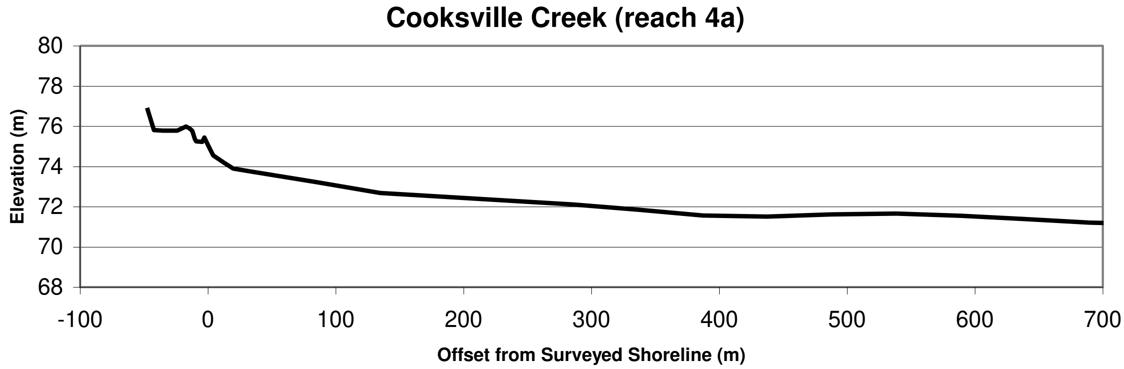
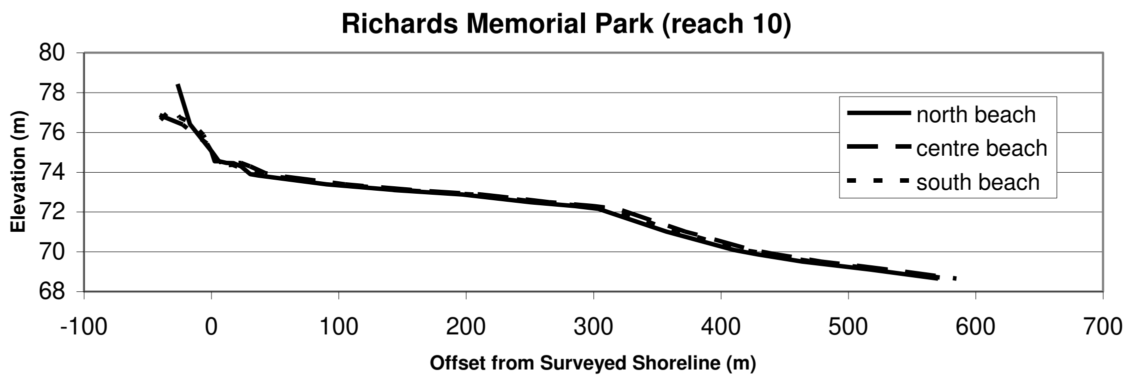
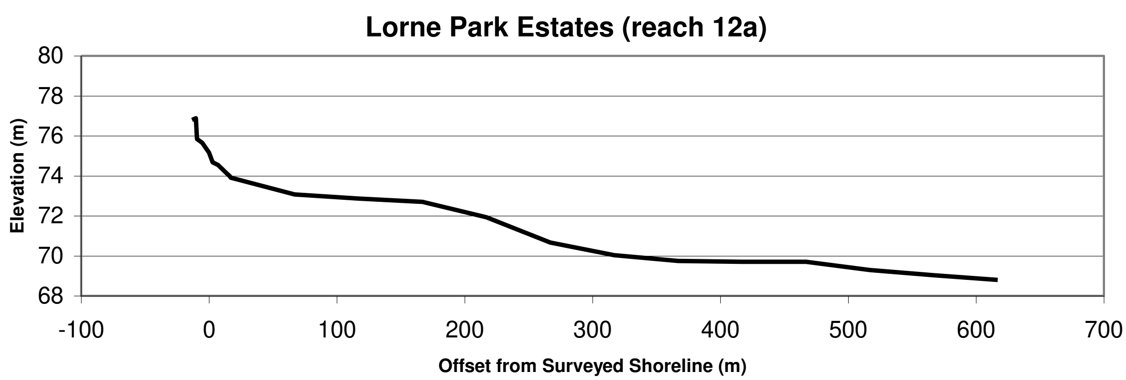
Appendix A

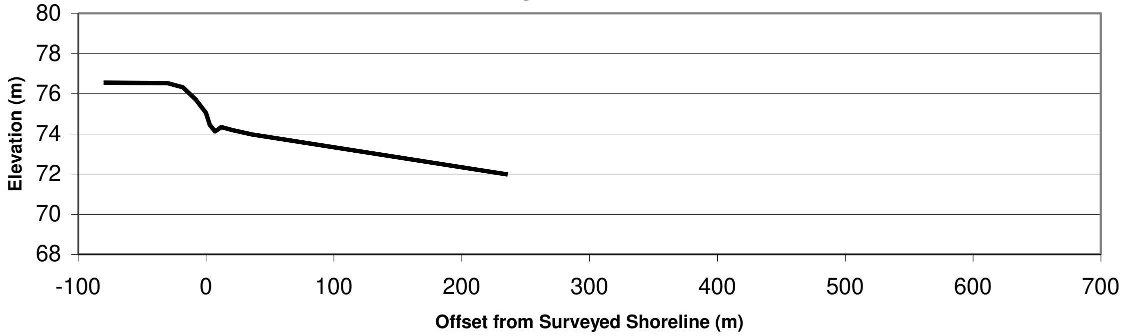
Beach Profiles


Cooksville Creek (reach 4a)
Elevation (m)
80
78
76
74
72
70
68
-100
0
100
200
300
400
500
600
700
Offset from Surveyed Shoreline (m)

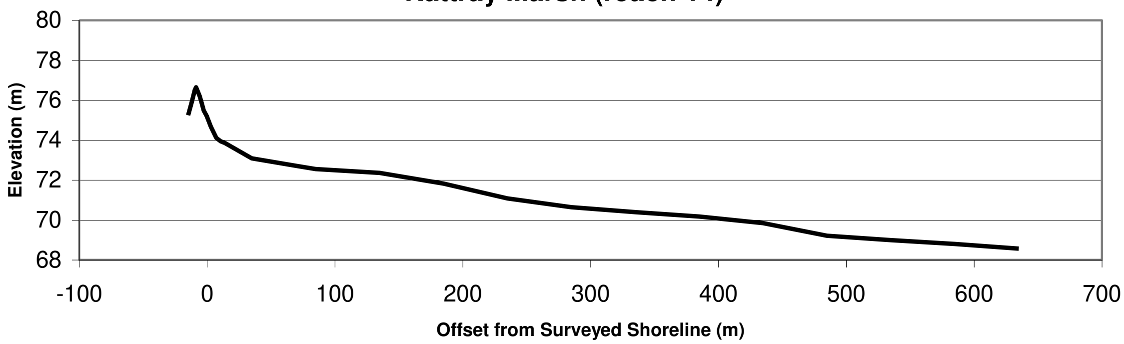

Richards Memorial Park (reach 10)
Elevation (m)
80
78
76
74
72
70
68
-100
0
100
200
300
400
500
600
700
Offset from Surveyed Shoreline (m)
north beach
centre beach
south beach


Lorne Park Estates (reach 12a)
Elevation (m)
80
78
76
74
72
70
68
-100
0
100
200
300
400
500
600
700
Offset from Surveyed Shoreline (m)

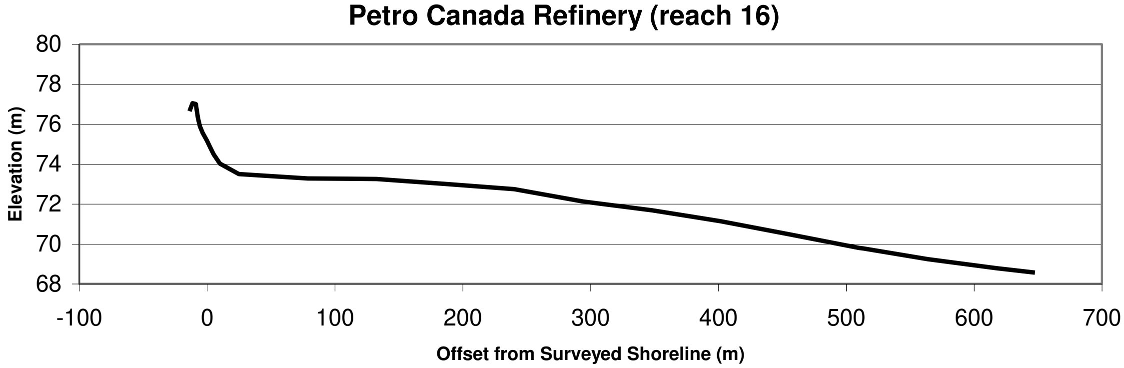
Jack Darling Park (reach 12c)

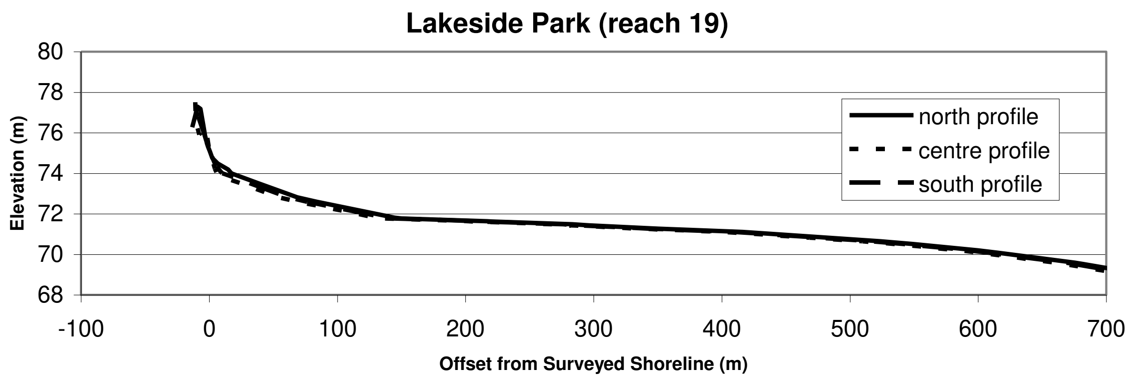


Rattray Marsh (reach 14)



Petro Canada Refinery (reach 16)




Lakeside Park (reach 19)
Elevation (m)
80
78
76
74
72
70
68
-100
0
100
200
300
400
500
600
700
Offset from Surveyed Shoreline (m)
north profile
centre profile
south profile

Appendix B

Reach Attributes

ATTRIBUTE	DESCRIPTION
SUMMARY	
Location description	name of shoreline reach, property or nearby street
Erosion hazard limit	erosion hazard limit in metres from toe of bank
Flood elevation	flood hazard limit in metres GSC if elevation based
Flood hazard limit	flood hazard limit in metres if based on offset
Length along hazard limit	Reach length in metres measured along the lakeward most contour line from the City of Mississauga 2002 digital mapping
GENERAL DESCRIPTION	
Controlling substrate	estimated controlling substrate– the controlling substrate is the underlying material which makes up the main body of the lakebed and tends to control the long-term recession of the shoreline
General shore type	estimated shore type – general description of the shoreline includes protected and artificial shores
Surficial substrate	estimate of material that forms the surficial nearshore substrate
Exposure/ Planform	indicates severity of exposure to offshore wave conditions
Land use	estimated current land use (from unverified sources)
Ownership	estimated ownership (from unverified sources)
Protection type	type of protection structure assumed to be in this reach when calculating hazard limits
EROSION HAZARD PARAMETERS	
Toe elevation	toe elevation used in erosion calculations
Toe description	source of toe elevation information
Bluff/bank crest elevation	bluff height used in erosion calculations
Crest description or source	source of bluff height information
Bluff height	calculated as crest elevation minus toe elevation
Stable slope [x:1]	stable slope used in erosion hazard calculation
Erosion rate	long term average annual recession rate used in erosion hazard calculation
Protection structure life	estimated life of structures as per Table 3.1
Protection effectiveness	estimated effectiveness of existing structures as per Table 3.2
Erosion hazard notes	any reach specific notes about the erosion hazard calculations
FLOOD HAZARD PARAMETERS	
Toe elevation for uprush	toe elevation used for wave uprush calculations
Crest elevation for uprush	crest elevation used for wave uprush calculations
Offset to Bluff/Structure Crest	estimated offset from lakeward most contour line to

ATTRIBUTE	DESCRIPTION
	crest of protection structure – used to compare flood and erosion hazard limits from a common starting point
Structure type	type of structure assumed during uprush calculations
Uprush elevation	design wave uprush elevation
Wave uprush offset	estimated equivalent offset when waves overtop
Flood elevation	flood hazard limit if elevation based
Flood hazard notes	any reach specific notes about the flood hazard calculations
DYNAMIC BEACH HAZARD LIMITS	
Dynamic beach limit (m)	width of additional dynamic beach limit
Dynamic beach notes	any reach specific notes about the flood hazard calculations

Appendix C

Accompanying CD

- Digital copy of Shoreline Hazard Mapping
- Digital copy of Final Report
- ESRI Shapefiles
- Oblique Aerial Photographs

Appendix D

Geological Setting of Study Area

(excerpt from CVCA, 1988)

RESOURCES

GLACIAL HISTORY OF LAKE ONTARIO

Fifteen thousand years ago, the retreat of Pleistocene glacial ice marked the end of the Wisconsin continental glaciation period. During retreat, the Lake Ontario Ice Lobe scoured a basin in ancient bedrock. Meltwaters filled this basin and were augment6ed by Lake Erie outflow via the original Nigagra Gorge. Known as Lake Iroquois, this basin had a shoreline roughly 50 meters higher than today (between the 110 m.a.s.l and 130 m.a.s.l contour). The old shoreline can be most easily seen along Dundas Street between Highway 10 and Wolfedale Road. This shoreline is actually around 22 meters higher than its original elevation because of isostatic rebound (the uplifting of the earth's surface after the release of glacial crushing pressure).

Before the ice lobe had receded down the St. Lawrence Valley, Lake Iroquois found outflow routes through the States of New York and Vermont. Lake levels fluctuated dramatically in response to the shifting ice front and warming climate. Upon further regression of the ice front, water levels dropped when outflow down the St. Lawrence was gained.

Between 12,000 and 7,500 years ago, the recent shape of Lake Ontario became well defined from Lake Iroquois. The evolving landscape of the Great Lakes had stabilized. The narrowly linked large basin became self-regulating to the climatic fluctuations. Recent geologic evidence suggests that water level changes on the magnitude of more than a few meters ended 300 years ago.

GEOLOGY

Local bedrock is the major parent material of overlying sediments, soils, and shore deposits. Glacial till scoured from ancient bedrock has shaped the major landforms seen today. In turn, as post glacial vegetation colonized the area, a soil profile eventually developed in the uppermost till layers. The unique land/water interface has also produced shoreline deposits through ongoing erosion.

The following discusses shoreline geology in terms of bedrock and shore deposits while physiography and soils are reviewed separately.

BEDROCK

Bedrock is dominated by the Georgian Bay Formation of Meaford-

Dundas Shale. This formation is sedimentary in nature laid down as horizontal strata of waterborne clays in the Paleozoic Era, Ordovician Period 440-500 million years ago. Roughly 165-metres thick, this bedrock was formed by cementation in the presence of lime and compression by overlying bearing pressure.

Meaford-Dundas Shale is dominated by gray and blue/blue-green hardbands with occasional layers of limestone, dolomite, and sand/siltstone. These latter layers are often found near the uppermost surface. The shale is relatively impervious to water percolation but quite subject to fissuring and splitting exposed to water in the upper layers. The limestone content represents layer of dead marine organisms such as molluses and coral. As a result, it is fossiliferous with well-preserved trilobites noted locally.

The uppermost surface of bedrock has been found buried very close to the surface of existing sediments. The depth to bedrock is site specific but is generally no greater than 0.5 – 1.5 meters at the shoreline. This shallow depth is significant in that it provides a solid bearing surface for the foot of shoreline works.

SHORELINE DEPOSITS

Shoreline deposits are represented by distinctly separate or variably mixed sand and cobble profiles. These deposits have been formed as a result of constant wave attack and erosion processes acting on the exposed glacial deposits and soils along the shore. In recent times, as man-made modifications alter the shore, natural exposures are becoming increasingly rare. Field surveys show the following range of current shoreline exposures:

A clearer breakdown of the final component listed in Table 1 is difficult considering the nature of consolidated or unconsolidated protection works, and lakefill, that leave no trace of the original exposure. IN summary, natural exposures represent 36.7 percent of the shore and protected reaches equal 63.3 percent.

Shoreline cobbles are dominated by gravel to boulder sized shale stones. Sandstone, siltstone, limestone, granite, and quartzite are also represented. Foreign materials such as glass, asphalt, and concrete add to the cobble profile. Damaged or waste stock from the National Sewer Pipe Co. contributes red clay cobbles between the Petro Canada refinery and the St. Lawrence Cement Co. pier.

Cobbles are characteristically thin and flat, reflecting parent strata, with a smooth and clean texture because of ongoing abrasion and weathering. Constant wave and drift energy at the water's edge keeps smaller pebble and gravel sized cobbles in motion down drift. Larger stones overcome all but the greatest energy of waves and are deposited to the backshore. A stable cobble beach has an approximate slope of 1:5+/- while pebble beaches are maintained at 1:10+/-.

Sand beaches occur wherever suspended solids overcome down drift energy and are deposited. Known as depositional sinks, local beach areas are dynamic in that relatively equal amounts of sand are gained and lost in the sort term. Increased shore protection limits available eroded sediment for beach formation, and long-term artificial nourishment may be necessary if beaches are to be sustained.

Beaches are best preserved and formed where littoral drift is abated by shoreline discontinuities. Features that create such situation include the lee side of headlands or man-made structures as groynes.

Locally shoreline sands are medium to coarse in structure with a variety of graded to well-mixed gravelly profiles. Typically 80-95 percent of available sand is too fine to remain in high energy beach areas and is lost to the deep-water environment. Medium to coarse sand that does form beaches is maintained at slopes of 1:20+/-.

PHYSIOGRAPHY

There are two basic shoreline physiographic zones each having characteristics unique to their respective terrestrial and aquatic systems. Onshore physiography is largely a reflection of glacial deposits scoured from and formed over bedrock. Offshore physiography reflects a complex of glacial deposits and recent sediments which are continuously subjected to local currents and wave action.

ONSHORE PHYSIOGRAPHY

Once inundated by glacial Lake Iroquois, the lowlands which now surround the border of Lake Ontario are known as the *Iroquois Plain,* or locally the *Peel Plain.* Glacial till piled on bedrock is made up of ground-up shale, sand, and clay. Specific landforms reflect minor glacial advances and retreats acting on these till deposits. Lake Iroquois nearshore currents and wave action have also acted on these deposits. More recently, wind and rain weathering, and human occupation have further modified the shoreline landscape. Significant landforms along the shoreline include landscape. Significant landforms along the shoreline include Rattray Marsh, the Lorne Parke Bluffs, Port Credit Harbour, and artificially created headlands at Lakefront Promenade Park.

The most environmentally-significant feature is Rattray Marsh at the mouth of Sheridan Creek. The formation of a sand and cobble beach spit across the mouth of the creek protects Rattray Marsh from the influences of Lake Ontario. Shoreline marshes were once common along the Lake Ontario waterfront; however, Rattray Marsh is the only major examples locally which has escaped development.

The marsh is a sink for alluvial sediments of Sheridan Creek, and it supports a quality habitat for wildlife. Water levels in the marsh are maintained by the damming effect of the beach spit along the lake. A small protected outflow gap exchanges water and sediment with the lake. Lake and marsh water levels are thus maintained relatively equal.

The Lorne Park Bluffs are 10-meter-high exposures of glacial till created by the differential piling of glacial sediments. They have also experiences further modification by wave action during the Lake Iroquois era.

The Port Credit Harbour is a physiographic feature which has been highly modified by man. Once supporting bank marsh communities and protected by a sand and grave spit, the harbour is now fully developed. Encroachment into marsh lands has occurred for recreational, marina and residential purposes. The area is now plagued by continuous sediment loading from the Credit River at a rate of roughly 30,000 metric tones per year. The harbour requires dredging every few years in order to maintain an efficient draft for sail craft.

Large-scale lakefilling along shoreline areas represents the most pronounced and rapid physiographic change in the Authority's area of jurisdiction. The extent of fill used by small industry and residential landowners for slope modification, erosion recovery, and backfill of protective works is difficult to quantify. It appears that lakefilling has taken place in recent years to reclaim short-term losses which occurred primarily during the 1972-73 high water erosion period.

Mass filling and shoreline modifications to create recreational and industrial land bases can easily be identified by comparing 1953 and 1987 shoreline mapping. Figure 4 shows major lakefill development sites such as J.C. Saddington Park, Port Credit Harbour Marina, Lakefront Promenade Park, Lakeview Thermal Generating Station, and the Lakeview Water Purification Control Plant. It is also interesting to note the areas that have receded since 1953 and which have not been reclaimed. There has also been a dramatic change in the character of the numerous small watercourses discharging into the lake since 1953.

Major modifications in outlet characteristics have altered the mouths of five creeks, including Serson, Cawthra, Cooksville, Avonhead, and Clearview. The mouths of Applewood, Tecumseh, Lornewood, Birchwood, Turlte, Sheridan, and Lakeside Creeks remain unchanged even though modifications may exist upstream. Both Kenolli and Mary Fix Creeks have had their Lake Ontario outlets eliminated and these creeks have been diverted into Credit River.

The increase in runoff from small urbanizing watersheds have resulted in higher flows and sediment loading discharge into Lake Ontario. This has had some impact on the volume of material available for littoral transport and, potentially, nearshore water quality. However, no investigations have been carried out to assess this impact.

<u>OFFSHORE PHYSIOGRAPHY</u>

Local offshore physiography consists of three definable zones. A shorefast belt of drifting glacial and recent sediments occurs out to a depth no greater than about 7 meters. A broader zone of glacial deposits occurs between Rattray Marsh and the Lakeview Thermal Generating Station out to about the 16-metre-depth contour. Exposed bedrock clean of major sediment deposits is known to occur over the remaining area to about the 20-metre-depth contour. Lake basin contours define a gently to moderate slope with a slightly rolling profile in some areas. Figure 5 shows these features.

The shorefast belt of pre-existing glacial deposits and recently eroded sediments exists within the influence of longshore currents. Within the zone of breaking waves, longshore currents are created sending suspended sediments in motion resulting in nearshore turbidity. Finer sediments can remain trapped in motion for long distances but, when currents reverse or die off due to changing weather and new wave patterns, they are lost to deep water areas.

Coarse sands to boulder-sized glacial deposits are known to fill the minor basin created between the Lakeview and Clarkson headlands. These deposits are unsorted and may be undergoing erosion to nearshore or deep-water areas.

The remaining nearshore area is known to show bedrock exposure. Sediment areas so far defining cover bedrock by no more than about 1.5 meters. Some thin sediment coverage may exist over bedrock beyond these areas while, towards the centre of the lake, sediment accumulations reoccur.

It is interesting to note that, during the latter half of the 1800's "stone hooking" was practiced within the nearshore area to supply the building material industry. This practice has depleted the local nearshore of boulder concentrations important to fish spawning and has potentially aggravated nearshore sediment erosion.

SOILS

Shoreline sols consist of sands, sandy loams, and clay loams. Erodible soil exposure of backshore bluffs behind sand and cobble beaches occur along 37 percent of the shore without artificial protection.

Soil profiles occur in the uppermost layers of parent glacial till. The accumulation of acidic plant litter, over time, has created chemical leaching within these layers to produce roughly four zones or horizons. The upper humus and topsoil layers represent increasingly decomposed organic matter mixed with parent clay or sand. Leachate is the chemical transition horizon to the deepest horizon of sub-soil where leached chemicals accumulate. Sand soils have characteristically poor or immature profile development. Sandy loam represents well-developed humus and top-soil horizons mixed with sand. In turn, clay loam represents good organic mixing with finer clay particles.

All shoreline soils are subject to erosion under wave attack and slumping, rain splash and runoff, and human activity. Sand and sandy loams are loose soils with a high percentage of voids. They are very susceptible to erosion while clay loams which are denser and more firmly compacted are less susceptible. Clays, however, become plastic when saturated allowing for accelerated erosion subject to wave action.

Figure 6 shows the extent of shoreline soils with proper name soil series identification and characteristic profile depths. Table 3 identifies major characteristics of the solid types.

The shoreline also has areas of important landfill as noted in Figure 4. In addition to small-scale fill activity by individual property owners, these sites will have highly mixed solid types reflecting the nature of specific parent sites. For the most part, this represents clean fill, free of organic debris, rubble, and chemical contamination. Soil characteristics will be variable and profile development will be relatively nonexistent. This soil is very susceptible to erosion unless well compacted and protected from wave action.

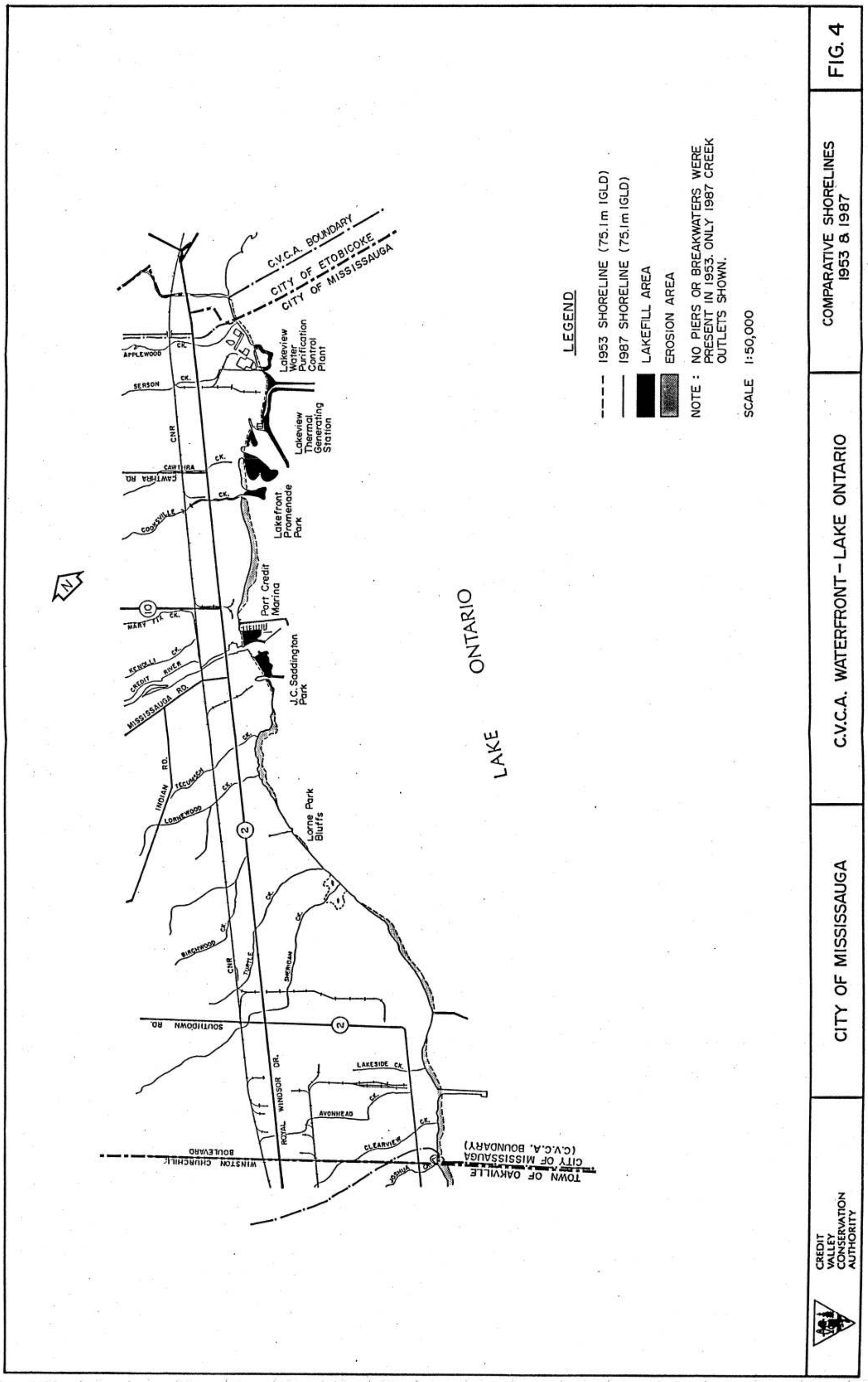
TABLE 1
SHORELINE EXPOSURES (JUNE 1987)

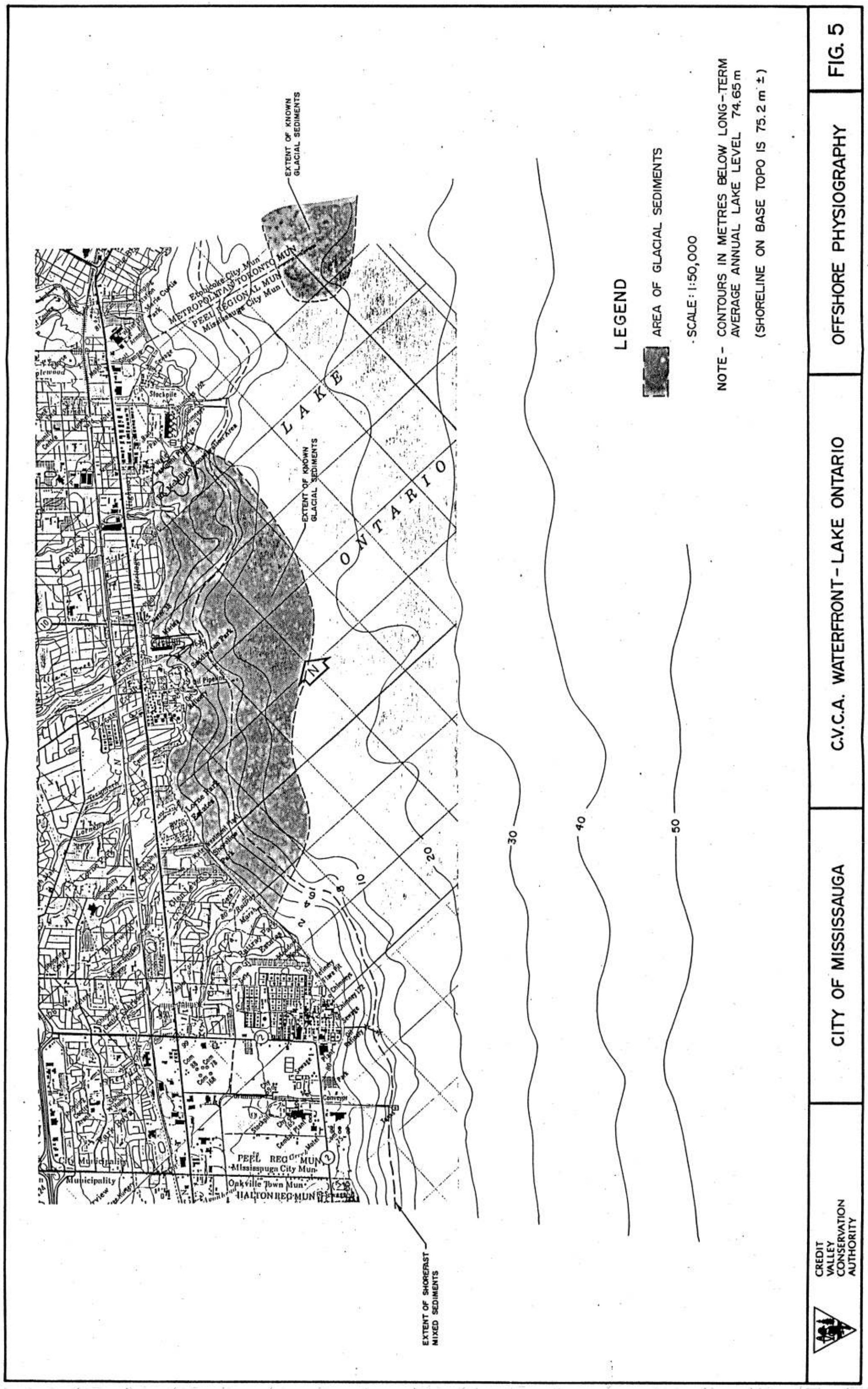
Shoreline Composition	Length (Meters)	Percentage of Total
Natural		
- low (4 meters) bluff with cobble toe	1,090	8.2
- cobble beach	1,430	10.8
- sand beach	1,320	9.9
- cobble and sand mixed beach	1,040	7.8
Protected		
- high (> 4 meters) bluff	1,080	8.1
- remaining low bluff, cobble or sand	7,340	55.2
	13,300	100.0

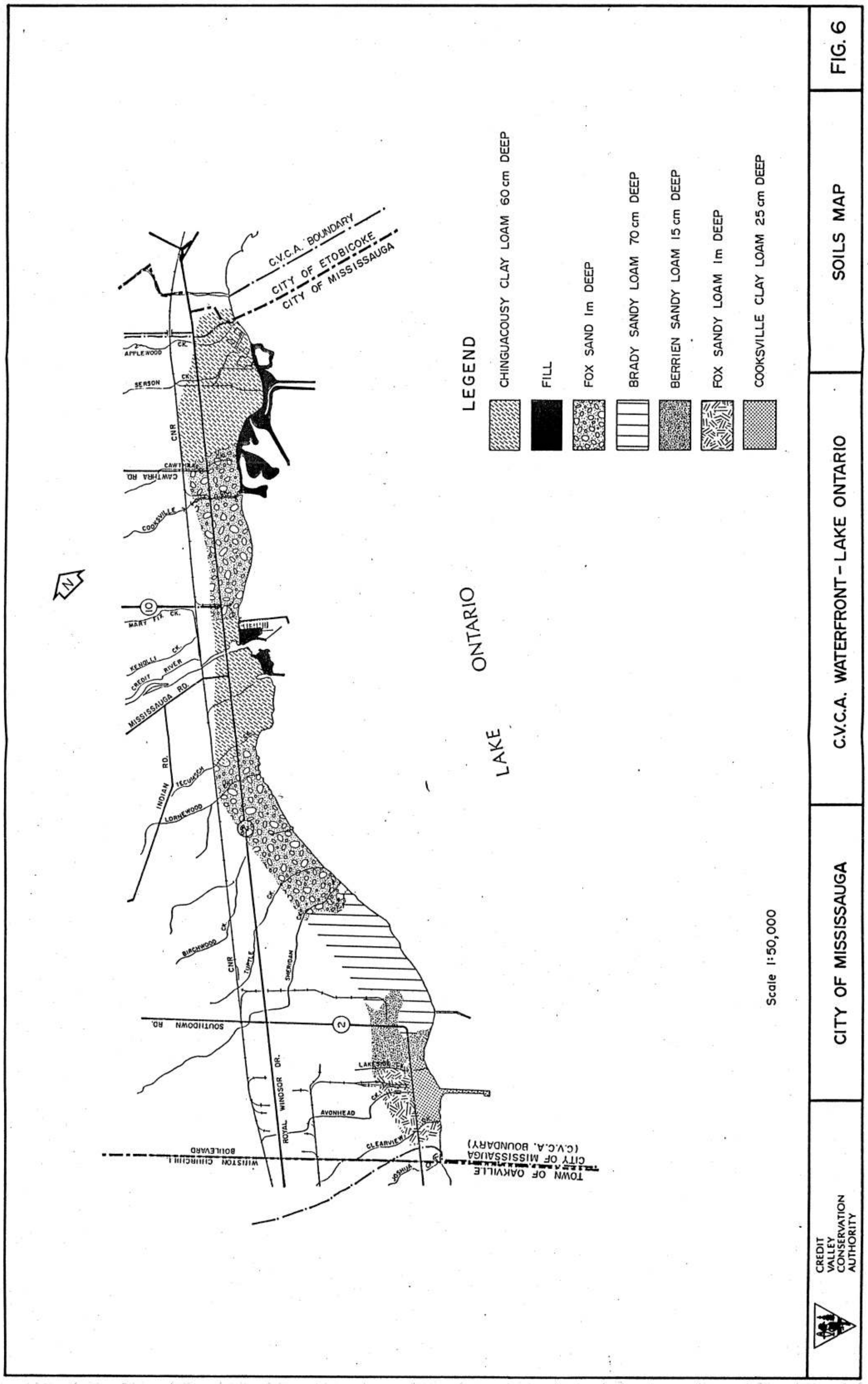
Note: This table does not include measures of piers, groynes, breakwaters, or inner basins of Lakefront Promenade Park.

TABLE 3
SHORELINE SOIL CHARACTERISTICS

	Soil Type	
Characteristics	Clay Loam	Sand / Sandy Loam
- structure / con sistency	- fine grained, very water retentive, compact at depth, friable	- large grained, water retentive, maintains looseness at depth, very friable
- drainage	- imperfect	- good to imperfect
- stoniness	- low	- stone free
- surface pH	- 5.2 – 5.5	- 6.3 – 6.8
- erodibility	- moderate	- high


LEGEND
1953 SHORELINE (75.1m IGLD)
1987 SHORELINE (75.1m IGLD)
LAKEFILL AREA
EROSION AREA
NOTE : NO PIERS OR BREAKWATERS WERE PRESENT IN 1953. ONLY 1987 CREEK OUTLETS SHOWN.
SCALE 1:50,000
LAKE ONTARIO
N
C.V.C.A. BOUNDARY
CITY OF ETOBICOKE
CITY OF MISSISSAUGA
Lakeview Water Purification Control Plant
Lakeview Thermal Generating Station
Lakefront Promenade Park
Port Credit Marina
J.C. Saddington Park
Lorne Park Bluffs
APPLEWOOD CK.
SERSON CK.
CAWTHRA CK.
CAWTHRA RD.
COOKSVILLE CK.
CNR
MARY FIX CK.
KENOLLIE CK.
CREDIT RIVER
MISSISSAUGA RD.
INDIAN RD.
TECUMSEH CK.
LORNEWOOD CK.
BIRCHWOOD CK.
SHERIDAN CK.
SOUTHDOWN RD.
LAKESIDE CK.
ROYAL WINDSOR DR.
AVONHEAD CK.
CLEARVIEW CK.
WINSTON CHURCHILL BOULEVARD
CITY OF MISSISSAUGA (C.V.C.A. BOUNDARY)
TOWN OF OAKVILLE
CREDIT VALLEY CONSERVATION AUTHORITY
CITY OF MISSISSAUGA
C.V.C.A. WATERFRONT – LAKE ONTARIO
COMPARATIVE SHORELINES 1953 & 1987
FIG. 4


EXTENT OF KNOWN GLACIAL SEDIMENTS
L A K E
O N T A R I O
EXTENT OF KNOWN GLACIAL SEDIMENTS
10
20
30
40
50
EXTENT OF SHOREFAST MIXED SEDIMENTS
LEGEND
AREA OF GLACIAL SEDIMENTS
SCALE: 1:50,000
NOTE - CONTOURS IN METRES BELOW LONG-TERM AVERAGE ANNUAL LAKE LEVEL 74.65 m
(SHORELINE ON BASE TOPO IS 75.2 m ±)
CREDIT VALLEY CONSERVATION AUTHORITY
CITY OF MISSISSAUGA
C.V.C.A. WATERFRONT - LAKE ONTARIO
OFFSHORE PHYSIOGRAPHY
FIG. 5


LEGEND
CHINGUACOUSY CLAY LOAM 60 cm DEEP
FILL
FOX SAND 1m DEEP
BRADY SANDY LOAM 70 cm DEEP
BERRIEN SANDY LOAM 15 cm DEEP
FOX SANDY LOAM 1m DEEP
COOKSVILLE CLAY LOAM 25 cm DEEP
C.V.C.A. BOUNDARY
CITY OF ETOBICOKE
CITY OF MISSISSAUGA
LAKE ONTARIO
TOWN OF OAKVILLE
CITY OF MISSISSAUGA
(C.V.C.A. BOUNDARY)
Scale 1:50,000
CREDIT
VALLEY
CONSERVATION
AUTHORITY
CITY OF MISSISSAUGA
C.V.C.A. WATERFRONT - LAKE ONTARIO
SOILS MAP
FIG. 6

Appendix E

Shoreline Hazard Mapping
(reduced scale copies)

1:2,000 scale copies
supplied under separate cover