Ajax Waterfront Project

Environmental Assessment and Conceptual Design Development

April 5, 2023 | 13804.101.R1.RevB

B. — 1981

Baird.

Innovation Engineered.

baird.com

Ajax Waterfront Project

Environmental Assessment and Conceptual Design Development

Prepared for:

Toronto & Region Conservation Authority
101 Exchange Ave.,
Vaughan, ON, L4K 5R6

Prepared by:

W.F. Baird & Associates Coastal Engineers Ltd

For further information, please contact:
Derek Williamson, P.Eng at +1 613 731 8900
dwilliamson@baird.com
www.baird.com

13804.101.R1.RevB

Z:\Shared With Me\QMS\2023\Reports_2023\13804.101.R1.RevB_AjaxWaterfront.docx

Revision	Date	Status	Comments	Prepared	Reviewed	Approved
A	Nov 29, 2022	Draft	Envir input pending	DCW	MD	DCW
B	April 5, 2023	Draft	Geotech added, envir pending	DCW	MD	DCW

Executive Summary

Pending

Table of Contents

Tables

Figures

1. Introduction

1.1 Background

The Ajax waterfront was developed in a manner that prioritized the preservation of public lands along the waterfront. This is in contrast to many developed areas where private residences or industry dominate the waterfront, often in close proximity to the shoreline. In these instances, shoreline erosion can threaten structures in the present or immediate future; much of the Ajax waterfront does not have this immediate need for protection.

The rates of erosion along the Lake Ontario waterfront (up to 0.5 m/yr in some areas) are such that there is clearly a limited timeframe over which the public park will remain in a similar condition to today. There has already been the need to realign walkways in some areas after severe erosion due to high lake levels in 2017 and 2019, where levels came close to the 100 year level. A total of about 530 m of the Waterfront Trail were retreated since 2017.

An approach to preserving the shoreline needs to look at the significance of infrastructure, including elements ranging from roads and building to recreational amenities, and the cost of undertaking this protection. Costs need to be assessed in terms of capital costs, maintenance costs and environmental impacts during construction and into the future. Some areas present an imminent problem, while other areas may erode slowly enough that monitoring and assessing when action is required is a viable approach

1.2 Length of Shoreline to be Protected

The study area is approximately 5.7 km in length and reaches from Frisco Road in the west to the west end of Ontoro Blvd in the east. The shoreline in this region is all publicly owned with the exception of one property at the east end of Paradise Beach. This property may be purchased and transferred to public ownership in the future and therefore the entire length is being assessed as if it were public land.

The 5.7 m shoreline length consists of:

- 820 m of creek mouth and barrier beach
- 440 m of artificially protected shoreline (at water treatment plant and the rubble to the west of Paradise Beach)
- 1080 m of predominantly beach shoreline at Paradise Beach
- 3360 m of bluff shoreline, with elevations typically from 1.5 to 10 m above the 100 year high water level (76.2 m IGLD85)

There are some localized features such as pipe outlets or piles of rock that are relatively small in size and are not specifically identified in this concept level assessment.

1.3 Project Objective and Concept Design Approaches

The project objective is to provide protection to the shoreline in a balanced manner that considers the rates of erosion, the impacts on the park/amenities from the erosion and the cost of protecting the shoreline. This includes financial, environmental and social costs. The following design approaches could be considered:

- **1. Do-nothing and monitor erosion:** This design approach takes a hands-off approach and allows the shoreline to evolve naturally in response to high water levels and storm events. Any future erosion can be monitored and may lead to future recommendations.
- **2. Reduce erosion rate:** Reducing the erosion rate may involve undertaking works that will slow the rate of shoreline recession, but do not involve significant alterations at the toe of the bluff. These are typically works that are further offshore and significantly reduce, but do not stop wave attack at the toe of the bluff.
- **3. Stabilize the shoreline**: Shore protection works that involve changes directly at the toe of the bluff can stabilize the shoreline and limit further erosion of the bluff. Any effort to prevent bluff erosion must consider lakebed downcutting which will increase the wave conditions at the toe in the future. Any effort to stabilize the shoreline should be considered long-term stabilization (perhaps a century or more), but is not "permanent" stabilization.

These protection approaches are shown in Figure 1.1, where the overall erosion hazard (distance from the shore to the back of the stable slope allowance) is reduced through more substantial shoreline works. In the case of a significant armouring of the shoreline, the erosion allowance would be reduced and perhaps zero in the short term, but should not be considered zero in the longer term.

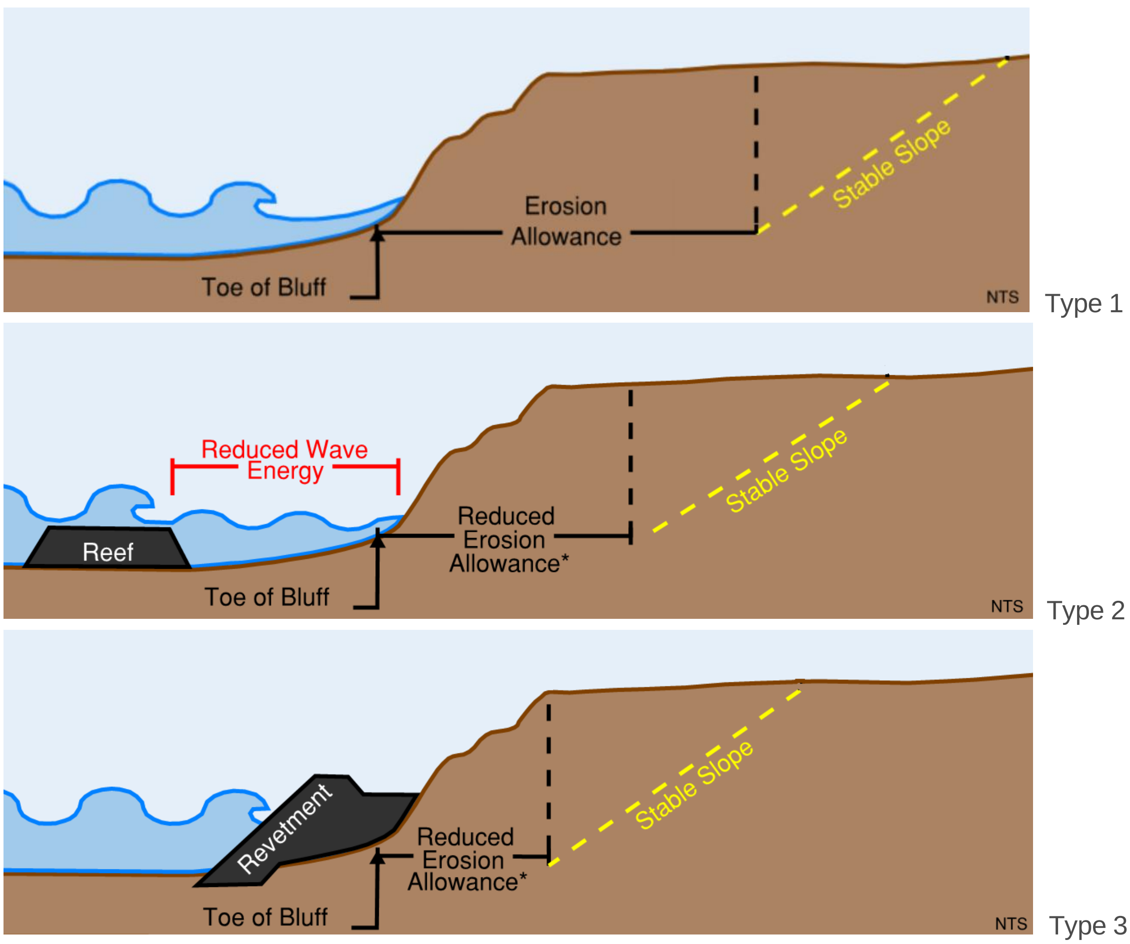

Figure 1.1: Reduction in Erosion Hazard from Shoreline Works

The schematic in Figure 1.1 shows how erosion may be mitigated through the addition of coastal works. However, the manner in which these coastal works are seen to influence the position of the hazard allowance (normally defined based on unprotected erosion rates) may vary depending on the type of protection that is installed, and how policy may evolve in decades to come.

This report includes conceptual development and assessment of five concepts for shore protection, as follows:

1. Offshore breakwater with gaps (type 2 approach to shoreline protection)
2. Nearshore reefs, just below typical low water (type 2 approach to shoreline protection)
3. Groynes, with some sort of beach fill (type 2/3 approach to shoreline protection)
4. Improved cobble/boulder beach (type 2/3 approach to shoreline protection)
5. Conventional revetment (type 3 approach to shoreline protection)
6. Do nothing (type 1 approach)

2. Site Conditions

2.1 Waves

Wave conditions at the site were assessed in the Ajax Waterfront Shoreline Assessment and Gap Analysis report (Baird, 2021). This report shows the distribution of waves that approach the site, with southwesterly waves being the most common direction, but the easterly directions as having the largest wave conditions. With the gentle nearshore slopes in the Ajax waterfront, all of the larger wave conditions approach the shoreline as depth-limited waves. This is apparent in Figure 2.1, which shows the wave heights becoming gradually smaller as they reach the shore. The final transition in wave height from about 2.5 m to less than 1 m happens in the shallow water close to the shore.

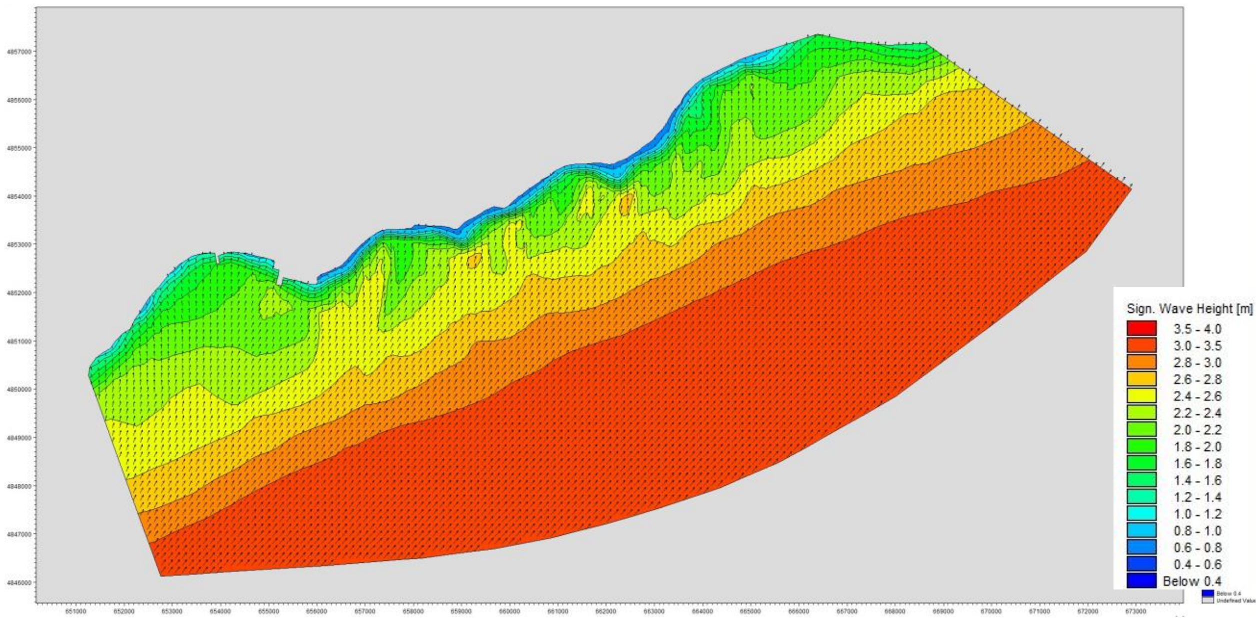

Figure 2.1: Example of SW Storm Condition in M21SW Model

An overview of the wave conditions approaching the shoreline is provided in the wave rose shown in Figure 2.2.

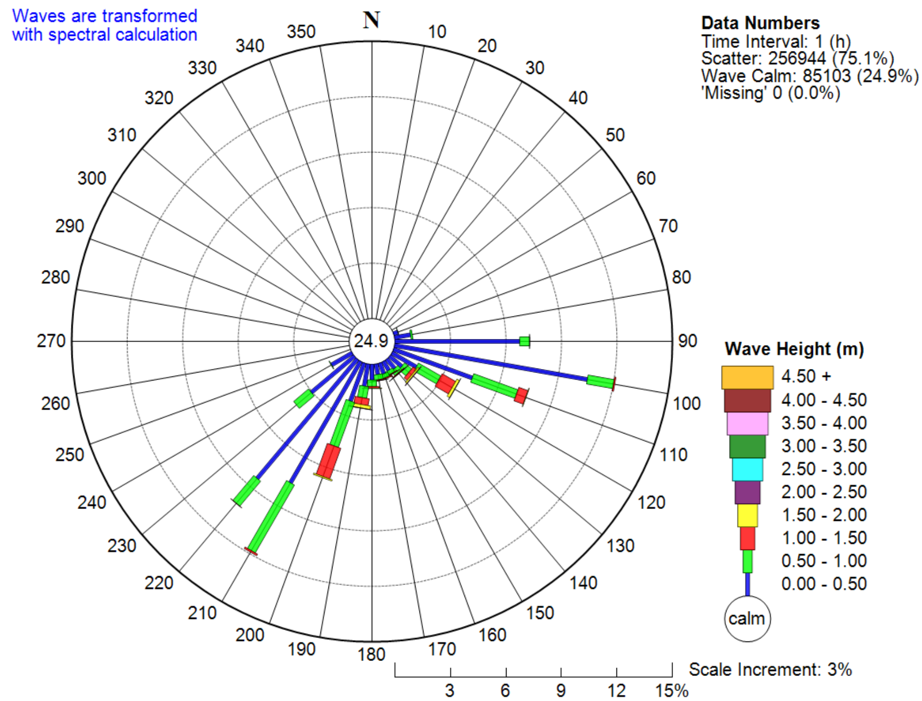

Figure 2.2: Nearshore Wave Conditions (6 m water depth, 155° shoreline azimuth)

Wave heights that impact the bluffs or nearshore structures are largely defined by the available water depths at the toe of the structure.

2.2 Water Depths

Water depths are critical to the design of any structure along the shoreline as the water depth will define the maximum wave condition that will impact the structure and therefore also many of the design details. A 100 year water level of 76.2 m IGLD85 was determined for the hazard mapping study completed by Baird (2022) for TRCA. The water depth in front of a bluff or structure is defined by this water surface elevation and the toe depth in the region of interest.

Toe depths will be very dependent on the type of structures that are being considered. A structure that is further up the beach may have a toe elevation of 75 m, and therefore only 1.2 m of water during a 100 year water level event. A structure that is further offshore, such as a reef, may have a toe elevation of 72.2 m and therefore a total water depth of 4 m during a 100 year water level event.

In addition to the toe level today, there is also the need to consider the toe depth as a result of downcutting in the nearshore. Lakebed downcutting would ideally be assessed based on detailed measurements many decades apart. However, these data are rarely available and instead it is common to use a geometric approach to understand downcutting as a function of shoreline retreat. Table 2.1 provides an estimate of nearshore downcutting based on the nearshore slope and the rate of erosion. For example, a shoreline erosion rate of 0.5 m/yr and a slope of 100:1 indicates a downcutting rate of about 0.5 m in 100 years.

Table 2.1: Downcutting (m) after 100 Years

Nearshore Slope (X:1)	Rate of Shoreline Erosion (m/yr)						
	0.05	0.1	0.15	0.2	0.3	0.4	0.5
25	0.20	0.40	0.60	0.80	1.20	1.60	2.00
50	0.10	0.20	0.30	0.40	0.60	0.80	1.00
75	0.07	0.13	0.20	0.27	0.40	0.53	0.67
100	0.05	0.10	0.15	0.20	0.30	0.40	0.50
200	0.03	0.05	0.08	0.10	0.15	0.20	0.25

The presence of cobbles and boulders in the nearshore profile generally indicates a slower rate or erosion and downcutting. Regions without this natural lakebed armouring may be more prone to downcutting and erosion and therefore may result in deeper water depths in front of structures.

2.3 Nearshore Design Wave Heights

After transformation over the shallow nearshore area, the waves that will impact the structures can be determined based on the water depth and the nearshore slope. Goda (2000) provides a simple but reasonable estimate of the significant breaking wave height in depth limited conditions. Figure 2.3 shows the significant (average of the highest one-third of the waves in a sample of waves) wave height as a function of nearshore slope and toe elevation, based on a 100-year water level (76.2 m). A slope of 100:1 is a reasonable approximation for most of the region, although some steeper slopes may occur very close to the beach face.

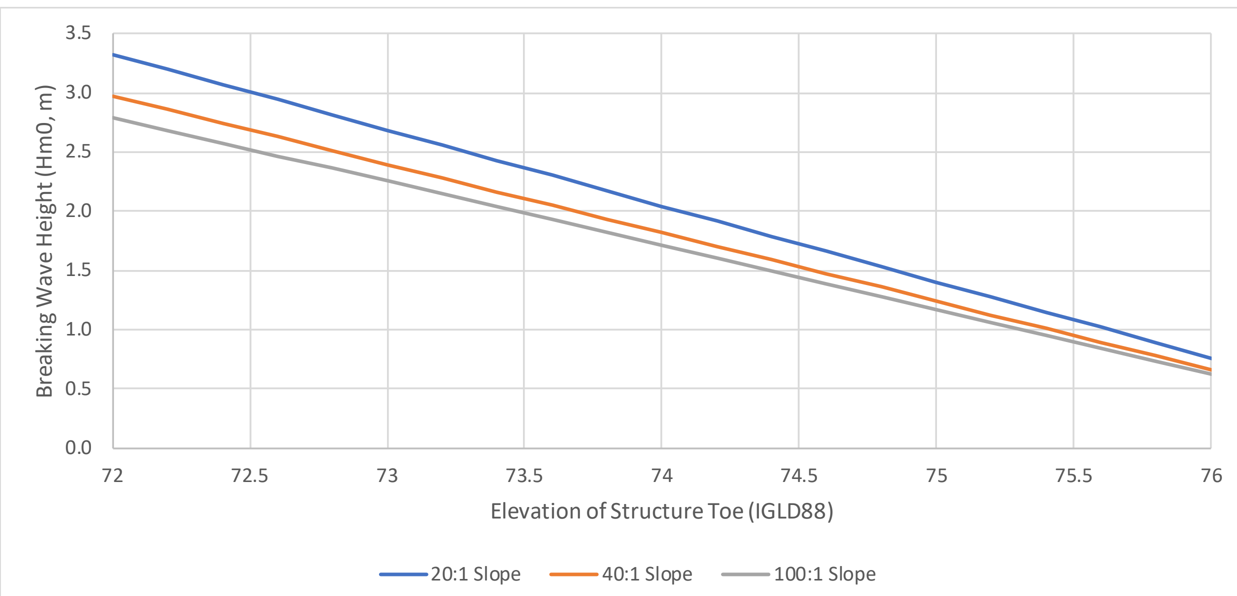

Figure 2.3: Breaking Wave Height in Shallow Water from Goda (2000)

Structures must be designed to consider the present day water depth, plus an allowance for nearshore downcutting. For example, an offshore structure where the slope is 100:1 and the toe depth is at 73.5 m (0.7 m below low water datum) might be designed for a toe elevation of 73.0 m to accommodate downcutting. This means that the significant breaking wave height would be about 2.20 m. Note that all of these calculations assume an offshore wave height of 5 m and a period of 9 s. A reduction in the offshore wave height from 5 m to 4 m results in a reduction in the nearshore wave height of only about 6 cm (2.22 m vs. 2.16 m). Therefore, slight variations in offshore wave height are not important in these depth limited conditions.

2.4 Shoreline Erosion

Shoreline erosion was assessed in Baird (2021) and an overview of the study area and the positions that were digitized for the shoreline assessment is shown in Figure 2.4. Note that these reaches (A through E) were defined in the 2021 study and are not the recommended reaches for protection of the shoreline.

The central and eastern parts of Reach D are dynamic beaches, and adjacent sections of shoreline were often obscured in the aerial imagery and therefore no long term erosion rate was determined for this reach. Other areas that were not digitized include regions where vegetation obscured the shoreline and regions where shore protection is in place.

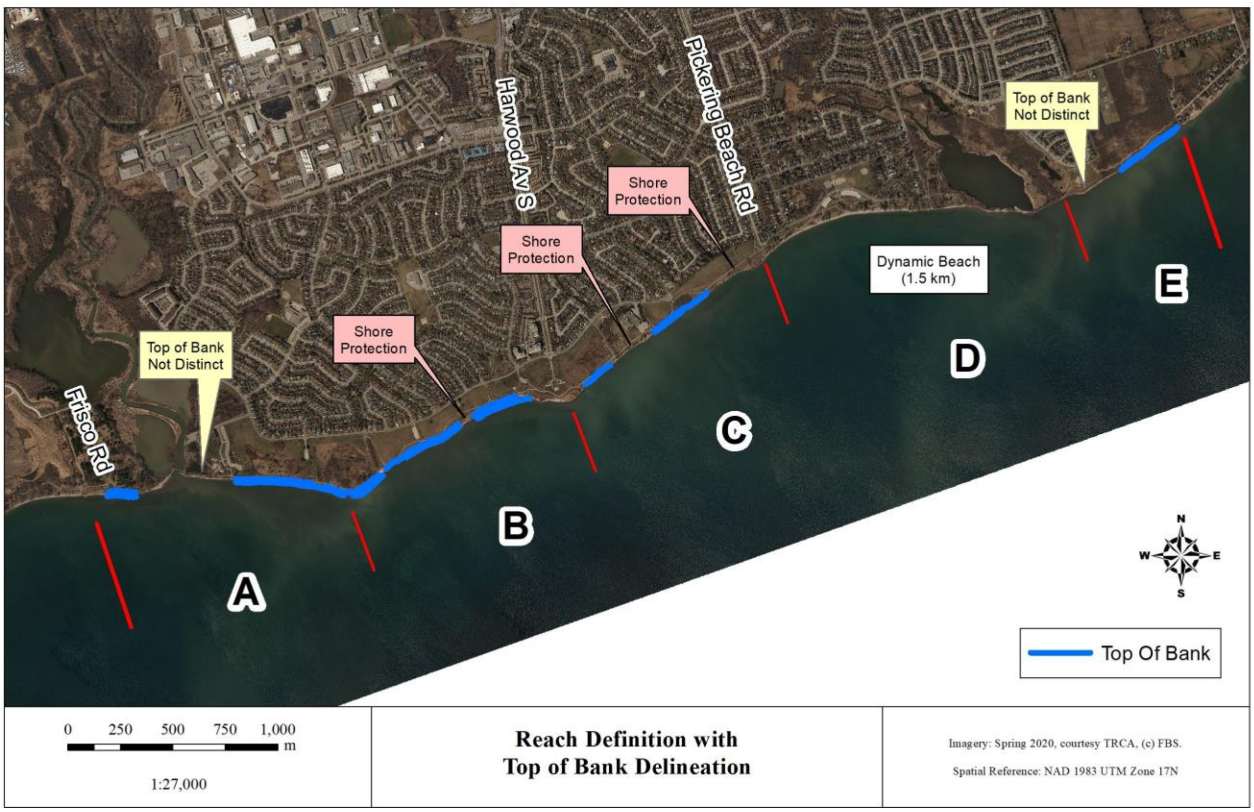

Figure 2.4: Shoreline Reaches (from previous study) and Bluff Position Identification

The results of the shoreline recession assessment are provided in Table 2.2. The average annual recession rate is presented as well as the standard deviation of the recession estimate. For hazard assessments it is common to use the average and then add one standard deviation to include some conservatism. For this assessment both are presented.

Table 2.2: Shoreline Recession Rates from Aerial Imagery

Reach	# Transects	Date Range	Years	Ave. Recession (m)	Ave. Annual Recession (m/yr)	Standard Deviation (m/yr)	Comment
A west	63	1978-2020	42	21.00	0.50	0.04	West of Duffins Cr.
A east	227	1981-2020	39	13.33	0.34	0.03	East of Duffins Cr.
B west	208	1981-2020	39	15.81	0.41	0.11	Western third
B east	97	1972-2020	48	24.11	0.50	0.02	Eastern two thirds
C	117	1972-2020	48	6.43	0.13	0.06	WTP protected
E	133	1972-2020	48	5.62	0.12	0.02	

Differences in recession rate can be influenced by wave exposure, shoreline orientation, or by differences in the bluff and nearshore characteristics. Examination of the project site suggests that where there are significant headlands along the shoreline, there are often more boulders on the nearshore lakebed. A higher amount of large material in the bluff could result in a slower recession rate in these areas due to increased protection of the lakebed.

Recession rates are computed on a reach-by-reach basis; however, it is important to understand that variations in the erosion rate will occur locally due to a number of factors, including any shore protection that may be present.

With very high water levels in 2017 and 2019, additional comparisons were completed to document locations where there had been significant recession of the shoreline between the 2015 LiDAR and 2020 aerial photography. Most of the areas that showed the greatest recession were in Reach B (Figure 2.5), with some areas averaging over 1 m per year during that five-year span. Many of the bluffs may have been over-steepened through toe erosion during high water levels and a higher rate of erosion cold persist in the following years as the bluffs gradually stabilize. The long term erosion rate is determined through a much greater interval than just a few years of high water levels, resulting in a more meaningful long term average that spans a range of water levels.

Figure 2.5: Reach B Recession from 2015 to 2020

2.5 Geotechnical Overview

Based on the physiographic region, the study area in located in the Iroquois Plain, where the St. Lawrence Valley was inundated by the historic Lake Iroquois during the last glacier recession. The Iroquois Plain generally comprises historic sand and boulder shorelines around undulating glacial till plains contrasting the lacustrine deposits, smoothed by historic wave action.

There are two distinct physiographic landforms present across the study area. There are drumlinized glacial till plains in the centre of the study area, with clay plains along the west and east boundaries.

Surficial geological mapping created by the Ontario Geological Survey (OGS) for the study area describes the area as a stonepoor sandy silt to silty sand textured till on Paleozoic terrain. In low lying regions, the subsurface soils are fine-textured glaciolacustrine deposits of silt and clay, with sand and gravel. This unit is massive to well laminated. Around Caruthers Creek there is a littoral deposit comprising coarse textured lacustrine sand and gravel, with some silt and clay. There are modern alluvial deposits around both Duffins Creek and Caruthers Creek.

Surface water flow direction is generally from areas of higher topography to the lower lying areas, with some of the flow intercepted by roadway drainage. Closer to the lake, runoff either is absorbed into the ground or flows along the surface in more intense rainfalls and/or frozen ground conditions.

In general, the glacial till deposit has a low permeability and will yield only minor seepage in the long-term, thereby acting as an aquatard. The earth fill near the surface and sands and silts unit are generally cohesionless and will allow the free flow of water, thereby acting as aquifers. Depending on the stratigraphy, there may be perched infiltrated water in the upper stratigraphy.

3. Summary of Concepts

3.1 Goals

The goals of the concepts are outlined as follows:

- Protection of the park area: Reduce the rate of erosion so that the park is preserved and need for retreat of the infrastructure is minimized. This must be balanced against other needs including costs.
- Environmental: Maintain the existing or natural environment as much as possible. Overall improvement would be preferred but should consider that this is a highly utilized urban park area.
- Public Access: Public use of the shore (below bluffs) is much less than above the bluffs but does occur and needs to be considered. However, unlike other sections of the TRCA's waterfront, there is already an established corridor along the top of the bluffs, so that access at the base of the bluffs is less critical.
- Public Safety: Safety concerns relate to falls from the top of the bluff. Also developing linear isolated areas (e.g., a dead end at the base of bluff) can raise safety issues. Collapse of bluffs (hazard for those on the top and at the base) is infrequent but does occur and should be considered.

3.2 Design Considerations

Design considerations for shore protection at the site includes:

- Long term erosion: The erosion rates along the shore are variable as outlined in Section 2.4. Regions with lower erosion rates will typically have more time before the shoreline amenities are impacted. Some areas are rapidly retreating while other areas have more natural protection in the form of boulders.
- Height of bluff: Bluffs range from zero to 12 m in height and present different challenges. Some bluffs are vegetated and more stable, while some are steep and have been experiencing recent failures. Higher bluffs require more horizontal distance for stabilization.
- Environmental issues: Vegetated bluffs have a range of species that are present, while the steepest bluffs have essentially no vegetation. However, this does not imply that there are no significant species in the area. For example, bank swallows (*Riparia riparia)* are a threatened species in Ontario and are nesting in numerous locations along the shoreline.
- Creek Mouths: In regions where there are creek mouths, protection of the shore is probably not appropriate. The natural process of shoreline retreat should be allowed to continue, leaving all parts of the barrier beach ecosystem is a more natural state. Elevated walkways, or no walkways exist in these areas.
- Outfalls: There are some larger and smaller outfalls in the area. The larger outfalls, which are typically at a lower elevation, are considerations in how a shoreline may be developed. However, many of the smaller outfalls protrude from the bluff at a higher elevation and are typically less important in assigning a protection approach in the area.
- Upland infrastructure: The horizontal distance and anticipated number of years until failure is an important consideration in assigning a protection strategy. However, one must also consider that shoreline erosion is a very non-linear process and periods of higher or lower lake levels will accelerate or slow the process. This can make predicting the number of years until infrastructure is adversely impacted a general guideline at best.

- Sediment Supply: As bluffs erode, they supply sediments to the nearshore area. Larger elements, such as boulders and cobbles remain close to where they were exposed, while the finer fractions (silt, clay) are washed away by wave action and deposited offshore. Sand fractions may remain on the beach and nourish nearby areas. For example, Paradise Beach likely obtains its sand from erosion of nearby bluffs.

The terms of reference specifically note limiting the use of hard solutions in favour of more natural approaches to shoreline protection. There are sometimes suggestions of developing wetlands and planted areas as a way to mitigate erosion from waves. However, there are few if any examples around Lake Ontario where such a system exists in anything other than protected back-bays. The range in water levels, wave conditions and ice conditions generally preclude the soft approaches that are sometimes preferred. In order to develop these systems, much larger alterations to the shoreline would be required in order to create protected bay areas. This is not considered to be a viable alternative at this site.

Climate change is another topic of consideration when assessing shoreline protection options. Climate change on the Great Lakes is most likely going to involve a lengthening of the open-water season; however, this part of Lake Ontario is mostly open and only minor differences in ice cover might be experienced in the future. Since the shoreline is all governed by depth limited wave conditions, water levels are the most important factor in future erosion of the lakeshore. Recent reports such as ECCC (2022) outline the potential for an increase in the 100 year water levels to possibly 76.5 m (30 cm increase over today). However, there is no clear consensus on the likely impact of climate change on Lake Ontario water levels. This is due to the complexity of the water level forecasting process, possible impacts of lake level regulation, and uncertainties in the scope of climate change that may occur (e.g., RCP2.6, RCP4.5, RCP8.5, etc.). With significant levels of uncertainty, any concept should be adaptable for a range of water levels in the future; the future water levels should be considered uncertain.

All the concepts that are discussed in this report have the potential to be adapted to climate change by adjusting the elevation of the structures, either at the time of construction or by adjusting elevations in the future. None of the concepts involve structural elements that could not be easily changed (e.g., steel or concrete walls) and all the concepts should have future access that is comparable to the present access route.

3.3 Overview of Concepts

There is a wide range of approaches that could be used to reduce erosion along the Ajax waterfront. A list of possible approaches is provided below, from offshore to inshore:

1. Offshore breakwater with gaps
2. Nearshore reefs (just below typical low water)
3. Groynes, with some sort of beach fill
4. Improved cobble/boulder beach
5. Conventional revetment
6. Do Nothing

The goal of this study is to recommend alternatives for the immediate and longer term objectives of protecting the park. In the short term, the do nothing alternative is viable for the majority of the project area; however, this does not preclude planning for the future in areas that may be “do nothing” for many years or decades to come.

3.3.1 Offshore Breakwater with Gaps

Offshore breakwaters would be emergent structures and provide significant protection from the oncoming waves. Over longer lengths of shoreline, gaps are included to improve circulation and for navigation, etc. It also allows some wave action to penetrate to the shoreline and possibly move some sediment during storms.

Advantages:

- Does not significantly change the shoreline, although some sediment accretion may occur
- Provides good protection to the site by reducing wave significantly at high water, when it matters most
- Provides some sheltered area behind the structures, which provides some diversity of habitat
- Variations in gap width can impact the degree of wave penetration to meet some compromise between level of protection, cost and other factors
- Shoreline would become more useable with better protection

Disadvantages:

- Visually changes the character of the shoreline with emergent structures in the nearshore
- The structure is in deeper water, so waves and armour stone will be larger than if this is adjacent to the shoreline, therefore more expensive
- Requires significant in-water work
- Failure is harder to repair and could reduce effectiveness of protection

Offshore breakwaters would be built in a location where water depths might be 1.5 m below Chart Datum (CD, which is 74.2 m). Downcutting could result in lowering of the nearshore depths of about 2.25 m below CD (reaching approx. 72 m elevation). Wave heights in this water depth would be depth-limited based on the 100 year water level and the lakebed elevation. Using Goda (2000), this corresponds to a stone size of about 2.25 t (using USACE, 1977) and a stone size of about 4 t (using USACE, 1984, which is known to be conservative). A mean armour stone size of 3 t would meet this criterion, so assume 2 to 4 t as a range (2:1 front slope).

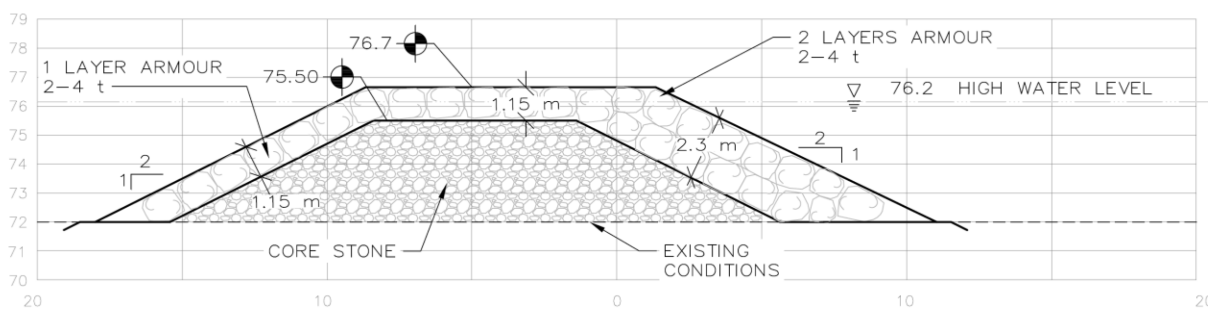

Figure 3.1: Cross Section of Offshore Breakwater

The crest on these structures would be 76.7 m (0.5 m above high water) and the crest width would be a minimum of about 7 m at the core level (about 75.5) for constructability reasons. The structures would most likely be built by driving on top of the structures; the water is too shallow for reliable marine access along the side. The breakwaters would be built without a filter layer, but a coarser core would be used so that there is not too big a size difference from armour to core. This is done to make the structure more drivable at the "core level" without resulting in a very high crest level. When driving on the core during construction, a blinding layer would need to be installed and then cleaned up as they backed off the structure.

3.3.2 Nearshore Reefs

Nearshore reefs are built with a crest elevation so that they are submerged almost all of the time. This submergence means that gaps are less important as there is some exchange of water over the reefs. These structures must be wide enough so that energy is expended through the breaking process as the wave crests cross the reef; narrow submerged structures have limited impact on the wave heights.

Advantages:

- Does not change the physical makeup of the shoreline (although some accretion may occur)
- Does not significantly alter the aesthetic character of the shoreline (remains open water)
- Shoreline would become more useable with better protection
- Adjustments to height/width of reef can adjust the degree of wave penetration
- Failure (if it occurs) would be a gradual process, rather than a sudden loss
- Provides fish habitat
- Smaller armour is less expensive on a unit cost basis than armour for larger emergent structures

Disadvantages:

- Less effective at high water when it is needed most
- Must be a wider structure (therefore more costly) to provide adequate protection at high water
- Requires significant in-water work
- Large volume of material to bring to site

An example of a nearshore reef cross section is shown in Figure 3.2. The most exposed part of this cross section is the lakeward edge where wave breaking takes place, requiring larger stone in this area. At higher water levels, waves at the reef may be larger; however, the reef is further below the water surface avoiding the need for very large stone. At lower water levels, waves may be depth limited before they reach the structure. Over the central and landward part of the reef, smaller material can be used. This mimics the features that are often seen on natural reef/rubble flats where moderately sized material makes up the bulk of the reef. A fairly wide range could be used, perhaps in the range of 100 to 500 kg, or about 300 to 600 mm. Focusing on a readily available and affordable riprap product could make this section more cost effective.

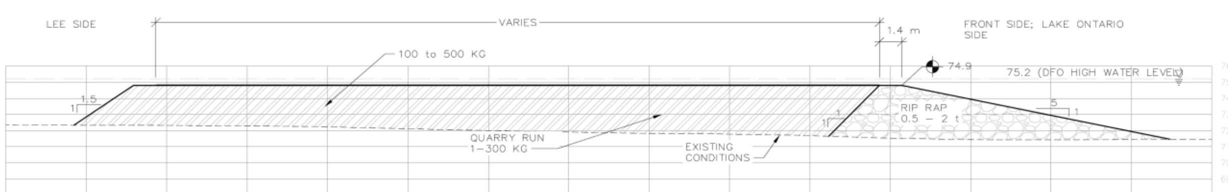

Figure 3.2: Example of Nearshore Reef Cross Section

3.3.3 Groynes with Beach Fill

Groynes with beach fill involve two types of structures. The groynes' function is to limit the longshore transport of material so that placed protection remains where it is required. Larger groynes (sometimes with a T-head) will provide more protection and will help stabilize the fill to a greater extent. However, these groynes add to the overall cost, and a coarser fill material may limit the need for very large groyne structures. There is therefore a balance that must be struck between the type of shoreline fill and the size/shape of the groynes.

Advantages:

- Failure (if it occurs) would be gradual process, rather than sudden loss
- Could become a more useable beach, depending on the character of the fill. This would probably require larger groyne structures.

Disadvantages:

- Groynes would need to be large to contain the fill and limit redistribution of gravel or sand protection
- Fill material could still move around within beach cells (if it is sand/gravel)
- Groynes do not provide any protection against oncoming waves during higher lake levels and therefore the beach may erode and result in significant loss of material (particularly with shorter groynes)

An example of a possible cross section for a beach fill section is shown in Figure 3.3. This section includes some widening from the existing shore to provide access for future maintenance, some width for slope stabilization and a buffer to accommodate some shoreline reshaping. Groynes would be needed to limit lateral movement of material. Final sizing of the fill is to be determined.

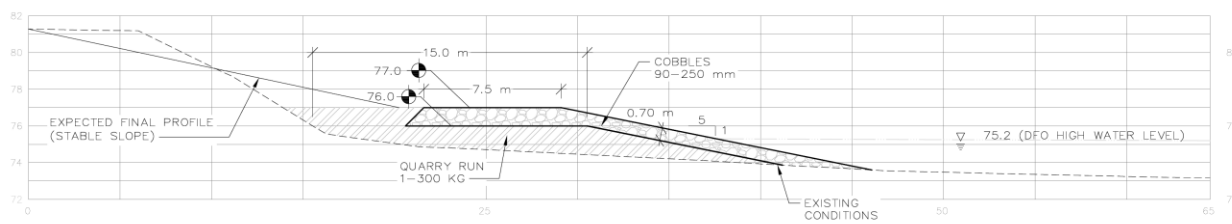

Figure 3.3: Cross Section of Beach Fill

Sourcing of gravel is a relatively straight forward process; gravel is generally small enough that the difference between natural gravel (slightly rounded) and quarry-produced gravel is less of a concern. Natural gravel is better for walking in bare feet, but with any footwear, quarry-produced gravel is adequate.

Sourcing cobbles is more problematic in any large volume. Sometimes a riprap product is substituted for natural cobbles; however, cobble size (64 to 256 mm) riprap is very different in character than natural cobbles. Natural cobbles do not have the sharp edges of riprap and in this size range there is a large difference in the walkability of a natural cobble and a riprap beach. The cobble-sized riprap beach would be unwalkable, and therefore only slightly more people-friendly than a revetment.

3.3.4 Improved Cobble/Boulder Beach

This concept is very similar to the previous concept; however, in this case the shoreline material is coarse enough that longshore transport is minimal and therefore there is lesser requirement for lateral stabilization structures. The natural cobble/boulder beach at the base of Veteran's Point (Figure 3.4) is an example of the type of material that would be stable at this site.

Figure 3.4: Natural Cobble/Boulder Beach at Veteran's Point

The cross section for this structure would be similar to that in Figure 3.3; however, layer thicknesses would need to be adjusted in order to accommodate the larger stone sizes.

Advantages:

- Consistent with the natural site conditions
- Does not significantly alter the character of the shoreline
- Failure (if it occurs) would be gradual process, rather than sudden loss

Disadvantages:

- Fill material would need to be large to avoid lateral movement of material
- Cobbles/boulders are difficult to source and may be expensive and possibly cost prohibitive for natural boulders
- Limited design guidance for the stability of large cobbles & boulders

Cobbles and boulders are often used on smaller projects where the volume requirements can be met by local sources. Large volumes of cobbles and boulders could be problematic to obtain. In some locations along the Toronto waterfront, scrap brick and concrete were historically used for shore protection. While this material may be similar in size, it is less aesthetically pleasing and does not typically have the same durability as natural cobbles and boulders.

Boulder size riprap is another option; however, this starts to function more as a revetment since the surface would be generally unwalkable with riprap of this size. This may be a lower cost option and starts to become more similar to a very gently sloped revetment.

3.3.5 Conventional Revetment at Bluff

A revetment near the bluff toe essentially stops any further toe regression of the bluff, provided that long term maintenance of the revetment occurs. Downcutting at the base of the revetment could increase the risk of damage to the revetment over the course of many decades and must be considered in the design. The revetment is therefore set far enough lakeward to allow for slope adjustment and maintenance access.

Advantages:

- Well established design criteria
- Material is available from many quarries
- Failure (if it occurs) would be gradual process, rather than sudden loss
- Mostly above-water work (assuming normal water levels during construction)

Disadvantages:

- A beach would only exist (if at all) at lower lake levels in front of the structure toe
- Beach would become narrower as toe downcuts, eventually with no natural shoreline
- Reflections from the revetment may accelerate loss of natural material (sand, gravel, etc.) at the toe of the revetment
- Change in shoreline habitat

An example of the cross section is shown in Figure 3.5. The stone size shown in this figure represents the required stone size for a toe depth of 73.7 m (after downcutting)

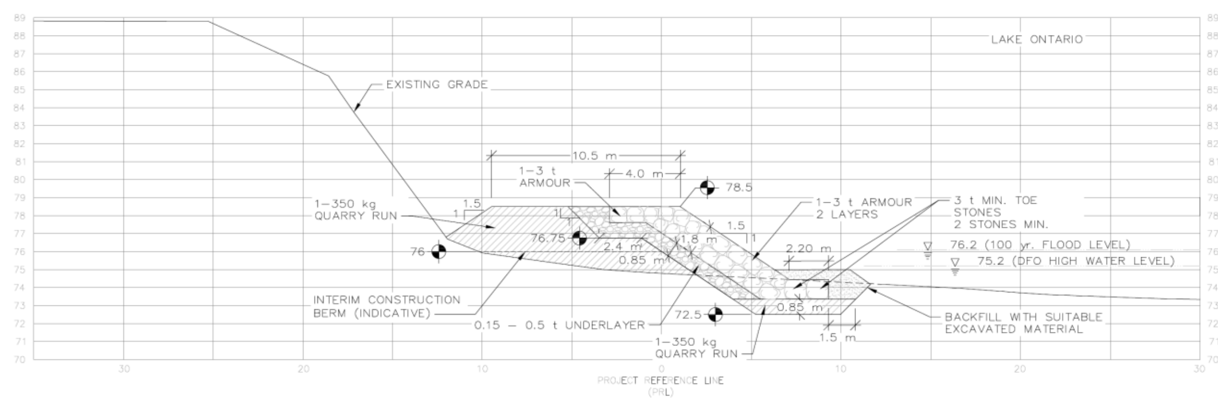

Figure 3.5: Example Revetment Cross Section

There is a broad spectrum of stone sizes and structure slopes that might be considered for a revetment. If large volumes of smaller material are available, then flatter slopes may make this possible. In this sense, there is a progression from the revetment section to the cobble/boulder (natural or riprap substitute) beach previously discussed.

3.3.6 Do Nothing

There are many regions of the Ajax waterfront where a do-nothing approach is probably the correct choice, either in the near-term (a few years) or perhaps also in the long term (many decades). The advantages and disadvantages are shown below.

Advantages:

- Low cost
- Natural shoreline
- Sediment continues to nourish nearby shoreline as erosion occurs

Disadvantages:

- Loss of park area
- Eventually will lead to loss of residential areas

A do-nothing approach should also be coupled with a monitoring plan that accurately outlines the evolution of the shoreline. The 2015 LiDAR and 2020 aerial photography represent the best recent information upon which to assess the shoreline evolution. The position of the bluff should be monitored through regular imagery, and transects through the nearshore would also help in understanding the rate of downcutting of the shoreline.

Depending on the results of this monitoring and the prevailing thoughts on park preservation and budget availability, a do-nothing approach could evolve to some other concept that may become well proven in the area.

3.4 Geotechnical Considerations

The slope stability analysis was completed by Grounded Engineering with 2D limit equilibrium analysis software (see Appendix B). The software evaluates the factor of safety of a mass of soil by determining theoretical circular or non-circular slip surfaces through the slope.

The factor of safety is a ratio defined for each slip surface by calculating the available soil strength resisting movement and dividing it by the gravitational forces tending to cause movement. When the factor of safety is 1.0, the forces resisting movement are approximately equal to the forces causing movement and the slope is in a condition where failure may occur. A slope is unstable when the factor of safety is less than 1.0 and marginally stable when the factor of safety is 1.0. The MNR Policy Guidelines dictate that a minimum factor of safety of 1.2 to 1.3 is required for light land use and a minimum factor of safety of 1.3 to 1.5 is required for active land use.

The slope stability model was built using the topographic information and the factual subsurface condition information. The slope was analyzed using both circular and non-circular slip surfaces. It was determined that circular surfaces govern the minimum factor of safety for the overall slope.

The concepts that have been proposed are all in front of the bluff, with the intention that there is adequate space for the bluffs to reach a natural stable slope over time. The stable slope is this area has been determined to be 2.0:1.0 (H:V).

Evidence from the erosion events of 2017 and 2019 show that some slope failures occur is large blocky sections and result in a near vertical bluff at the top. Figure 3.6 shows different phases of erosion at Lions

Point in June 2019. The western half of the bluff is being eroded at the toe where there was a partially vegetated slope (approaching a stable slope) to the lake. The scattered vegetation is still visible below the table lands, but above the lake. Near the center of the image is a more recent collapse where the talus has not yet been eroded by the waves. The eastern part of the image has no talus at the base, and a near-vertical and unstable drop from the tablelands to the lake.

Figure 3.6: Google Earth Image of Lion's Point from June 2019

With shore protection in place, we anticipate that steeper bluffs will eventually reshape (possibly larger failures or a gradual erosion through rainfall and other processes), but the talus will not be eroded away from the toe. Adequate space between the bluff and any shoreline structures is required to allow for bluff stabilization but still leave a corridor for maintenance. This is a larger issue where bluffs are higher, and the width for stabilization becomes higher.

3.5 Assessment of Concepts

A location-independent assessment of the concepts is provided in Table A1 in Appendix A. This table provides a general comparison of the various concepts under a number of headings.

A numeric scoring of these concepts is also provided in Table 3.1. In this table, each concept is assigned a score from 1 to 3, where 1 is least favourable and 3 is most favourable. These values are then averaged for each concept and the concepts are ranked from 1 to 6. The unweighted ranking assumes that all categories are of equal importance. By assigning a weighting it is possible to place more emphasis on certain categories. The last two lines of Table 3.1 provide the weighted average and rank for each concept.

For both the weighted and unweighted approaches, the results are very similar. The most preferred option is "Do Nothing"; however, this table does not consider the consequence of doing nothing, which is site specific. The most favourable protection option is the revetment, followed by the offshore breakwater with gaps. The least favourable is the groynes and shore fill.

These scores and rankings should be considered as general guidance, but all of these concepts are viable approaches to shore protection and have been used along the TRCA's waterfront. There is also the potential to use a composite approach where some of these elements are combined. Site specific considerations are assessed in the following section.

Table 3.1: Numeric Scoring and Ranking of Concepts

Concept #:	Weight (1 to 3)	Offshore Breakwater with Gaps 1	Nearshore Reefs 2	Groynes & Shore Fill 3	Cobble / Boulder Beach 4	Quarried Stone Revetment 5	Do Nothing 6
Design Uncertainty	3	3	3	1	1	3	3
Level of Protection to Shoreline	3	2	2	1.5	3	3	1
Risk of Damage if Design Exceeded	3	2	2	1	1	2	1
Difficulty to Repair in Future	3	1	1	2	2	2	3
Navigation Issues	2	2	1	2	3	3	3
Bank Swallow Habitat	2	2	2	2	2	2	3
Impacts During Construction (Land)	1	2	2	1	1	1	3
Impacts During Construction (Marine)	1	1	1	2	3	3	3
Fish Habitat (Post Construction)	3	3	3	2	1	1	2
Public Access Along Shore	2	2	2	2	2	1	2
Impacts on Adjacent Shores	3	2	2	2	3	3	3
Average (Unweighted)		2.0	1.9	1.7	2.0	2.2	2.5
Rank (Unweighted):		3	4	6	4	2	1
Average (Weighted):		4.91	4.73	3.95	4.64	5.27	5.55
Rank (Unweighted):		3	4	6	5	2	1

3.6 Concept Costs

Cost analysis was completed at a high level, focusing on the primary elements (armour, filter, core, fill, cobbles, boulders, etc.) and adding an allowance for general items (mobilization, demobilization, etc.) of 25% and a contingency of 30%. Unit costs for the primary elements were determined based on recent projects in the Toronto region and an allowance was also included for inflation over a two year period. A summary of the unit costs assumed at this stage of the project for the primary materials is provided in Table 3.2.

Table 3.2: Cost per Tonne for Primary Materials

Item	Cost / tonne
Filter Stone	$ 150
Armour Stone	$ 250
Core Stone	$ 80
General Fill	$ 80
Gravel/Cobble	$ 150
Boulders	$ 200

These costs are most useful for determining a general order of magnitude assessment between the different concepts. However, there are some significant challenges in determining more accurate costs. Including:

- The total quantity is not known. This is important for items such as cobbles and boulders that can be more difficult to source. A small quantity may be more achievable than a large quantity. This can result in highly variable costs depending on the size of the project.
- The timing of construction could be in the next few years or in decades to come. Uncertainties related to inflation could significantly impact the final costs.
- The cross section of some elements, especially the nearshore submerged reef, is uncertain as it will depend on the overall goals of the project and especially the performance at high water levels. The reef at Gibraltar Point is very wide and serves as shore protection and as fish habitat. Specific goals related to fish habitat could lead the reef to take on very different forms, and quantity of stone and cost would vary accordingly.
- Final design has not been completed. Final design will impact the cross section of many different elements. Moving a structure landward or lakeward will affect the base elevation for construction and will impact quantities.

A summary of the costs is provided in Table 3.3. The cost for each of these sections is relatively similar, especially when considering that the lower cost structures have greater uncertainty in the cost, and certainly the possibility for significant increases. These costs should all be considered to be in the range of ±25% or more.

Table 3.3: Costs Summary for Shore Protection Concepts

Concept	Cost $/m	Assumptions / Comments
Offshore Breakwater	$ 32,000	Built with a crest elevation 0.5 m above 100 year water level, and wide enough to drive on during construction. Assumption is that gaps in breakwater are 25% of total length of shoreline
Nearshore Reef	$ 27,000	A reef crest near chart datum is assumed and a crest width of 30 m. Inclusion of more fish habitat could impact reef width.
Groynes & Beach Fill	$ 24,000	This concept has significant uncertainty in the cost for the gravel/cobble beach fill. The price uncertainty for this concept is greater than it is for most other concepts.
Cobble/Boulder Beach	$ 31,000	This concept has significant uncertainty in the cost for the cobble/boulder material. The price uncertainty for this concept is greater than it is for most other concepts. However, use of an alternative large riprap product could be significantly less expensive.
Revetment	$ 33,000	Although this is marginally more expensive, there is significantly less uncertainty in the volume and cost of the materials

The costs outlined above represent construction costs in the near future and do not include any future maintenance costs. Maintenance costs will depend on the type of structures that are built. Structures that have more precise elements (stairs, pathways, services, etc.) require more maintenance requirements than structures that are more detached from human interaction (such as a nearshore reef). For the structures that are considered for this site, the long term maintenance costs could be in the range of 2% per year of the construction cost. Depending on the type of structure, this could be small frequent maintenance tasks, or it could be infrequent but more expensive repair tasks. For example, some of TRCA's headlands that were built thirty or more years ago and now undergoing more major repairs, involving significant cost.

The conclusion from this cost comparison is that the cost will be significant for any of the approaches that are undertaken. $30,000/m is $3 million for every 100 m of shoreline. With costs of this magnitude, a phased approach that addresses the immediate needs today, and monitors and addresses future needs at the appropriate time is recommended.

4. Assessment by Reach

4.1 Revised Reach Delineation

Characteristics along the project site were identified to determine natural breaks in the shore protection requirements. This meant that the reaches that were defined in 2021, primarily on the basis of shoreline orientation, were revised based on a wider range of characteristics. These characteristics included:

- Bluff height: There is a significant range in bluff height along the site, from no bluff to about 12 m in height. In particular, regions with very low (or no) bluffs are treated differently then higher bluff areas.
- Erosion rate: This was documented based on measured shoreline erosion rate from the aerial imagery, but also from observations along the site, such as degree of vegetation along the bluff. Only limited areas along the site had documented erosion rates from aerial imagery.
- Toe Protection: In most areas, the toe protection is natural in the form of sand, gravel, cobbles or boulders, or a combination of these. In a few limited areas there is armour stone or a concrete headwall at an outfall.
- Landside amenities: The distance to pathways or more significant development (roads or buildings) was an important consideration. Pathways can typically be realigned with limited cost; however, more significant development generally warrants protection.
- Waterfront usage: Regions such as Paradise Beach have a more heavily used waterfront than at the base of a high bluff with limited access.

Figure 4.1: Revised Reaches (1 to 12)

A total of 12 reaches were identified, with brief descriptions provided in Table 4.1. The original terms of reference describe five reaches, which had been defined by Baird (2021) when assessing shoreline orientation for sediment transport assessments. However, our assessment of the site conditions when assessing more factors resulted in a greater number of reaches.

Table 4.1: Summary of Shoreline Reaches

Reach	Land-side Amenities	Erosion Rate	Toe Material	Bluff Type	Comment
Reach 1	Pathway ~20 m away	~0.5 m/yr	Sand, gravel	Low bluff	Rapid erosion, but limited infrastructure
Reach 2	Boardwalk	N/A	Sand, gravel	none	Creek mouth with boardwalk
Reach 3	Rotary Park Pavilion	~0.34 m/yr	Sand, gravel	Low, eroding	Significant infrastructure
Reach 4	5-8 m to walkway, ~200m to road	~0.34 m/yr	Gravel, cobbles	Medium, eroding	
Reach 5	Some pathways relocated	0.4 to 0.5 m/yr	Gravel, cobbles		Higher erosion and narrow park. Likely first reach where erosion may reach road
Reach 6	10 to 15 m to path	0.13 m/yr	Boulders, cobbles	Higher, vegetated low erosion	Wide park and low erosion rate.
Reach 7	Water treatment plant	N/A	Gravel, Armour	Low, armoured	Armour wall with some damage. Will need to hold shore position.
Reach 8	Path close to edge, some relocated	0.13 m/yr	Gravel	Low	Some failure of revetment needs repair along crest
Reach 9	Path along shore	<0.13 m/yr	Stone, concrete	Moderate, protected	Rubble shore protection has reduced erosion here
Reach 10	Nearby paths, etc.	Low	Sand, gravel	Mostly gentle slope	Paradise Beach & private property (until sold)
Reach 11	None – creek mouth	N/A	Sand, gravel	Gentle slope	Private property & creek mouth
Reach 12	Pathways	0.12 m/yr	Gravel, cobbles	Moderate height, eroding	Pathways and playground, but limited significant development

4.2 Priorities by Reach

The priorities for protection are influenced by what could be lost in terms of infrastructure, and the timeline over which this is likely to happen. Data were assembled for each reach and are provided in Table 4.2. One of the key factors in assessing the timeframe until the bluff reaches the infrastructure is the allowable proximity. In areas where keeping significant parkland is important, it may be desirable to have 100 m between the road and the edge of the bluff; in other areas a lesser amount may be acceptable. The proximity to minor infrastructure may result in very small (sometimes zero) years until a problem needs to be addressed; however, this may be addressed through retreat of the minor infrastructure versus construction of major coastal works.

There are some subjective aspects to Table 4.2, but it does provide a framework for discussion and consideration of options. Erosion at creek mouths was not assessed, nor was it assessed at Paradise Beach. Also, the rate of erosion for Reach 7 (water treatment plant) is listed as 0.13 m/yr and should be considered to be a long term rate of erosion of an unprotected shoreline. In the short term (until the structure fails) this area would have a near-zero erosion rate, although that could change quickly after some failure of the structure in the future.

Table 4.2: Erosion Rates and Proximity of Infrastructure

Reach Num.	Erosion Rate (m/yr)	Distance to Infrastructure		Min. Dist. Allowed (m)		Expected Years		Comment
		Minor	Major	Minor	Major	Minor	Major	
1	0.50	31	100	5	25	52	150	Low eroding bluffs, limited development
2	N/A							Erosion not determined at Creek Mouth
3	0.34	8.5	34	5	30	10	12	Rotary Park Pavilion
4	0.34	5	175	5	100	0	221	Higher bluffs, eroding, reasonable space
5	0.40	5	105	5	100	0	13	Narrower, eroding
6	0.13	6	46	5	25	7	157	Boulders around headland
7	0.13	7	10	5	10	15	0	Water treatment plant, armoured
8	0.13	7	65	5	25	15	299	Slowly Eroding, path nearby
9	0.13	10	100	5	25	37	560	Rubble along shore
10	N/A	7	40	5	40			Paradise Beach
11	N/A							Erosion not determined at Creek Mouth
12	0.12	10	110	5	25	42	708	Less developed, low erosion

To better understand the future risk to infrastructure, the projected alignment of the bluff crest was plotted and is shown in Figure 4.2 through Figure 4.5. Reaches 2, 10 and 11 were omitted from this assessment as they do not have a defined erosion rate. Reach 7, at the water treatment plant, was also omitted as there is significant protection at this location and future maintenance of the revetment to protect the water treatment plant is almost certainly going to occur. The plot shows the immediate need to protect reaches 3 and 5 where minor infrastructure is already threatened and where major infrastructure will be threatened before the 25 year timeframe occurs.

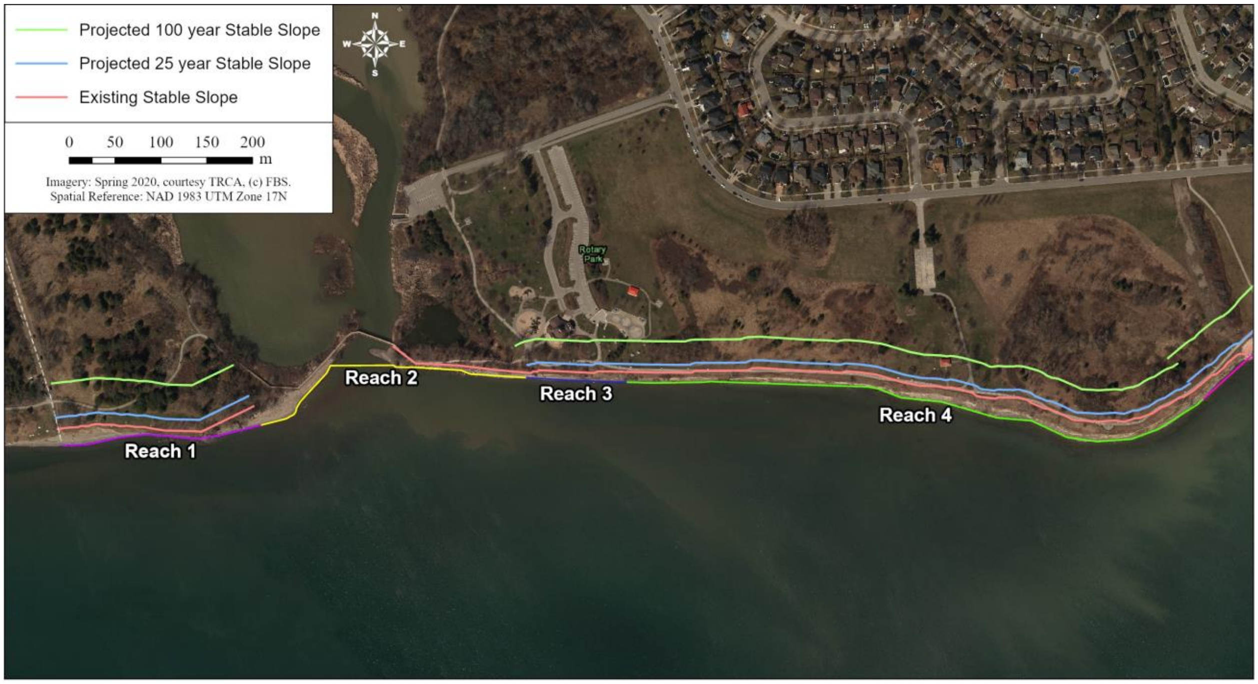

Figure 4.2: Projected Future Bluff Stable Slope for Reaches 1 to 4

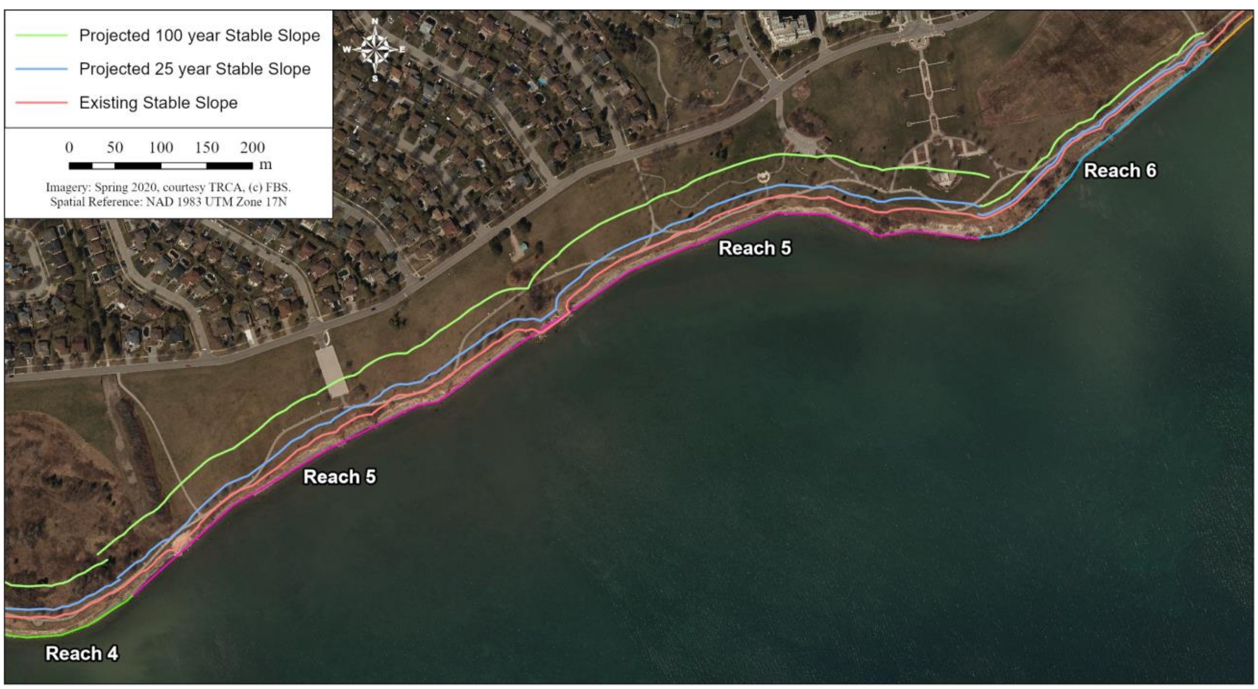

Figure 4.3: Projected Future Bluff Stable Slope for Reaches 5 & 6

Figure 4.4: Projected Future Bluff Stable Slope for Reaches 7 to 9

Figure 4.5: Projected Future Bluff Stable Slope for Reach 12

Based strictly on the potential losses along the study area, the priorities are defined as outlined in Table 4.3. This table provides an approximate ordering from highest to lowest priority; however, these priority levels depend on user preferences as well as how conditions progress with time in response to storms and high water level periods.

Table 4.3: High to Low Reach Priorities

Reaches	Discussion
	Highest Priorities (limited time for major infrastructure impacts)
3	Reach 3 has significant infrastructure inland (Rotary Park Pavilion) that is about 30 m from the edge of the bluff. With adjacent pathways and other land uses in this area, there is perhaps half of this distance before loss of land becomes a serious problem. With the erosion rate in the area, this could occur in 10 to 15 years, depending on tolerance for proximity
5	Reach 5 also has one of the narrowest regions of park (~100 m) and a high erosion rate (0.5 m/yr). Pathways could be under threat within the next decade (water level dependent), and parking areas within about 50 to 70 years. This level of erosion would also include significant losses to the width of the park area.
	Medium Priorities (7 to 20 year for minor assets, 100+ years to major assets)
7	Reach 7 has existing shoreline protection in the form of a stacked stone wall. There are some structural issues with the wall that will need to be addressed in the long term in order to protect the path and the water treatment plant further inland
8	Reach 8 has already had some landward realignment of the pathways, and the erosion rate is less than reaches such as 4 and 5. The park is narrower here,
4	Reach 4 has a higher erosion rate than many areas; however, the width of the park in the area means that some retreat is allowable. Bank swallows in this area preferentially select
6	Reach 6 has some natural cobble protection, especially near the headland which has infrastructure behind it. The bluff is vegetated with trees, suggesting a low erosion rate.
	Lower Priorities (30+ years for minor assets, 100+ for major assets)
9	Reach 9 is protected with scrap concrete and stone that appears to have been dumped along the toe, probably from the land above. This has provided a reduction in erosion that in the long term could increase as lakebed downcutting occurs. This area should be monitored.
10	Reach 10 is a popular beach and is relatively stable. Rapid erosion in this area is not expected, but it should be monitored due to the level of activity in this area.
1	Has a higher level of erosion but limited infrastructure in the area (only pathways)
12	Lower level of erosion and limited infrastructure (only pathways)
2,11	Barrier beaches at creek mouths. Limited infrastructure other than pile supported pathways.

4.3 Recommended Option by Reach

The recommended option for each reach was determined based on the site-independent scoring of the reaches presented in Table 3.1, and a consideration of the individual site characteristics. In some cases, such as at the two creek mouths, the preferred concept is to do nothing both in the near term and in the longer term and no other concepts were proposed.

Site specific considerations were used as a primary guide in how concepts were selected. There was no formal scoring process for this assessment because there are different considerations at each site and different priorities. Development of a scoring system would have involved creating a tool to provide the outcome that was already determined through discussion and consideration of the characteristics.

The site-independent assessments were then used to fine-tune which option may be preferred. For example, at Rotary Park, the site requires robust protection, but the bluffs are low and access to the shoreline and the nearby creek mouth may be an attractive feature. In this region, installing a revetment would protect the building but would not achieve other goals in the area such as shoreline access. A recommendation of installing offshore breakwaters was seen as effective for protecting the shoreline and providing a more useable beach that may connect into the shoreline at the creek mouth. The alternative at this site is a revetment because it provides reliable protection if beach/shore access is not a concern. There will undoubtedly be a range of interests and opinions on the most appropriate protection type.

There are a number of reaches where it is clear that some sort of protection will eventually be required; however, the need for protection is not immediate. This was outlined in Table 4.2, where the number of years was estimated until minor or major infrastructure was impacted. In the case where minor infrastructure is impacted (e.g., a pathway), a retreat of the minor infrastructure is a viable approach.

Table 4.4 provides a summary of the recommended concept by reach, while additional discussion is provided in Appendix A. For each reach, two concepts are listed, with the first being the preferred approach. These recommendations are preliminary and are subject to change in response to environmental inputs, stakeholders inputs and longer term changes to priorities and costs. The two creek mouths are defined as “do nothing”; Paradise Beach (reach 10) has “do nothing” as the first choice and a nearshore reef as the second choice. An overview of the proposed near-term protection for the Ajax shoreline is provided in Figure 4.6.

Figure 4.6: Proposed Near-Term Protection of Ajax Shoreline

These 12 reaches are significantly more than what was described in the terms of reference, where five reaches were suggested. To better align the reaches with the proposed level of detail for the environmental assessment, the 12 reaches can be collapsed into six reaches. This is done by ignoring the three "do nothing" reaches (two creek mouths and Paradise Beach) and then combining adjacent reaches with the same primary preferred concept. This means that the reaches become: 1, 3, 4+5, 6+7+8, 9, 12.

An overview of the preferred concepts is shown in Figure 4.7. For many of these reaches, it may be decades before protection is required. Therefore, the protection shown in Figure 4.7 should not be considered to be a near-term plan.

Figure 4.7: Overview of Preferred Concepts by Reach

Table 4.4: Reach-Specific Concept Recommendations

Reach	Overview	Concepts Considered				Comment	Priority	Suggested Concepts*
1	Low eroding bluffs, limited development	4	5		6	For narrow length, better to use at-shore options	Low	CBB, NR
2	Creek mouth	1	2		6	Long term is also do nothing	Long term: Do nothing	
3	Rotary Park Pavilion	1	2	5	6	Access to shore preferred	High	OB+G, R
4	Higher bluffs, eroding, reasonable space	3	4	5	6	Eroding more slowly than R5	Medium	R, CBB
5	Narrower, eroding	3	4	5	6	In need of immediate action	High	R, CBB
6	Boulders around headland	4	5		6	Natural boulder shore exists	Medium	CBB, R
7	Water treatment plant armoured	1	2	4	6	Protection at toe of existing	Medium	CBB, OR
8	Slowly eroding, path nearby	3	4	5	6		Medium	CBB, R
9	Rubble along shore	1	2	3	6	Deeper water at shore	Medium	OB+G, CBB
10	Paradise Beach	1	2	3	6	Popular area – monitor beach	Low	DN, NR
11	Creek mouth	1	2		6	Long term is also do nothing	Long term: Do nothing	
12	Less developed, low erosion	5			6	Higher bluffs, access less important	Low	R, CBB

* NR = Nearshore Reef; OB+G = Offshore Breakwater with Gaps; CBB = Cobble/Boulder Beach; R = Revetment; DN = Do Nothing

Paradise Beach is unique along this shoreline as the only region where there are lower elevations and an accessible beach. While this area has been described as do-nothing, that does not imply that regular maintenance on the beach will not be needed. Beach maintenance is regularly completed and will need to be continued into the future. The “do nothing” label is referring to major coastal works that would significantly change the shoreline. In the future some sand nourishment may be required. There was also discussion at the site meeting of ongoing maintenance at the site involving removal of gravel from the beach. This type of activity could have a detrimental effect on the beach stability both due to loss of material and the benefits that a coarser sediment fraction may have to reduce erosion.

4.4 Monitoring and Triggers for Action

There are two regions of the shoreline that should be monitored to understand future changes to the shoreline. The bluff position will show more obvious changes to the shore, while the nearshore water depths can also be used to understand shoreline evolution.

The position of the bluff can be monitored through aerial imagery or through LiDAR surveys of the area. Imagery, which often has a resolution of 10 to 15 cm using modern techniques, is one method for comparing the bluff position. However, this is also subject to the interpretation of the analyst that is identifying the edge of the bluff in a GIS system.

LiDAR is another viable option; however, the use of smoothed DEMs can lead to uncertainties in bluff positions. It is important that the DEM is prepared in such a manner as to better preserve bluff edges (higher resolution and less smoothing), or that other data (e.g., LAS files from the LiDAR) are used in the assessment.

Another method for understanding evolution of a shoreline is documenting the long-term downcutting of the shoreline. These differences may be more difficult to observe and require a higher order of survey than might typically be used for bathymetric surveying. This may involve wading transects in the nearshore with a total station or GPS and should have an accuracy of a few centimeters. Surveys of 20 years or more apart would be needed to have some confidence & understanding of the downcutting rates. Surveys into deeper water can also be undertaken from a boat but would require a higher level of precision than is often associated with hydrographic surveys.

Monitoring should take place in repeatable locations and would ideally also include spot checks on established monument/features in the area.

Monitoring will provide two pieces of information: a more accurate assessment of the shoreline erosion rate, and an accurate measurement of where the bluff edge lies relative to infrastructure. A decision on when a trigger for shore protection is met should consider the following information:

- What is an acceptable maximum erosion into the parkland? This should consider paths, buildings, park space, etc.
- What is the height of the bluff and an acceptable long term stable slope allowance? The recent hazard mapping project (Baird, 2022) defines the stable slope for Reach 45 (Ajax area) as 2.0:1.0. This means that the stable position of the bluff crest would be 20 m inland from the toe of a 10 m high bluff.
- What is the long term rate of erosion in the area? This can be ascertained from surveys and photos several decades apart. This was already completed but past data were limited. Future comparisons to recent LiDAR data and photographs will provide a more complete understanding in the future.
- What is the potential for a sudden retreat of the bluff in response to a high lake level event?
- What is the present information on long term lake levels? Is there any consensus towards more or less extreme high lake levels? ECCC (2022) provides the latest assessment; however, that is not to suggest that further adjustment to expected levels will not occur.

Therefore, the trigger for acting on shore protection should be considered to be met when non-retreatable infrastructure (or amenity) is within the sum of the stable slope allowance, a construction buffer along the toe, and some allowance for a rapid erosion event due to high water. This requires planning ahead and there should generally be a period of several years over which these construction decisions should be made. It is also best to complete these works during low water periods, meaning that waiting until problems occur at high water is much later than ideal for taking action.

Defining a trigger of when action must be taken along the shore should first involve determining what infrastructure will not be treated and what setback in front of this infrastructure is required. There is no correct answer to this question and there will be different opinions from different people and it may evolve over time. However, a more conservative assessment (a line closer to the lake) is a better location to start, as the requirement can always be relaxed in the future if needed.

A reassessment of shoreline protection priorities should be carried out every five years, until a better understanding of the process has been developed. This frequency may be relaxed along some reaches where changes are very slow to occur.

5. Environmental Considerations

6. References

Environment and Climate Change Canada. (2022). Great Lakes coastal wetland response to climate change using the CWRM (Coastal Wetland Response Model). Great Lakes Protection Initiative (2017-2022). Sévigny, C., Thériault, D., Maranda, A., Gosselin, R., Roy, M., Hogue-Hugron, S., Fortin, N., Bachand, M. and Morin, J. 537 p.

Appendix A

Evaluation of Concepts

Comparison Table for Concepts

Evaluation Criteria	Concept 1 Offshore Breakwaters with Gaps	Concept 2 Nearshore Reefs	Concept 3 Groynes and Shore Fill	Concept 4 Improved Cobble/Boulder Beach	Concept 5 Quarried Stone Revetment
Design Uncertainty	Low (depth-limited conditions)	Low (depth-limited conditions)	Moderate – gravel & cobbles have less well-defined parameters	Moderate – cobbles & boulders have less well-defined parameters	Low (depth-limited conditions), well established parameters
Level of Protection to Shoreline	Moderate. Still gaps in the breakwaters and some protection required.	Moderate. Least effective at high water when it is really needed. Needs to be wide to be effective	Moderate. Shore fill still somewhat mobile	Moderate. Cobble & boulder beach will reduce erosion	High (stabilizes shoreline)
Risk of Damage if Design Event Exceeded	Low	Low	Moderate – protection at shoreline	Moderate – protection at shoreline	Moderate – protection at shoreline
Difficulty to Repair in Future	Moderate – marine plant or offshore causeway required	Moderate – marine plant or offshore causeway required	Low – provided access along the shore is possible	Low – provided access along the shore is possible	Low – provided access along the shore is possible
Navigation Issues	Moderate. Obstructions but visible	High. Submerged obstructions	Moderate. Groynes could present problems	Low risk	Low risk
Bank Swallow Habitat	Reduces recession of bluff, no direct impact	Reduces recession of bluff, no direct impact	Reduces recession of bluff, no direct impact	Reduces recession of bluff, no direct impact	Reduces recession of bluff, no direct impact
Impacts During Construction (Land)	Could be marine only, otherwise shoreline access required	Could be marine only, otherwise shoreline access required	Impact along access route and along structure corridor	Impact along access route and along structure corridor	Impact along access route and along structure corridor
Impacts During Construction (Marine)	Footprint impacted, land/lake access points impacted, turbidity in area	Footprint impacted, land/lake access points impacted, turbidity in area	Footprint impacted, turbidity in area	Footprint impacted, turbidity in area	Footprint impacted, turbidity in area
Fish Habitat	Footprint in the water creates net loss of lakebed	Structure footprint remains below water. Improvement in habitat	Moderate impact with expanded beach and groynes	Small impact with widened beach	Limited impact at toe of structure
Public Access Along Shore	Improved over present	Improved over present	Improved over present, but groynes can present obstacles	Improved over present	Reduced access, unless walkway provided along back of structure
Morphological impact and flank effects	Could accumulate sediment if improperly built. May reduce supply of sand to adjacent areas	Could accumulate sediment if improperly built. May reduce supply of sand to adjacent areas	Unlikely to accumulate significant sediment. May reduce supply of sand to adjacent areas	May reduce supply of sand to adjacent areas	May reduce supply of sand to adjacent areas
Estimated Construction Cost (per linear meter)	$32,000	$27,000	$24,000	$31,000	
Potential Operational Cost (NPV per linear meter)	2% of construction cost	2% of construction cost	2% to 5% of construction cost due to greater design uncertainty	2% to 5% of construction cost due to greater design uncertainty	2% of construction cost
Potential for Design Refinement and Cost Savings	Low	High – width/height to be finalized	Moderate	Low, other than refining material costs	Low – well established design approach

Considerations by Reach

Reach 1: This area has limited development on the land above the bluff, and allowing some erosion in this region is acceptable. It is a relatively short distance, which is generally better addressed by at-shore options. The shore is also convex (a small point), making is less likely to hold a beach in place. The most cost effective at-shore solution is recommended for this location. That is likely a revetment.

Reach 2: The creek mouth area should be left in a natural state. There may be some erosion in the long term; however, that normally takes the form of a retreating spit of land. There is a pile-supported walkway in this area that will allow some retreating to occur. If there is too much retreating of the shoreline, the walkway may become more exposed. At some point (decades away) there may be a need to consider retreating the walkway or protecting the area, but nothing in the near-term.

Reach 3: Rotary Park has more activity than other areas to the west in the Ajax area. There is a large parking lot here as well as the pavilion at the site. This is an area that is eroding rapidly and in need of protection. The bluffs are not too high, making access to the shoreline possible in this area. An offshore breakwater would create a wider beach, perhaps with a small tombolo that would make a good beach at the base of the access from the top. A submerged reef would be less reliable at higher water levels and would be less likely to maintain some minimum shore width. The presence of the creek mouth to the west may allow for some walking along a more natural section of shoreline to the west. If an offshore structure is not desired, then a revetment or cobble beach would be considered as at-bluff protection; however, this would provide a less natural shoreline in this area. With a higher degree of erosion in this area, a more robust option is probably appropriate.

Reach 4 and 5: This is an area with high erosion and a need for protection. There is little need to provide access along the shoreline as there is a path at the top of the bluff. The bluffs are generally faily high so that access up and down the bluff would be limited to a few areas. A revetment or cobble beach could be considered, with the revetment likely being a more cost effective solution with more certain design parameters and performance. A natural cobble product would be difficult to source on such a long section, making a quarry-produced product more likely. A revetment is probably more cost effective in this area.

Reach 6: At Veteran's Point there is a natural cobble/boulder beach that appears to be protecting the shoreline through natural means. We believe that a higher bluff and/or a greater proportion of cobbles/boulders has supplied this material. The region is slowly eroding, and it may be possible at the final design stage to design an approach where we are supplementing a reasonably stable cobble/boulder beach. For this reason, a cobble/boulder beach is recommended, in hope that this is augmentation of an existing system, rather than an entirely new structure.

Reach 7: At the water treatment plant there is already a stacked stone revetment along the shoreline to protect the path that goes between the plant and the shore. There have been some minor stability issues along this section of shoreline that could be repaired with the existing blocks. Offshore structures are not recommended at this site because of the outfall from the plant – we did not want to get involved in environmental issues, plant performance issues etc. The greatest threat to an existing structure of this kind erosion of the toe. For this reason, we recommended a cobble/boulder beach. It could provide additional stability to the existing structure and prolong its life span. Given the existing protection in the area, this is probably a low priority site, other than repairs to the existing structure.

Reach 8: This reach is an area where some path realignment has already occurred and there are trees toppling towards the water at the bluff edge. The erosion rate is slow, but is certainly having an impact on the shoreline. Public access along the water's edge will occur near the water treatment plant, but should not be encouraged to the east of there (in reach 8) because it will be an isolated dead end access, with the path at the top already retreated. This could make this area very isolated. We do not foresee extending a pathway through the next reach due to deeper water depths at the toe in Reach 9. In Reach 8 a cobble and boulder beach would work well, with a revetment being a similar option. Probably only for consistency with the recommendation for Reach 7, a cobble and boulder beach is the preferred option.

Reach 9: In this area, rubble was dumped along the shoreline many years ago, and the resulting retreat of the profile has created deeper water depths at the shoreline. Installing a cobble or boulder beach in this area would be more expensive as more fill would be required. The same would be true for a revetment. Since access along the shoreline is less of a concern here; we recommend that offshore breakwaters be built to provide further protection to the shoreline.

Reach 10: Paradise Beach is a popular public beach and should be maintained in a natural state as much as possible. Placing structures of any kind on the beach would probably not be seen as beneficial by beach-users. For this reason, and due to limited ongoing erosion, we recommend this as a do-nothing site. If some protection is required, then a submerged nearshore reef is the recommendation, although it would need to be clearly marked for navigation purposes and far enough offshore that it would not be a wading/swimming concern (people have been badly injured diving towards submerged rocks even from a position of standing in the water). The region to the east of Paradise Beach is private property that will reportedly be purchased by the city when it changes hands. This area is treated as an extension of Paradise Beach and is also a “do nothing” recommendation.

Reach 11: This is a creek mouth and should be a left in its natural state, as described for Reach 2.

Reach 12: This is a bluff area with pathways moderately set back from the shore and less usage than some other areas of Ajax. There is no parking in the immediate area and the eastern two-thirds of the reach is left in a more natural condition above the bluff. Access along the shoreline is not a consideration here and the most economical option is recommended. This is expected to be a revetment.