TECHNICAL GUIDE FOR
GREAT LAKES - ST. LAWRENCE RIVER SHORELINES

PART 5

DYNAMIC BEACH HAZARD

DYNAMIC BEACH HAZARD

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5.1 INTRODUCTION

Low-lying shoreline environments generally tend to undergo a continuous or "dynamic" change of form and configuration due to the natural processes of erosion and accretion. These processes can broadly be defined as the removal, movement and deposition of material in the onshore and offshore areas by wave action and currents. Depending on their magnitude and the sediment supply in the nearshore, the turbulence of breaking waves uprushing onshore can build or destroy shoreline beach environments.

On hard rock shorelines, these changes are so slow that they can only be detected when measured in geological time. On shorelines of unconsolidated materials (e.g., gravels, sands, silts and clays) significant changes, either a partial or entire loss of the beach, may be observed following a severe storm event or a series of storms, only to reappear days, months or years later.

In many cases, the existing land form and its natural physical and biological features offer a high degree of natural protection against flood and erosion damages. For instance, dunes or sand ridges that lie landward of beaches absorb the energy of large storm waves thereby protecting inland areas from flood and erosion damage. In addition, they provide a valuable reservoir of sand to replace beach material that is carried off during severe storm events. After a storm has passed, the dune is then restored with new beach sand carried in by wind or aeolian forces.

Due to the highly dynamic and highly valued naturally occurring protective benefits realized by maintaining the physical integrity of these dynamic beaches, implementing agencies must ensure that policies established to address these areas recognize these benefits and maintain these dynamic beaches in their natural state.

In examining these issues, the intent of **Part 5: Dynamic Beach Hazard** of this Technical Guide is to provide an in depth analysis of the *dynamic beach hazard* defined in the *Provincial Policy Statement* (1996; Policy 3.1, Public Health and Safety: Natural Hazards) and the supporting *Natural Hazards Training Manual* (1996). For purposes of clarification, Part 5 will provide a detailed procedure for classifying and mapping dynamic beaches, outline supporting background information on the nature of dynamic beach forms and processes, and promote an awareness and understanding of the response of a particular dynamic beach to natural or human-induced changes in the following manner:

- **Section 5.2** provides a general **definition of beaches**, outlines commonly referenced beach terminology, and provides a descriptive explanation of the term "**dynamic beach**"
- **Section 5.3** provides a definition of the *dynamic beach hazard*, as contained in the *Provincial Policy Statement* and the supporting *Natural Hazards Training Manual* (1996)
- **Section 5.4** provides **background information** on **beach characteristics** and their interaction with **controlling processes** based on a **recommended dynamic beach classification scheme** used in the determination and mapping of dynamic beaches along the shorelines of the *Great Lakes - St. Lawrence River System*
- **Section 5.5** provides general guidelines to be used in the **determination of recession rates on dynamic beaches**, as well as identifying any **special precautions** which should be taken or recognized in the determination and measurement of recession rates
- **Appendix A5.1** provides a summary of the **factors that act to control the dynamic response** of each of the 18 dynamic beach sub-classifications; identifies the **potential problems** on this determination; provides guidance in where studies using **acceptable scientific and engineering principles** should be used in determining the **dynamic beach allowance**; and provides descriptions and examples of most 18 dynamic beach types on the Great Lakes

- **Appendix A5.2** presents a general procedure for determining the classification as well as the alongshore boundaries of the dynamic beaches

5.2 DYNAMIC BEACH PROCESSES

By definition, a beach is simply an accumulation of detrital material or sediment along marine or lake shorelines that has been transported and deposited by waves and by currents generated by wind and waves. Although beach sediment commonly consists of sand, beach sediment may also consist of gravel, cobbles or boulders and may even include varying amounts of shell fragments.

5.2.1 Definition of Beach and Dynamic Beach

In a very restricted sense, the term beach can be used to describe the sediment that is exposed above the mean waterline during low wave conditions. Observations quickly show, however, that this sediment does not remain stationary for very long and that some of the sediment may be transported offshore during storms, only to be returned during periods of calmer weather. In addition, sand-sized sediment may be transported landward to be deposited in the form of sand dunes. During low lake level periods, the sand deposited and stored in the dunes may remain there for years and then be returned to the water by storm wave action during periods of high lake levels.

As such, for the purposes of this Technical Guide, the term beach is broadly defined to include the whole shoreline over which sediment is transported by wave action, extending offshore to the limit of wave action on the underwater bed and onshore to a point just landward of the maximum limit of wave action during intense storms.

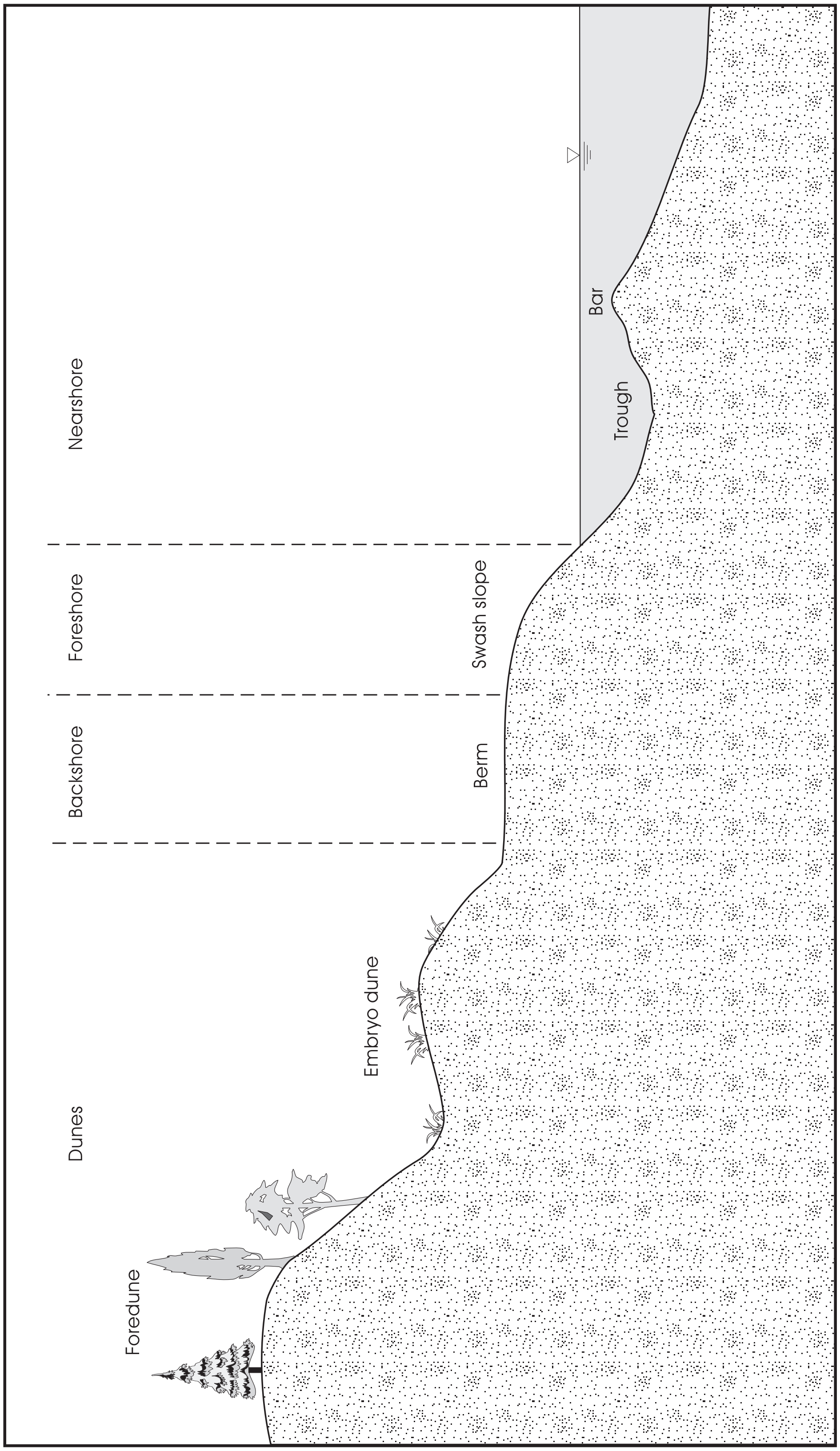
For instance, on sandy shorelines where a dune system is developed, the beach will be defined as including the embryo dune and foredune which lie adjacent to the top of the beach proper, and which receive sand directly from the beach. In general, sediment that is transported beyond these onshore and offshore boundaries cannot be returned and is permanently lost to the beach system.

To provide an illustrative description of a sandy shoreline, a generalized profile including the dominant features and commonly used terminology is provided in Figure 5.1. Typical of sandy shorelines, the beach is divided into the underwater nearshore; the foreshore, which is subject to wave action during low wave conditions; the backshore, which is only subject to wave action during storms; and the dune area which is subject to wave action near the beach and to sand transport by wind over the whole area. The features shown are not found on all beaches and may vary with seasonal and long-term changes in lake level and storm activity.

The term dynamic beach is used to emphasize and describe beach profiles which undergo changes on a broad range of time-scales, from hours or days to years and decades, in response to changing wave, wind, and water level conditions and to changes in the rate of sediment supply to a particular section of shoreline. An important consequence of this variability is that the elevation of any point on the beach profile is not a constant, instead this elevation varies through time. As such, it is not possible to define the landward limit of the dynamic beach based on a single elevation. Instead, to define the landward extent of the dynamic beach requires that the range of the profile variation along each section of beach be evaluated.

The *dynamic beach hazard*, as identified in the *Provincial Policy Statement* (1996, Policy 3.1, Public Health and Safety: Natural Hazards for the shorelines of the *Great Lakes - St. Lawrence River System*) and the supporting *Natural Hazards Training Manual* (1996), recognizes that a combination of criteria are required to properly define and delineate the landward extent of dynamic beaches on sections of shoreline characterized by beaches in contrast to cohesive bluffs or bedrock shorelines.

Figure 5.1: Generalized Profile of a Sandy Beach



5.2.2 Beach Profile Definition and Terminology

On shorelines of the *Great Lakes - St. Lawrence River System* , changes in beach profile elevation generally occur on two time scales:

- annual changes related to seasonal water level fluctuations and to the frequency and intensity of storm wave action; and

- long-term changes, ranging from several years to several tens of years, reflecting the long-term lake level variations and/or the sediment budget of the beach.

A schematic illustration of these changes, based on actual measured profile changes at Long Point on Lake Erie (Figure 5.2), serves to demonstrate why it is not possible to establish a fixed horizontal position for a particular beach profile elevation, as well as illustrating the overall dynamic nature of such a shoreline environment.

Of the two general time scales of beach profile changes, depiction of the annual and seasonal changes, over the six month period from May to December 1985 at the Long Point location are shown in Figure 5.2a. Within this illustration, the May profile reflects seasonal lake level highs as well as the effects of early spring storms which tend to transport sediment from the beach offshore. The September profile reflects the typical seasonal drop in water levels in the late summer and, with the return to a relatively calm period over the summer months, the landward transport of sand from the nearshore and the resultant build up of the beach berm. Alternatively, the December profile shows the effects of an intense winter storm which led to the erosion of about 10 metres of the foredune. Using this example, if the landward limit of the dynamic beach was to be defined by a single criteria, the 100 year flood level elevation, for instance, the landward limit would have moved horizontally over the beach profile by more than 20 metres over the sample six month period.

By comparison, beach profile changes over a period of years are typically related to the long-term lake level variations. To demonstrate the impact of these long-term changes, Figure 5.2b provides a schematic depiction of the 1985, 1986 and 1992 beach profiles for the same Long Point location. First, the 1985 profile shows the beach and dune during high lake levels and prior to a major storm event. Second, the 1986 profile shows beach erosion and an approximate 10 metre landward retreat of the dune following a major storm in late 1985. The 1985 and 1986 profiles are the same as profiles 1 and 3 in Figure 5.2a. The third profile, for 1992, shows some continued retreat of the top of the foredune as a result of destabilization of the dune by wave action during the 1985 storm. Re-establishment of vegetation at the base of the dune during this period, however, has led to the trapping of sand transported off the beach by wind action and ultimately, to the growth and lakeward extension of the dune system.

Similar to the seasonal or annual profile changes, if the landward extent of long-term changes in the dynamic beach, as illustrated over the sample five year period, were defined by a single criteria, such as the 100 year flood level elevation, this elevation would have first moved horizontally landward and then moved significantly lakeward. As such, to accurately define the landward limit of the *dynamic beach hazard* requires a comprehensive understanding and recognition of the processes impacting on dynamic beach environments.

5.2.3 Factors Controlling Beach Dynamics

The factors controlling the dynamic nature of a beach environment are numerous and their interaction produces a highly complex set of processes and responses (Figure 5.3). In general terms, beach dynamics reflect:

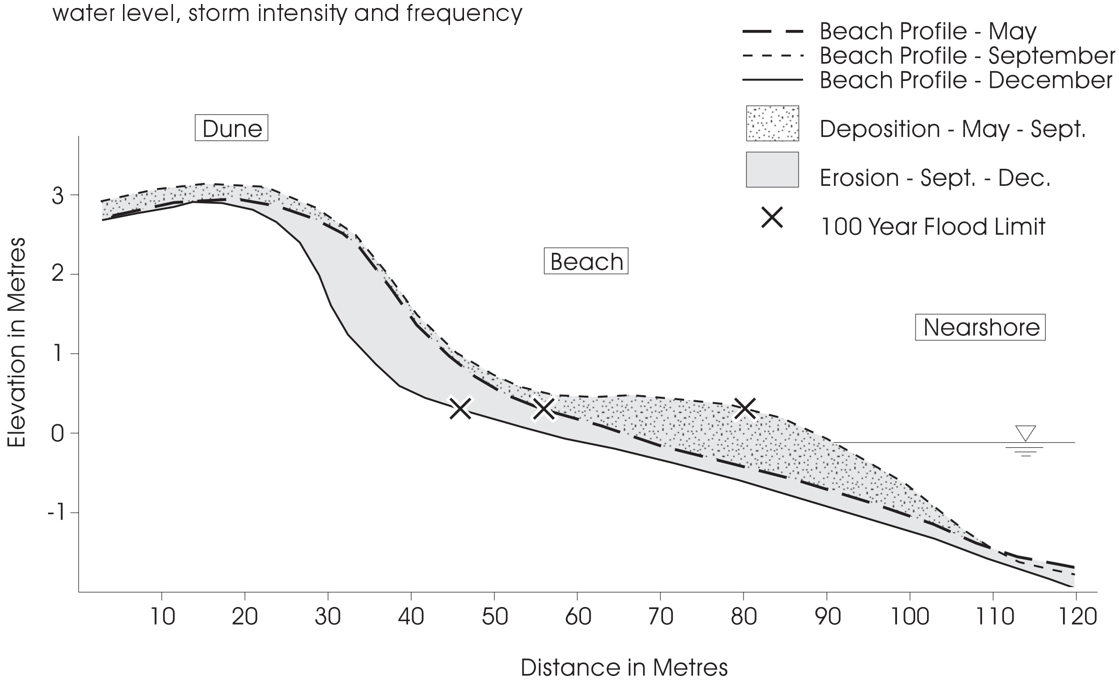
- the operation of shoreline processes such as wave generated and wind generated currents in the lake or connecting channel;

- the transport of sand by wind on the sub-aerial part of the beach and dune; and

- the direct and indirect effects of lake ice.

Figure 5.2: Effects of Changes in Beach Profile on Horizontal Position of Flood Hazard Limit

a) Profile changes over one season reflecting changes in water level, storm intensity and frequency



b) Profile changes over several years showing dune erosion during high lake level and recovery during period of lower level. The crosses mark the horizontal position of a particular elevation such as the 100 Year flood elevation and illustrate how changes brought about by beach erosion or progradation can affect the horizontal location of the elevation through time.

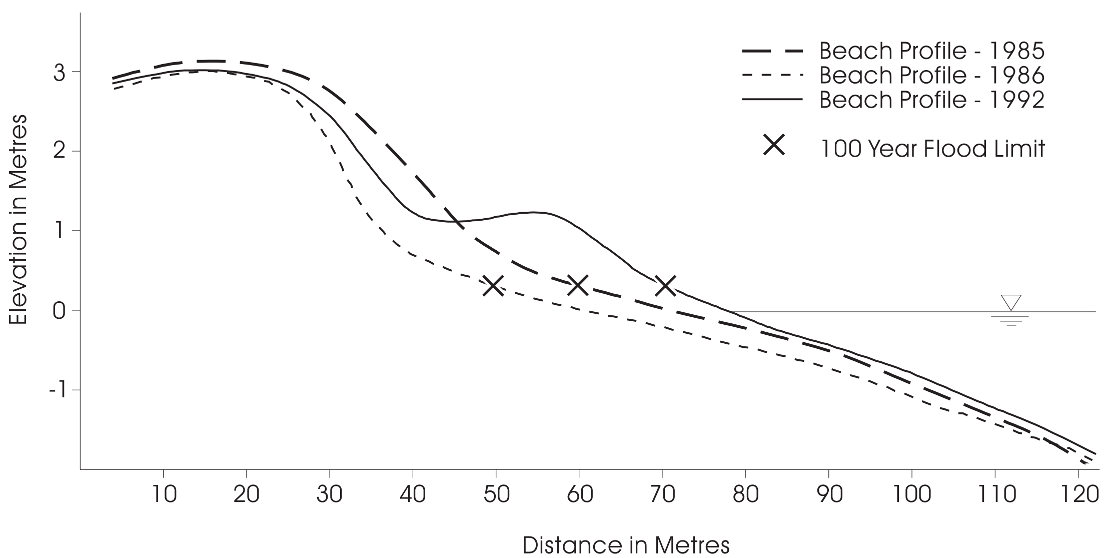
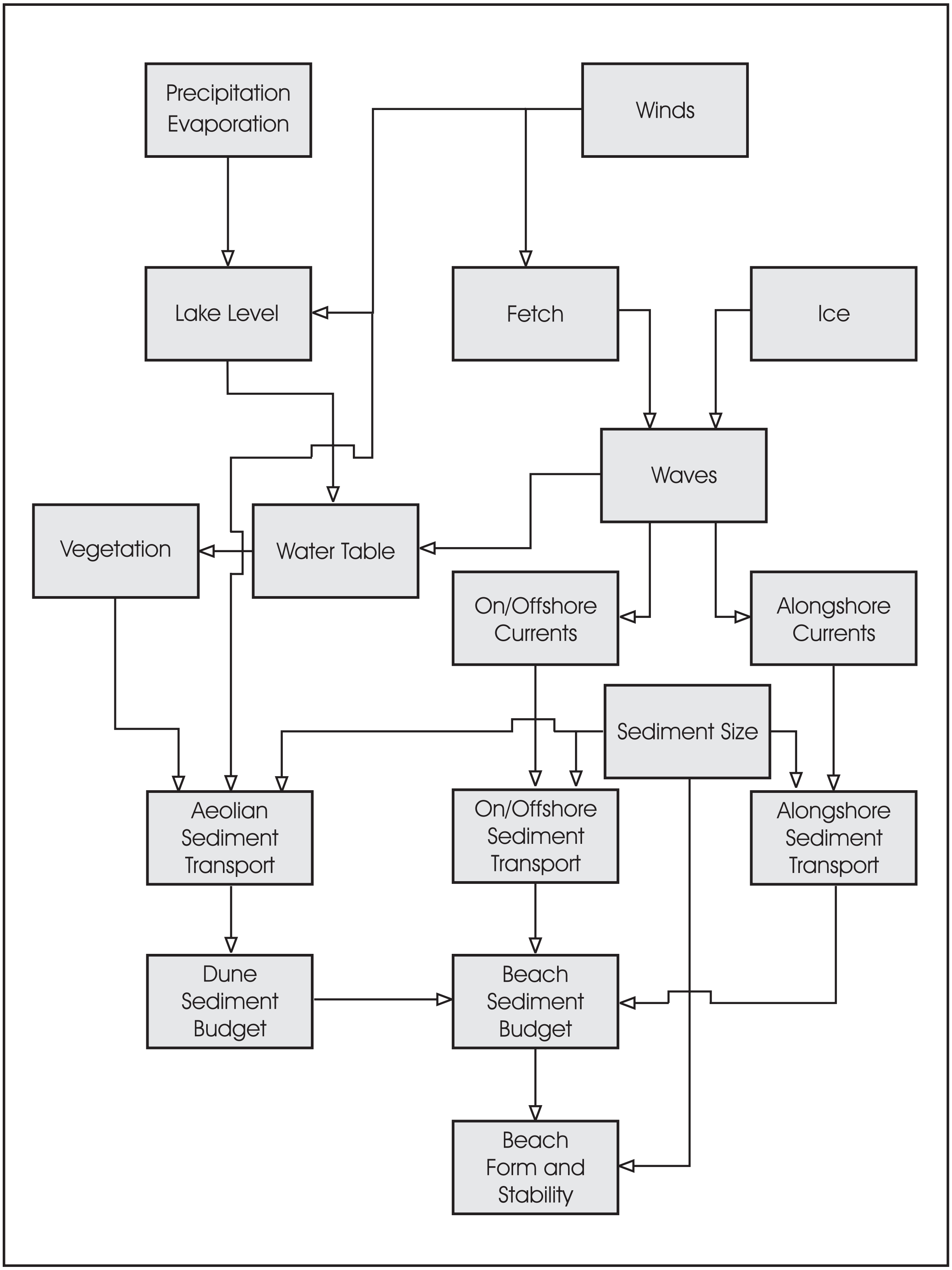


Figure 5.3: Complex Interaction of Processes and Factors Controlling Beach Dynamics



The frequency and magnitude of these processes in turn are dependent on factors such as:

- weather and climate;
- fluctuations in lake level over a range of time scales;
- extent of winter ice cover; and
- orientation and fetch of the beach.

Finally, the physical attributes of the beach, such as the size of beach sediments, the sediment supply and beach sediment budget, shoreline orientation and the alongshore and onshore-offshore morphology of the shoreline, also act to determine the dynamic range of an individual beach.

5.3 PROVINCIAL POLICY: DYNAMIC BEACH HAZARD

The *dynamic beach hazard*, identified in the *Provincial Policy Statement* (1996; Policy 3.1 Public Health and Safety: Natural Hazards for the shorelines of the *Great Lakes - St. Lawrence River System*)and the supporting *Natural Hazards Training Manual* (1996), involves the calculation of the cumulative impact of the flooding hazard, the average annual recession rate and a dynamic beach allowance.

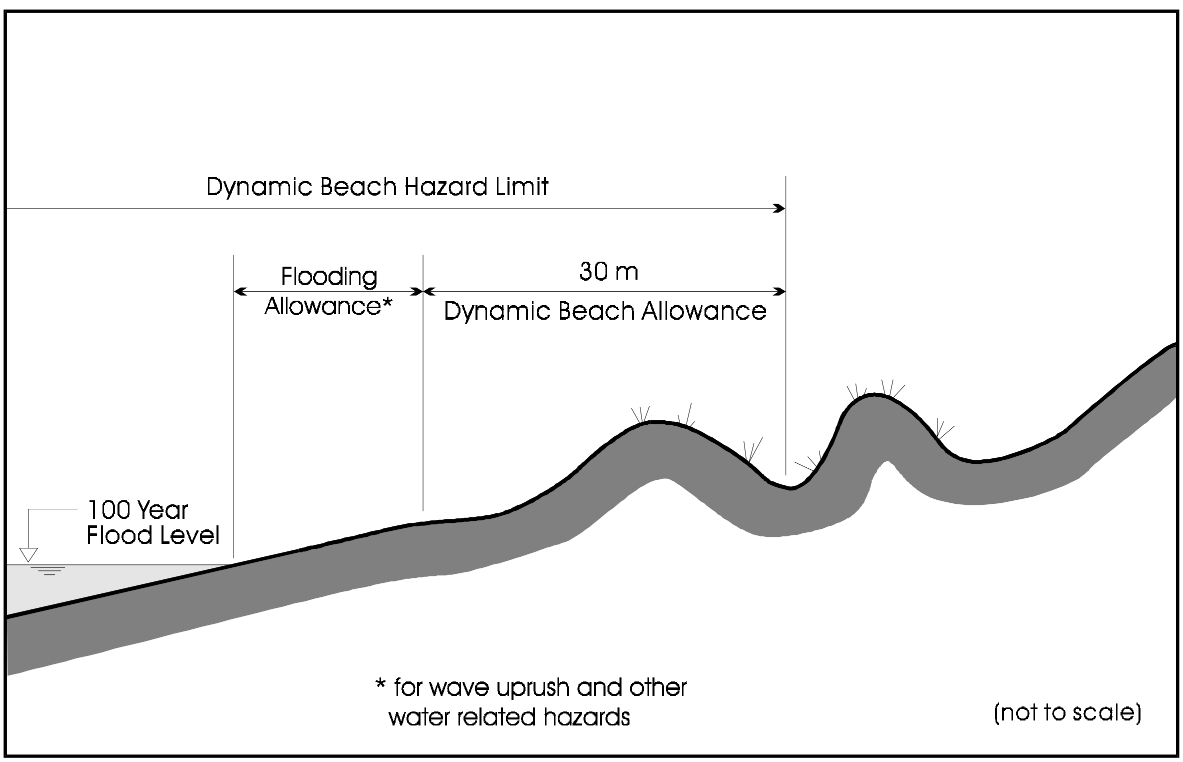
In addressing these factors, the *dynamic beach hazard* is defined as:

- **the landward limit** of the ***flooding hazard*** **(100 year flood level plus a flood allowance for wave upursh and other water related hazards) plus a 30 metre *dynamic beach* allowance** (Figure 5.4);

OR

- **the landward limit** of the ***flooding hazard*** **(100 year flood level plus a flood allowance for wave upursh and other water related hazards) plus a *dynamic beach* allowance based on a study using accepted scientific and engineering principles**.

Figure 5.4: Dynamic Beach Hazard Limit



The *dynamic beach hazard* **is applied** to all shorelines of the *Great Lakes - St. Lawrence River System* **where there is an accumulation of surficial sediment landward of the stillwater line** (defined at the time of mapping under non-storm conditions), **such that action by waves and other water and wind-related processes can lead to erosion of the sediments and a resultant landward translation of the shore profile.**

The *dynamic beach hazard* **is only applied where**:

- beach or dune deposits exist landward of the water line (e.g., land/water interface), AND
- beach or dune deposits overlying bedrock or cohesive material are equal to or greater than 0.3 metres in thickness, 10 metres in width and 100 metres in length along the shoreline, AND
- where the maximum fetch distance measured over an arc extending 60 degrees on either side of a line perpendicular to the shoreline is greater than 5 km (this normally does <u>not</u> occur where beach or dune deposits are located in embayments, along connecting channels and in other areas of restricted wave action where wave related processes are too slight to alter the beach profile landward of the waterline.

The criteria used to define and classify a section of shoreline as a dynamic beach are intended to be applied over a stretch of shoreline on the order of 100 metres or more in length. Where shorter sections of sediments occur on a rocky or cohesive shoreline they are likely to be transitory. Beach width and thickness should be evaluated under calm conditions and at water levels between datum (IGLD) and the average annual low water level. When lake level conditions are higher, consideration should be given to the submerged portion of the beach. If possible, mapping should not take place during high lake level conditions. It is expected that the person carrying out the mapping will exercise judgement, based on knowledge of the local area and historical evidence, in those areas where the beach width is close to the suggested criteria for defining a dynamic beach.

While the criteria used for defining and mapping of dynamic beaches generally tend to be based on "landside" characteristics or limits of the exposed beach, to ensure the proper identification and protection of the dynamic range of the beach, all delineations of shoreline dynamic beaches should also include a "lakeward" limit into the sub-aqueous portion of the profile to a depth of about 6 metres.

On the majority of beaches in the *Great Lakes - St. Lawrence River System* , including those located along the connecting channels, the range of dynamic profile change due to waves and other processes can be accommodated within the defined landward limit of the *dynamic beach hazard*. However, it should be recognized that the *dynamic beach hazard* is designed to provide a minimum landward limit which can be easily interpreted, mapped and staked in the field, in the absence of more detailed studies.

For those situations where a municipality or planning board determines that for various reasons a scientific and engineering study would be a more appropriate method in determining the landward limit of the *dynamic beach hazard*, there should be flexibility provided to:

- **permit or require the undertaking of a study using accepted scientific and engineering principles to determine the** *dynamic beach hazard* **limit.**

These studies may be initiated by the implementing agencies as part of the process of mapping of the *hazardous lands* (i.e., landward limit of the *flooding, erosion* and *dynamic beach hazards*). Where the studies have been undertaken using accepted scientific and engineering principles and have been approved by the implementing agencies (i.e., municipalities), the scientific/engineered *dynamic beach hazard* limit is to be applied only in the area studied.

Guidelines to assist in determining when and where such studies are appropriate and what constitutes accepted scientific and engineering principles and procedures are provided in Sections 5.5 and Appendix A5.1 of this Technical Guide. Depending on the particular dynamic beach environment being studied, a study using accepted scientific and engineering principles may result in either a reduction <u>or</u> an increase in the landward limit of the *dynamic beach hazard* (i.e., Policy 3.1).

A study-defined increase in the dynamic beach allowance should be considered where the potential range of profile adjustment and extent of wave action is likely to exceed the limit defined by the *dynamic beach hazard*. In these areas, the landward limit of potential beach profile adjustment and of the area subject to wave action and other related shoreline processes, is based on site investigation and analysis using accepted geomorphological and engineering principles. Beaches that may warrant such an investigation include, but are not limited to, barrier beaches, beaches backed by dune systems, filet beaches and nourished beaches. In addition, where there is historical evidence that shoreline recession is occurring, (e.g., due to a negative sediment budget or to shoreline subsidence relative to the lake outlet) consideration should be given to increasing the dynamic beach allowance to accommodate the shoreline recession within the planning framework (i.e., 100 times the average annual recession rate (AARR))(Figure 5.5). Procedures for distinguishing between long-term shoreline erosion and short-term fluctuations around a mean are given in Section 5.5 of this Technical Guide.

There are several circumstances under which natural factors may require redefining the landward limit of the *dynamic beach hazard* based on field investigations that may result in the *dynamic beach hazard* limit being adjusted lakeward. These include:

- where a cliff or bluff, consisting of cohesive sediments or bedrock, exists landward of the beach, the toe of the bluff/cliff acts to limit the landward extent of dynamic beach profile adjustment. In these areas the *dynamic beach hazard* limit should be defined as the toe of the cliff or bluff (Figure 5.6). The stable slope allowance and the erosion allowance should be applied to the cliff/bluff (see Section 5.5).

- where the dynamic beach exists on a narrow barrier system, the landward limit of the *dynamic beach hazard* may fall within the marsh or bay that exists landward of the barrier. In these areas the *dynamic beach hazard* limit should be defined by the toe of barrier slope on the landward side (i.e., intersection of the unconsolidated material and the marsh or bay bottom) (Figure 5.7).

- on some low shoreline plains the beach and associated dune deposits, or cobble deposits in the case of cobble beaches, may be of such low height and width that the *flooding hazard* is at a higher elevation or extends landward of the beach deposits. In this case the landward limit of the *dynamic beach hazard* is mapped as the lesser of the landward boundary between the beach and associated dune deposits and the material forming the low plain <u>or</u> 30 metres measured landward from the first break in slope on the lee side of the first dune (Figure 5.8).

Figure 5.5: Dynamic Beach Hazard Limit for a Recessional Beach

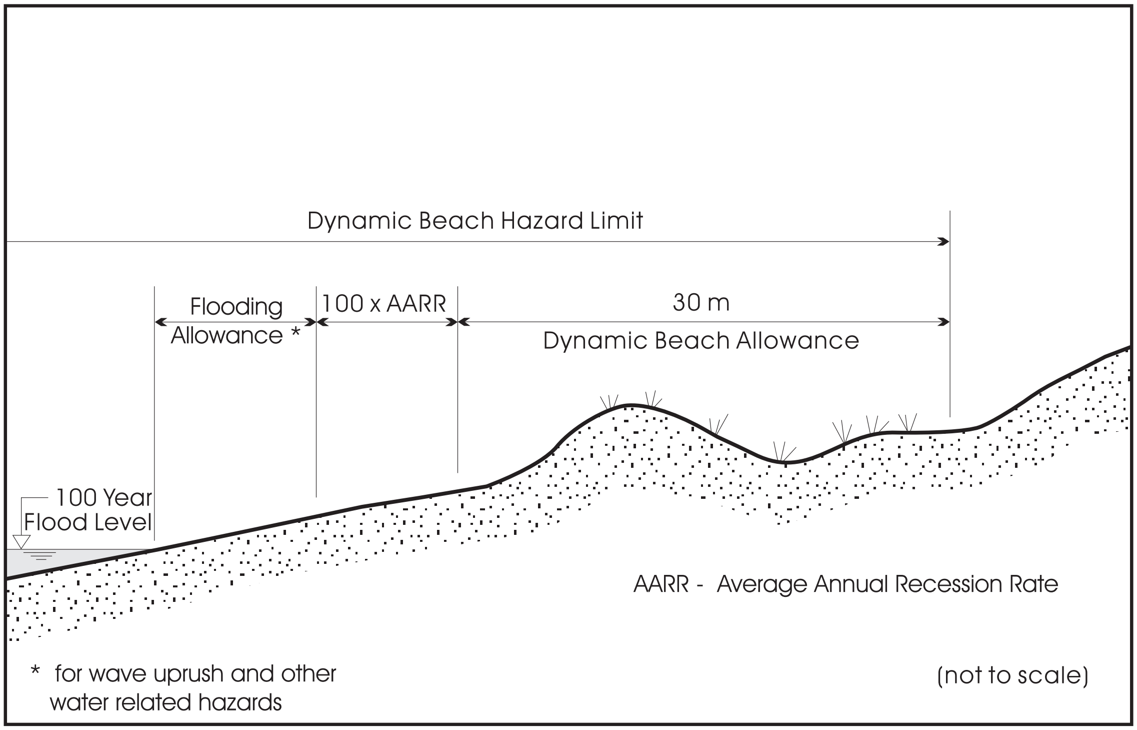


Figure 5.6: Dynamic Beach Hazard Limit for a Beach Backed by a Cliff or Bluff

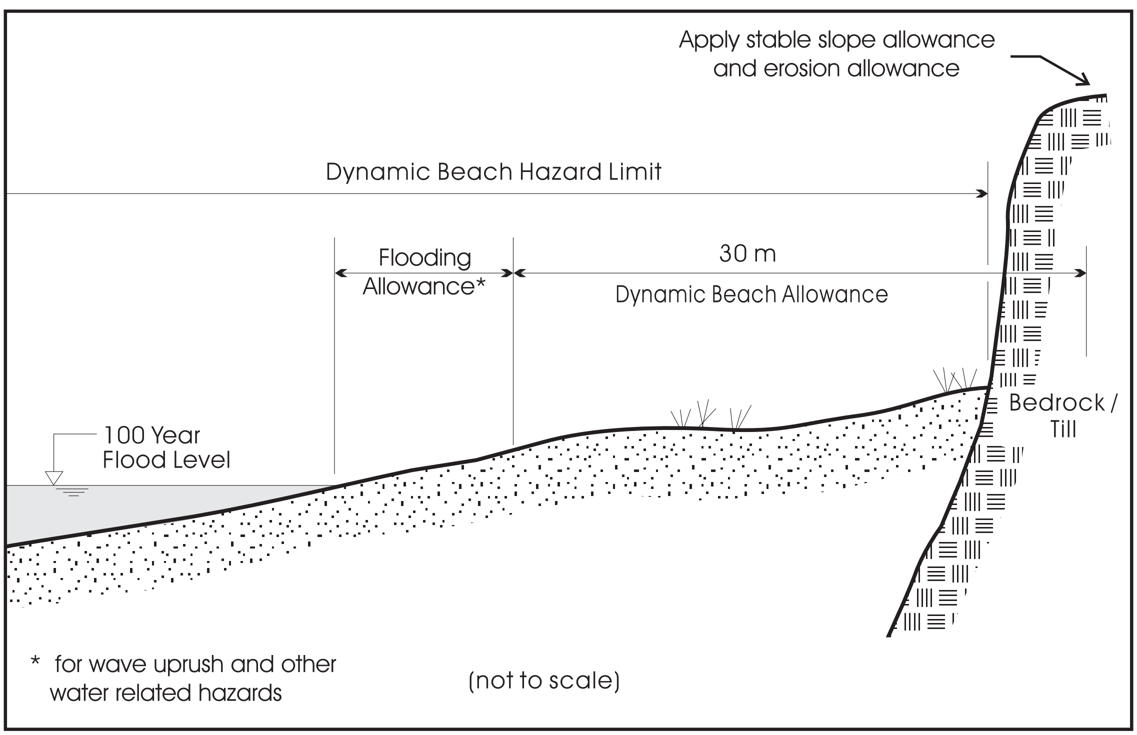
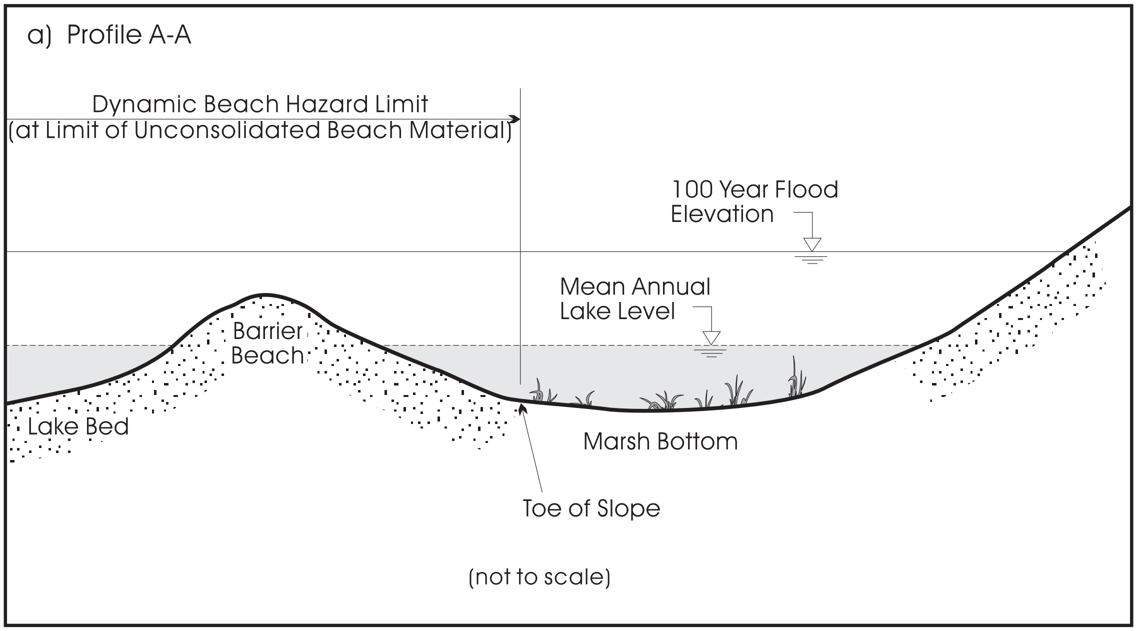


Figure 5.7: Dynamic Beach Hazard Limit for a Narrow Barrier System



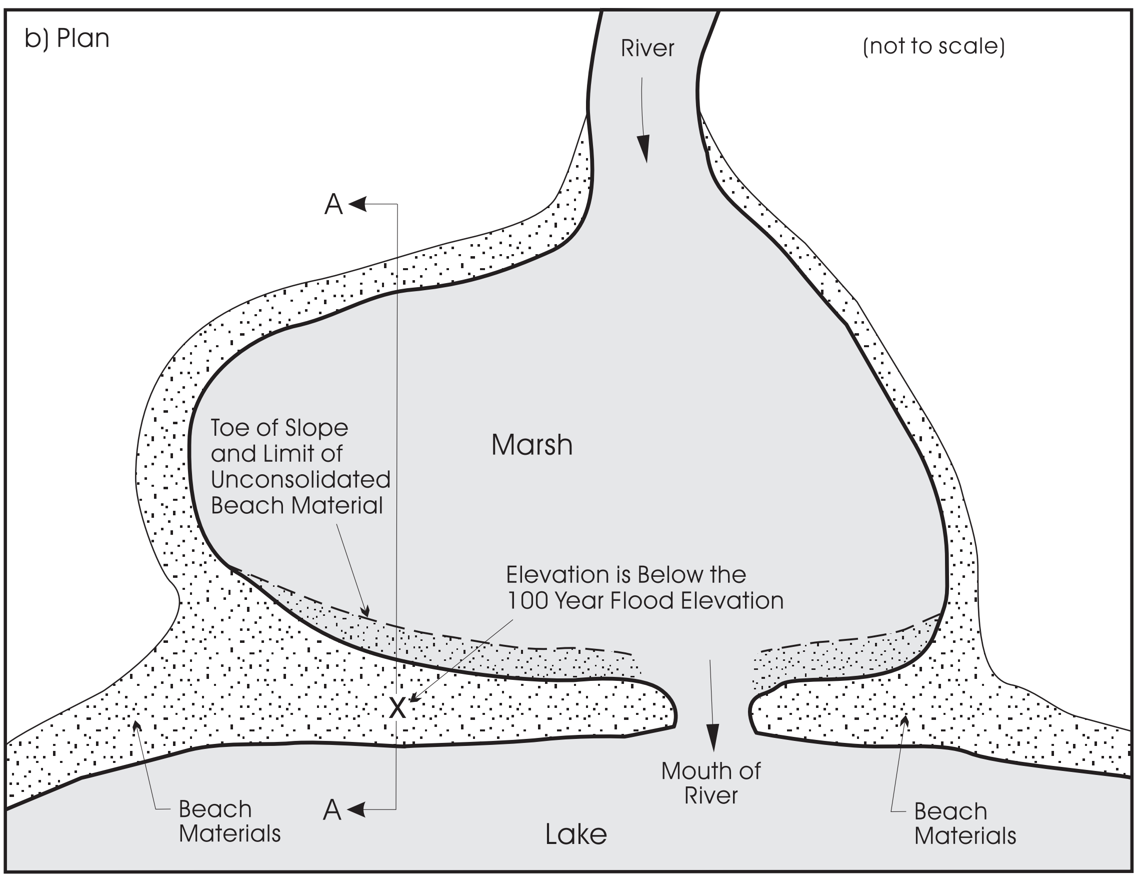
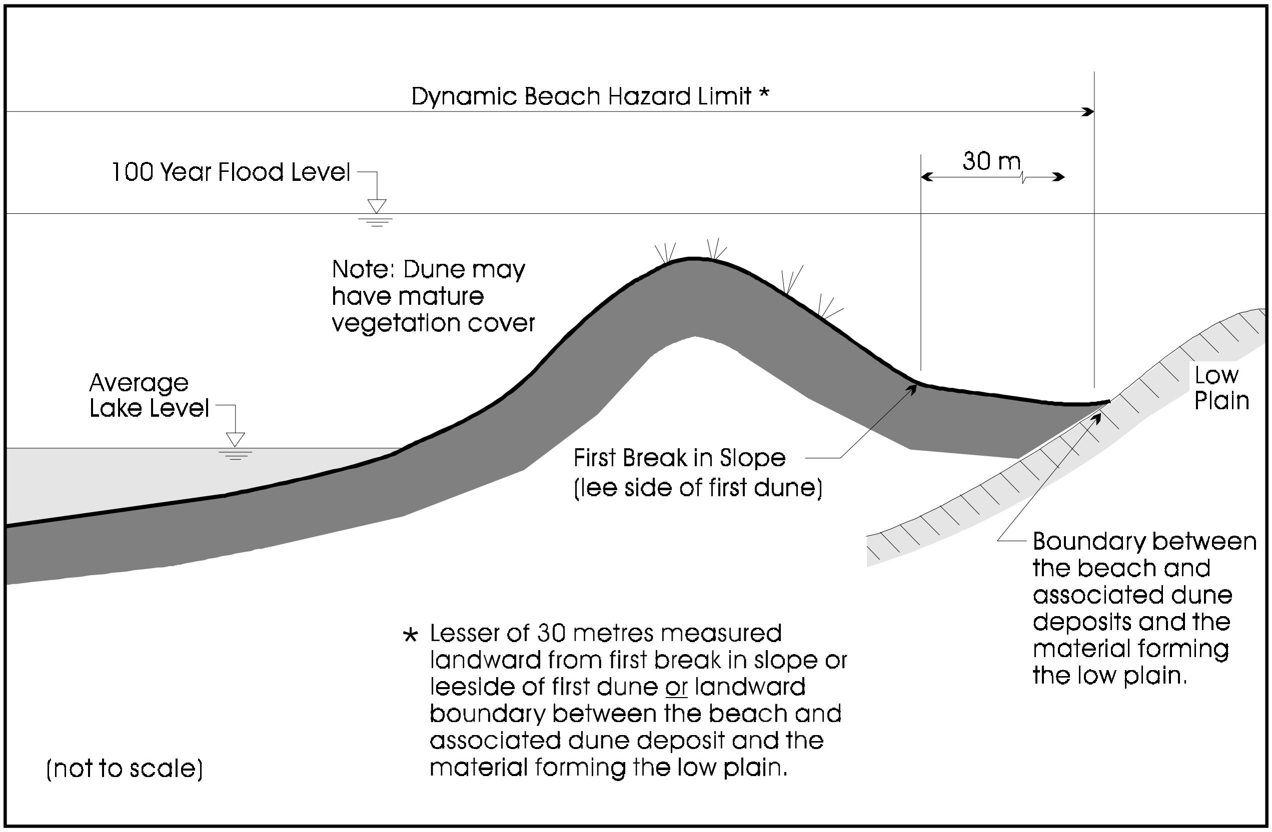


Figure 5.8 Dynamic Beach Hazard for a Beach Profile Lower than the 100 Year Flood Level



- **Defined Portions of the Dynamic Beach**

Defined portions of the dynamic beach means those portions of the dynamic beach which are highly unstable and/or critical to the natural protection and maintenance of the first main dune feature and/or beach profile, where any development or site alteration would create or aggravate flooding or erosion hazards, cause updrift and/or downdrift impacts and/or cause adverse environmental impacts.

In determining the critical or "*defined portions of the dynamic beach*", various factors should be considered including, but not limited to:

- physical characteristics,
- each individual component of the *flooding hazard* (i.e., water levels, wave uprush, other water related hazards),
- duration and frequency of flooding,
- pre-development/post-development flood conditions/impacts,
- date and reliability of the flood information,
- availability, accuracy, applicability of existing engineering studies,
- dynamic nature and range of the shoreline sediments, profile and planform,
- sediment/material (i.e., type, size, depth, width, composition, etc.),
- exposure to wave action,
- nearshore/offshore bathymetry,
- orientation of prevailing winds relative to the shoreline alignment, exposure, etc.,
- aeolian forces (magnitude, duration, etc.), and
- influence of vegetation in stabilizing the dynamic beach.

Caution should be exercised in designating chronic problem areas as non-critical. While development in such areas could adequately be floodproofed or the "hazards" potentially addresses through the use of protection works, past experience throughout the Province has repeatedly demonstrated that such decisions result in the creation of new *hazards*, the aggravation of existing *hazards* on updrift/downdrift properties, adverse environmental impacts, and ever increasing maintenance and replacement costs.

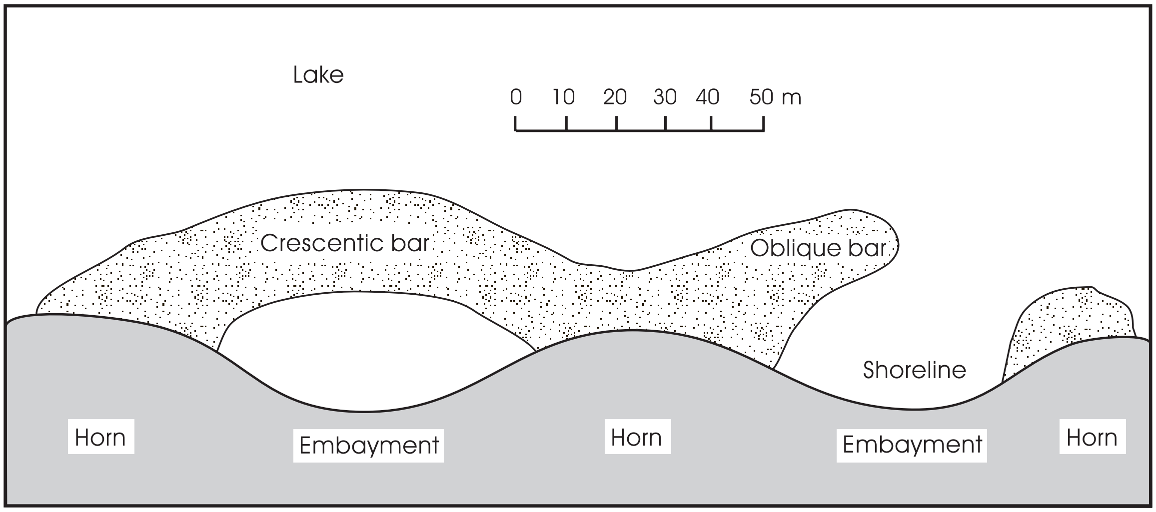
Past experience has also demonstrated that beach and dune formations left unaltered by humans, often naturally protect inland shoreline developments and lands from the destructive impacts of shoreline flooding and erosion. For example, where developments and site alterations have been directed to locations inland of the beach or dune features (i.e., landward of the first main foredune), these features often naturally prevent flood waters from reaching inland areas and absorb the erosive impacts and forces of wave action. Where left unaltered, as water levels recede these same beach and dune features naturally rebuild to once again provide protection to inland shoreline developments.

It should be noted that defining the area of provincial interest, or *hazardous lands* (as per Policy 3.1) is based on the furthest landward of the *flooding, erosion* and *dynamic beach hazard* limits. In some instances (e.g., narrow barrier system, low shoreline plain) the flooding hazard or erosion hazard limits may govern the landward limit of the *hazardous lands*. Where applicable (i.e., a river empties into a dynamic beach) the *flooding hazard* and *erosion hazard* limits for the *river and stream systems* must also be considered when defining the area of provincial interest.

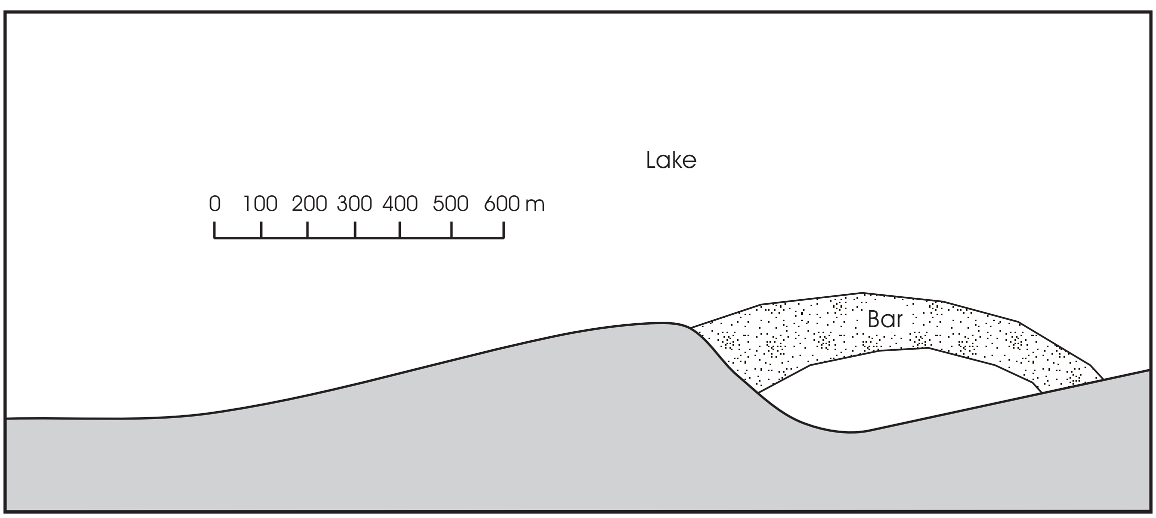
As outlined in Section 5.2, the vertical and horizontal limits of changes in beach profile are controlled by a number of factors and processes (Figure 5.3) reflecting onshore-offshore sediment transport (Figure 5.2). In addition to the profile changes, beach width may also vary spatially and temporally along the shoreline as a result of the presence of a number of features that in combination are termed rhythmic topography (see Figure 5.9). The presence of these influences can result in variations in beach width along the shore ranging from less than 1 metre for beach cusps to over 50 metres in the case of alongshore sandwaves.

As a result, care should be taken to ensure that this variability is properly identified and accounted for in any studies conducted to determine the landward limit of the *dynamic beach hazard* at a specific location on the shoreline of the *Great Lakes - St. Lawrence River System* , and that any such studies also include an estimate of the precision and accuracy of the defined landward limit for the *dynamic beach hazard* at that location.

Figure 5.9: Alongshore Variations in Beach Width



a) Alongshore variations in beach width resulting from giant beach cusps and associated rhythmic nearshore bars which develop, particularly during the summer, on beaches with medium to coarse sand.



b) Alongshore variations in beach width resulting from the migration of alongshore sandwaves on a shoreline with high rates of alongshore sediment transport. The sandwave is migrating from left to right.

Note the difference in scale between a) and b).

5.4 BEACH PROCESSES AND THE DYNAMIC BEACH SUB-CLASSIFICATION

To assist in determining where detailed studies and field investigations may be required or appropriate for determining the landward limit of the *dynamic beach hazard*, one must first develop an understanding of the controls on, and the behaviour of, dynamic beaches.

The dynamics of beaches in the *Great Lakes - St. Lawrence River System* are determined by the interaction of controlling processes such as waves, wind and ice, and a number of physical beach attributes such as sediment size and supply, shoreline orientation, and the alongshore and the onshore-offshore form of the shoreline.

While each dynamic beach can be regarded as unique, it is possible to produce a simple classification scheme based on a combination of the controlling factors which would then provide a mechanism for identifying the major controls on the dynamic nature of an individual beach. Application of this classification scheme would then serve as a guide to the selection of the appropriate procedure for mapping and field staking of the *dynamic beach hazard*.

For the purposes of clarification, the recommended dynamic beach sub-classification scheme is in fact an expansion of the "recommended shoreline classification scheme" initially outlined in Part 2: Recommended Shoreline Classification Scheme to Determine Shoreline Reaches of this Technical Guide. For dynamic beaches the surficial nearshore substrate material will be the same as the underlying controlling substrate.

5.4.1 Criteria for Classification of Dynamic Beaches

The criteria for developing the recommended dynamic beach sub-classification scheme have been selected to reflect their role in controlling the dynamic nature of beaches in the *Great Lakes - St. Lawrence River System* and as a representation of their relationship to the hazard and to environmental sensitivity.

Fundamental to the recommended shoreline classification scheme are the **three primary criteria**:

1) BEACH PROFILE TYPE
- **1) cliff/bluff**
- **2) low plain**
- **3) barrier**

2) BEACH PLANFORM AND EXPOSURE
- **1) headland-bay**
- **2) partial headland**
- **3) exposed**

3) BEACH MATERIALS
- **1) gravel, cobble or boulder;**
- **3) sand**

Application of these three criteria (i.e., beach profile type, beach planform and exposure, and beach materials) and their respective sub-classifications produces a total of **18 different beach types or classes**, each being identified by a class name and associated number (see Table 5.1).

Table 5.1
Dynamic Beach Sub-Classification

PROFILE TYPE	PLANFORM AND EXPOSURE	MATERIALS *	SUB-CLASS #
CLIFF/BLUFF	Headland-Bay	cobble sand	1-1-1 1-1-3
	Partial Headland	cobble sand	1-2-1 1-2-3
	Exposed	cobble sand	1-3-1 1-3-3
LOW PLAIN (mainland beach and dune)	Headland-Bay	cobble sand	2-1-1 2-1-3
	Partial Headland	cobble sand	2-2-1 2-2-3
	Exposed	cobble sand	2-3-1 2-3-3
BARRIER	Headland-Bay	cobble sand	3-1-1 3-1-3
	Partial Headland	cobble sand	3-2-1 3-1-3
	Exposed	cobble sand	3-3-1 3-3-3

* The term cobble is used here for simplicity although the class includes sediments ranging from gravel through cobble to boulder.

Within each of the 18 classes recognition is also given to two other factors which act to influence the dynamic nature of the beach:

- whether the beach profile is fully developed in sediment, or instead is underlain by bedrock or cohesive materials which act to limit the dynamic range of the beach profile; and

- whether the beach is the product of natural processes or has been artificially created, in part or as a whole, by structures and/or beach nourishment.

Under the recommended shoreline classification scheme, a combination of three numbers are used first, to describe the physical characteristics of the beach, and secondly, to provide an indication of the relative dynamic range associated with each particular beach type.

Within the three number combination (see Table 5.1), the first number relates to the profile type, the second to the planform and exposure of the beach, and the third number provides a description of the beach material. For example, a 1-1-1 beach class type identifies a beach backed by a "cliff" or "bluff", developed within a "headland-bay" area and having "coarse beach sediments" (e.g., cobble).

In addition to providing a direct description of the physical characteristics of a particular beach, the numbering scheme also provides an indication of the relative dynamic range of the particular beach. For instance, a category 1 is associated with beach environments having a small dynamic range while a category 3 has a potentially large dynamic range. As a result, a 1-1-1 beach class type is likely to be much more stable than 3-3-3 (i.e., an "exposed" "sand" "barrier").

As such, the recommended shoreline classification scheme is based primarily on the physical attributes of the shoreline and associated beach deposits, which in turn exercise some control on the dynamic behaviour of the beach. A more detailed description of the physical and dynamic natures of each beach class type is provided in Appendix A5.1: Description of Dynamic Beach Types.

When using the recommended shoreline classification scheme, one should recognize that the dynamic range of each particular beach type is also determined by a number of process variables, including wave climate, wind setup potential, alongshore sediment transport patterns and beach sediment budget, as well as by the impact of human activities such as harbour construction, fill and shoreline protection measures (see discussions in Part 1: *Great Lakes - St. Lawrence River System* : Physical Features and Processes, and Appendix A1.2: Lake/Land Interaction). Any determination of the appropriate landward limit of the *dynamic beach hazard* at any location must therefore involve an evaluation of these factors and may require field inspection and additional geomorphological and engineering studies in some locations.

Given the complexity of the natural environment, one must acknowledge that the recommended and simplified shoreline classification scheme outlined for the purposes of this Technical Guide cannot be assumed to describe all the shoreline situations that may occur with the *Great Lakes - St. Lawrence River System* . Testing of the recommended shoreline classification scheme, would suggest that the scheme should encompass 90-95% of them.

Two possible exceptions where the recommended shoreline classification scheme may be potentially unable to appropriately identify a single beach class type are:

- transitional sections of shoreline where one shoreline type changes to another (e.g., the transition from low, eroding shoreline bluff to sandy mainland beach); and

- sections of shoreline which are dominated by a unique factor or process that is not reflected in the shoreline classification scheme (e.g., the area immediately adjacent to a large river mouth).

5.4.2 Beach Profile Type

Of the three fundamental criteria used to describe beach class type under the recommended shoreline classification scheme, the first is the beach profile type normal to the shoreline.

For the purposes of this Technical Guide and for the application of the recommended shoreline classification scheme, a generalized profile beginning several hundred metres offshore and extending 200 to 300 metres inland is all that is required to determine the type of beach profile within a particular shoreline location.

In terms of beach profiles, three separate profile types can usually be recognized:

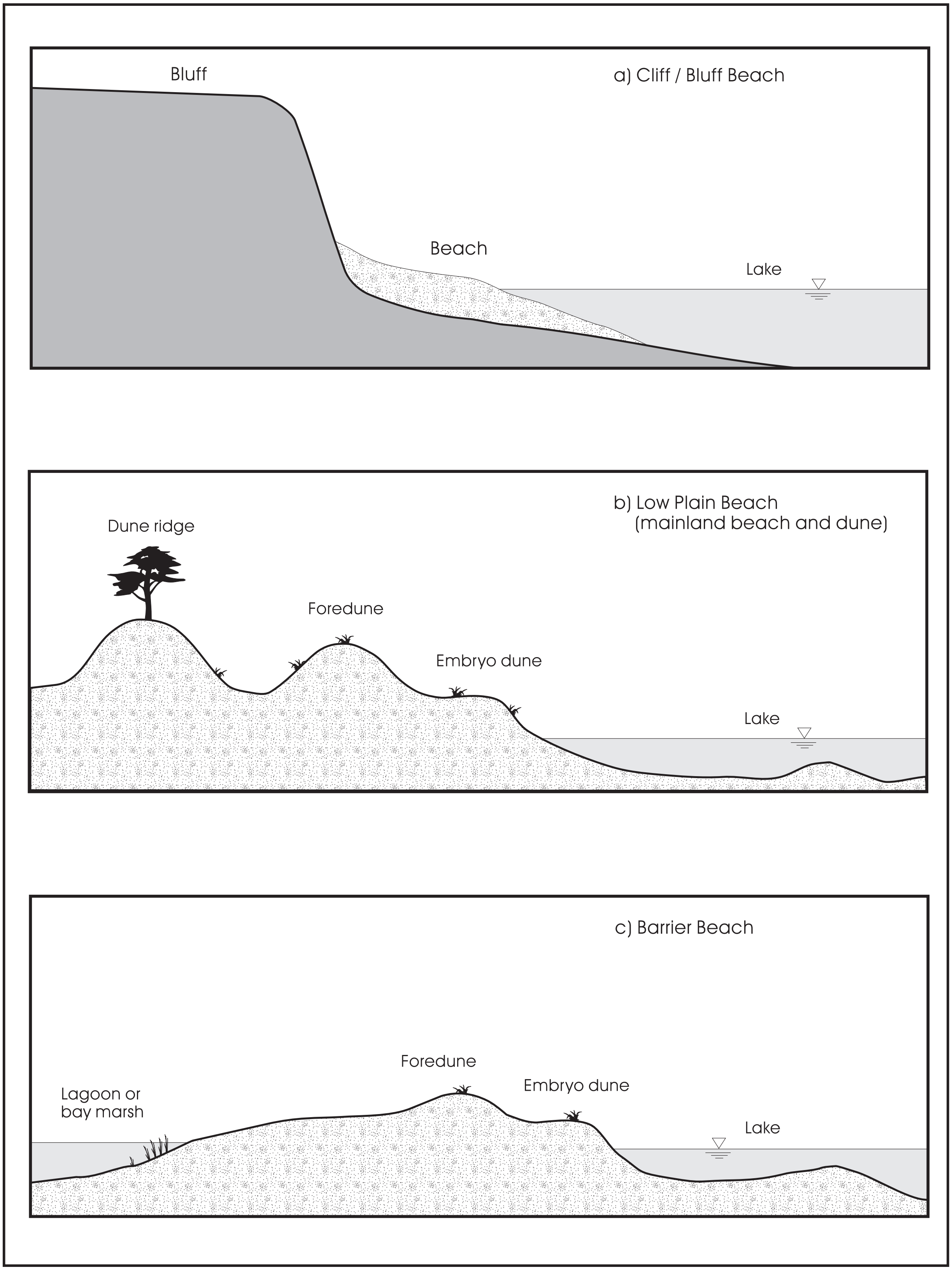
- **cliff/bluff beaches**

- **low plain beaches** (mainland beach and dune)

- **barrier beaches** (i.e., separated from the mainland by a bay, lagoon or marsh)

For the purposes of clarification, a graphic illustration of each of the three general beach profile types are provided in Figure 5.10.

Figure 5.10: Beach Classification Based on Profile Form



a) Cliff/Bluff Beaches

For the purposes of this Technical Guide and for the application of the recommended shoreline classification scheme, the term cliff or bluff is used to describe a shoreline where the shore profile landward of the beach material rises steeply, where the slope angle is commonly greater than 18^{o} and where the elevation above the beach is greater than 2 metres. To aid in interpretation, a distinction should be made between bedrock cliffs, which are usually resistant to erosion and associated with very low recession rates, and bluffs which are usually developed in cohesive sediments (e.g., with varying amounts of silt and clay present) or sand, having relatively little resistance to wave erosion and commonly associated with high recession rates.

In cliff and bluff beaches the size, dimensions and maintenance of the beach are influenced by a number of physical processes. Where the potential exists for wave action to reach the base of the cliff or bluff, the base of the cliff or bluff feature will form the landward extent of the mapped *dynamic beach hazard*.

In addition to the effects of wave and ice action, a beach in front of a cliff or bluff may also be subject to the downslope movement of material from the cliff or bluff features. This is especially true of bluffs developed in cohesive or sandy material that are retreating rapidly, where large-scale failures can result in slumped material extending right across the beach and into the water. Similarly, on bedrock cliffs failure can also result in large blocks falling or sliding onto the beach. In these locations, at any given time, the landward limit of the beach may be obscured by the slumped materials.

On most cliff shorelines the beaches tend not to be fully developed and usually consist of a sediment veneer over the underlying bedrock or cohesive material (Figure 5.10a). In these locations, the beach profile can be described as partial or incomplete. In addition, vertical changes in the beach profile due to storm waves are usually restricted by the presence of the underlying material. Although storm wave action may remove most or all of the sediment from the beach, the sediment may be returned slowly to re-form the beach profile over a period of days or weeks. Similarly, along bluff shorelines during periods of high lake levels where the stillwater line may be located right at the bluff toe, beach sediment may not be directly exposed making the existence and delineation of the beach difficult to determine. This situation is common during periods of high lake levels along portions of the cohesive shoreline on Lakes Ontario, Erie and southern Lake Huron.

Where bluff shorelines have been developed in sedimentary material, the beaches are usually formed either in sand with some gravel, or are dominated by gravel with some sand present, particularly in the nearshore zone. True cobble and boulder beaches are rarely found on cohesive shorelines.

Where the cliff shorelines are formed in bedrock material, the beach material is usually derived from erosion of the bedrock with the size of the sediment making the beach dependent, in part, on the characteristics of the bedrock and on the amount of transport and abrasion that has taken place. As such, beaches associated with bedrock cliffs may be sandy, or they may consist of cobbles and boulders.

b) Low Plain Beaches

In low plain beach shorelines the shore profile slopes gently upward from the beach and there is no abrupt change in slope angle as is normally seen with cliff or bluff shorelines. This description does not include slope changes associated with the presence of sand dunes which are superimposed on the general slope of the land surface. In addition, there is no topographic restriction on the landward limit of the dynamic range of profile adjustment of the beach (Figure 5.10b).

There are situations, however, where a cliff or bluff may appear to be in close proximity to the lake yet, in actual fact, is well landward of the maximum limit of wave action. This often occurs where the old cliff or bluff shorelines resulted from an extended period of higher lake levels. In these situations, the defined landward limit of the *dynamic beach hazard* may not extend to the base of the cliff/bluff feature as the cliff/bluff feature may be well landward of the water's edge and the dynamic range of the beach profile adjustments.

Unless field examination indicates the need to extend the *dynamic beach hazard* to the base of the cliff/bluff, the shoreline should be treated as a low plain beach. The characteristic form and dynamics of low plain beaches are then determined primarily by the nature of the sediments making up the beach and by the other factors controlling exposure to wave action. While there are by definition no topographic constraints to profile adjustment horizontally, bedrock or cohesive sediments may exist close to the surface and this may act to restrict the vertical range of profile adjustment.

c) Barrier Beaches

Barrier beaches are essentially depositional features resulting from alongshore transport of sediment and are formed when the beach and any associated dune system is separated from the mainland by a bay, lagoon or marsh area (Figure 5.10c).

The profile of the barrier generally consists of the barrier platform which is deposited on the underlying lakebed by sediments being transported along the shoreline, and of the sub-aerial beach, dune and back-barrier system built on the barrier platform by wave and wind action (Figure 5.11).

Barrier beaches can be classified into several different types based on their position on the shoreline, on the number of "free" ends, and on the dominant sediments forming the barrier. These include:

- sandy barriers, where the shore profile can be built up above the limit of wave activity through the formation of sand dunes by aeolian sediment transport, and

- gravel or cobble barriers, where the height of the barrier is limited to the maximum limit of sediment transport by waves

For the purposes of additional clarification, barrier beaches can be further described in terms of their physical configuration (Figure 5.12) as:

- barrier islands, with two free ends

- barrier spits, which are attached to the updrift mainland and where the distal or downdrift end of the barrier is free; and

- bay barriers, where the barrier is attached to the mainland at both ends, completely enclosing the bay or marsh behind it. Depending on the location of the barrier within the bay it is possible to recognise baymouth, mid-bay and bayhead barriers.

- cuspate forelands, where sediment transport occurs from opposite directions (e.g., Pt. Pelee).

- tombolos, formed where sediment builds up to join an offshore island to the mainland or to another island.

Barrier islands do not appear to occur along the shorelines of the *Great Lakes - St. Lawrence River System*. Long Point on Lake Erie and the Toronto Islands are examples of barrier spits, while the Burlington Bar and the bar across Frenchman's Bay on Lake Ontario are typical examples of baymouth barriers. In locations where baymouth barriers have developed, some form of channel breaching usually occurs across the baymouth barrier to allow for the natural exchange of water between the bay and the main lake body. In general, the channel breaching the barrier is often unstable in location and may open only during and after storms or during a period of spring flooding or high lake levels.

i) Sandy Barriers

For shorelines consisting of sandy barriers there may be large dunes formed on the barriers with elevations well above wave uprush limits during smaller storm events. Recognizing, however, that the sand forming the dunes can be easily eroded by storm wave action, the dune may be breached during major storm events leading to the occurrence of overwash or inlet formation.

Figure 5.11 Cross-section of Barrier System Showing Major Sedimentary and Morphological Units

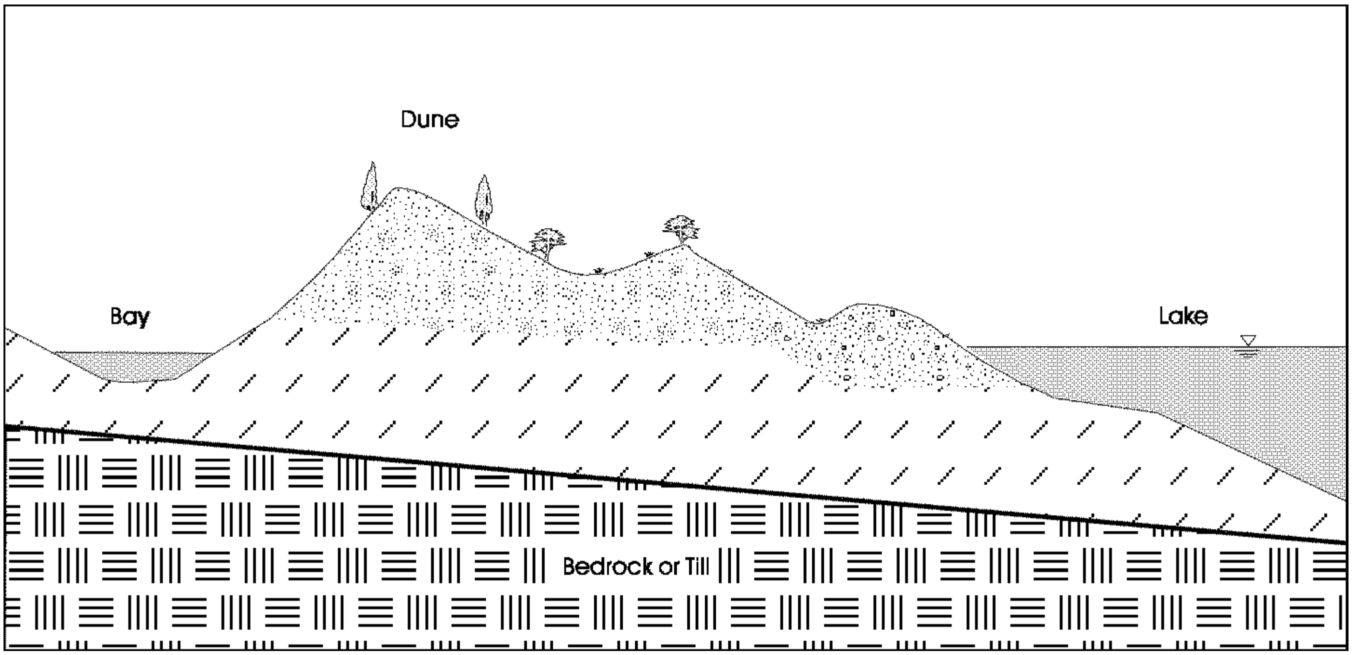
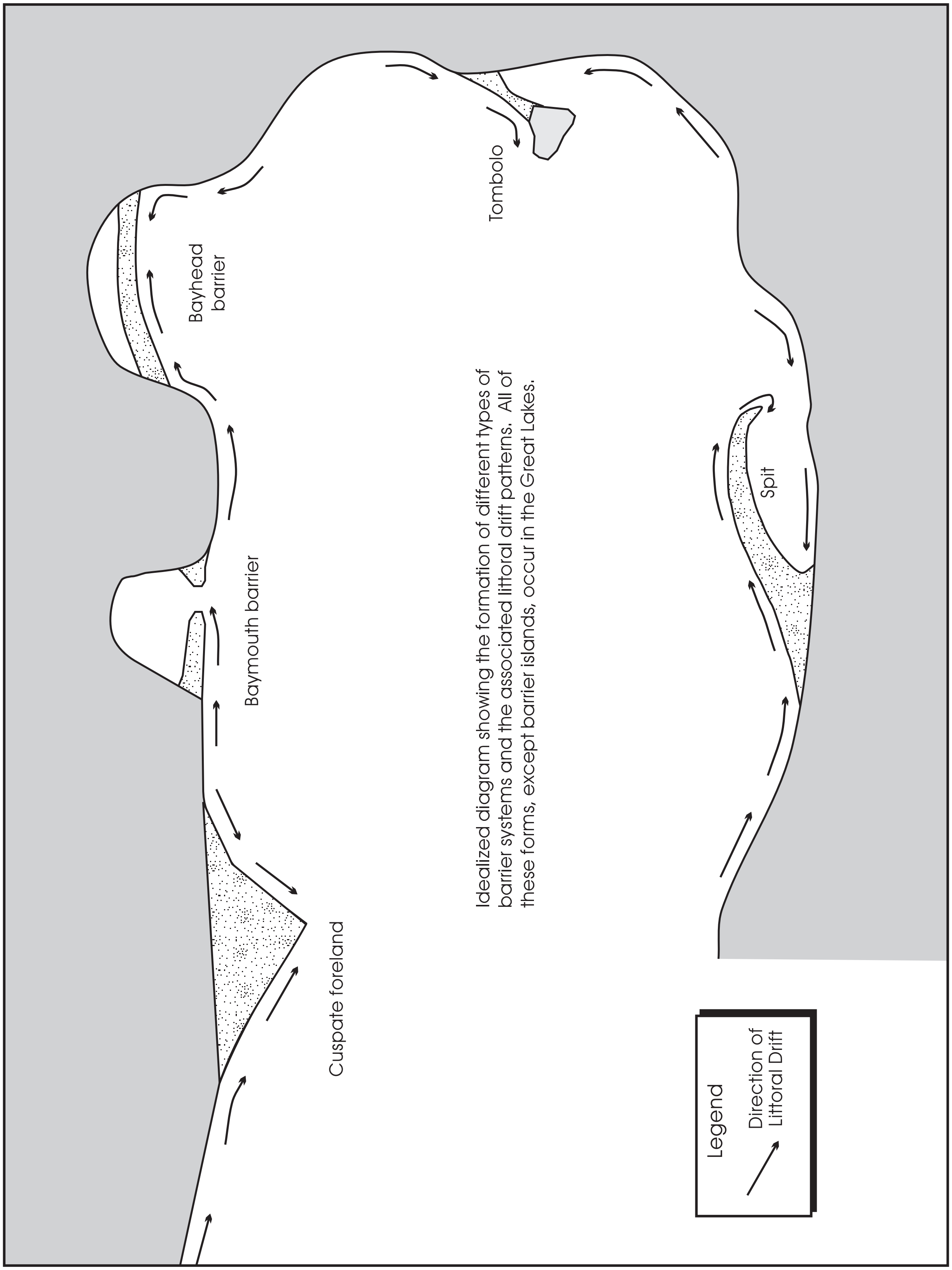


Figure 5.12: Formation of Different Types of Barrier Systems and the Associated Littoral Drift Patterns



Idealized diagram showing the formation of different types of barrier systems and the associated littoral drift patterns. All of these forms, except barrier islands, occur in the Great Lakes.

Most sandy barrier overwash and inlet breaching occurs during periods of high lake levels. The process of overwash occurs when waves uprushing onto the beach, during a storm, erode the dune to such an extent that the dune itself is breached and/or overtopped by the waves. The waves then flow across the back barrier and into the marsh or bay behind (Figure 5.13). Sediments eroded from the top of the beach and from the dune are then transported and deposited onto the back barrier area and may build into the marsh or lake behind.

The deposits created by the overwash event tend to form a washover fan. The washover fan may be re-activated several times during a high water period, with the fan being extended further into the bay or marsh by the action of the waves. The surface of the overwash fan is usually a metre or more above the stillwater level of lake. During the subsequent low water period, washover healing takes place. This healing is usually evidenced by the growth of an embryo dune and later the development of a new foredune across the washover throat.

When the whole barrier is eroded to provide a connection between the open lake and the bay behind the barrier this process is referred to as inlet breaching.

Inlets are typically formed across narrow sections of beach barriers where, after the barrier has been breached by storms waves, the returning lakeward flow from the bay, behind the barrier, to the open lake, again crosses and subsequently erodes the barrier feature. Inlets on Great Lakes barriers heal rapidly through infilling by sediments transported alongshore and eventually the barrier is restored to its previous form.

Overwash and inlet formation are a normal process on barriers, particularly when the sediment budget is neutral or negative. However, while the dunes and vegetation communities exist in dynamic equilibrium with the processes controlling the barrier evolution, properties located on the barrier are likely to be heavily damaged or destroyed by such an event. In addition, some portions of the beach barriers are more prone to overwash than others and some barriers experience overwash more frequently than others.

Most barrier beaches are considered to be highly susceptible to overwash and it is recommended that in most cases the whole of a barrier system should be contained within the *dynamic beach hazard*. As such, new development should not occur on any barrier or portion of a barrier unless it can be demonstrated that factors such as isostatic uplift or long-term progradation have removed the possibility of overwash occurring.

ii) Cobble Barriers

Cobble barrier beaches generally have little or no vegetation on them and are subject to overwash during intense storms, particularly during periods of high lake level. Where the elevation of cobble barriers is well above the limits of present wave action, it is likely that the lake level has fallen since the initial barrier formation due to changes in the level of the lake outlet or to isostatic uplift of the shoreline. Where this has occurred and the top of the barrier is relatively high and wide, overwash of the barrier may not be possible and, as such, the overall barrier formation will be relatively stable.

5.4.3 Beach Planform and Sediment Transport Patterns

Beach dynamics are also influenced by the overall three-dimensional planform and orientation of the shoreline on which they are developed, and consequently on the exposure of the beach and the significance of alongshore sediment transport in the sediment budget.

Although there are a wide range of possible beach planforms, for the purposes of this Technical Guide beach planforms will be described in terms of three main types (Figure 5.14):

- **headland-bay beaches**;
- **partial headland** and **log spiral beaches**; and
- **exposed beaches**.

Figure 5.13: Barrier Overwash Plan and Profile

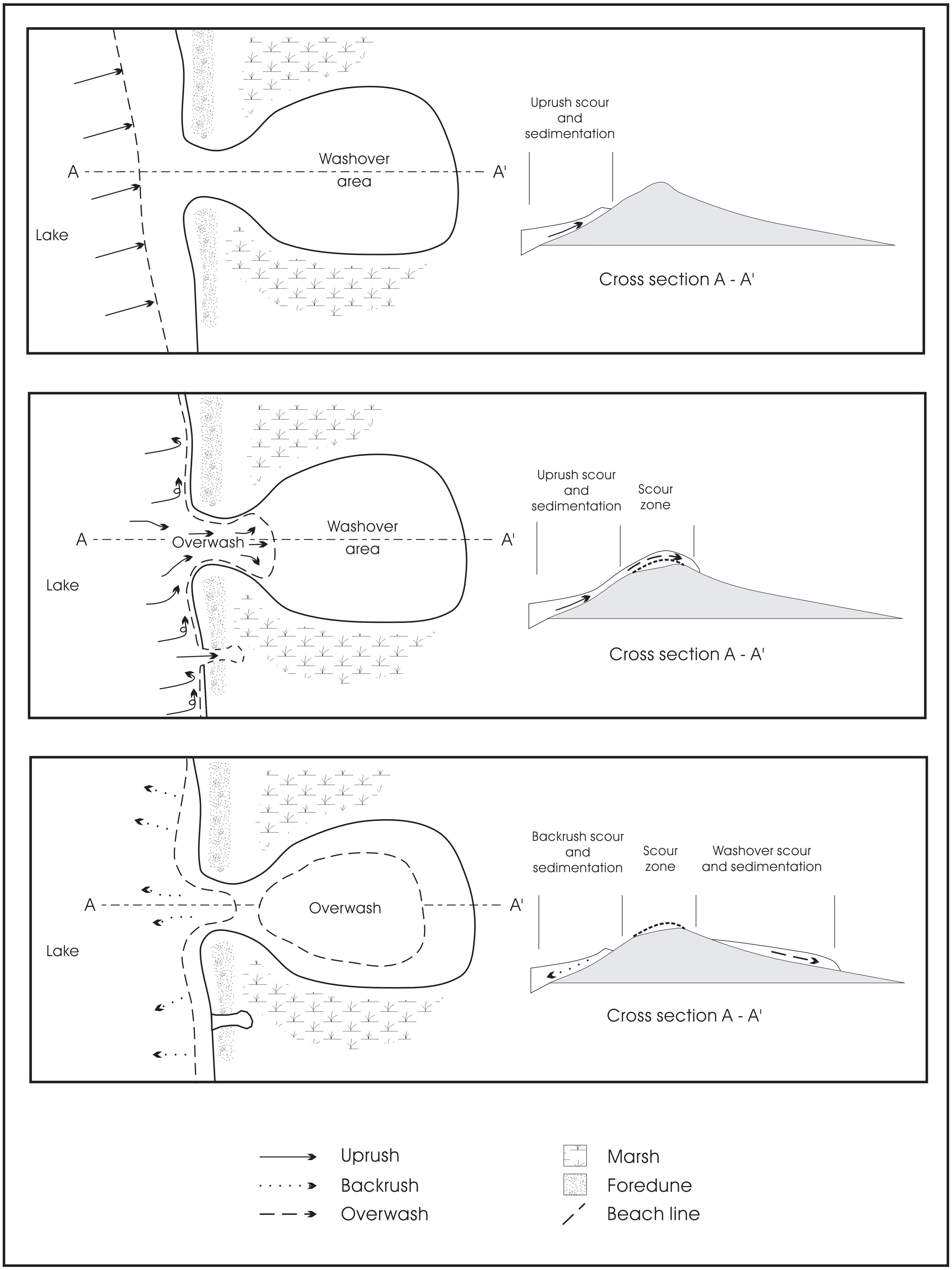
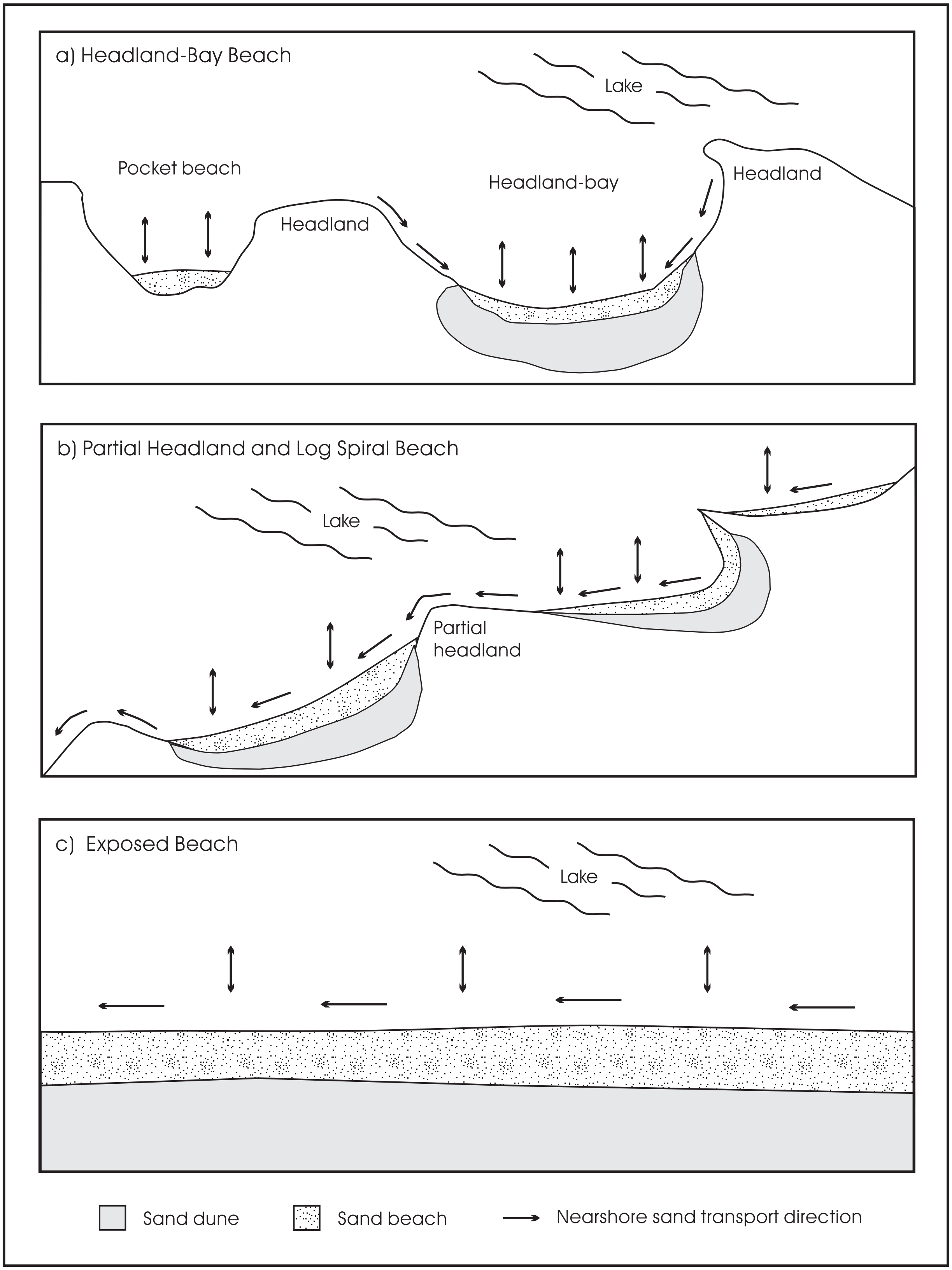


Figure 5.14: Beach Classification Based on Planform



The division of beach planforms into three broad types serves to emphasize the effect of increasing fetch width (i.e., range of wave directions affecting the beach) and the increasing importance of alongshore sediment transport in the overall beach sediment budget. In general, the more a beach is exposed to a range of wave directions and the greater the significance of alongshore sediment transport, the greater the dynamic range of beach volume and the greater the sensitivity to interference with shoreline processes along the updrift shoreline.

a) Headland-Bay Beaches

In general, headland-bay beaches can be sub-divided into two main types:

- pocket beaches, which are limited in size and in the extent of surficial sediment; and
- full headland-bay beaches where there is a large sediment body.

Ideally, a headland-bay forms a single shoreline beach compartment characterised by two symmetric littoral cells (Figure 5.14a). Within this compartment, the headlands restrict the range of wave directions that can affect the bay and this, together with refraction of waves, means that net sediment transport is always from the headlands and sides of the bay towards the head of the bay. As a result, the updrift end of each littoral cell is defined by the headland, with the sides of the bay generally being erosional in nature with the eroded material supplying the beach at the head of the bay.

The beach at the head of the bay forms the sink for two converging littoral cells. Recognizing that offshore sediment losses are restricted by the protection offered by the headlands, the bayhead beach tends to be stable or progradational. Excellent examples of headland-bay beaches in the *Great Lakes -St. Lawrence River System* include Barrow Bay and Hope Bay on the east side of the Bruce Peninsula, with Wasaga Beach at the head of Nottawasaga Bay being one of the largest on the Great Lakes.

b) Partial Headland and Log Spiral Beaches

Partial headland and log-spiral beaches occur where headlands are not large enough to form a complete barrier to alongshore sediment transport and as a result, provide only partial shelter to a portion of the shoreline (Figure 5.14b).

Within partial headland and log spiral beaches, the partial headland planform provides some sheltering effect from waves from the updrift direction, leading to a reduction in the rate of alongshore sediment transport and consequently to the development of a beach.

The resultant planform of this shore type typically assumes a characteristic shape having a very tight curvature at the headland and a decreased curvature away from the headland. This type of planform can be closely approximated by the mathematical equation that describes a log spiral, hence the name **log spiral beach**. The beach planform itself results from the complex pattern of wave refraction around the partial headland and from the tendency for the beach at any point to orient itself perpendicular to the resultant refracted waves. Typical examples of log spiral beaches can be found along the east shore of Nottawasaga Bay from Balm Beach south to Wasaga Beach, and at the eastern end of Lake Erie from Port Dover to Fort Erie.

c) Exposed Beaches

Exposed beaches occur where beaches develop along a straight or gently curving shoreline where there are no major headlands to shelter a portion of the shoreline from waves from one direction or to act as a barrier to alongshore sediment transport (Figure 5.14c).

Beaches along this type of shoreline are typically exposed to waves from a wide range of directions (i.e., up to 180^{o}) and in areas of potentially high gross alongshore sediment transport rates. As a result of their exposure to waves from a wide range of directions, exposed beaches tend to have a greater dynamic range than the other two categories (i.e., headland-bay beaches and partial headland and log spiral beaches). In addition, with alongshore sediment transport generally being a significant component of the beach sediment budget, exposed beaches are likely to be sensitive to changes in the sediment supply from updrift. Exposed beaches occur on all of the shorelines of the Great Lakes.

5.4.4 Beach Sediment Size

The size of the sediment forming the beach exercises an important control on the dynamic behaviour of beaches and to some extent on long-term stability. Sediment size is defined as the diameter of particles that are roughly spherical in shape or the length of the intermediate axis where the particles are blocky or rectangular in shape.

a) Definition and Determination of Sediment Size

The mean size of sand and fine gravel is usually determined by "sieving" where a sample on the order of 50-150 grams is passed through a stack of wire mesh sieves having a decreasing size of the mesh openings. The weight retained on each sieve is recorded (see Figure 5.15a). Where sediments are greater than 1 centimetre, mean sediment size is usually determined by measuring the intermediate axis of a sample of 50-100 particles directly with a set of callipers or with a tape measure (see Figure 5.15b).

For the purposes of clarification, a descriptive classification of sediments and the corresponding size ranges for each sediment class, Table 5.2 should be consulted.

Of the 18 dynamic beach classifications, all can be divided into two broad groups on the basis of sediment size:

- **coarse sediment beaches** consisting of gravel, cobble and boulders, having a mean sediment size greater than 2 millimetres; and

- **sand beaches**, having a mean sediment size ranging from 0.062 to 2.0 millimetres.

This differentiation or classification of beach type according to sediment size applies primarily to the material in the zone from the bottom of the step across the foreshore and backshore to the limit of normal wave activity. Detailed information derived from analysis of samples taken from the beach may be necessary for some studies related to beach dynamics. For the purpose of classifying the beach, a simple visual estimation, based on photographs, shoreline videos or field inspection, is generally sufficient to place it in the appropriate classification of sediment size.

b) Effects of Sediment Size on Beach Profile Shape and Stability

In practice, sediment sizes finer than about 0.05 millimetres are removed from beaches by wave action and deposited either in the deep lake basin or in sheltered bays and lagoons. As such, an accumulation of silt and clay near the edge of the water is an indication that wave activity is below the threshold required for a "dynamic beach" and the shoreline under investigation should not be classified as a "dynamic beach".

Similarly, at the other end of the scale, boulders greater than 1 metre are not usually transported by wave action. Accumulations of boulders at the foot of bedrock cliffs, such as occurs along sections of the east side of the Bruce Peninsula, are essentially stable and as such, these sections of shoreline should also not be classified as a "dynamic beach".

The size of the sediments making up the beach effects the beach dynamics in several ways. For example, the slope of the beach foreshore and backshore generally increases in steepness as grain sizes become coarser (i.e., larger). As a result, the steepest beaches are usually associated with cobble-sized sediment. In addition, cobble or larger sized sediment beaches frequently have a steeper slope of the nearshore profile close to the beach which

Figure 5.15: Determining Sediment Size of Sand and Cobble

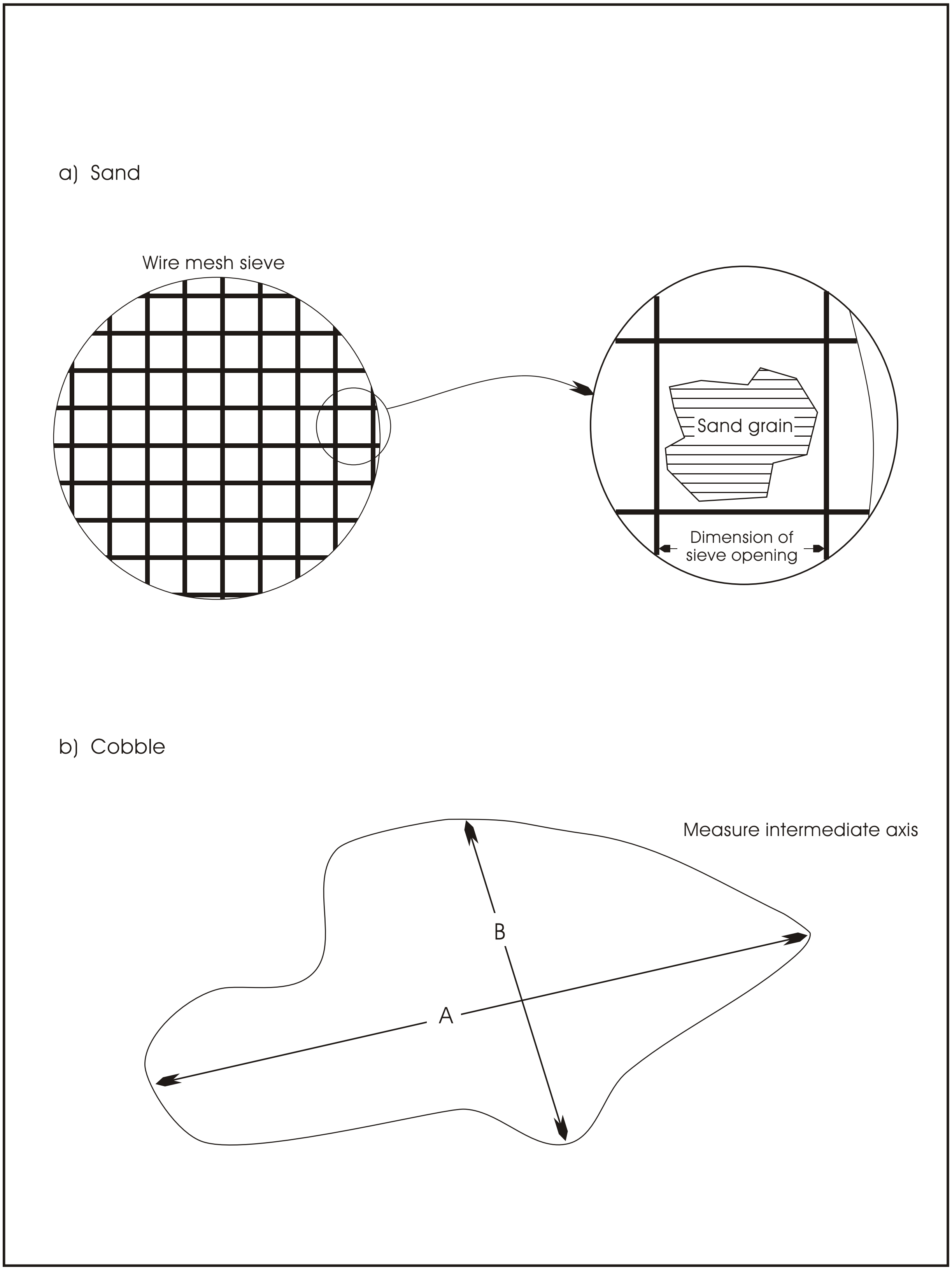


Table 5.2: Sediment Size Classification

Unified Soils Classification	ASTM esh	mm Size	Phi Value	Wentworth Classification
Cobble				Boulder
		256.0	-8.0	
				Cobble
		76.0	-6.25	
Coarse Gravel				
		64.0	-6.0	
				Pebble
		19.0	-4.25	
Fine Gravel				
	4	4.76	-2.25	
Sand – Coarse				
	5	4.0	-2.0	
				Gravel
	10	2.0	-1.0	
Sand – Medium				Sand – Very Coarse
	18	1.0	0.0	
				Sand – Coarse
	25	0.5	1.0	
				Sand – Medium
	40	0.42	1.25	
Sand – Fine				
	60	0.25	2.0	
				Sand – Fine
	120	0.125	3.0	
				Sand – Very Fine
	200	0.074	3.75	
Silt				
	230	0.062	4.0	
				Silt
		0.0039	8.0	
Clay				Clay
		0.0024	12.0	
				Colloid

in turn permits large waves to break at, or close to, the shoreline. Conversely, where sand sized sediments are abundant, the nearshore profile is usually gentle, forcing large waves to break some distance offshore, thereby reducing wave energy at the shoreline.

Beaches composed of medium to coarse sand sediments exhibit the greatest range of profile changes in response to changes in wave and water level conditions. At opposite ends of the scale, cobble beaches and, to a lesser extent gravel beaches, are more resistant to transport by waves and the resultant range of profile change is less than those experienced by sand beaches.

A final distinction in beach type can be derived from an assessment of the influence of wind or aeolian transport. Sediment transport, particularly of sand sized particles, by wind generally results in the development of sand dunes beyond the top of the beach. In beaches dominated by gravel or cobble sized sediment, sand dunes are typically poorly developed or absent.

c) Coarse Sediment Beaches

Gravel, cobble and boulder beaches are derived from three main sources:

- erosion of bedrock material by wave action
- rockfalls produced by the undercutting of the cliff face,
- reworking of glacial sediments.

Recognizing that few beaches are developed primarily of gravel, the following description of coarse sediment beaches is geared primarily to sediments that fall into the cobble and boulder size range (Table 5.2). Coarse sediment beaches are found primarily at the eastern end of Lake Ontario, on the east shore of the Bruce Peninsula, in Georgian Bay north of Midland and including Manitoulin Island, and on Lake Superior.

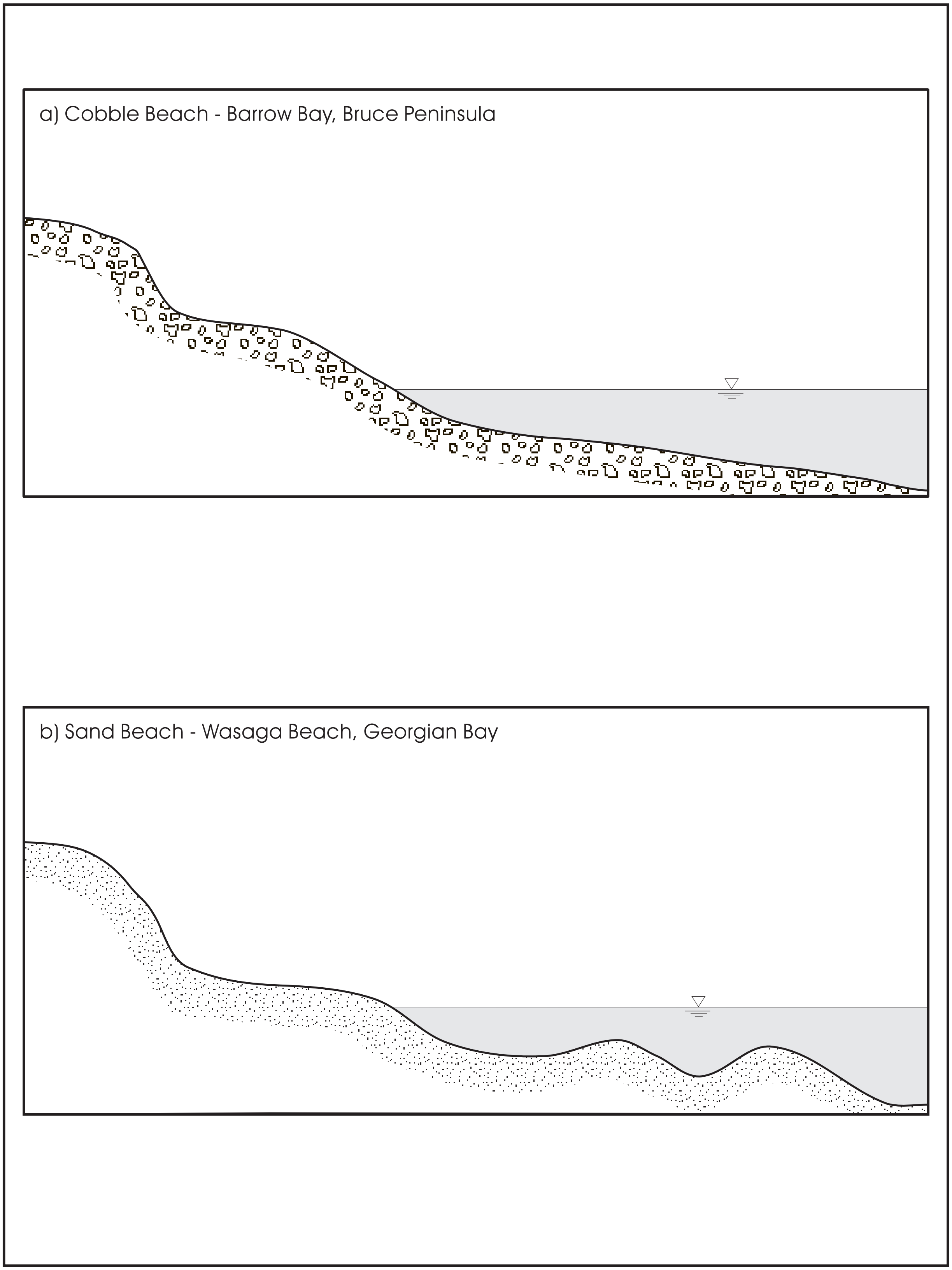
Coarse sediment beaches are characterised by very steep sub-aerial profiles, commonly with one or two storm ridges (Figure 5.16a). The steep slope reflects the rapid drainage of water into the gravel or cobbles during wave uprush (i.e., swash) which results in a very limited return of water during the backwash. As a result, particles moved landward by the swash tend to get stranded near the upper part of the slope as the backwash is not strong enough to initiate downslope movement. Consequently, the slope builds up until it is steep enough for gravitational effects to compensate for the low depth and velocity of the backwash. The resultant equilibrium slope that develops is much steeper than that for most sand beaches and tends to be in the order of 25^{o}-35^{o}, with some boulder beaches having slopes in excess of 40^{o}.

The nearshore profile of coarse sediment beaches is also steep and, except in a few cases where sand deposits are present offshore, there are no bars in the nearshore zone. As a result of the steep nearshore profile and deep water close to the shoreline, wave breaking takes place at or very close to the shoreline. As such, wave energy at the shoreline is often much greater than on an equivalent sandy beach where storm waves break some distance offshore.

The steep nearshore also means that ice action during the winter, and particularly during the spring breakup, can lead to rafting of sediments alongshore and offshore and to the development of ice-push ridges. In some cases, strong onshore winds during ice break-up can lead to ice being piled up against the shoreline and pushed some distance inland.

The crest of the highest ridge on coarse sediment beaches is often flat and marked by the accumulation of large, flat stones. Rounded stones tend to roll down the swash slope more easily and as such, accumulate near the bottom of the slope. Recognizing that the dynamic range of beach sediments is governed by sediment size and slope adjustments in response to changing wave conditions, the dynamic range on cobble and boulder beaches, typified by limited slope adjustments to wave action, is generally less than on sand beaches. As a consequence, the major considerations influencing the dynamic range on cobble and boulder beaches are the effects of large waves breaking close to the shoreline and ice push.

Figure 5.16: Beach and Nearshore Profile for a Cobble Beach and a Sand Beach

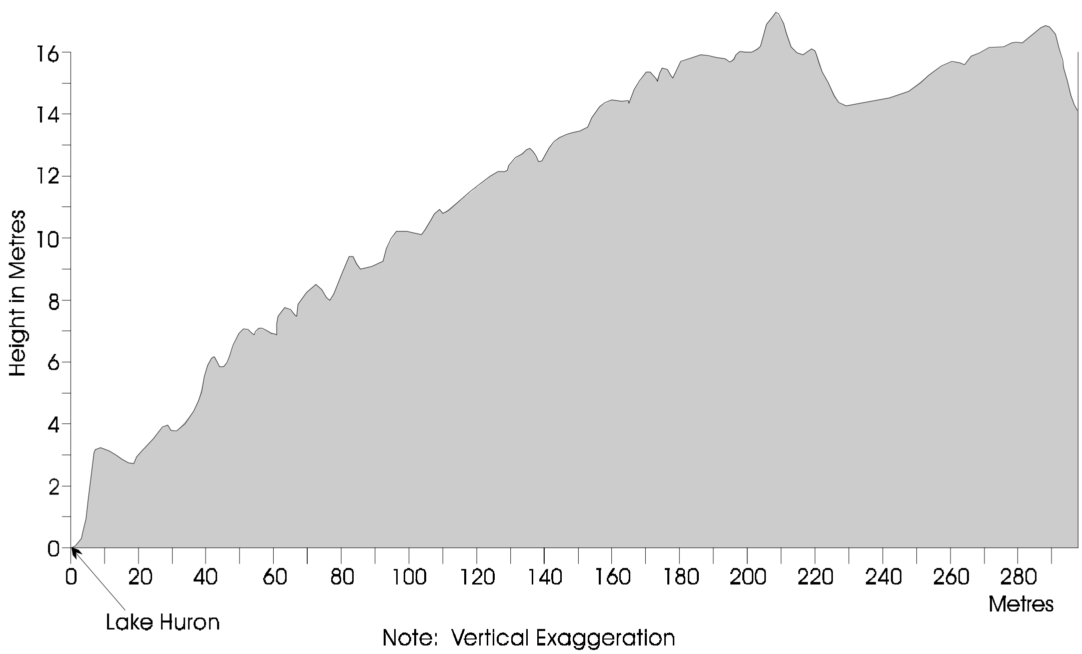


The landward limits of ice push often show up in two ways: 1) by the presence of ridges of cobbles that are disturbed and free of lichen growth, and 2) by the presence of scars on the stems of trees and shrubs growing close to the top of the beach.

Given their weight, coarse sediments cannot be transported by wind action. As a result, most beaches formed in coarse sediments do not have active dunes landward of the beach.

Along stretches of Lake Huron and Lake Superior shorelines where cobble beaches are found, the shorelines have experienced either isostatic uplift or a lowering of lake levels in the past several thousand years. Consequently, the profile landward of the beach may be marked by a succession of cobble ridges and troughs which increase in elevation inland (Figure 5.17).

Figure 5.17 Profile Across Raised Cobble Beaches Following Isostatic Uplift, Bruce Peninsula



Profile of Cape Dundas Beach Ridges

d) Sandy Beaches

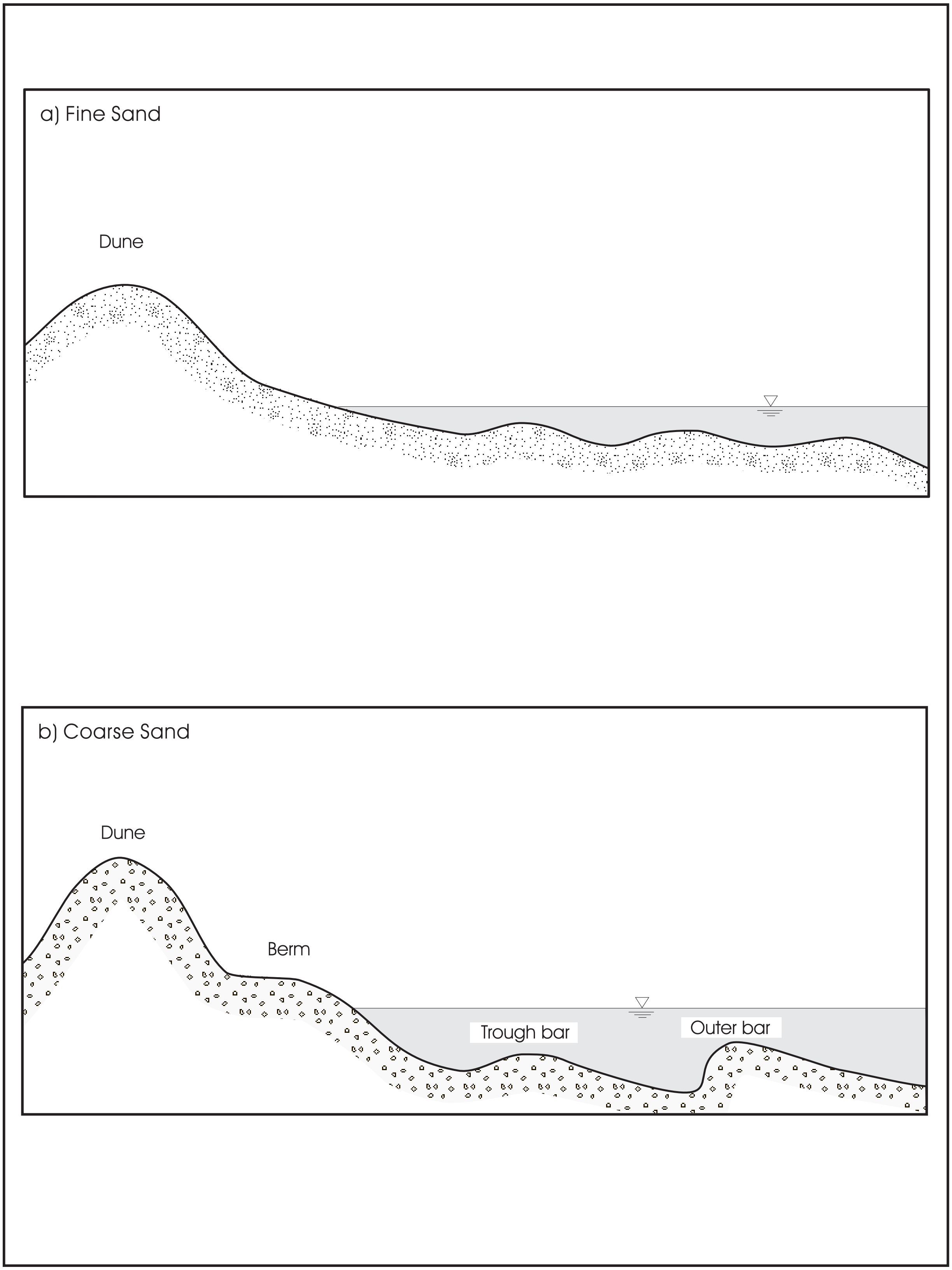
Virtually all sandy beaches in the *Great Lakes - St. Lawrence River System*, where there is sufficient sediment, are characterized by the presence of sand bars in the nearshore zone. On sand shorelines where the waves break on the lakeward slope and crest of the sand bars during storm events, strong currents can develop in the troughs landward of the bar.

Shore profiles developed in fine sand typically have a gentle slope in the nearshore and up to five or six sand bars. Examples of these types of shorelines are found at Wasaga Beach on Nottawasaga Bay, on Georgian Bay; at Sauble Beach on the west shore of the Bruce Peninsula; and at Presqu'isle on Lake Ontario (Figure 5.16b).

Profiles developed in medium and coarse sand tend to have steeper slopes in the nearshore, and have one to three bars. The sand bars found in medium to coarse sands are typically larger (i.e., have a greater relief) than those found on shore profiles developed in fine sand. Examples of medium to coarse sand beaches include those found at Grand Bend on Lake Huron, and the Burlington Bar on Lake Ontario.

For the purposes of clarification, characteristic shore profiles of beach developed in fine sand and in medium-to-coarse sand are graphically illustrated in Figure 5.18.

Figure 5.18: Hypothetical Profiles Associated with Beaches Developed in Fine and Coarse Sand



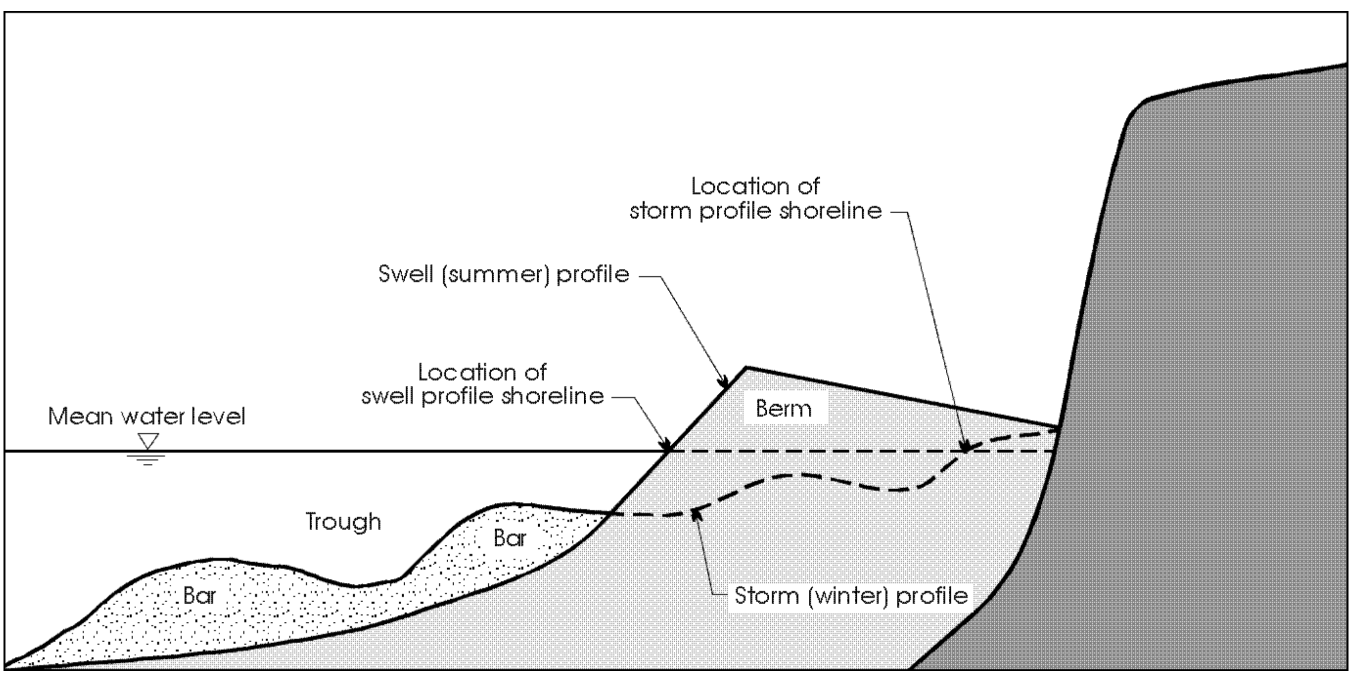
The position of the nearshore bars tend to change in direct response to changing wave, wind and water level conditions. Bars, especially those found in shallower water close to the shoreline, tend to migrate offshore during large storms and to migrate landward during periods of smaller waves. During the summer months when wave activity is usually quite low, the inner bars on medium to coarse sand beaches may migrate to the waterline and "weld" to the beach, thereby increasing the beach height and width.

In addition, the average position of the bars changes in response to long-term lake level fluctuations. For instance, the bars tend to migrate onshore during periods of rising water levels and offshore during periods of falling lake levels. The ultimate effect of this continuous onshore and offshore migration is that the depth of water over each bar crest is roughly the same level.

Bar migration, however, may lag behind water level changes by several months or more until storm wave action occurs to move the bars. As a result, wave energy reaching the shoreline at the end of a period of rapid water level rise may be much greater than for the same storm intensity and water level six months later when the bars have migrated to their equilibrium position. Similarly, as water levels drop, there may be a lag between that drop and the offshore movement of sediment resulting in beaches that are wider than the equilibrium condition and a greater risk of grounding of boats close to shore.

The beach foreshore and backshore are also more gently sloping on fine sand beaches and show quite limited change in response to changing wave energy and water levels. On medium and coarse sand beaches, sand is moved onshore during periods of low wave activity resulting in a build-up of sediment. As this build-up continues, a wedge of sediment commonly referred to as a berm is formed having a nearly horizontal surface and steep lakeward-facing swash slope (Figure 5.19).

Figure 5.19 Storm and Non-storm Profiles on a Medium Sand Beach



During storm events, higher waves and water levels may result in the erosion of the berm and a flattening of the beach profile with much of the original sediment being returned to the nearshore. With storm events generally tending to be more frequent and of a greater intensity in spring and fall (i.e., (winter) storm profile), sand beaches tend to be flatter and narrower in the those periods and higher and wider in the summer months (i.e., (summer) swell profile). When undertaking site investigations in sand beaches, it is important to keep this fact in mind.

Where sand beaches are formed they are generally backed by sand dunes formed by the landward transport of sand from the top of the beach by strong onshore winds and by the deposition of the sand in vegetation established beyond the limit of wave action.

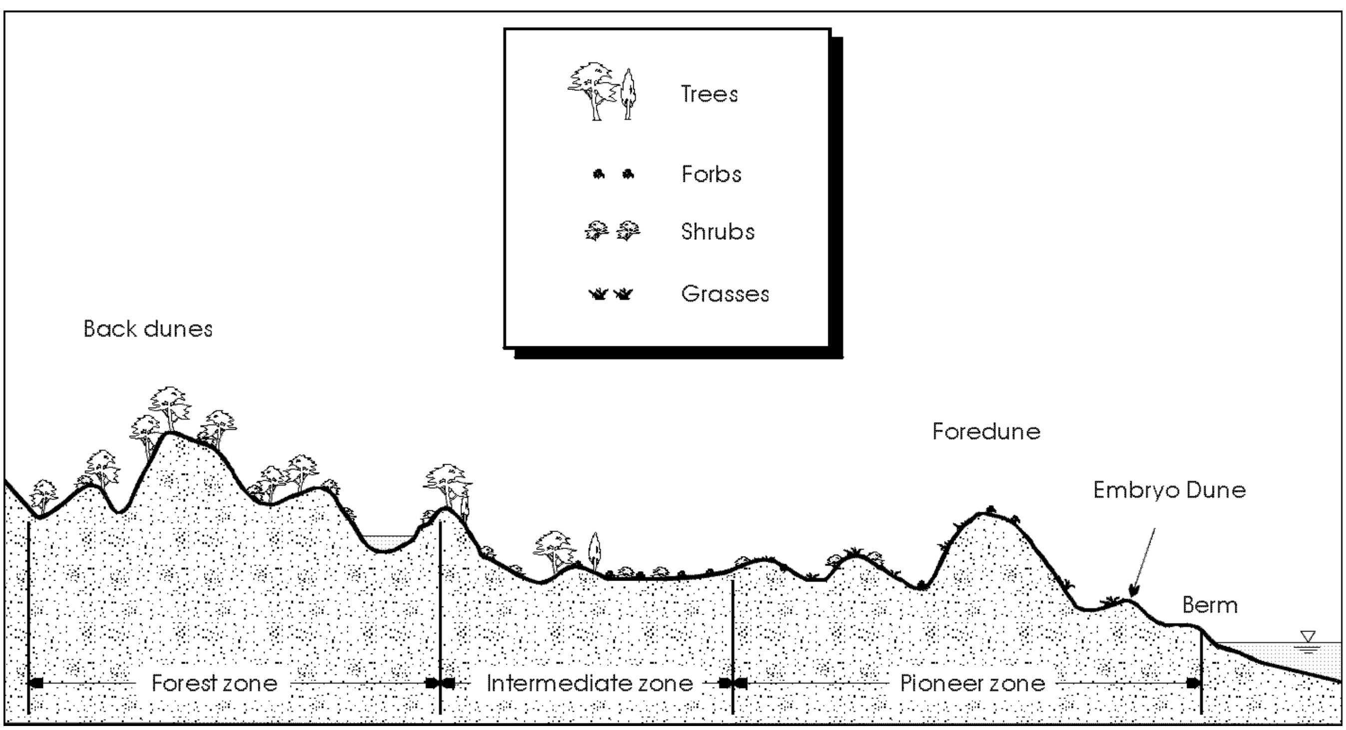
Across a typical sand dune field there are three main topographic and vegetational variations (Figure 5.20):

- pioneer zone, consisting of embryo dunes and main foredunes ridges,
- intermediate zone, consisting of transverse dune ridges, and the
- forest zone, consisting of the back dunes.

Embryo dunes develop closest to the beach and consists of low, often discontinuous, mounds of sand that gradually coalesce into a continuous ridge or platform. Vegetation in this zone is adapted to high rates of sand transport and low moisture. The dominant colonisers of this zone are perennial grasses such as marram (i.e., Ammophila breviligulata), switch grass (i.e., Panicum virgatum) and sand reed grass (i.e., Calomovilfa longifolia), and a number of annual plants such as sea rocket (i.e., Cacile edentula) and saltwort (i.e., Salsola pestifer). In some areas poplar trees (i.e., Populus deltoides or P. balsamifera) may also be a primary coloniser.

Behind the embryo dune is the main foredune ridge that frequently ranges from 2 to 10 metres in height. In addition to the primary colonisers noted above, the foredune may be colonised by beach pea (i.e., Elymus japonicus), by other species of grass such as Canada bluegrass (i.e., Poa compressa), little bluestem (i.e., Andropogon scoparius) several species of shrub such as bayberry (i.e., Myrica pensylvanica), dogwood (i.e., Cornus stoloifera), and a number of annuals that favour dry areas. A wide range of wetland vegetation may be present in the wet areas of ponds and dune slacks associated with dune fields.

Figure 5.20 Topographic and Vegetational Variation Across a Typical Dune Field



In the *Great Lakes - St. Lawrence River System* , embryo dunes generally tend to form in areas where the shoreline is stable or accreting, usually during periods of low lake level when beaches are their widest and when vegetation can propagate onto the upper beach (Figure 5.21 Scenario 1a). During the peak of the high water cycle, however, these dunes may be eroded during large storms and the foredune itself cliffed by wave action (Figure 5.21 Scenario 1b). Wave action during these larger storms tends to remove vegetation from the windward (i.e., lakeward) slope of the foredune resulting in erosion of the slope by wind and sediment transport up and over the dune crest to then be deposited on the leeward slope (Figure 5.21 Scenario 1c).

In places blowouts may develop in the dune ridge and may extend down to the watertable. Blowouts are large hollows eroded in the dunes by wind action when the stabilizing vegetation has been destroyed by natural processes or by human activities (Figure 5.22). When water levels begin to recede, vegetation re-establishes itself on the foredune resulting in some vertical growth and the stabilization of the windward slope. Vegetation may also propagate lakeward from the foredune or become established there from seeds or rhizomes to begin the establishment of an embryo dune zone (Figure 5.21 Scenario 1d).

Figure 5.21 Scenario 2 illustrates recession of the dune due to overwash and Scenario 3 illustrates a stable or propagating dune system.

In areas where there is a positive sediment supply, progradation of the beach takes place, and at some point the beach and embryo dune become wide enough that they are not destroyed during periods of high lake level. The embryo dune becomes established as a continuous ridge, and as it grows in width and height, the embryo dune cuts off sand supply to the foredune behind it.

Eventually the embryo dune grows high enough to be termed the foredune and a new embryo dune zone develops in front of it. As this process is repeated, a series of dune ridges, called transverse dune ridges is developed and the whole system is termed a dune field (Figure 5.20).

In areas where the lake level is falling relative to the land (i.e., due to isostatic rebound), dune fields may develop, even though sediment supply is limited, due to shoreline regression (i.e., migration of the shoreline in an offshore direction). This natural phenomena has occurred along much of the west shore of the Bruce Peninsula and along the north shore of Lake Superior. A visible characteristic of the existence of this natural phenomena is a rise in the elevation of the base of the dunes. If sediment supply is limited, the actual height of the individual dunes will decrease towards the modern shoreline. A good example of this phenomena can be seen in the dune fields around Red Bay and Howdendale on the Bruce Peninsula.

Storm waves, particularly during periods of high lake level, disturb the vegetation that holds the dune sand in position, and may initiate blowout formation and landward transfer of sediments. Where there is limited sediment supply or the net beach sediment budget is near zero, this landward migration of the foredune can ultimately lead to landward migration of the whole shoreline. This process may be initiated or reinforced by human disturbance of the embryo dune and foredune zones by trampling and other activities. Where this happens, the whole foredune may be breached during a storm allowing wave action to reach the dune slack depression lying landward of the foredune. It is important, therefore, that efforts should be made on sandy shorelines to ensure that the vegetation of the embryo dune and the windward slope of the foredune is not destroyed by these activities.

In areas where sediment supply is limited or where the beach sediment budget is negative, the embryo dune zone does not develop because the beach is generally too narrow. However, the foredune does undergo a similar cycle, with cliffing taking place during high water periods and re-establishment of vegetation on the windward slope during periods of low lake level.

Figure 5.21: Response of Shoreline Dunes to Long-Term Lake Level Cycles

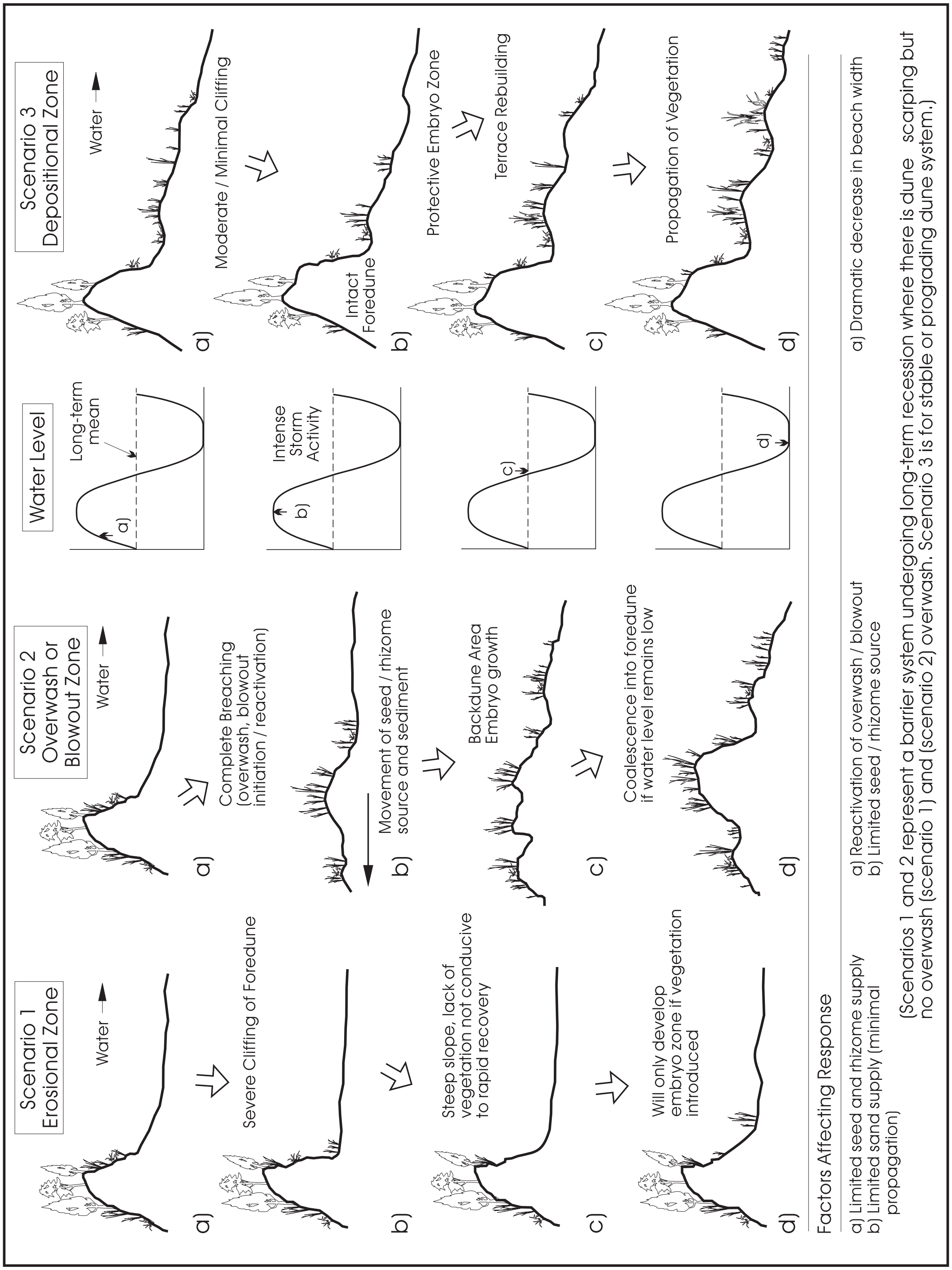


Figure 5.22: Photograph of Blowouts in Sand Dunes

5.4.5 Profile Development and Human Activities

Within the 18 dynamic beach sub-classifications identified in the recommended shoreline classification scheme, two other factors that are common to all beach types may act to influence the range of profile adjustment and dynamic nature of the beach:

- the extent to which the shore profile is developed in sediments or is constrained by underlying bedrock or cohesive material; and
- the extent to which the beach has been created, either directly or indirectly, by human actions and as such, to what extent the existence of the beach is dependant on the continued presence of that human activity.

a) Profile Development

In evaluating the development of a particular beach profile, a distinction can be made between beaches:

- where the profile is fully developed in the surficial sediments forming the beach; and
- where the beach materials form a thin cover over bedrock or cohesive material.

In the latter case, the underlying material may act to limit the extent of profile adjustment to varying wave energy and water levels and as a result, these beaches are likely to have a lower range of dynamic response compared to a similar beach where the profile is completely developed in sediments.

b) Human Activities

Beaches are directly and indirectly affected by a wide range of human activities ranging from trampling of vegetation in dunes, removal and mining of sediments from the beach and nearshore area, nourishment of beaches, and the effects of structures (e.g., piers, breakwaters) on the beach itself and on the updrift supply of sediment.

One beach form of particular concern is filet beaches. These are beaches created by the trapping of sediment behind a shore-perpendicular structure such as a harbour breakwater or beaches that are maintained through nourishment. As the continued existence of filet beaches is dependent on the continuous maintenance of the structure or continued nourishment, the potential exists for the beach to change drastically if the structure is removed or damaged due to natural processes, or if the programme of beach nourishment is discontinued.

As such, prior to selecting a management or development strategy for a particular beach feature, it is important to determine the extent to which the beach is dependant on human-related activities (i.e., maintenance of structures, beach nourishment) and the likelihood that these may change over time.

5.4.6 Description and Classification of Dynamic Beach

Appendix A5.1: Description of Dynamic Beach Types provides a summary of the factors that control the dynamic response of each of the 18 dynamic beach sub-classifications. This summary can be used to assist shoreline managers in identifying potential problems and to provide guidance as to whether studies using accepted scientific and engineering principles to determine the landward limit of the dynamic beach allowance may be warranted. Examples of the 18 dynamic beach sub-classifications are provided in Appendix A5.1. The descriptions of the 18 dynamic beach sub-classifications are given for the purpose of "flagging" those situations or issues that should be considered before reaching a final decision on the location of the landward limit of *dynamic beach hazard*.

For classification and mapping of dynamic beaches Appendix A5.2: Classification and Mapping of Dynamic Beaches of this Technical Guide should be consulted.

5.5 DETERMINATION OF RECESSION RATES ON A DYNAMIC BEACH SHORELINE

On dynamic beaches backed by a cliff or bluff the calculation and definition of the *erosion hazard* is applied to the cliff or bluff feature and as such, recession of the beach is accounted for in the determination of the landward limit of the *erosion hazard* for the cliff or bluff feature. Within the shorelines involving low plain beach and barrier beach classifications, however, there is no explicit inclusion of an erosion allowance to address shoreline recession. The primary reason for this is the difficulty associated with obtaining precise and accurate measurements of the average annual recession rate on these shoreline types. However, where shoreline managers have found evidence that shoreline recession is occurring on these shoreline types, efforts should be taken to obtain the best estimate of the recession rate and to incorporate this measurement into the determination of the landward limit of the *dynamic beach hazard.*

To assist in this task, a brief description is provided in this section on the methods of calculating recession rates within dynamic beaches, of the visible indicators of long-term recession in the field, and of the ultimate impacts of these factors on the delineation of the *dynamic beach hazard*. For more general information on techniques for measuring shoreline recession, Part 4: Erosion Hazard, Section 4.4: Average Annual Recession Rates of this Technical Guide should be consulted.

On many dynamic beach types, the natural profile adjustments associated with seasonal changes in water level and wave activity, and particularly with the response of the beach to long-term lake level fluctuations, makes it difficult to define a reference point whose change in position through time on maps, aerial photographs or surveyed profiles can be used to determine a recession rate. For instance, the position of a reference point (e.g., waterline, edge of vegetation, and toe or top of foredune) will change in response to water level fluctuations and particularly in response to seasonal and long-term changes in the volume of sediment on the beach, which in turn lead to adjustments of the profile (see Figure 5.1). The greater the magnitude of these profile adjustments, the more difficult it is to separate a progressive landward displacement (i.e., recession) of that point from its movement due to dynamic profile adjustments.

To assist in ensuring a more accurate determination of the average annual recession rate, the following section will outline:

- a definition of a suitable reference point for making the measurements on different dynamic beach types;
- the likely dynamic range of these reference points;
- the implications of the definition of these reference points for the accuracy of measured recession rates; and
- visible evidence of long-term recession within dynamic beaches which can be determined through field investigation.

The decision as to whether measurements of the long-term shoreline recession rate should be made will depend on the availability and perceived reliability of evidence from previous studies, the results of preliminary field investigations, on the magnitude or severity of recession currently occurring at the location, and on the extent of existing or proposed shoreline development.

As a general guide, three situations can be envisaged:

- **recession rate is zero**

  There is no visible or measured evidence of shoreline erosion and recession identified in available studies or from field investigations.

- **recession rate is low**

  There is evidence that shoreline recession is occurring through available studies or from field investigations. The measured or visible rate of recession appears to be relatively slow (e.g., less than 0.2 to 0.3 metres/year). In most cases, the limited precision of the techniques for determining recession and the uncertainties introduced by the dynamic profile adjustments make it uneconomical to undertake studies to determine actual recession rates for small lengths of shoreline.

  In these locations, it is recommended that for mapping purposes, the average annual recession rate should be set at 0.3 metres/year and detailed measurements of recession be undertaken only in conjunction with a proposal for development accompanied by a request to reduce this value (i.e., work is undertaken by the proponent).

- **recession rate is high**

  There is evidence that the shoreline recession rates are high and probably exceeding 0.3 metres/year as determined from available studies or from field investigation.

  In these locations, it is suggested that the municipalities give consideration to undertaking preliminary studies to determine the long-term recession rates using the approach described below. Where the shoreline is undeveloped and no development is proposed the rate need only be determined for a few localities and these values used for mapping purposes. Where development is proposed, the level of field study and the degree of precision required in the calculation of the recession rate should be reflective of the type, density and level of investment associated with the proposed development.

For the purposes of identifying and measuring long-term recession rates, dynamic beach types found within the *Great Lakes - St. Lawrence River System* can be arranged into three broad groups:

- sand or cobble beaches backed by cliffs/bluffs (1-1-1, 1-1-3, 1-2-1, 1-2-3, 1-3-1, 1-3-3)

  For these beach types the recession rate should generally be related to the recession of the cliff/bluff toe or crest. This should be determined by using the procedures outlined in Section 4.4, Part 4: Erosion Hazard, of this Technical Guide.

- low mainland and barrier cobble beaches (2-1-1, 2-2-1, 2-3-1, 3-1-1, 3-2-1, 3-3-1)

  For cobble beach types, the beach slope is generally steep and involves a modest range of dynamic profile adjustment. As such, measurement of the horizontal displacement of the waterline over time should provide a good estimate of long-term recession rates.

- low mainland and barrier sandy beaches (2-1-3, 2-2-3, 2-3-3, 3-1-3, 3-2-3, 3-3-3)

  Sandy beaches, having gentle slope profiles, provide the greatest range of profile change, including changes to the form and location of the foredune complex. As a result, the selection of a suitable reference point for measuring shoreline recession is difficult, and the accuracy of the measurements is consequently much lower than for the other dynamic beach types. In some areas recession of the foredune crest provides the best indicator of recession, while in other areas the base of the dune may be better.

For the purposes of clarification, Table 5.3 summarizes the factors indicative of stability in the absence of long-term recession rate information, visible indicators of long-term recession, and suggested reference points for determining and measuring long-term recession rates for the three broad groupings of dynamic beaches. In addition to the information provided in Table 5.3, cobble and sandy dynamic beaches will be examined in greater detail to assist shoreline managers in the proper identification and measurement of recession rates of these broad groupings of dynamic beaches within the *Great Lakes - St. Lawrence River System* .

Table 5.3
Factors Indicative of Stability in the Absence of Long-Term Recession Rate Information

BEACH TYPE	INDICATORS OF STABILITY	INDICATORS OF LONG-TERM EROSION	REFERENCE POINT
sand or cobble beaches backed by cliff/bluff 1-1-1, 1-1-3, 1-2-1 1-2-3, 1-3-1, 1-3-3	- vegetated backshore between beach and cliff/bluff - debris accumulation at cliff/bluff toe	- narrow backshore - absence of trees - evidence of toe erosion rockfall - slumping on cliff/bluff face	- cliff/bluff - crest or toe
cobble low mainland and cobble barrier 2-1-1, 2-2-1, 2-3-1, 3-1-1, 3-2-1, 3-3-1	- cobble ridges - inland from modern beach - trees close to beach but no erosion of trees	- exposure of tree roots - toppling of trees - fresh (i.e., lichen-free) cobbles deposited in vegetation - peat exposure on barrier foreshore	- waterline - vegetation line
sandy low mainland and sandy barrier 2-1-3, 2-2-3, 2-3-3 3-1-3, 3-2-3, 3-3-3	- dune ridges inland from foredune - vegetation succession inland - hardwoods occur 50 m or more landward of beach	- dune cliffing and toppling of trees - soil layers exposed in eroding dunes - peat outcrops on foreshore of barriers	- lakeward edge of foredune crest

5.5.1 Identification and Measurement of Recession Rates on Cobble Beaches

In general, beaches composed of cobbles and other coarse sediments are more stable than sandy beaches. As such, where long-term erosion and recession does occur, the rate of recession on cobble and other coarse sediment beaches usually takes place at a much slower rate than on sandy beaches.

In addition to having slower rates of recession, the majority of cobble beaches, particularly those located along Lake Superior, Georgian Bay and the Bruce Peninsula, and the eastern end of Lake Ontario, are currently experiencing isostatic uplift. This in turn generally counteracts any tendency to shoreline recession due to erosion. As such, examples of cobble beaches experiencing recession within the *Great Lakes - St. Lawrence River System* are limited to a very few areas.

Where cobble beaches are backed by cliffs or bluffs, the best indicators of long-term recession will be the evidence of toe erosion at the base of the cliff/bluff and of rockfall, slumping and other forms of mass movement on the bluff slope and base. Slope instability may also be shown by disturbance to vegetation and by the absence of old trees. As noted previously, measurement of recession rates should be with respect to retreat of the cliff/bluff using the techniques outlined in Section 4.4 in Part 4: Erosion Hazard of this Technical Guide.

On low plain cobble beaches, tree growth often occurs right to the limit of storm wave action. The degree of beach stability is indicated by the absence of disturbance to tree growth bordering the beach and by the presence of lichen growth on cobbles or boulders above the beach. Long-term stability is also evidenced by the presence of cobble or boulder ridges inland from the modern beach indicative of progradation or falling lake levels. Conversely, high rates of long-term recession are evidenced by exposed tree roots and the toppling of trees into the water, particularly during or immediately following periods of high lake levels. A second indicator of long-term recession is the presence of fresh cobbles/boulders, without lichen growth, within the vegetation at the back of the beach. Where scarping of the beach face is evident and there is some exposure of older cobble deposits, although these may be indicative of long-term recession, care must be taken to distinguish between localized erosion and deposition associated with the dynamic adjustment of the beach profile and long-term recession.

On cobble barrier beaches, evidence of disturbance to vegetation, particularly the undermining of trees where they are present, is an indicator of long-term recession. A second indicator of long-term recession may be the overwash of the whole barrier and the deposition of fresh rock material on the landward side of the barrier. Care should be taken in using overwash as an indicator of long-term recession, as overwash may also occur on stable cobble barriers during periods of high lake level. As such, evidence of overwash should only be considered as an indicator of long-term recession in the absence of other visible indicators of erosion. Where the barrier is backed by marsh growth, landward migration of the barrier, resulting in the appearance of old marsh deposits (e.g., peat) on the lower part of the beach foreshore, may also be indicative of long-term recession.

Due to the steep slopes and narrow horizontal range of beach profile adjustments, typical of cobble beaches, there is less horizontal variability in the location of reference features on cobble beaches than on sandy beaches. As such, where recession is measured on aerial photographs, changes in the location of the waterline or of the vegetation line marking the top of the beach may be used to determine the rate of long-term recession.

a) Waterline

On the majority of cobble beaches in the *Great Lakes - St. Lawrence River System* , horizontal profile changes resulting from changes in the level of wave activity are quite limited, probably less than 5 metres. As such, the rate of recession may be determined by measuring the change in location of the waterline shown on two successive aerial photographs, assuming that the recession rate is greater than the level of precision determined by the quality of the aerial photographs and the length of elapsed time between the two photographs. When using this procedure for measuring recession, allowance must be made for the horizontal shift in water level due to differences in the lake level for each photograph (Figure 5.23). Assuming that the difference in water elevation is known, the effect of this can be determined geometrically using an average slope angle measured in the field or, if this is not available, by using an angle of 30^{o} for cobble beaches and 40^{o} for boulder beaches.

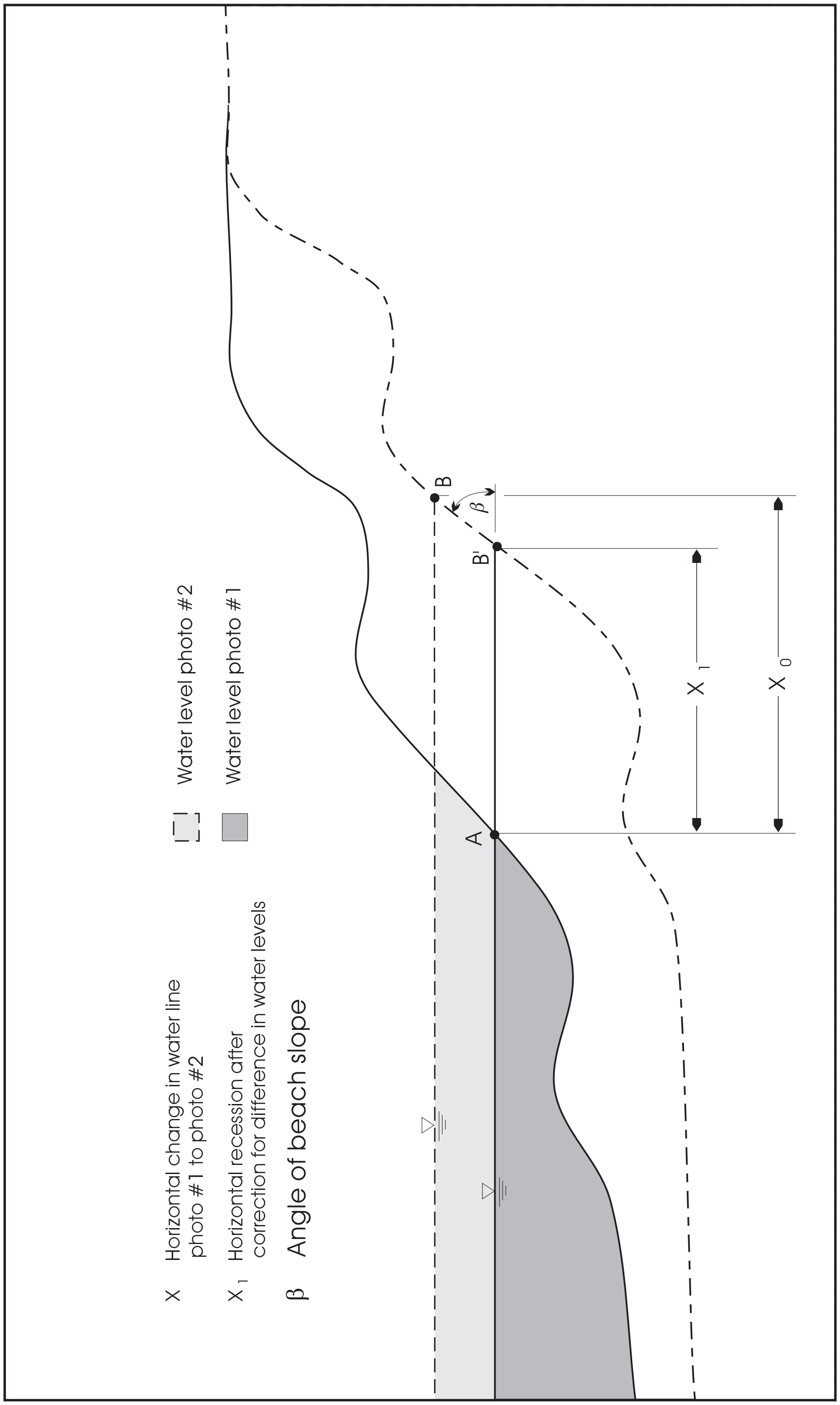
b) Vegetation Line

Where vegetation exists close to the water and there is no evidence of human disturbance through clearing or logging, the horizontal change in the location of the vegetation line can be used to determine the long-term recession rate.

5.5.2 Identification and Measurement of Recession Rates on Sandy Beaches

Similar to cobble beaches, the best indicators of long-term recession along sandy beaches backed by cliffs/bluffs will be evidence of toe erosion at the base of the cliff/bluff, and of rockfalls, slumping and other forms of mass movement on the slope and at the base of the cliff/bluff slope. Slope instability may also be shown by disturbance to vegetation on the slope and by the absence of old trees. Recession rates are measured with respect to retreat of the toe or crest of the cliff/bluff using the techniques described in Section 4.4, in Part 4: Erosion Hazard, of this Technical Guide.

Figure 5.23: Determination of Horizontal Change in Location of Waterline on a Cobble Beach



The apparent change in location from A to B must be corrected for differences in lake level on the dates on which the photographs were taken. The corrected distance is AB'. The average annual recession rate = AB'/ n where n = number of years between photographs.

On sandy low mainland beaches and barrier beaches, the existence of a dune field with a number of older dune ridges landward of the active foredune is an indication that progradation has taken place in the past and that the beach is likely to be stable or progradational. Within these same areas, there should be a zone over which plant succession is evident, with grasses and herbs near the beach giving way to shrubs, poplar and pines. Hardwoods, such as maples and oaks, are evident much later in the succession on dunes and will normally occur more than 100 metres inland from the beach.

On low mainland beaches, where there is sufficient sand for dune formation to have occurred, and on sandy barriers, evidence of erosion often takes the form of scarping or cliffing of the foredune and the removal of vegetation and embryo dunes in front of the foredune. During periods of long-term high lake levels most sandy beaches in the Great Lakes will show evidence of this type of erosion. Although this may pose a major difficulty in interpretation, particular care should be taken in distinguishing between erosion which is simply related to the dynamic adjustment of the profile to high lake levels and where there has actually been some net landward shift (i.e., recession) of the profile over time.

Within sandy beach shorelines, evidence of long-term recession can be seen in four ways:

- the presence of old pines and hardwoods close to the beach which are being destroyed during periods of high lake levels;

- the presence of moderate soil profile development in dune sediments which are being cliffed by wave activity. In a modern foredune there is generally too much active sand deposition and too little time for any significant organic matter accumulation and soil profile development. As a result, the presence of a soil profile in the dune near the beach should indicate that the ridge is old and has been exposed through shoreline recession;

- the occurrence of a single foredune ridge, on a barrier system, with evidence of cliffing of the dune and even complete destruction of the dune in places through overwash and inlet breaching, is an indicator of long-term instability. On stable or prograding barriers there is generally sufficient sediment supply to lead to the development of a series of older dune ridges landward of the foredune; and

- the landward migration of barrier ridges is often indicated by the outcrop of marsh deposits and peat on the lower part of the beach foreshore as the dunes roll over the marsh or bay sediments at the back of the barrier.

Due to the greater dynamic range of beach profile adjustment on sandy beaches, compared to cobble beaches, measurement of horizontal recession of the waterline from sequential aerial photographs is subject to considerable error (i.e., it is difficult to distinguish profile adjustment due to seasonal changes in water level and wave activity from long-term shifts in the location of the average beach position). Similarly, the vegetation line can shift over a considerable horizontal distance over a few years as part of the dynamic profile adjustment.

Where dunes exist, the best reference point for measuring shoreline recession on sandy beaches is the lakeward edge of the foredune ridge. Care must be taken to distinguish this from embryo dune ridges formed lakeward of the foredune ridge during periods of low lake levels and from older dune ridges that may be exposed temporarily due to breaching of the foredune through overwash or blowout activity during periods of high lake levels.

INDEX - PART 5

DYNAMIC BEACH HAZARD

TECHNICAL GUIDE FOR
GREAT LAKES - ST. LAWRENCE RIVER SHORELINES

APPENDIX A5.1

DESCRIPTION OF DYNAMIC BEACH TYPES

DESCRIPTION OF DYNAMIC BEACHES TYPES

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A5.1 DESCRIPTION OF DYNAMIC BEACH TYPES

In this section, a description and example site on the Great Lakes is provided for most of the 18 dynamic beach types presented in Part 5: Dynamic Beach Hazard of this Technical Guide. Each example is accompanied by a map, a profile, and two photographs. Where no example is provided, a hypothetical plan view and profile are provided. The description builds on the material covered in Section 5.4 and can also be used as a reference following the shoreline classification procedure described in Appendix A5.2. Figure A5.1.1 depicts the location of the 14 sites to be presented.

A5.1.1 Cliff/Bluff Beaches

a) Headland-Bay Beaches

This grouping of beach environments includes the following dynamic beach sub-classifications:

- **1-1-1 Cobble Headland-Bay Beach backed by a Cliff or Bluff**
- **1-1-3 Sandy Headland-Bay Beach backed by a Cliff or Bluff**

Typical factors to be considered when dealing within these dynamic beach sub-classifications include the following:

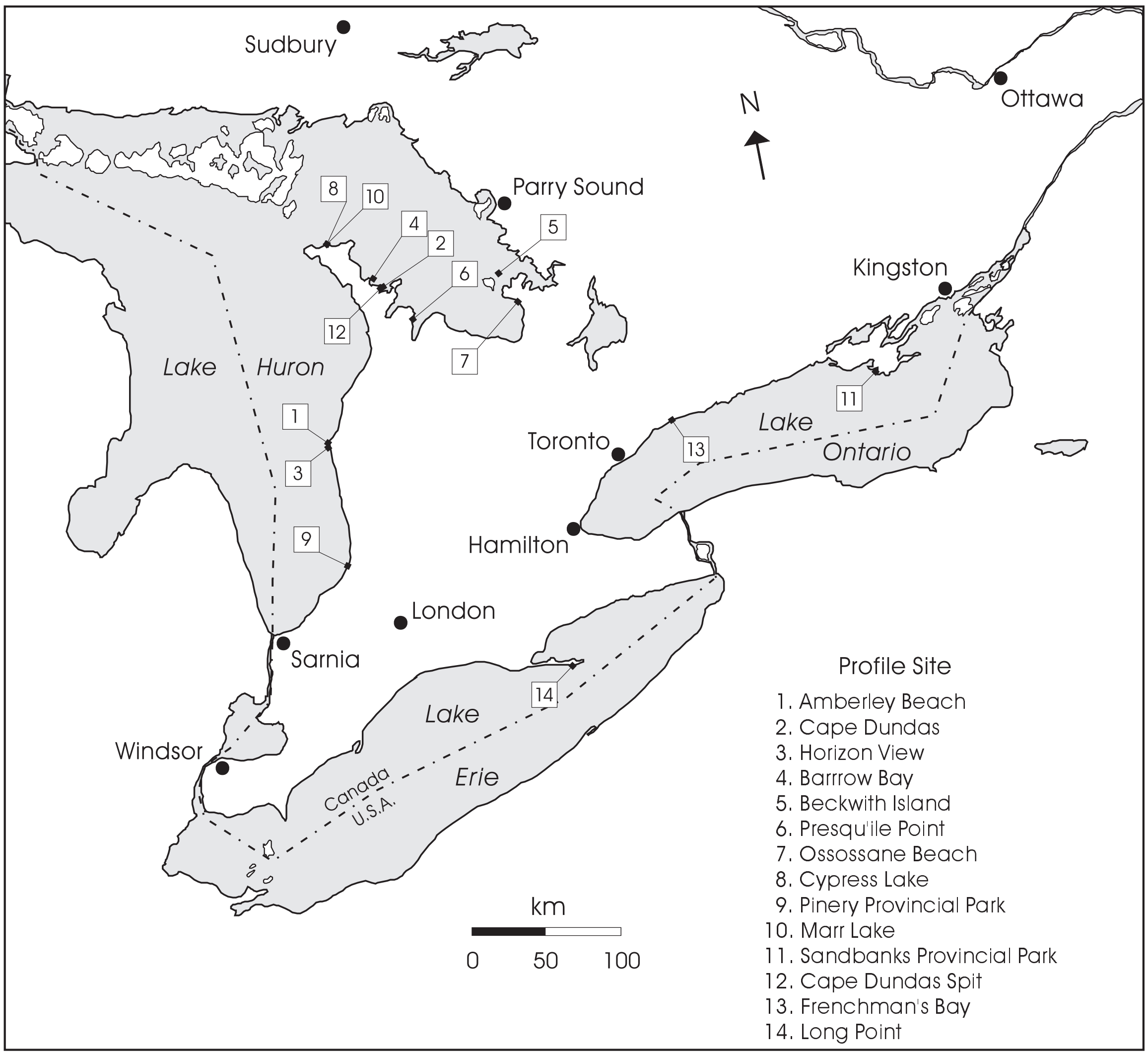
- Headlands restrict waves to a narrow range of directions. Most waves arrive nearly perpendicular to the beach shoreline at the head of the bay. Potential sediment transport is along the sides towards head of the bay. As a result, sediment is trapped within the bay and in most cases losses of sediment from the bay are small. Most headland-bay beaches are stable or accretional. In these areas, locating developments behind or landward of the *dynamic beach hazard* limit is the most effective means of protecting the development against flooding and wave damage. Where developments are located landward of the *dynamic beach hazard* limit the need for shoreline protection works should be precluded. Where the proposed development includes uses such as marinas which by nature must be located in close proximity to the water's edge, care should be taken in their approval, siting and design.

- Where the sides of the bay are formed in erodible material or where there is sediment input from rivers, alongshore sediment transport will occur towards the head of the bay. In these situations, there is the potential for interruptions in sediment transport due to the construction of shore protection or marinas. For this reason, proposals for new development should be examined carefully to ensure that the interruption of the alongshore sediment transport does not occur. In addition, there may also be some long-term recession due to erosion which would then require addressing in the development proposal.

- Where the beach is backed by a cliff/bluff, the landward limit of the *dynamic beach hazard* should be placed at the toe of the cliff/bluff. If the beach is backed by an erodible bluff and there are signs of toe erosion or bluff instability, the landward limit of the *dynamic beach hazard* should not be reduced. In areas where the slope at the back of the beach is developed in resistant bedrock (i.e., a cliff rather than a bluff) studies using accepted scientific and engineering principles may show that it is possible to reduce the landward limit of the *dynamic beach hazard* to permit development at the base of the cliff. Situations where development could possibly be considered may include:

  - a partial profile with the extent of the dynamic beach response limited by underlying bedrock;
  - a relatively steep profile landward of beach, resulting in elevations near the cliff toe being well above the *flooding hazard* (e.g., this may occur in areas that are still experiencing isostatic uplift); and
  - the development is to be sited landward of the maximum extent of wave action during the high water periods of 1972-73 and 1985-86 and the recession rate is zero.

Figure A5.1.1: Location Plan of Dynamic Beach Example Sites



- The dynamic range of cobble beaches is generally less than that of sandy beaches with similar exposure for two reasons: 1) their steeper beach slope; and 2) the rate of adjustment to wave action is generally much slower for cobble beaches than for sandy beaches. Where field inspection or studies show that the elevation of the backshore is well above the wave uprush limit it may be possible to reduce the landward limit of the *dynamic beach hazard* by as much as 10 metres. However, care should be taken to ensure that any reduction in the landward limit of the *dynamic beach hazard* is still landward of the furthest landward limit of wave and/or ice action as indicated by historical evidence, sedimentological and/or vegetational evidence found in the field. In these cases, there should be evidence that the toe of the bluff/cliff is stable and that it has not been subject to wave attack in the past 30-40 years. A reduction in the *dynamic beach hazard* on cobble beaches exposed to fetch lengths of greater than 100 kilometres should only be permitted after careful study and review using accepted scientific and engineering principles.

- In most cases where there is a sandy beach backed by a bluff, the bluff is normally recessional and there is little or no sand dune development. In some transitional areas, a narrow field of dunes may be present between the beach and the bluff toe. Since these shorelines are highly vulnerable to changes in the supply from updrift, development should not be permitted within the dune area unless:

    - it can be shown that the development will be outside of the *dynamic beach hazard*; <u>and</u>

    - that there is some other constraint or factor limiting the rate of erosion, such as resistant bedrock, limiting the extent of vertical erosion and horizontal recession of the bluff.

The following provides a discussion of these cliff/bluff dynamic beach sub-classifications.

<u>1-1-1 Cobble Headland-Bay Beach backed by a Cliff/Bluff</u>

Example Location: No example

No example of a cobble headland-bay beach backed by a cliff/bluff was identified along the *Great Lakes - St. Lawrence River System* shoreline. Examples of this class are rare and it is included primarily to maintain the symmetry of the classification scheme. Figure A5.1.2 shows a hypothetical plan view and profile of a cobble headland-bay beach backed by a cliff/bluff.

<u>1-1-3 Sandy Headland-Bay backed by a Cliff/Bluff</u>

Example Location: No example

No example of a sandy headland-bay beach backed by a cliff/bluff was identified along the *Great Lakes - St. Lawrence River System* shoreline. Examples of this class are rare and it is included primarily to maintain the symmetry of the classification scheme. Figure A5.1.3 shows a hypothetical plan view and profile of a sandy headland-bay beach backed by a cliff/bluff.

b) Partial Headland Beaches

This grouping of beach environments includes the following dynamic beach sub-classifications:

- **1-2-1 Cobble Partial Headland Beach backed by a Cliff or Bluff**

- **1-2-3 Sandy Partial Headland Beach backed by a Cliff or Bluff**

Typical factors to be considered when dealing within these dynamic beach sub-classifications include the following:

- The partial headland and associated log-spiral beach usually occurs on a shoreline where there is a well-defined direction of net alongshore sediment transport. The headland at the updrift end of each reach provides some shelter from waves from the updrift direction, usually the longest fetch, and the downdrift

Figure A5.1.2: Cobble Headland-Bay Beach backed by a Cliff/Bluff (1-1-1)

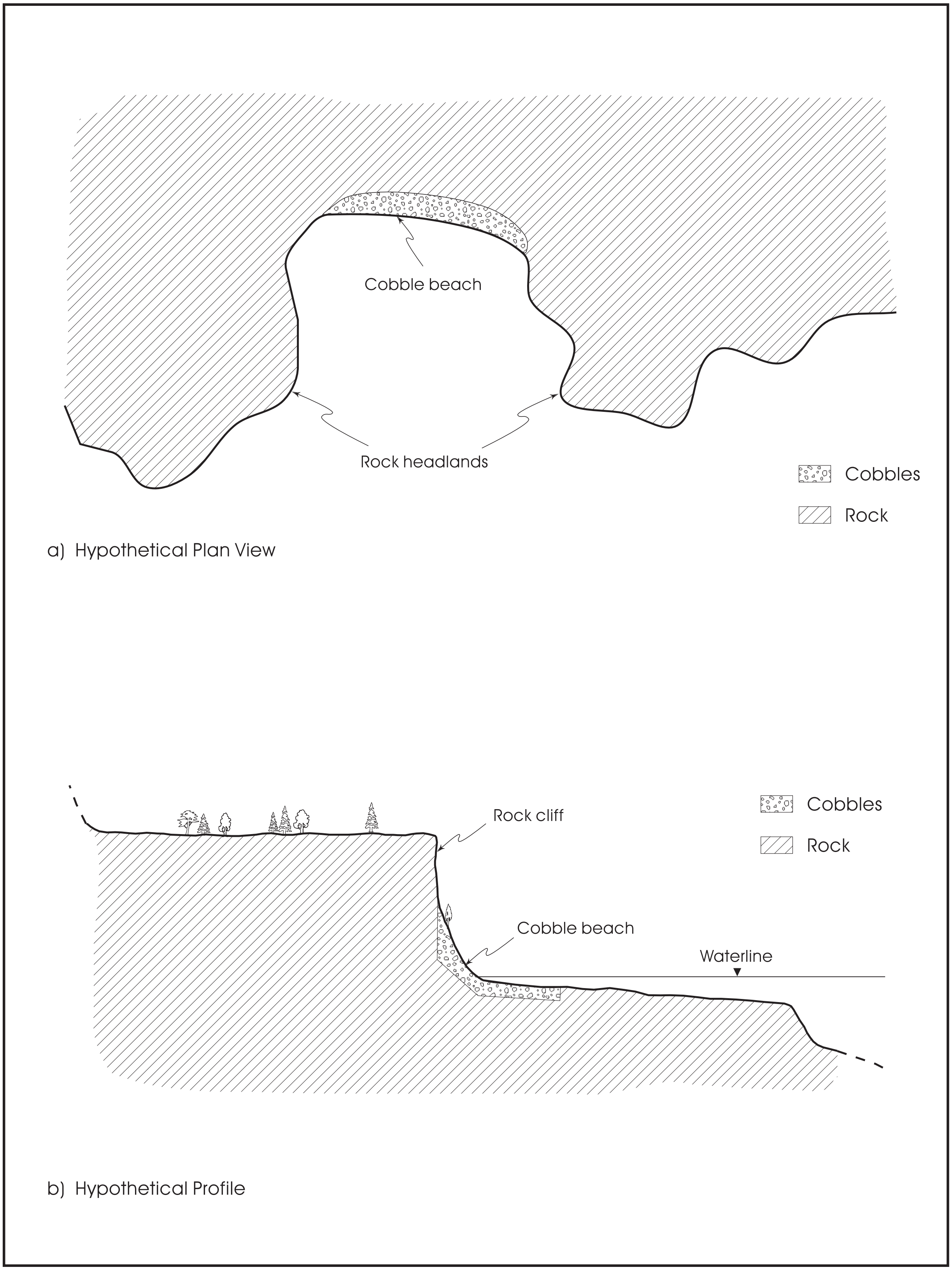
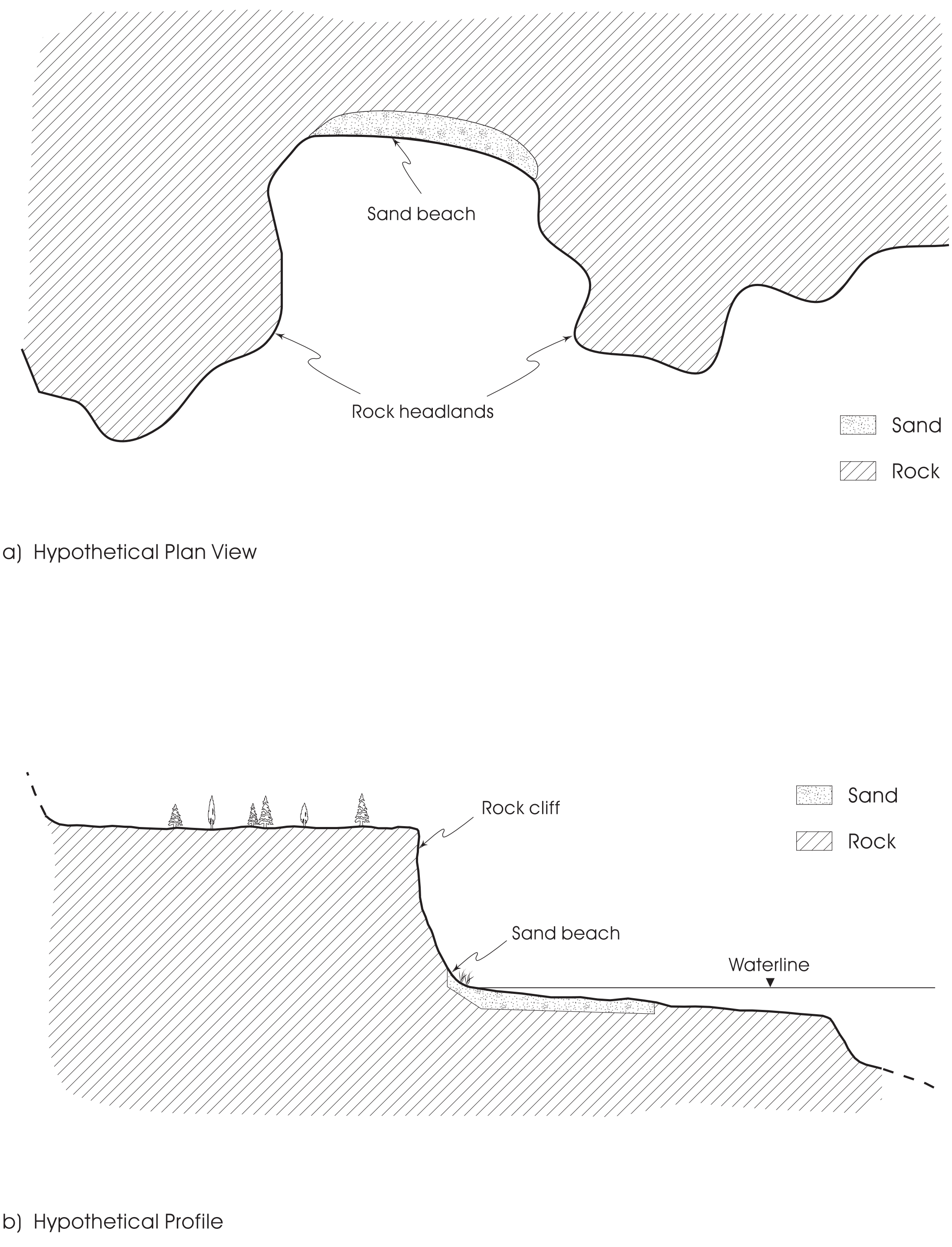


Figure A5.1.3: Sandy Beach Headland-Bay Beach backed by a Cliff/Bluff (1-1-3)



beach tends to be aligned quite closely to the resultant or net wave direction. The headlands provide some measure of stability and erosion and shoreline recession will generally be controlled by the rate of erosion of the headland. In resistant bedrock the rate of erosion is likely to be negligible, however, in relatively weak shales and thinly-bedded limestones it may be on the order of 0.05-0.1 m/yr. Beaches formed in either of these sub-classifications are considered to be intermediate, between Headland-Bay beach and Exposed beach sub-classifications, in terms of their sensitivity to interruptions in updrift sediment supply.

- Where the beach is backed by a cliff or bluff, the landward limit of the *dynamic beach hazard* should be placed at the toe of the cliff/bluff. If the beach is backed by an erodible bluff and there are signs of toe erosion or bluff instability, the landward limit of the *dynamic beach hazard* should not be reduced. In areas where the slope at the back of the beach is developed in resistant bedrock (i.e., a cliff rather than a bluff) studies using accepted scientific and engineering principles may show that it is possible to reduce the landward limit of the *dynamic beach hazard* to permit development at the base of the cliff. Situations where development could possibly be considered may include:

  - a partial profile with the extent of the dynamic beach response limited by underlying bedrock;

  - a relatively steep profile landward of beach, resulting in elevations near the cliff toe being well above the *flooding hazard* (i.e., this may occur in areas that are still experiencing isostatic uplift); and

  - the development is to be sited landward of the maximum extent of wave action during the high water periods of 1972-73 and 1985-86 and the recession rate is zero.

- The dynamic range of cobble beaches is generally less than that of sandy beaches with similar exposure for two reasons: 1) their steeper beach slope; and 2) the rate of adjustment to wave action is generally much slower for cobble beaches than for sandy beaches. Where field inspection or studies show that the elevation of the backshore is well above the wave uprush limit it may be possible to reduce the landward limit of the *dynamic beach hazard* by as much as 10 metres. However, care should be taken to ensure that any reduction in the landward limit of the *dynamic beach hazard* is still landward of the furthest landward limit of wave and/or ice action as indicated by historical evidence, sedimentological and/or vegetational evidence found in the field. In these cases, there should be evidence that the toe of the cliff/bluff is stable and that it has not been subject to wave attack in the past 30-40 years. A reduction in the *dynamic beach hazard* on cobble beaches exposed to fetch lengths of greater than 100 kilometres should only be permitted after carful study and review using accepted scientific and engineering principles.

- In most cases where there is a sandy beach backed by a bluff, the bluff is normally recessional and there is little or no sand dune development. In some transitional areas, a narrow field of dunes may be present between the beach and the bluff toe. Since these shorelines are highly vulnerable to changes in the supply from updrift, development should not be permitted within the dune area unless:

  - it can be shown that the development will be outside of the *dynamic beach hazard*; <u>and</u>

  - that there is some other constraint or factor limiting the rate of erosion, such as resistant bedrock, limiting the extent of vertical erosion and horizontal recession of the bluff.

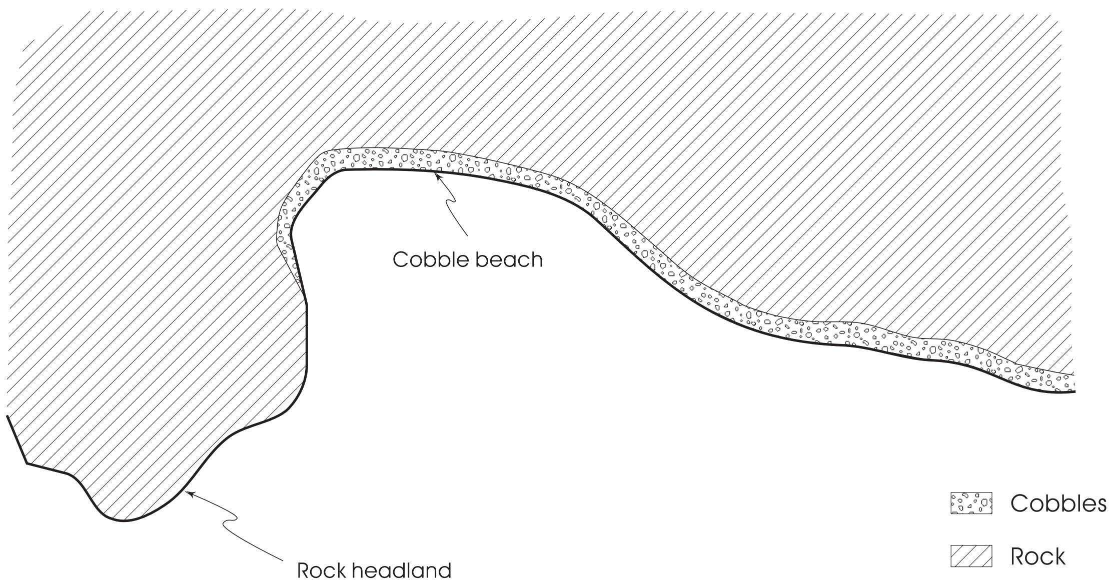
The following provides an example of each of these dynamic beach sub-classifications.

<u>1-2-1 Cobble Partial Headland Beach backed by a Cliff/Bluff</u>

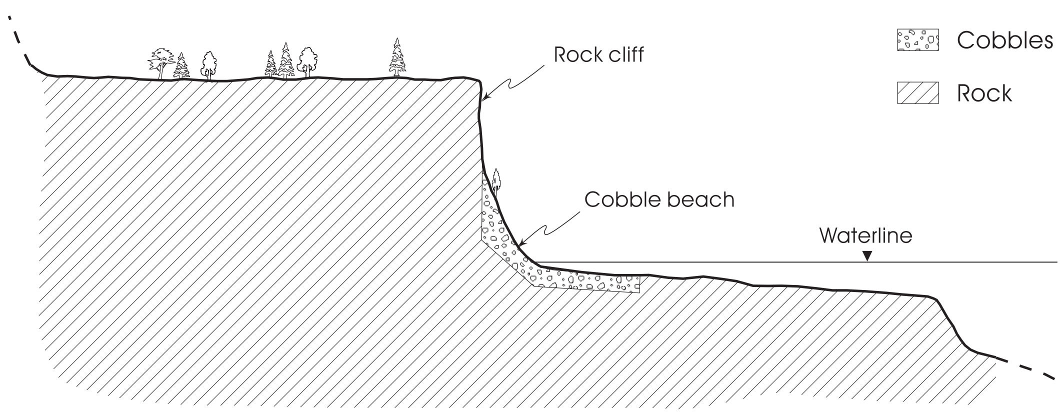
Example Location: No example

No example of a cobble partial headland beach backed by a cliff/bluff was identified along the *Great Lakes - St. Lawrence River System* shoreline. Examples of this class are rare and it is included primarily to maintain the symmetry of the classification scheme. Figure A5.1.4 shows a hypothetical plan view and profile of a cobble partial headland beach backed by a cliff/bluff.

Figure A5.1.4: Cobble Partial Headland Beach backed by a Cliff/Bluff (1-2-1)



a) Hypothetical Plan View



b) Hypothetical Profile

1-2-3 Sandy Partial Headland Beach backed by a Cliff/Bluff

Example Location: Amberley Beach, South of Point Clark, Lake Huron (site 1 on Figure A5.1.1)

The sandy beach at Amberley Beach, just south of Point Clark (Figure A5.1.5), is 20-40 m wide and is backed by 15-20m high cohesive sediment bluffs that are eroding at 0.0-0.1 m/yr on average. These bluffs are well vegetated and are subject to wave action only at extreme high water levels. These beaches are very dynamic and are subject to rapid change during storms. Figure A5.1.6 shows an aerial view of the beach. A generalized profile of the beach is illustrated in Figure A5.1.7. Figure A5.1.8 is a photograph of the site.

c) Exposed Beaches

This grouping of beach environments includes the following dynamic beach sub-classifications:

- **1-3-1 Cobble Exposed Beach backed by a Cliff or Bluff**
- **1-3-3 Sandy Exposed Beach backed by a Cliff or Bluff**

Typical factors to be considered when dealing within these dynamic beach sub-classifications include the following:

- Since waves can reach exposed beach shorelines from a wide range of directions, exposed beaches tend to experience a greater number of days impacted by high waves than is normally experienced on other shorelines. As such, changes in beach topography may occur more frequently on exposed beaches. In addition, exposed beaches tend to have a higher total (i.e., gross) sediment transport rate than other shorelines. Most exposed shorelines, where there is sediment available, are best evaluated within the framework of a littoral cell. The long-term stability of exposed beaches is dependent on whether the reach is located within the updrift (i.e., erosional) end of the cell or the downdrift (i.e., depositional) end of the littoral cell. In either case, the stability of the shoreline is sensitive to changes in the supply of sediment from updrift.

- Where the beach is backed by a cliff or bluff, the landward limit of the *dynamic beach hazard* should be placed at the toe of the cliff/bluff. If the beach is backed by an erodible bluff and there are signs of toe erosion or bluff instability, the landward limit of the *dynamic beach hazard* should not be reduced. In areas where the slope at the back of the beach is developed in resistant bedrock (i.e., a cliff rather than a bluff) studies using accepted scientific and engineering principles may show that it is possible to reduce the landward limit of the *dynamic beach hazard* to permit development at the base of the cliff. Situations where development could possibly be considered may include:

  - a partial profile with the extent of the dynamic beach response limited by underlying bedrock;

  - a relatively steep profile landward of the beach, resulting in elevations near the cliff toe being well above the *flooding hazard* (i.e., this may occur in areas that are still experiencing isostatic uplift); and

  - the development is to be sited landward of the maximum extent of wave action during the high water periods of 1972-73 and 1985-86 and the recession rate is zero.

- The dynamic range of cobble beaches is generally less than that of sandy beaches with similar exposure for two reasons: 1) their greater beach slope; and 2) the rate of adjustment to wave action is generally much slower for cobble beaches than for sandy beaches. Where field inspection or studies show that the elevation of the backshore is well above the wave uprush limit it may be possible to reduce the landward

Figure A5.1.5: Location Plan of Amberley Beach (1-2-3)

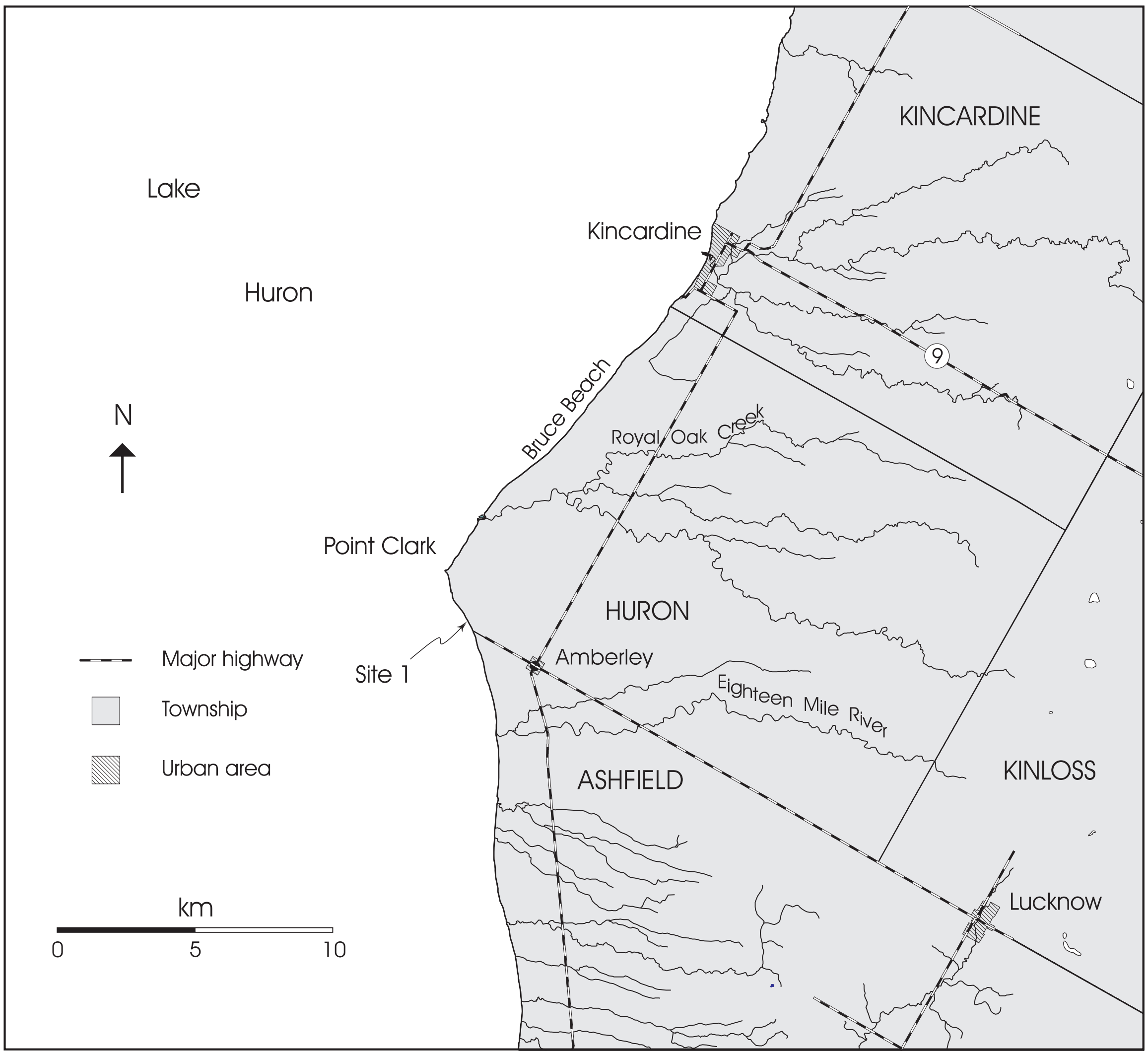


Figure A5.1.6: Aerial Photograph of Amberley Beach (1-2-3)

Box represents approximate location of profile and photograph

Figure A5.1.7: Generalized Profile of Amberley Beach (1-2-3)

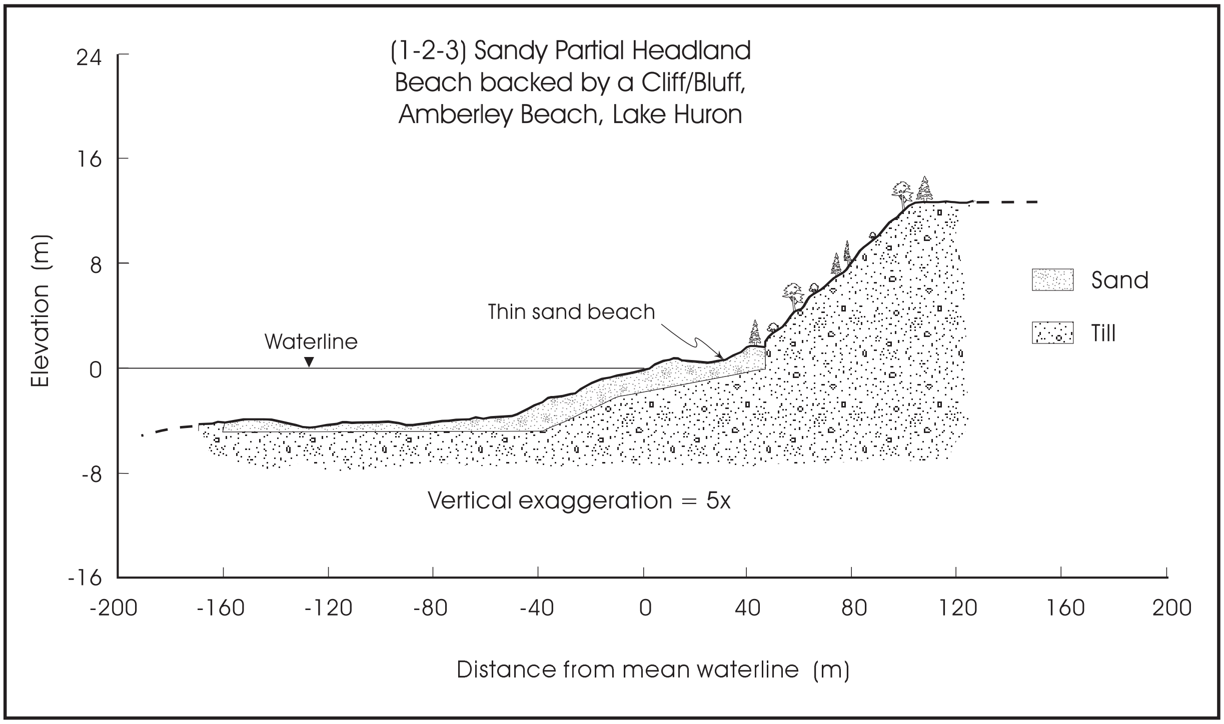


Figure A5.1.8: Photograph of Amberly Beach (1-2-3)

limit of the *dynamic beach hazard* by as much as 10 metres. However, care should be taken to ensure that any reduction in the landward limit of the *dynamic beach hazard* is still landward of the furthest landward limit of wave and/or ice action as indicated by historical evidence, sedimentological and/or vegetational evidence found in the field. In these cases, there should be evidence that the toe of the bluff/cliff is stable and that it has not been subject to wave attack in the past 30-40 years. A reduction in the *dynamic beach hazard* should not be permitted on cobble beaches exposed to fetch lengths of greater than 100 kilometres should only be permitted after careful study and review using accepted scientific and engineering principles.

- In most cases where there is a sandy beach backed by a bluff, the bluff is normally recessional and there is little or no sand dune development. In some transitional areas a narrow field of dunes may be present between the beach and the bluff toe. Since these shorelines are highly vulnerable to changes in the supply from updrift, development should not be permitted within the dune area unless:

    - it can be shown that the development will be outside of the *dynamic beach hazard*; <u>and</u>

    - that there is some other constraint or factor limiting the rate of erosion, such as resistant bedrock, limiting the extent of vertical erosion and horizontal recession of the bluff.

The following provides an example of each of these dynamic beach sub-classifications.

<u>1-3-1 Cobble Exposed Beach backed by a Cliff/Bluff</u>

Example Location: Cape Dundas, Bruce Peninsula, Georgian Bay (site 2 on Figure A5.1.1)

Cape Dundas is an exposed rock headland on the west shore of Georgian Bay, Lake Huron (Figure A5.1.9). The beach adjacent to the rock cliff is composed primarily of cobbles. The beach is quite narrow (e.g., 10-20 m) and steep. Isostatic uplift has raised the beach deposits directly adjacent to the cliff well above the modern lake level. Most of the cobble material was probably derived from the reworking of post-glacial sediments with some limited supply from talus supplied to the base of the cliff. New sediment input is now very limited. Figure A5.1.10 shows an aerial view of the site. A generalized profile of the beach is illustrated in Figure A5.1.11. Figure A5.1.12 is a photograph of the site.

<u>1-3-3 Sandy Exposed Beach backed by a Cliff/Bluff</u>

Example Location: Horizon View, Lake Huron (site 3 on Figure A5.1.1)

The sandy beaches just north of Horizon View (Figure A5.1.13) are 10 to 20 m wide and are backed by 15 to 20 m high cohesive sediment bluffs that are eroding at 0.5 to 1.0 m/yr on average. These bluffs have limited vegetation cover and are subject to significant mass wasting (i.e., erosion by shallow slides, slumps, and water). They are the primary source of sediment for the nearshore zone along this section of Lake Huron's shoreline. The sandy beaches in this area are 0.2 to 1.5 m thick and include a cobble component in most cases. These beaches are very dynamic and are subject to rapid change during storms. Figure A5.1.14 shows an aerial view of the site. A generalized profile of the beach is illustrated in Figure A5.1.15. Figure A5.1.16 is a photograph of the site.

Figure A5.1.9: Location Plan of Cape Dundas (1-3-1)

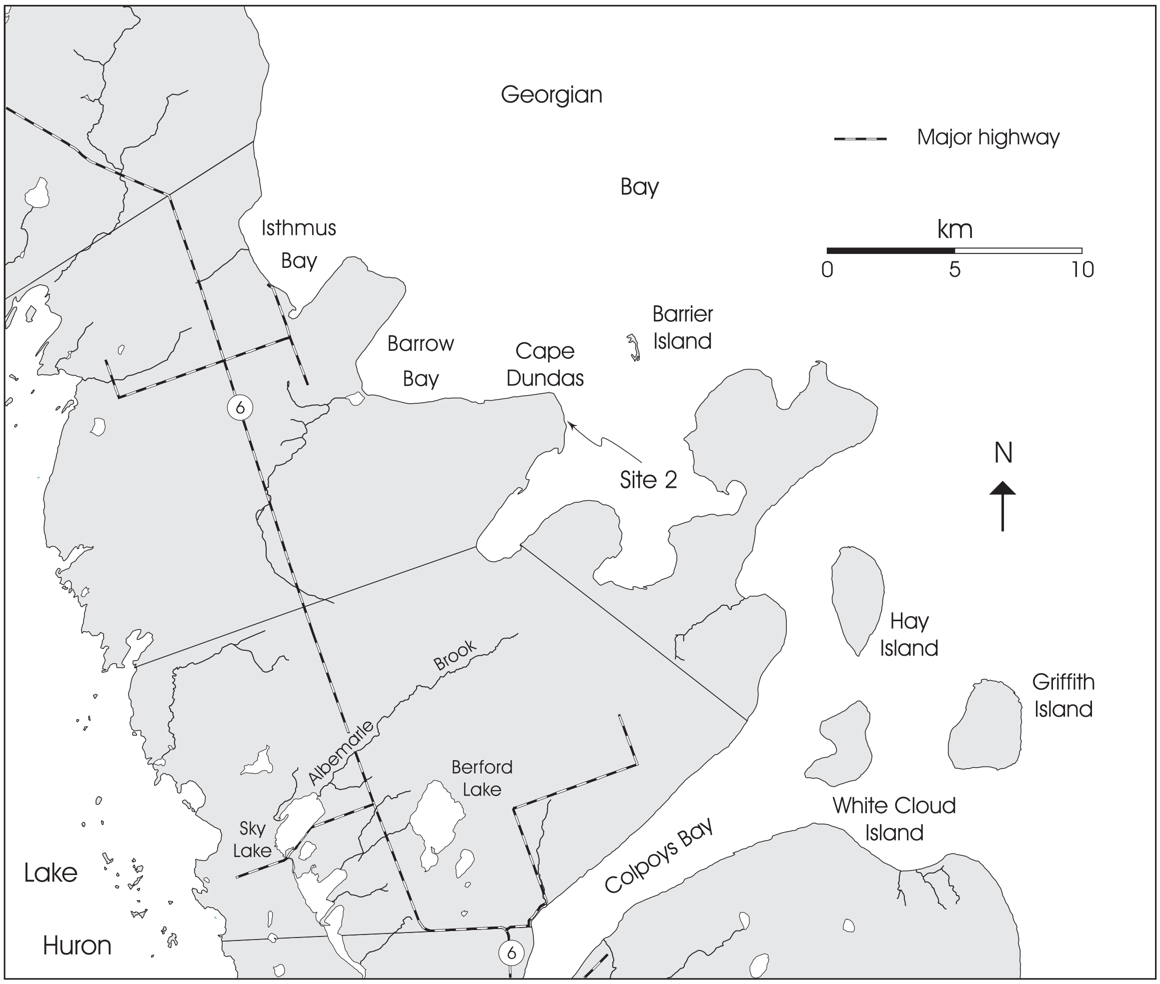
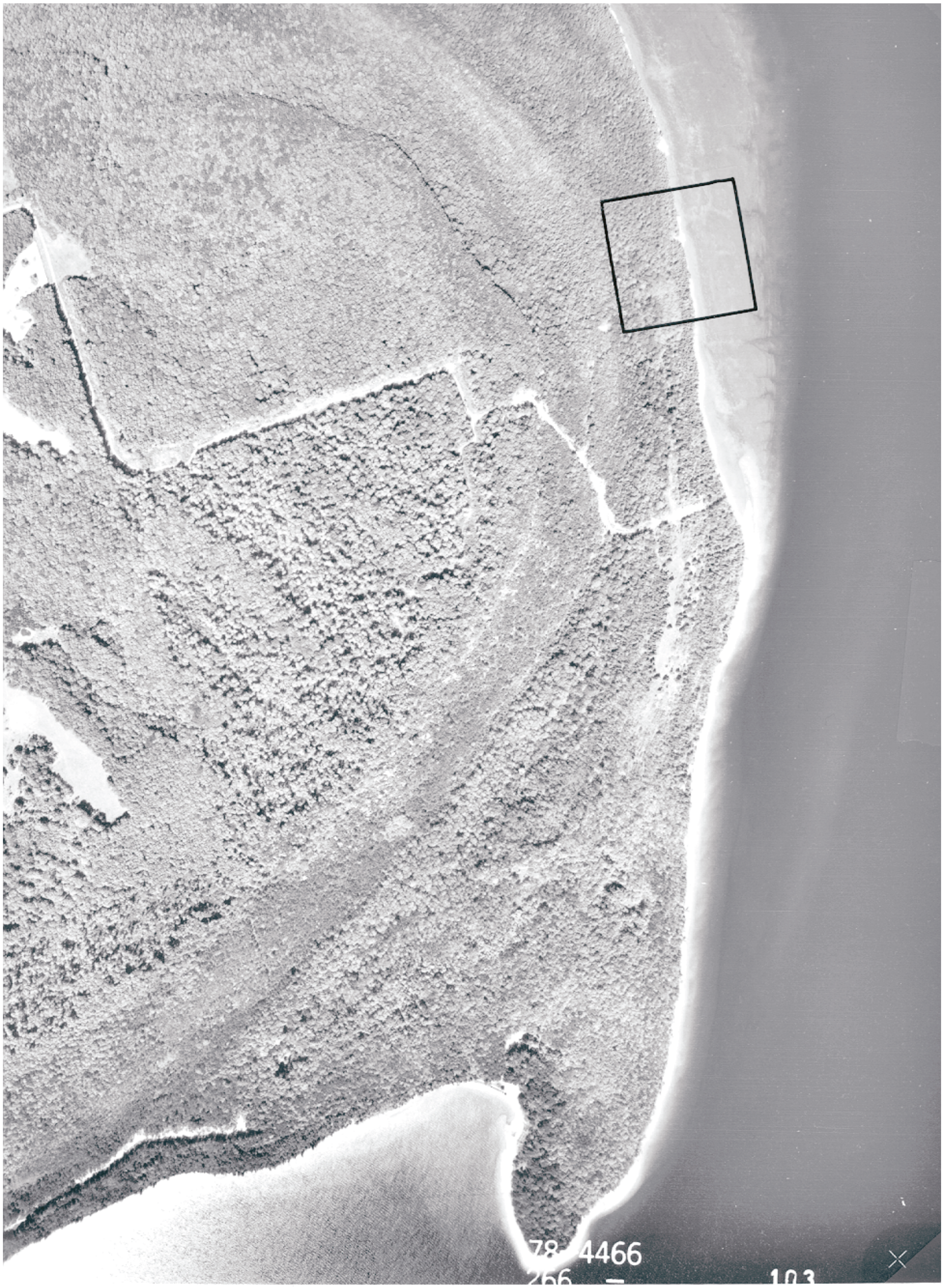


Figure A5.1.10: Aerial Photograph of Cape Dundas (1-3-1)



Box represents approximate location of profile and photograph

Figure A5.1.11: Generalized Profile of Cape Dundas (1-3-1)

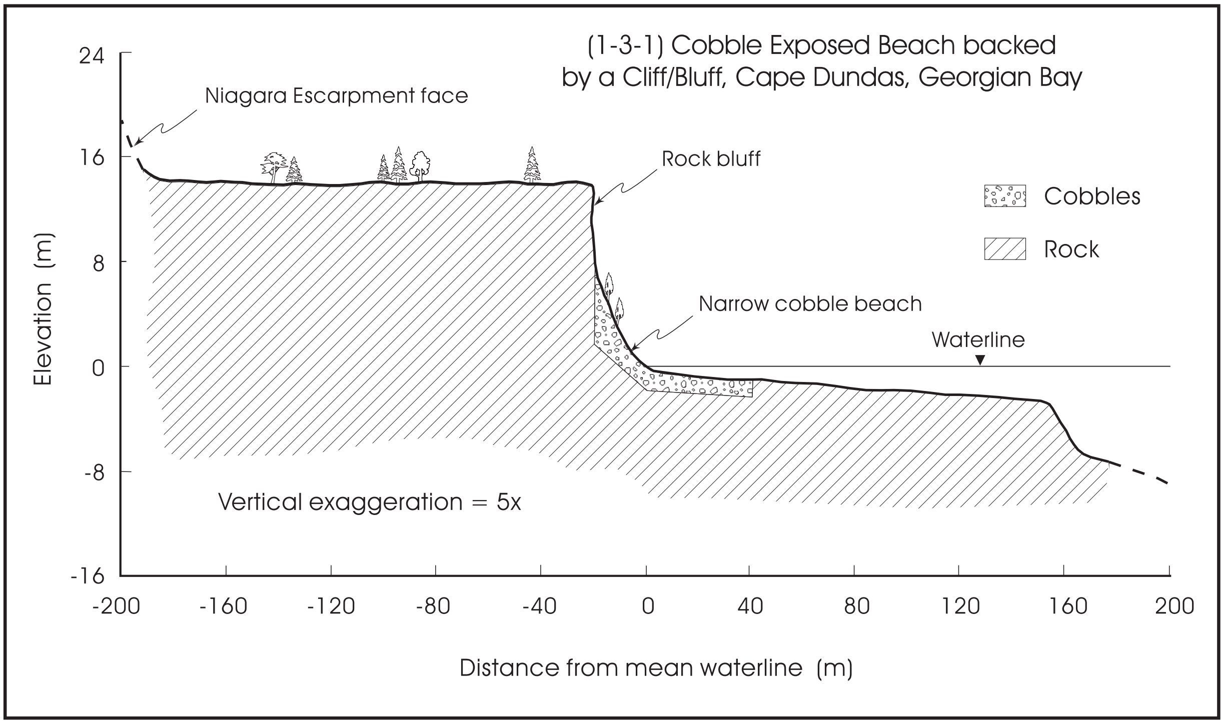


Figure A5.1.12: Photograph of Cape Dundas (1-3-1)

Figure A5.1.13: Location Plan of Horizon View (1-3-3)

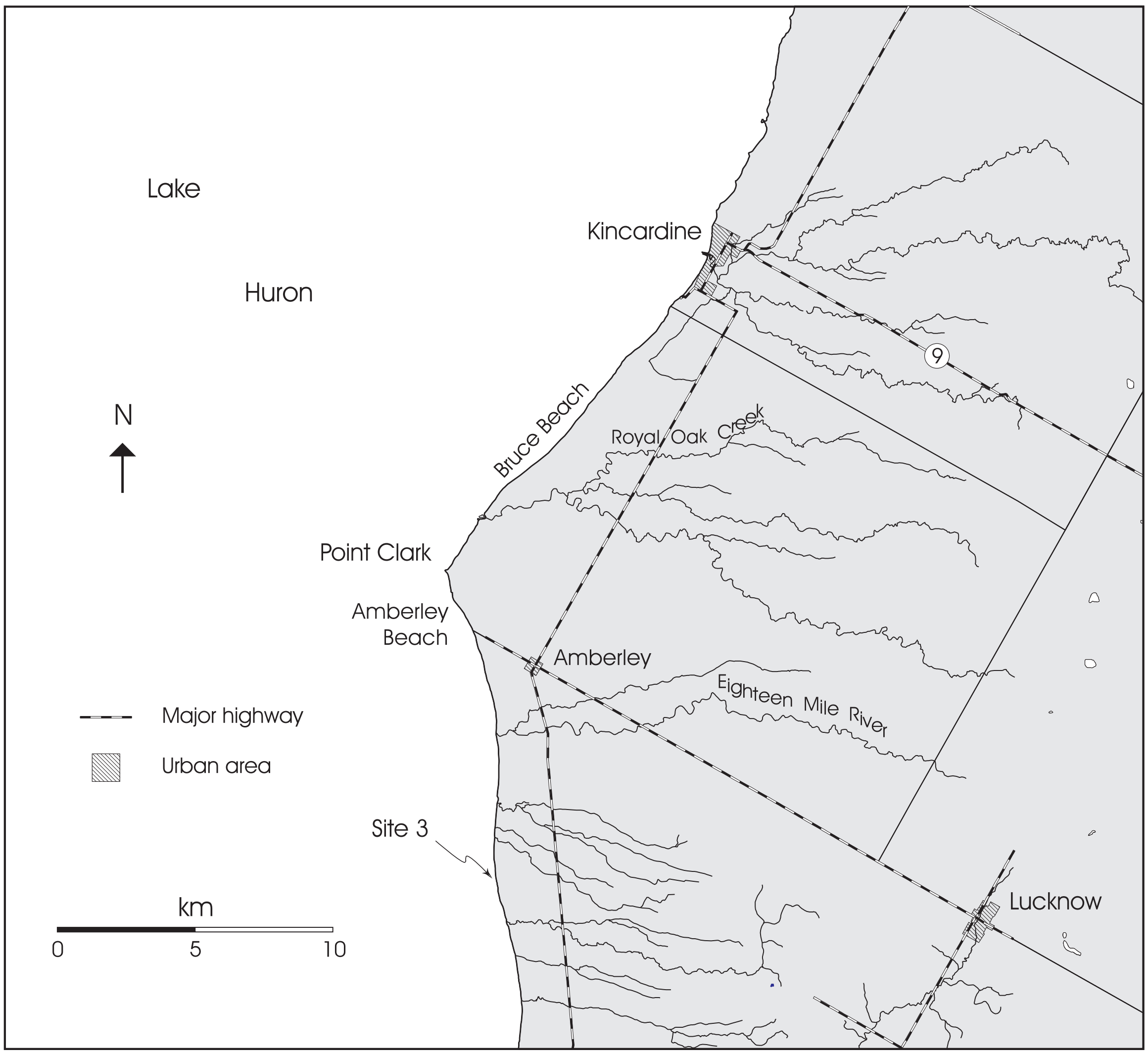


Figure A5.1.14: Aerial Photograph of Horizon View (1-3-3)

Box represents approximate location of profile and photograph

Figure A5.1.15: Generalized Profile of Horizon View (1-3-3)

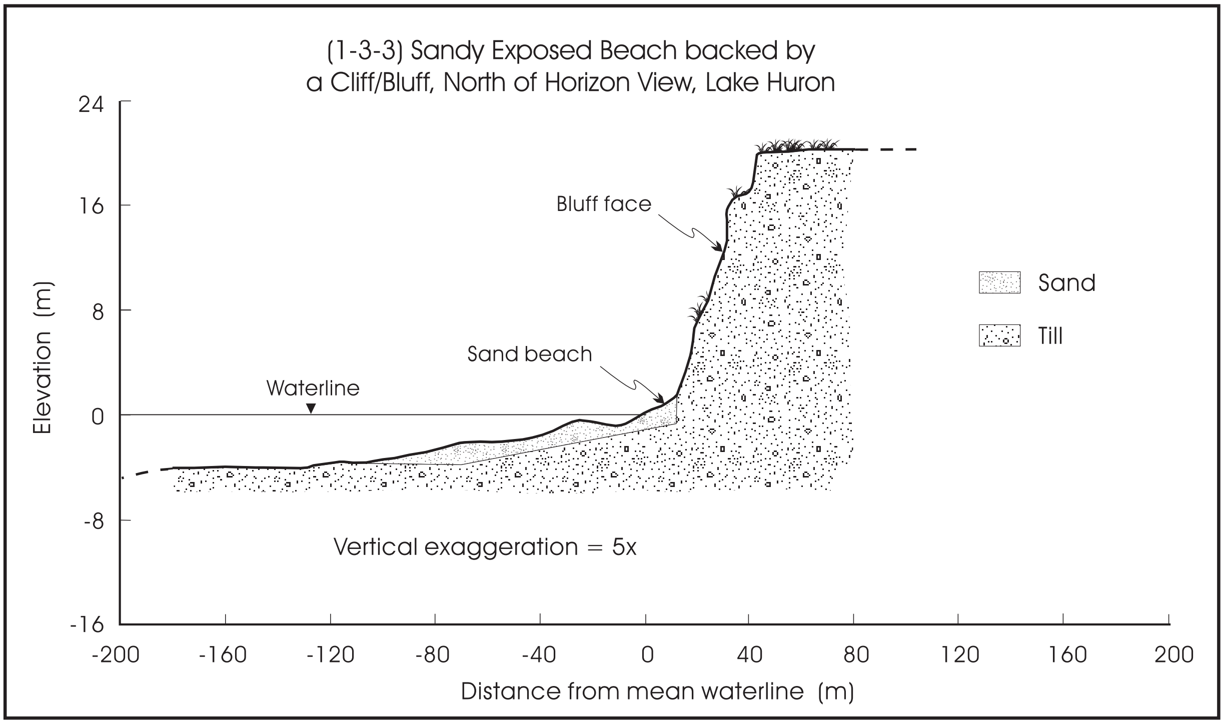


Figure A5.1.16: Photograph of Horizon View (1-3-3)

A5.1.2 Low Plain Beaches

a) Headland-Bay Beaches

This grouping of beach environments includes the following dynamic beach sub-classifications:

- **2-1-1 Cobble Headland-Bay Beach backed by a Low Plain**
- **2-1-3 Sandy Headland-Bay Beach backed by a Low Plain**

Typical factors to be considered when dealing within these dynamic beach sub-classifications include the following:

- Headlands restrict waves to a narrow range of directions. Most waves arrive nearly perpendicular to the beach shoreline at the head of the bay. Potential sediment transport is along the sides towards head of the bay. As a result, sediment is trapped within the bay and in most cases losses of sediment from the bay are small. Most headland-bay beaches are stable or accretional. In these areas, locating developments behind or landward of the *dynamic beach hazard* limit is the most effective means of protecting the development against flooding and wave damage. Where developments are located landward of the *dynamic beach hazard* limit the need for shoreline protection works should be precluded. Where the proposed development includes uses such as marinas which by nature must be located in close proximity to the water's edge, care should be taken in their approval, siting and design.

- Where the sides of the bay are formed in erodible material or where there is sediment input from rivers, alongshore sediment transport will occur towards the head of the bay. In these situations, there is the potential for interruptions in sediment transport due to the construction of shore protection or marinas. For this reason, proposals for new development should be examined carefully to ensure that the interruption of the alongshore sediment transport does not occur. In addition, there may also be some long-term recession due to erosion which would then require addressing in the development proposal.

- The dynamic range of cobble beaches is generally less than that of sandy beaches with similar exposure for two reasons: 1) their steeper beach slope; and 2) the rate of adjustment to wave action is generally much slower for cobble beaches than for sandy beaches. Where field inspection or studies show that the elevation of the backshore is well above the wave uprush limit it may be possible to reduce the landward limit of the *dynamic beach hazard* by as much as 10 metres. However, care should be taken to ensure that any reduction in the landward limit of the *dynamic beach hazard* is still landward of the furthest landward limit of wave and/or ice action as indicated by historical evidence, sedimentological and/or vegetational evidence found in the field. In these cases, there should be evidence that the toe of the cliff/bluff is stable and that it has not been subject to wave attack in the past 30-40 years. A reduction in the *dynamic beach hazard* should not be permitted on cobble beaches exposed to fetch lengths of greater than 100 km should be permitted only after careful study and review using accepted scientific and engineering principles.

- The standard 30 metre erosion allowance should be adequate enough to provide protection against wave activity on most of the sandy beaches under this classification. Locations where the 30 metre erosion allowance may not provide sufficient protection may include the very large shoreline bays (e.g., Nottawasaga Bay) where the headlands are so far apart that there is more scope for alongshore sediment movement at the head of the bay. Where dunes are formed, it is recommended that the landward limit of the *dynamic beach hazard* be adjusted to ensure that it lies landward of the base of the leeward slope of the main foredune in order to maintain the integrity of the dune and to protect the development landward of the main foredune. In small, well-protected bays where wave action tends to be limited and dunes are small (i.e., less than 2 m in height), studies using accepted scientific and engineering principles may show that the landward limit of the *dynamic beach hazard* could be safely be reduced.

The following provides an example of each of these dynamic beach sub-classification.

<u>2-1-1 Cobble Headland-Bay Beach backed by a Low Plain</u>

Example Location: Barrow Bay, Bruce Peninsula, Georgian Bay (site 4 on Figure A5.1.1)

This cobble beach lies at the head of Barrow Bay protected by the Cape Dundas and Lion's Head headlands (Figure A5.1.17). The beach began as a cobble barrier enclosing a small bay/pond. However, isostatic uplift has raised the beach deposit well above the modern lake level so that there is now no possibility of overwash. As a result, the older barrier deposits act now as a lowland shore. Much of the cobble material was probably derived from the reworking of post-glacial sediments with some limited supply from talus supplied by the adjacent headlands. New sediment supply is very limited. Figure A5.1.18 shows an aerial view of the beach. A generalized profile of the beach is illustrated in Figure A5.1.19. Figure A5.1.20 is a photograph of the site.

<u>2-1-3 Sandy Headland-Bay Beach backed by a Low Plain</u>

Example Location: West side of Beckwith Island, Georgian Bay (site 5 on Figure A5.1.1)

A wide, low, headland-bay sandy beach is found on the west side of Beckwith Island, Georgian Bay (Figure A5.1.21). The beach is primarily sand although some cobbles may also be present. This is a very protected beach with no alongshore sediment transport into or out of the bay. The beach is backed by small vegetated dunes. Offshore several parallel bars are present. Figure A5.1.22 shows an aerial view of the site. A generalized profile of the beach is illustrated in Figure A5.1.23.

b) Partial Headland Beaches

This grouping of beach environments includes the following dynamic beach sub-classifications:

- **2-2-1 Cobble Partial Headland Beach backed by a Low Plain**
- **2-2-3 Sandy Partial Headland Beach backed by a Low Plain**

Typical factors to be considered when dealing within these dynamic beach sub-classifications include the following:

- The partial headland and associated log-spiral beach usually occurs on a shoreline where there is a well-defined direction of net alongshore sediment transport. The headland at the updrift end of each reach provides some shelter from waves from the updrift direction, usually the longest fetch, and the downdrift beach tends to be aligned quite closely to the resultant wave direction. The headlands provide some measure of stability and erosion and shoreline recession will generally be controlled by the rate of erosion of the headland. In resistant bedrock the rate of erosion is likely to be negligible, however, in relatively weak shales and thinly-bedded limestones it may be on the order of 0.05-0.1 m/yr. Beaches formed in either of these sub-classifications are considered to be intermediate, between Headland-Bay beach and Exposed beach sub-classifications, in terms of their sensitivity to interruptions in updrift sediment supply.

- The dynamic range of cobble beaches is generally less than that of sandy beaches with similar exposure for two reasons: 1) their steeper beach slope; and 2) the rate of adjustment to wave action is generally much slower for cobble beaches than for sandy beaches. Where field inspection or studies show that the elevation of the backshore is well above the wave uprush limit it may be possible to reduce the landward limit of the *dynamic beach hazard* by as much as 10 metres. However, care should be taken to ensure that any reduction in the landward limit of the *dynamic beach hazard* is still landward of the furthest landward limit of wave and/or ice action as indicated by historical evidence, sedimentological and/or vegetational evidence found in the field. In these cases, there should be evidence that the toe of the cliff/bluff is stable and that it has not been subject to wave attack in the past 30-40 years. A reduction in the *dynamic beach hazard* should not be permitted on cobble beaches exposed to fetch lengths of greater than 100 kilometres should be permitted only after careful study and review using accepted scientific and engineering principles.

Figure A5.1.17: Location Plan of Barrow Bay (2-1-1)

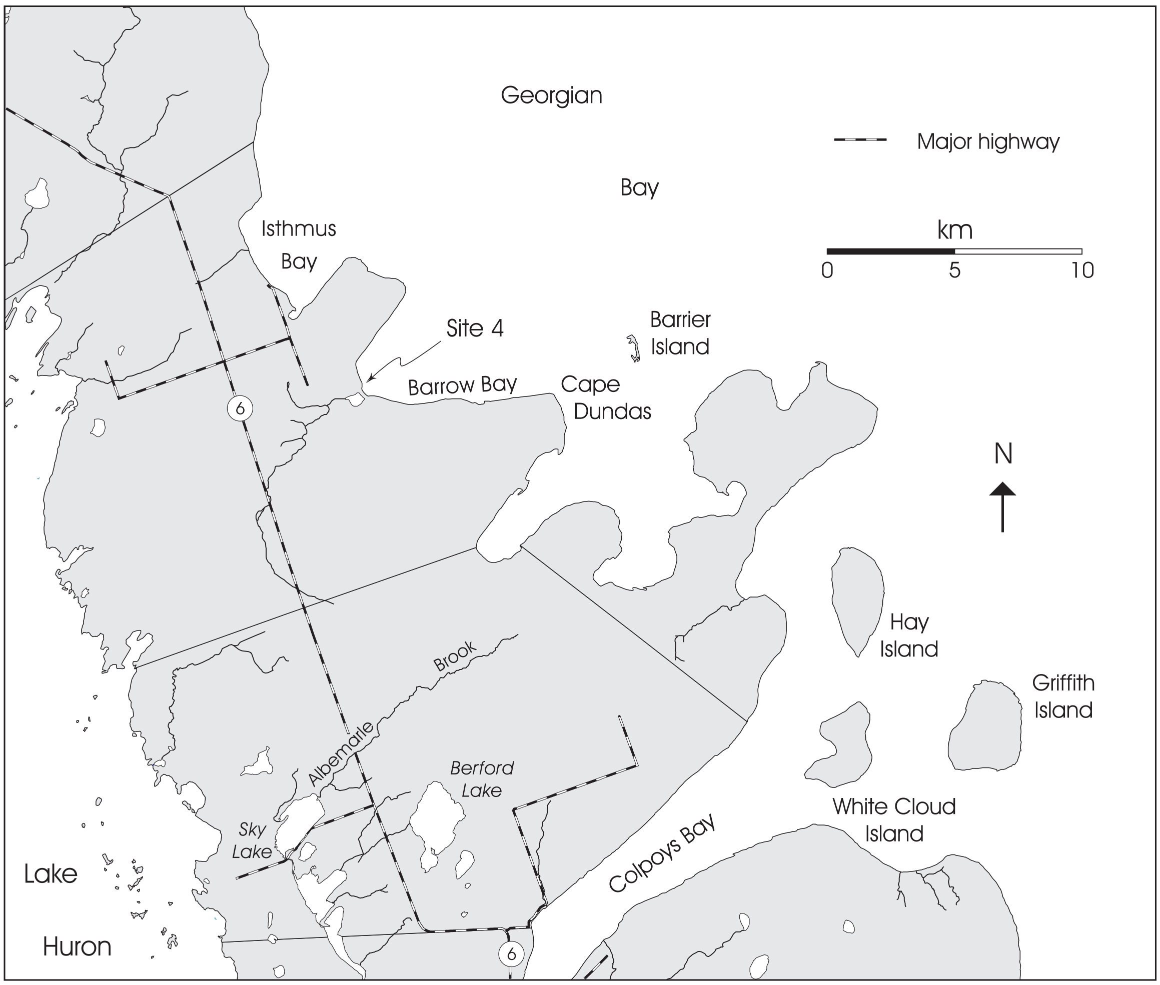


Figure A5.1.18: Aerial Photograph of Barrow Bay (2-1-1)

Box represents approximate location of profile and photograph

Figure A5.1.19: Generalized Profile of Barrow Bay (2-1-1)

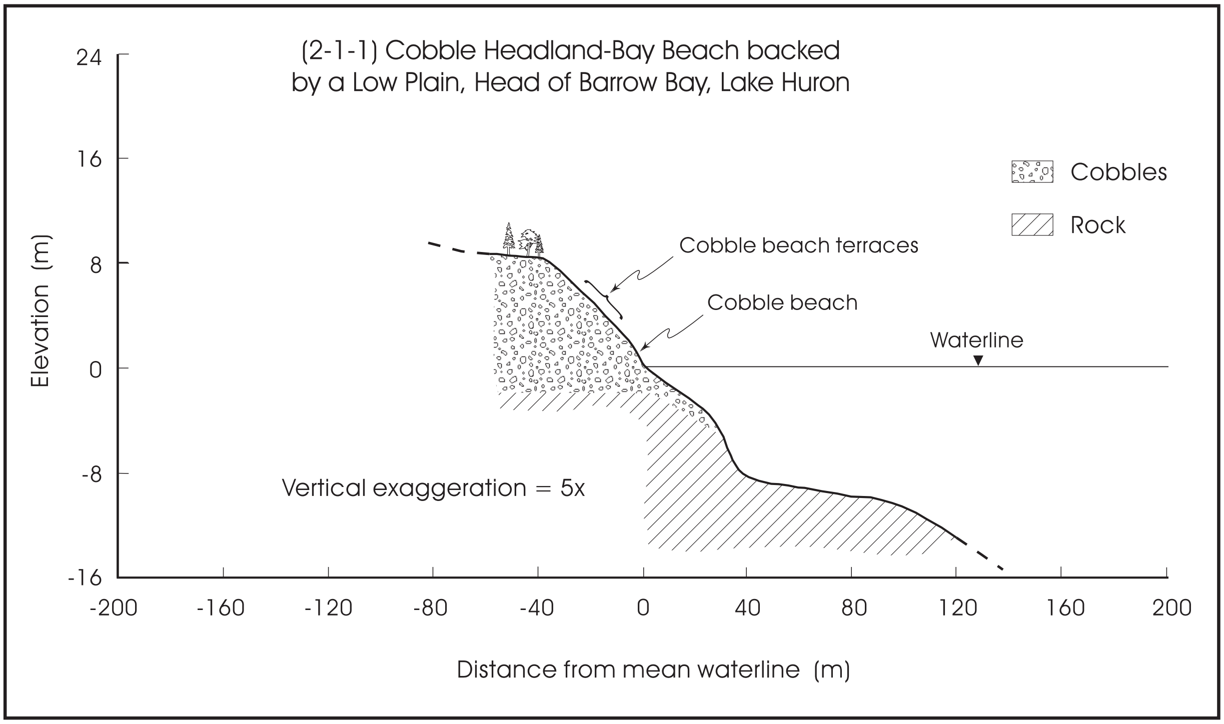


Figure A5.1.20: Photograph of Barrow Bay (2-1-1)

Figure A5.1.21: Location Plan of West Side of Beckwith Island (2-1-3)

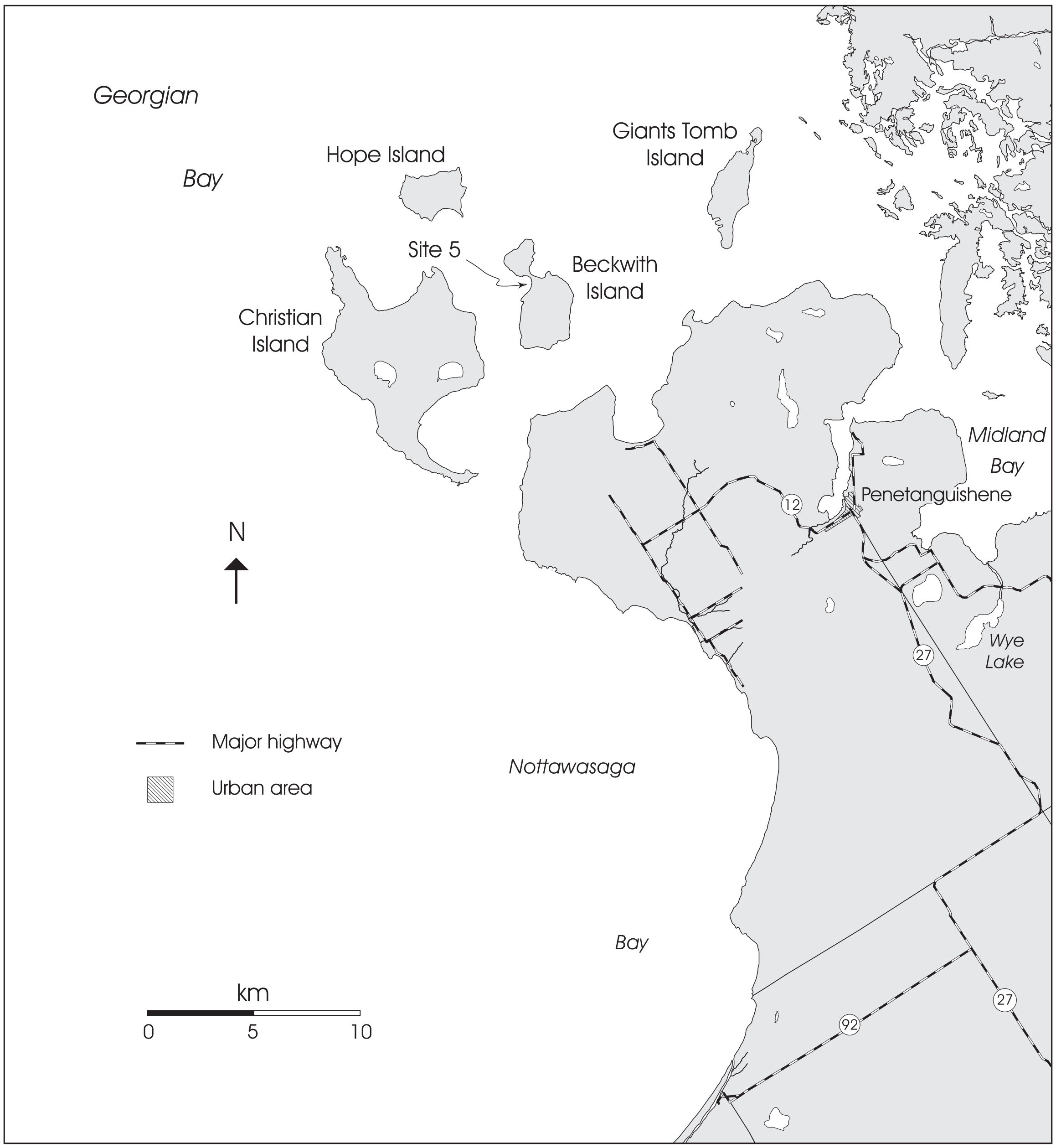
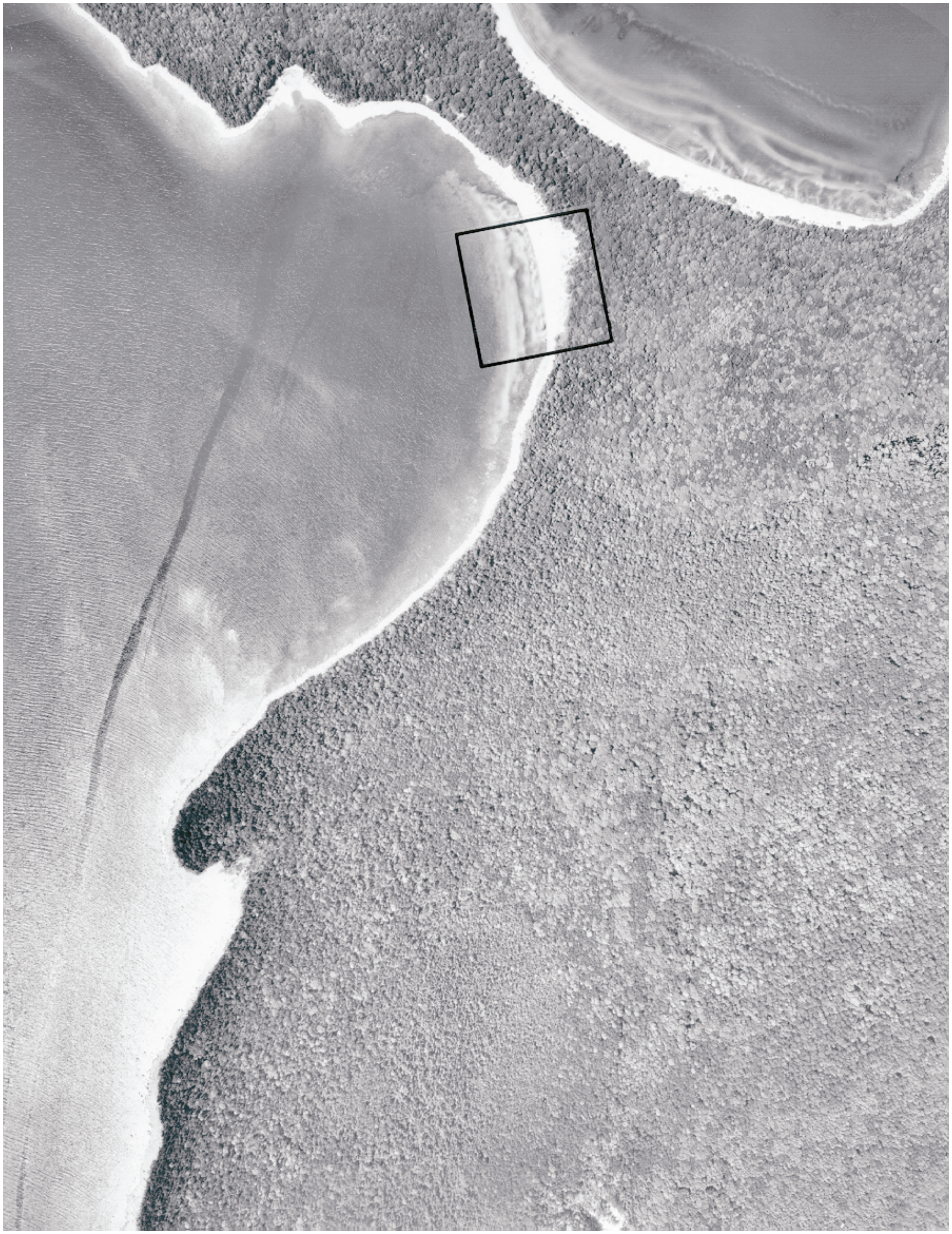
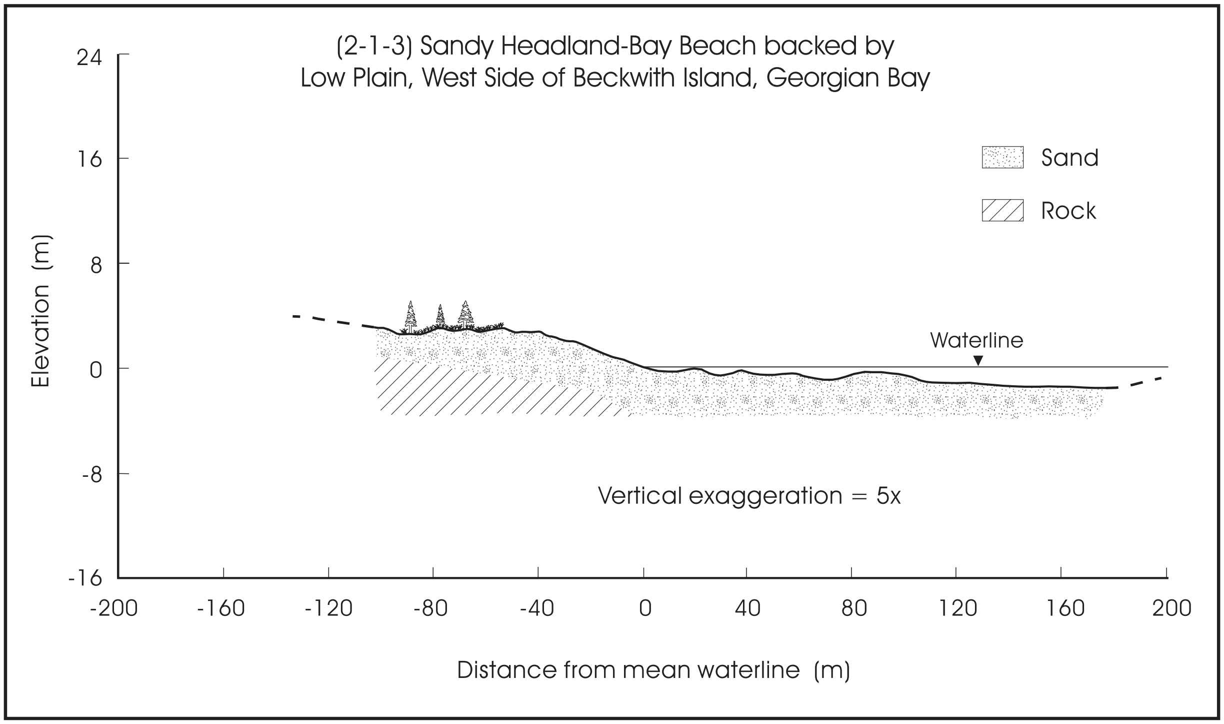


Figure A5.1.22: Aerial Photograph of West Side of Beckwith Island (2-1-3)



Box represents approximate location of profile and photograph

Figure A5.1.23: Generalized Profile of West Side of Beckwith Island (2-1-3)



- The standard 30 metre erosion allowance should be adequate enough to provide protection against wave activity on most of the sandy beaches under this classification. Where dunes are formed, it is recommended that the landward limit of the *dynamic beach hazard* be adjusted to ensure that it lies landward of the base of the leeward slope of the main foredune in order to maintain the integrity of the dune and to protect the development landward of the main foredune. In addition, consideration should be given to the development of a dune conservation plan for the defined section of shoreline to reduce the potential impact(s) of human activities on the stabilizing dune vegetation.

The following provides an example of each of these dynamic beach sub-classifications.

2-2-1 Cobble Partial Headland Beach backed by a Low Plain

Example Location: Presqu'ile Point, Owen Sound, Georgian Bay (site 6 on Figure A5.1.1)

This example site is a low plain, log-spiral, cobble beach located on the west shore of Owen Sound, Georgian Bay (Figure A5.1.24). The beach is quite steep adjacent to the water and the active portion of the beach is relatively narrow. The whole beach is lying over a bedrock platform which likely controls the plan morphology of the beach. Most of the cobbles in the beach are likely relict glacio-fluvial sediments with some sediment being added occasionally from bedrock outcrops north of the beach. Figure A5.1.25 shows an aerial view of Presqu'ile Point beach. A generalized profile of the beach is illustrated in Figure A5.1.26. Figure A5.1.27 is a photograph of the site.

2-2-3 Sandy Partial Headland Beach backed by a Low Plain

Example Location: Ossossane Beach, Nottawasaga Bay, Georgian Bay (site 7 on Figure A5.1.1)

Ossossane Beach is a perfect example of a low plain, log-spiral sandy beach protected by a partial headland. A location plan of Ossossane Beach is shown in Figure A5.1.28. The beach is relatively wide (i.e., 40 to 60 m) and is well protected by the headland to the north. It slopes gently into Nottawasaga Bay and has several parallel bars present in the nearshore. Well vegetated 2 to 3 m high dunes exist behind the beach, evidence of the abundant sediment supply along this shoreline. Figure A5.1.29 shows an aerial view of the beach. A generalized profile of the beach is illustrated in Figure A5.1.30. Figure A5.1.31 is a photograph of the beach.

c) Exposed Beaches

This grouping of beach environments includes the following dynamic beach sub-classifications:

- **2-3-1 Cobble Exposed Beach backed by a Low Plain**
- **2-3-3 Sandy Exposed Beach backed by a Low Plain**

Typical factors to be considered when dealing within these dynamic beach sub-classifications include the following:

- Since waves can reach exposed beach shorelines from a wide range of directions, exposed beaches tend to experience a greater number of days impacted by high waves than is normally experienced on other shorelines. As such, changes in beach topography may occur more frequently on exposed beaches. In addition, exposed beaches tend to have a higher total (i.e., gross) sediment transport rate than other shorelines. Most exposed shorelines, where there is sediment available, are best evaluated within the framework of a littoral cell. The long-term stability of exposed beaches is dependent on whether the reach is located within the updrift (i.e., erosional) end of the cell or the downdrift (i.e., depositional) end of the littoral cell. In either case, the stability of the shoreline is sensitive to changes in the supply of sediment from updrift.

Figure A5.1.24: Location Plan of Presqu'ile Point (2-2-1)

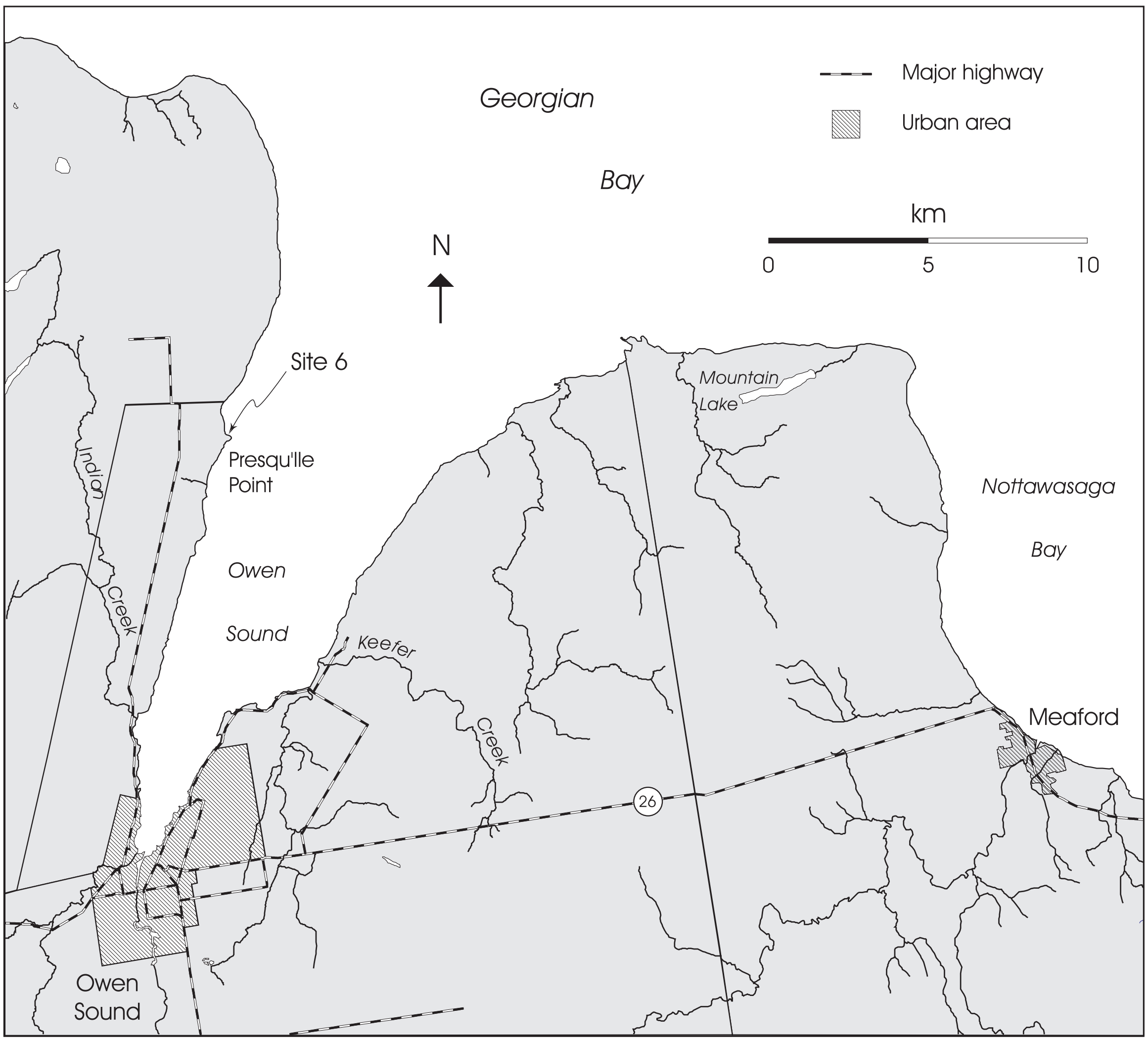


Figure A5.1.25: Aerial Photograph of Presqu'ile Point (2-2-1)

Box represents approximate location of profile and photograph

Figure A5.1.26: Generalized Profile of Presqu'ile Point (2-2-1)

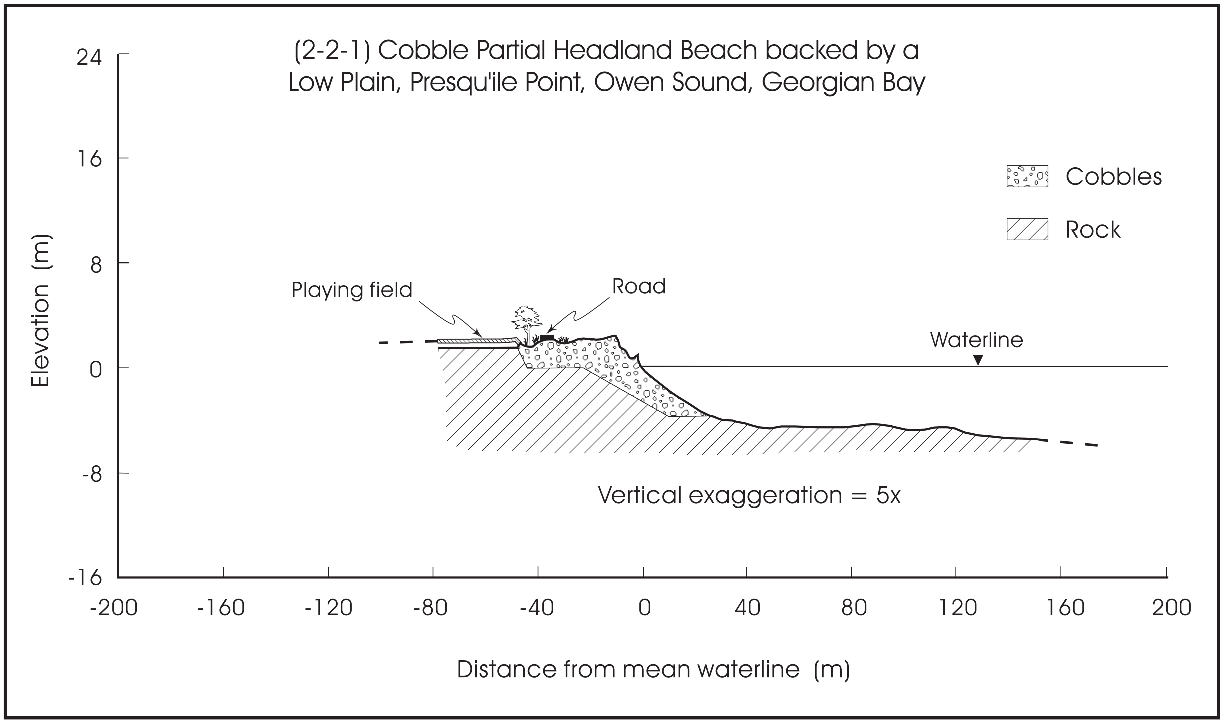


Figure A5.1.27: Photograph of Presqu'ile Point (2-2-1)

Figure A5.1.28: Location Plan of Ossossane Beach (2-2-3)

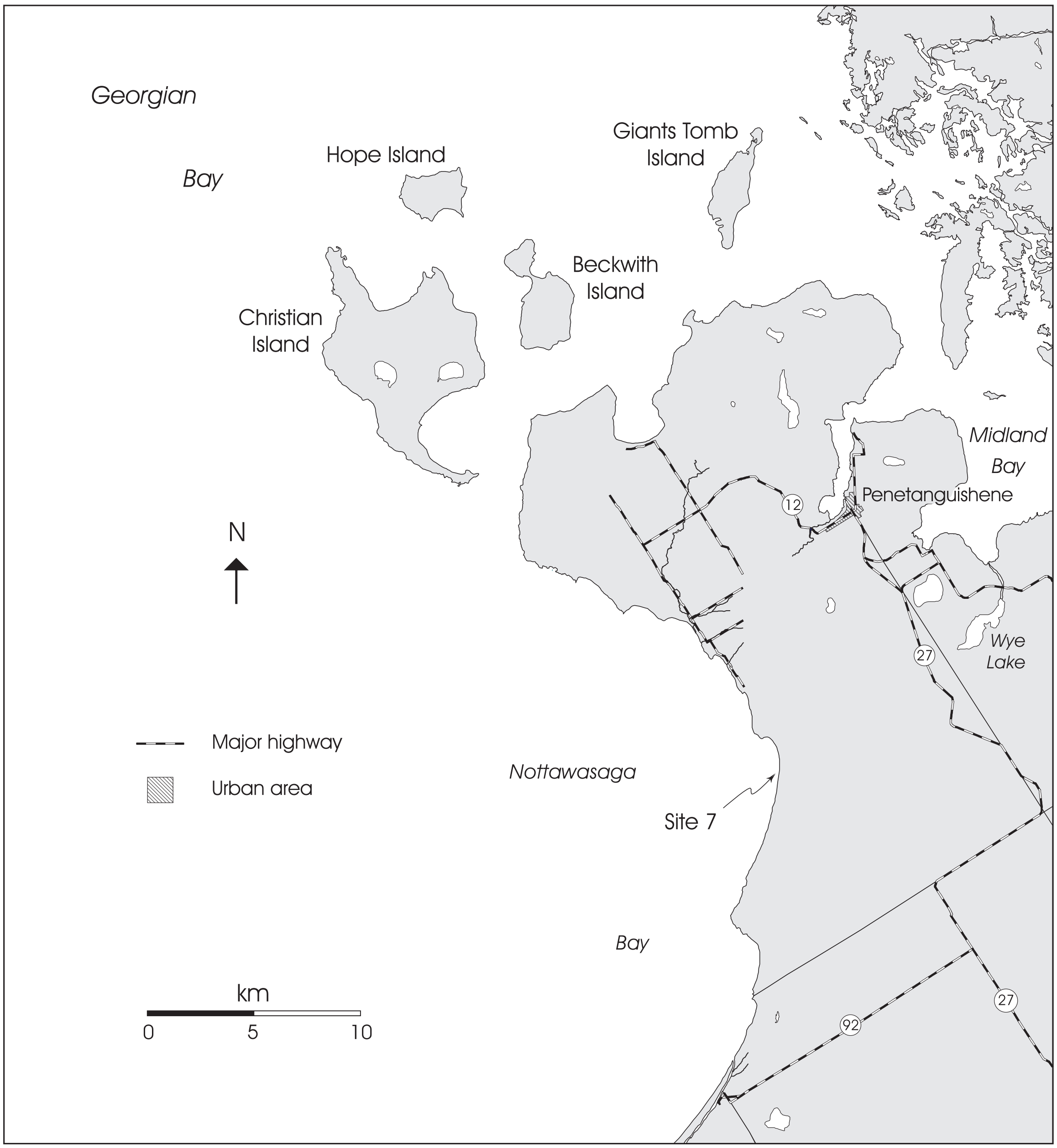


Figure A5.1.29: Aerial Photograph of Ossossane Beach (2-2-3)

Box represents approximate location of profile and photograph

Figure A5.1.30: Generalized Profile of Ossossane Beach (2-2-3)

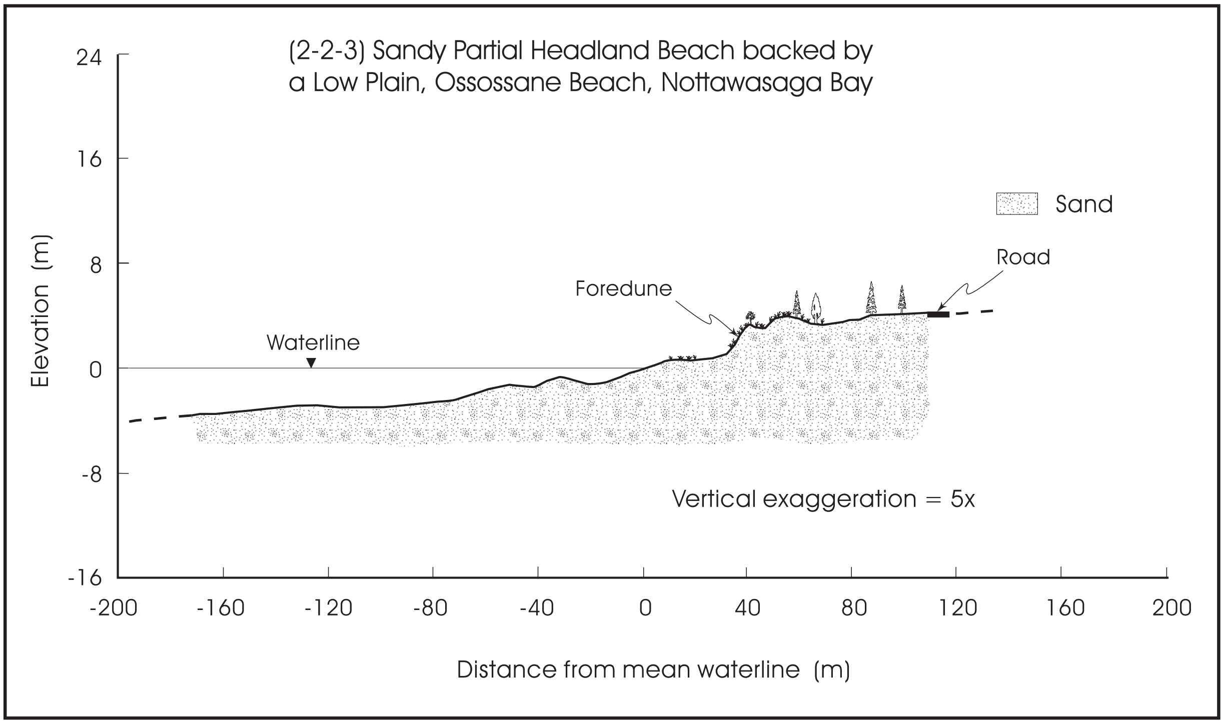


Figure A5.1.31: Photograph of Ossossane Beach (2-2-3)

- The dynamic range of cobble beaches is generally less than that of sandy beaches with similar exposure for two reasons: 1) their steeper beach slope; and 2) the rate of adjustment to wave action is generally much slower for cobble beaches than for sandy beaches. Where field inspection or studies show that the elevation of the backshore is well above the wave uprush limit it may be possible to reduce the landward limit of the *dynamic beach hazard* by as much as 10 metres. However, care should be taken to ensure that any reduction in the landward limit of the *dynamic beach hazard* is still landward of the furthest landward limit of wave and/or ice action as indicated by historical evidence, sedimentological and/or vegetational evidence found in the field. In these cases, there should be evidence that the toe of the cliff/bluff is stable and that it has not been subject to wave attack in the past 30-40 years. A reduction in the *dynamic beach hazard* should not be permitted on cobble beaches exposed to fetch lengths of greater than 100 kilometres should be permitted only after careful study and review using accepted scientific and engineering principles.

- The standard 30 metre erosion allowance should be adequate enough to provide protection against wave activity on most of the sandy beaches under this classification. Where dunes are formed, it is recommended that the landward limit of the *dynamic beach hazard* be adjusted to ensure that it lies landward of the base of the leeward slope of the main foredune in order to maintain the integrity of the dune and to protect the development landward of the main foredune. In addition, consideration should be given to the development of a dune conservation plan for the defined section of shoreline to reduce the potential impact(s) of human activities on the stabilizing dune vegetation.

The following provides an example of each of these dynamic beach sub-classifications.

<u>2-3-1 Cobble Exposed Beach backed by a Low Plain</u>

Example Location: Cypress Lake Area, Bruce Peninsula, Lake Huron (site 8 on Figure A5.1.1)

There are many large-scale, low plain, exposed, cobble beaches at the north end of the Bruce Peninsula, Lake Huron. Figure A5.1.32 shows the location of the beach at Cypress Lake. The beach is more than 50 m wide and rises over 7 m above the current mean lake level. The cobbles that comprise this beach are up to 0.3 m in diameter. They where likely derived from limestone bedrock outcrops that exist along this section of shoreline. There are numerous stranded beach ridges at the back of the beach, a result of isostatic uplift over the past few thousand years. The beaches are quite steep in this area and overlie narrow bedrock platforms. Figure A5.1.33 shows an aerial view of the site. A generalized profile of the beach is illustrated in Figure A5.1.34. Figure A5.1.35 is a photograph of the site.

<u>2-3-3 Sandy Exposed Beach backed by a Low Plain</u>

Example Location: Pinery Provincial Park, Lake Huron (site 9 on Figure A5.1.1)

The sediments deposited to form the beaches and dunes at Pinery Provincial Park have been, and are currently being, eroded from the bluffs north of the park. Figure A5.1.36 shows the location of the beach. The bluffs between Point Clark and Grand Bend, on Lake Huron, are 5 to 30 m high and primarily consist of glacial till. As these bluffs erode they contribute sediment to the nearshore zone which is then transported south (i.e., downdrift) along the shore. The low sandy beaches and extensive sand dunes at Pinery Provincial Park are maintained by this supply of sediment from the north. Figure A5.1.37 shows an aerial view of the site. A generalized profile of the beach is illustrated in Figure A5.1.38. Figure A5.1.39 is a photograph of the site.

Figure A5.1.32: Location Plan of Cypress Lake Area (2-3-1)

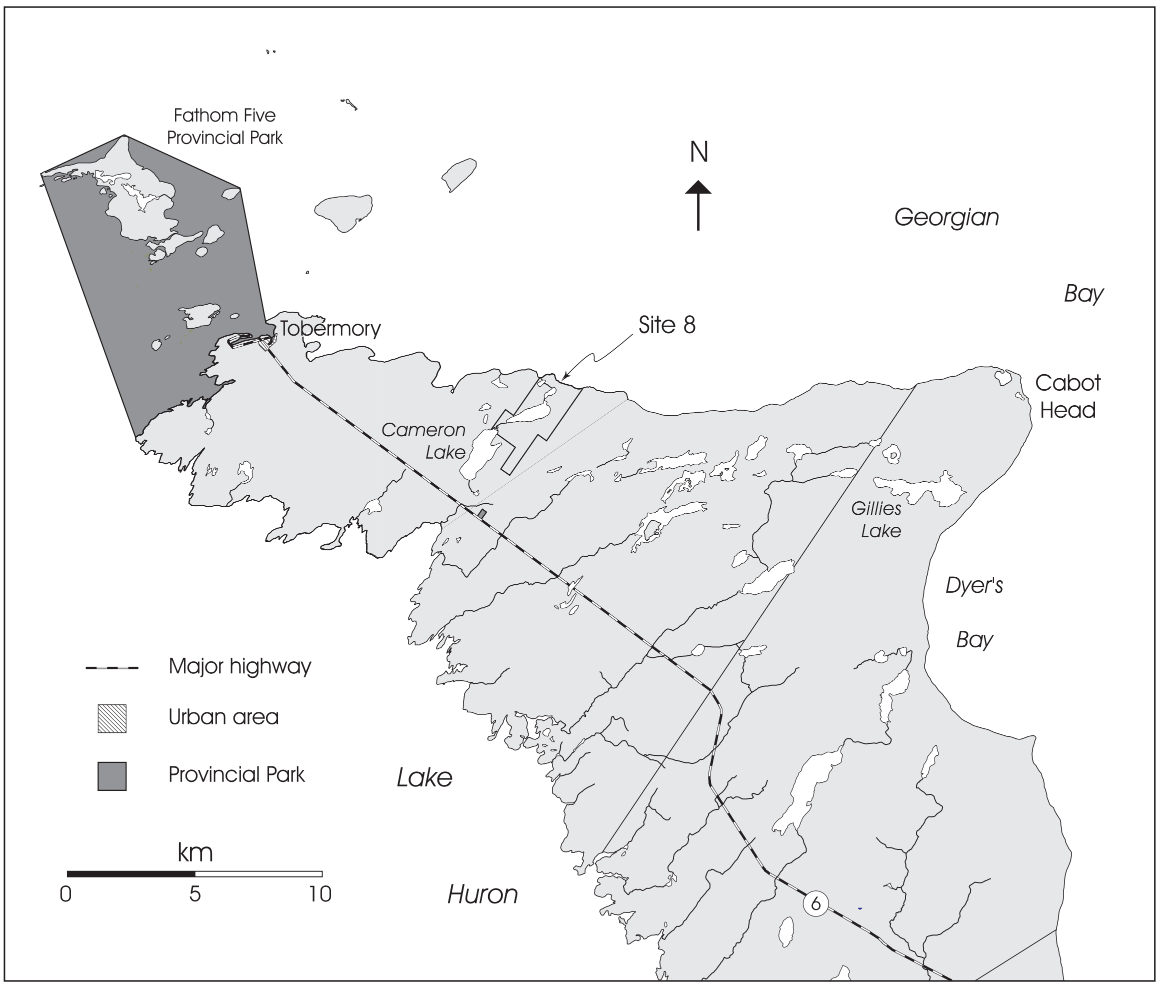
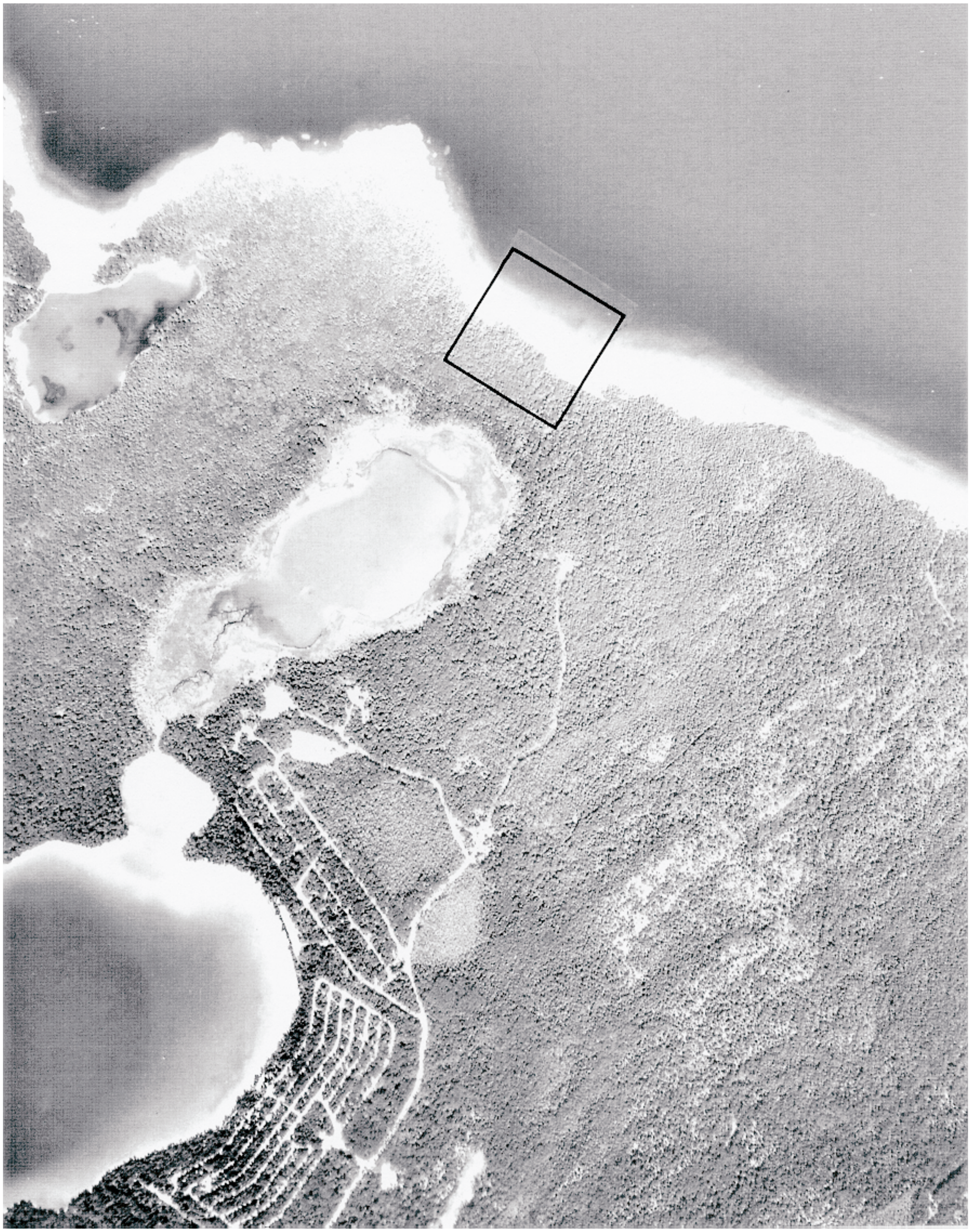


Figure A5.1.33: Aerial Photograph of Cypress Lake Area (2-3-1)



Box represents approximate location of profile and photograph

Figure A5.1.34: Generalized Profile of Cypress Lake Area (2-3-1)

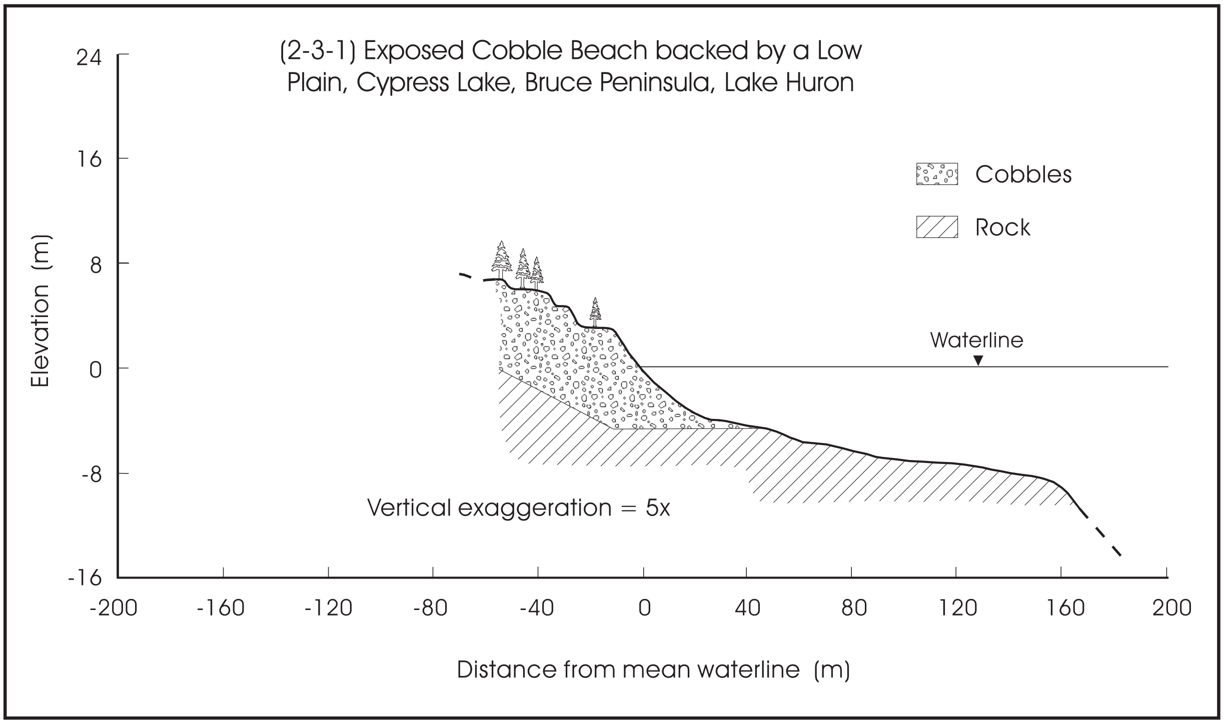


Figure A5.1.35: Photograph of Cypress Lake Area (2-3-1)

Figure A5.1.36: Location Plan of Pinery Provincial Park (2-3-3)

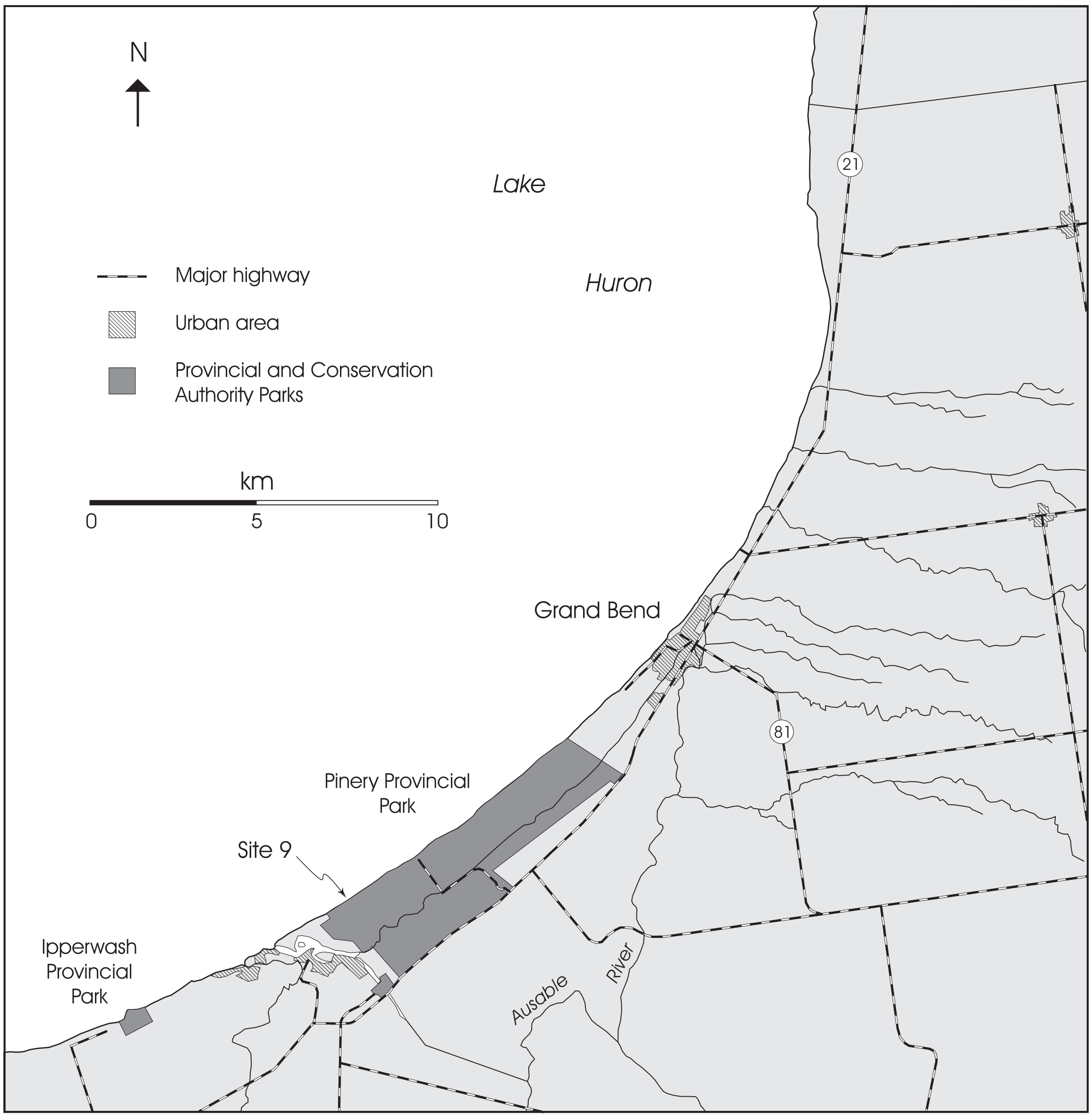
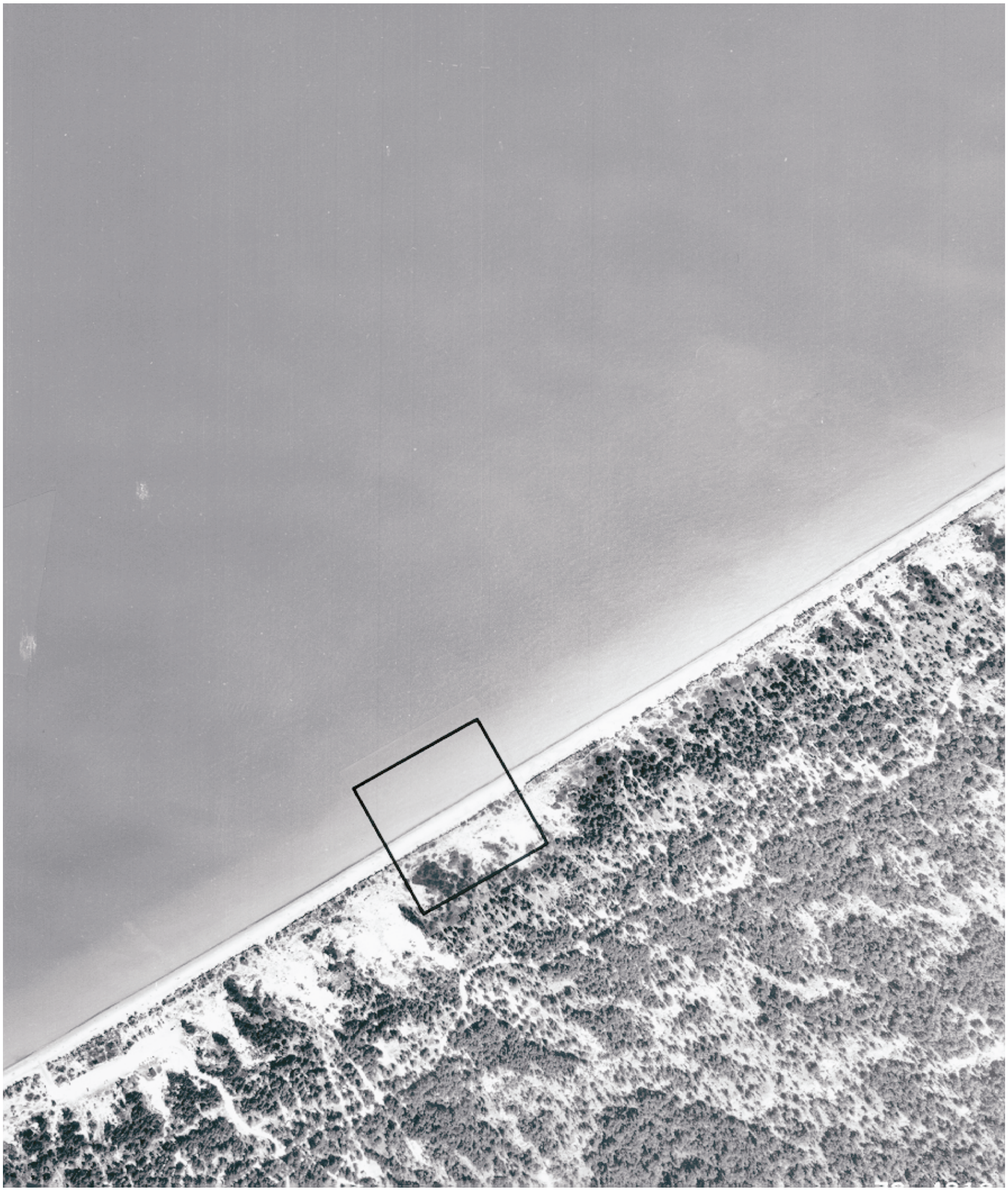


Figure A5.1.37:   Aerial Photograph of Pinery Provincial Park (2-3-3)



Box represents approximate location of profile and photograph

Figure A5.1.38: Generalized Profile of Pinery Provincial Park (2-3-3)

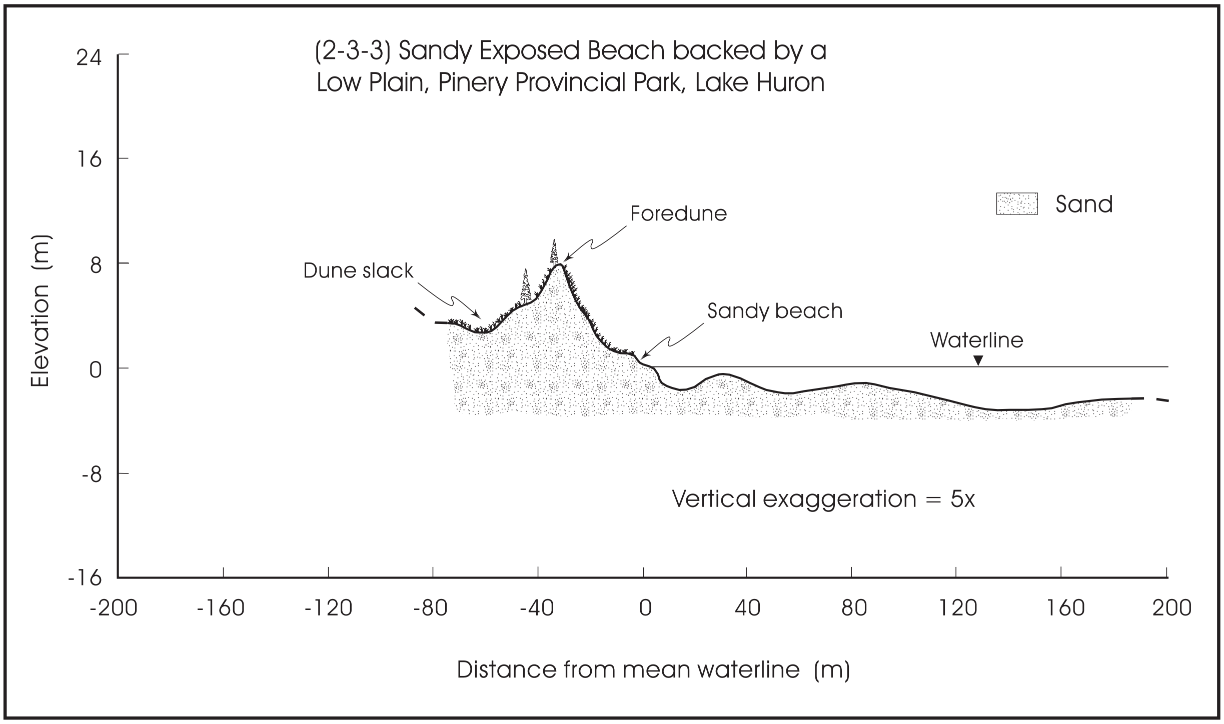


Figure A5.1.39: Photograph of Pinery Provincial Park (2-3-3)

A5.1.3 Barrier Beaches

a) Headland-Bay Beaches

This grouping of beach environments includes the following dynamic beach sub-classifications:

- **3-1-1 Cobble Headland-Bay Barrier Beach**
- **3-1-3 Sandy Headland-Bay Barrier Beach**

Typical factors to be considered when dealing within these dynamic beach sub-classifications include the following:

- Headland-Bay barriers form within a bay and are "anchored" to the sides of the bay. They are backed by an enclosed body of water such as a bay, an estuary, or a marsh. Headlands restrict waves to a narrow range of directions. Most waves arrive nearly perpendicular to the beach shoreline at the head of the bay. Potential sediment transport is along the sides towards head of the bay. As such, sediment is trapped within the bay and in most cases losses of sediment from the bay are small. Most Headland-Bay barrier beaches are stable or accretional. In these areas, locating developments behind or landward of the *dynamic beach hazard* limit is the most effective means of protecting the development against flooding and wave damage. Where developments are located landward of the *dynamic beach hazard* limit the need for shoreline protection works should be precluded. Where the proposed development includes uses such as marinas which by nature must be located in close proximity to the water's edge, care should be taken in their approval, siting and design.

- Where the sides of the bay are formed in erodible material or where there is sediment input from rivers, alongshore sediment transport will occur towards the head of the bay. In these situations, there is the potential for interruptions in sediment transport due to the construction of shore protection or marinas. For this reason, proposals for new development should be examined carefully to ensure that the interruption of the alongshore sediment transport does not occur. In addition, there may also be some long-term recession due to erosion which would then require addressing in the development proposal.

- All barriers are subject to overwash during storms, except where there has been extensive progradation, or where isostatic uplift has raised the barrier above the modern lake level. In general, due to the inherent possibility of overwash, development should not be permitted on the barrier unless it can be demonstrated that the selected/studied portion of the barrier is not subject to overwash or instability. Since cobble barriers do not have dunes, they are just as prone to overwash as sandy barrier systems. Reductions in the landward limit of the *dynamic beach hazard* on barrier systems are rarely recommended and as such, developments should not be permitted. In the rare occasions where they are considered, the barrier systems should be carefully studied to ensure that their long-term stability and maintenance is assured.

The following provides an example of each of these dynamic beach sub-classifications.

<u>3-1-1 Cobble Headland-Bay Barrier Beach</u>

Example Location: Marr Lake Area, Bruce Peninsula, Lake Huron (site 10 on Figure A5.1.1)

There is a small cobble headland-bay barrier beach located near Marr Lake on the Bruce Peninsula, Lake Huron (Figure A5.1.40). This barrier has a subaerial width of about 110 m and rises about 4 m above the current mean lake level. The cobbles that comprise the beach are quite large, up to 0.3 m in diameter. They were likely derived from the limestone bedrock outcrops that exist along this section of shoreline. There are numerous stranded beach ridges on the upper surface of the barrier, a result of isostatic uplift over the past few thousand years. The beaches on either side of the barrier are steep and overlie a narrow bedrock platform. Figure A5.1.41 is an aerial view of the site. A generalized profile of the beach is illustrated in Figure A5.1.42. Figure A5.1.43 is a photograph of the site.

Figure A5.1.40: Location Plan of Marr Lake Area (3-1-1)

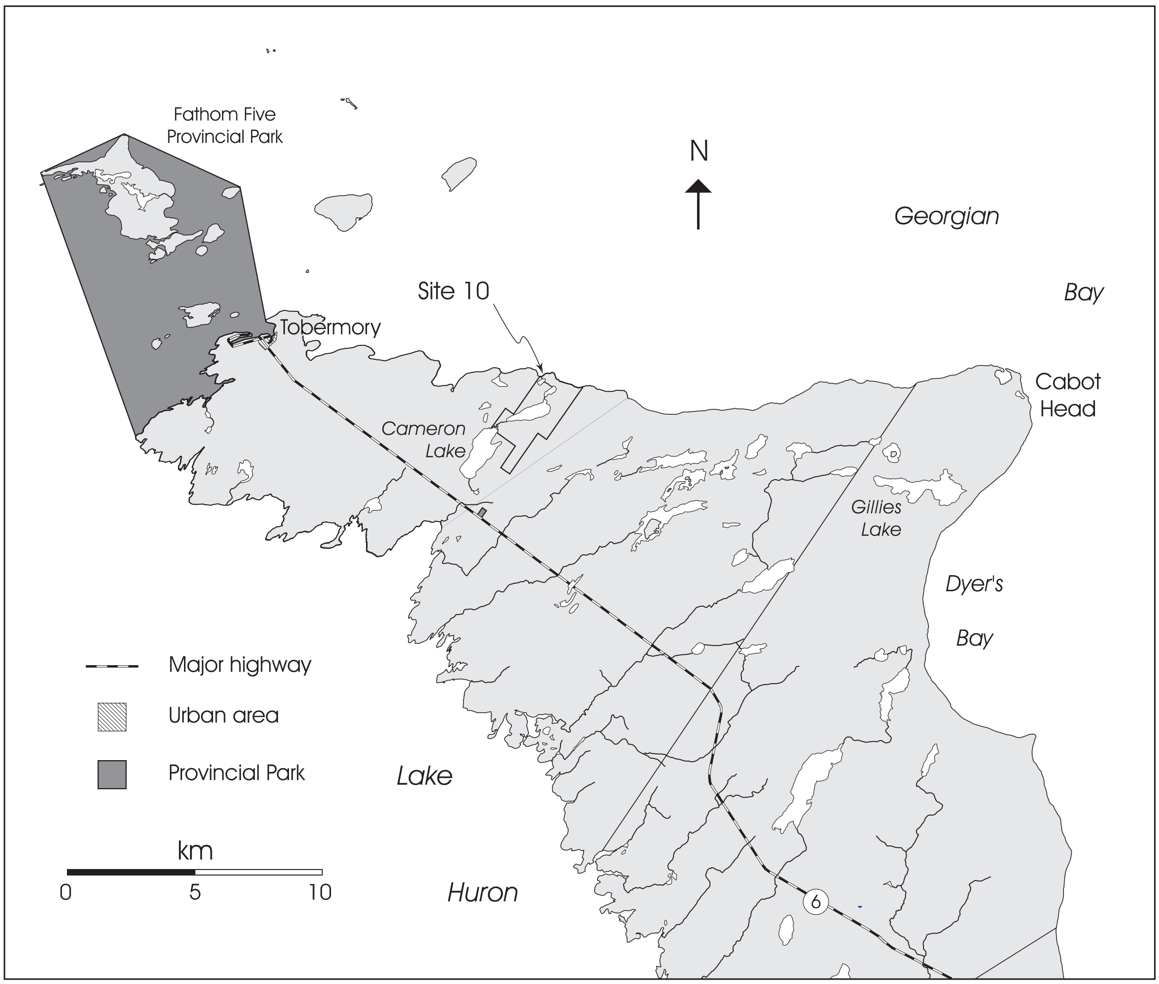
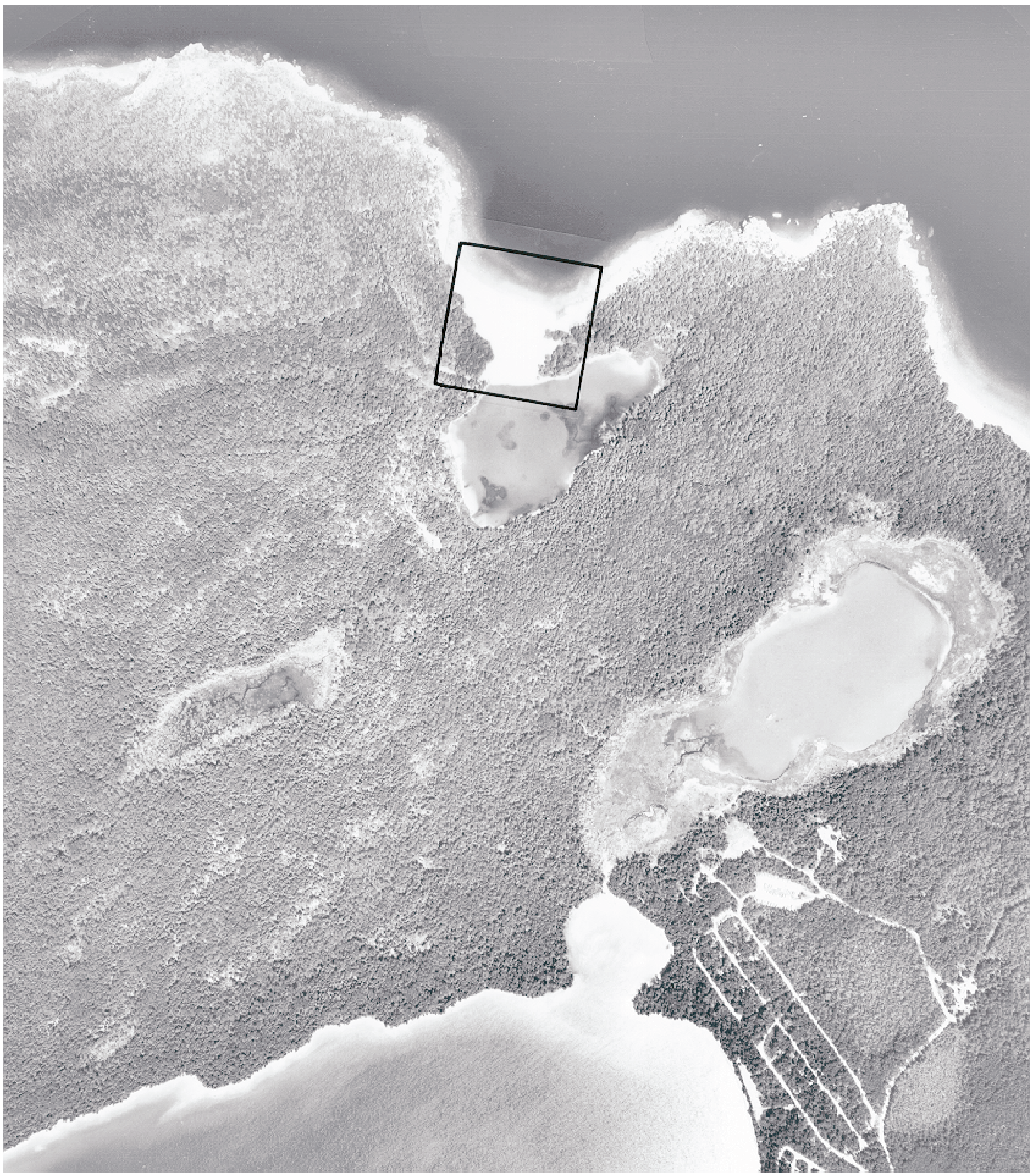


Figure A5.1.41: Aerial Photograph of Marr Lake Area (3-1-1)



Box represents approximate location of profile and photograph

Figure A5.1.42: Generalized Profile of Marr Lake Area (3-1-1)

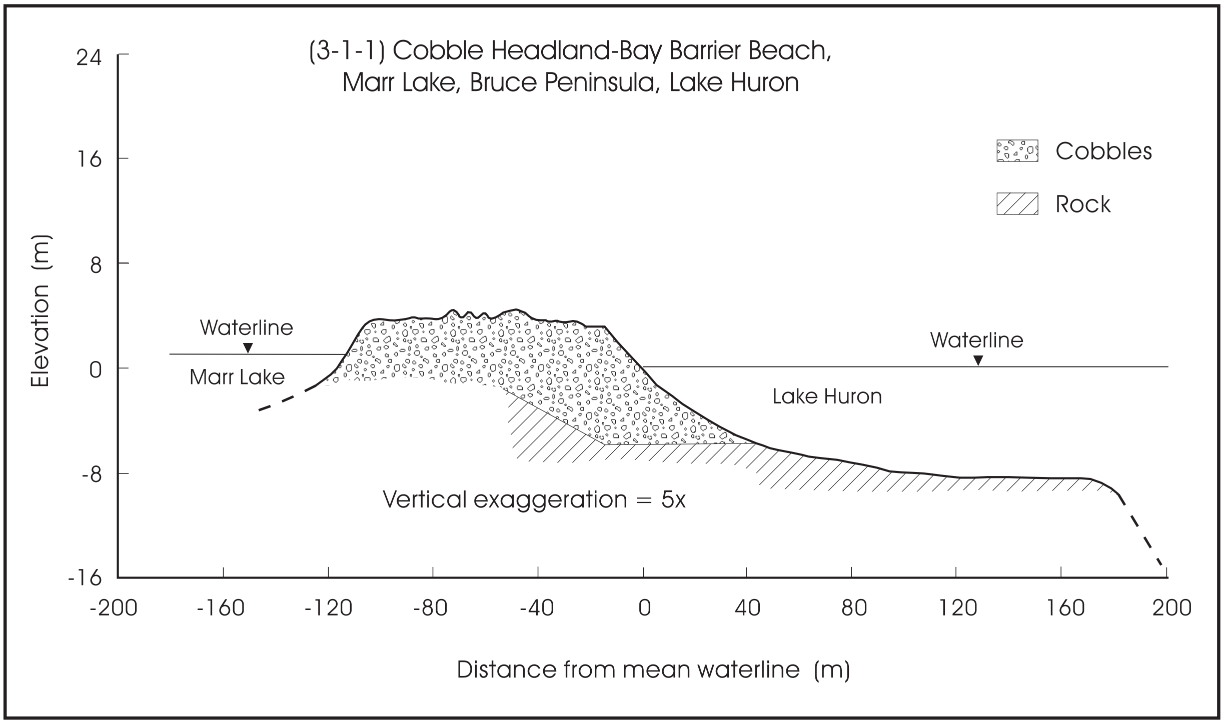


Figure A5.1.43: Photograph of Marr Lake Area (3-1-1)

3-1-3 Sandy Headland-Bay Barrier Beach

Example Location: Sandbanks Provincial Park, Lake Ontario (site 11 on Figure A5.1.1)

Sandbanks Provincial Park includes a large sandy headland-bay barrier beach which is protected by rock headlands on either side. The beach is 40 to 50 m wide and has a gentle slope. There is an outlet through the barrier that connects Lake Ontario to the lagoon behind (Figure A5.1.44). The beach is backed by several well vegetated 2 to 3 m high dunes. The sediments that comprise the beach are likely relict glacio-fluvial sediments, with no current source of sediment supply evident. Figure A5.1.45 shows an aerial view of the site. A generalized profile of the beach is illustrated in Figure A5.1.46 and Figure A5.1.47 is a photograph of the site.

b) Partial Headland Beaches

This grouping of beach environments includes the following dynamic beach sub-classifications:

- **3-2-1 Cobble Partial Headland Barrier Beach**
- **3-2-3 Sandy Partial Headland Barrier Beach**

Examples of these two classes are rare. They are included within the recommended shoreline classification scheme primarily to maintain the symmetry of the classification. Shoreline reaches falling into these two categories should be treated in the same way as the other exposed barriers environments (i.e., 3-3-1 and 3-3-3) are treated.

The following discusses these dynamic beach sub-classifications.

3-2-1 Cobble Partial Headland Barrier Beach

Example Location: No example

No example of a cobble partial headland barrier beach was identified along the *Great Lakes - St. Lawrence River System* shoreline. Examples of this class are rare and it is included primarily to maintain the symmetry of the classification scheme. Any shoreline reaches falling into this category should be treated in the same way as the equivalent exposed barrier beach (3-3-1). Figure A5.1.48 shows a hypothetical plan view and profile for a cobble partial headland barrier beach.

3-2-3 Sandy Partial Headland Barrier Beach

Example Location: No example

No example of a sandy partial headland barrier beach was identified along the *Great Lakes - St. Lawrence River System* shoreline. Examples of this class are rare and it is included primarily to maintain the symmetry of the classification scheme. Any shoreline reaches falling into this category should be treated in the same way as the equivalent exposed barrier beach (3-3-3). Figure A5.1.49 shows a hypothetical plan view and profile of a sandy partial headland barrier beach.

Figure A5.1.44: Location Plan of Sandbanks Provincial Park (3-1-3)

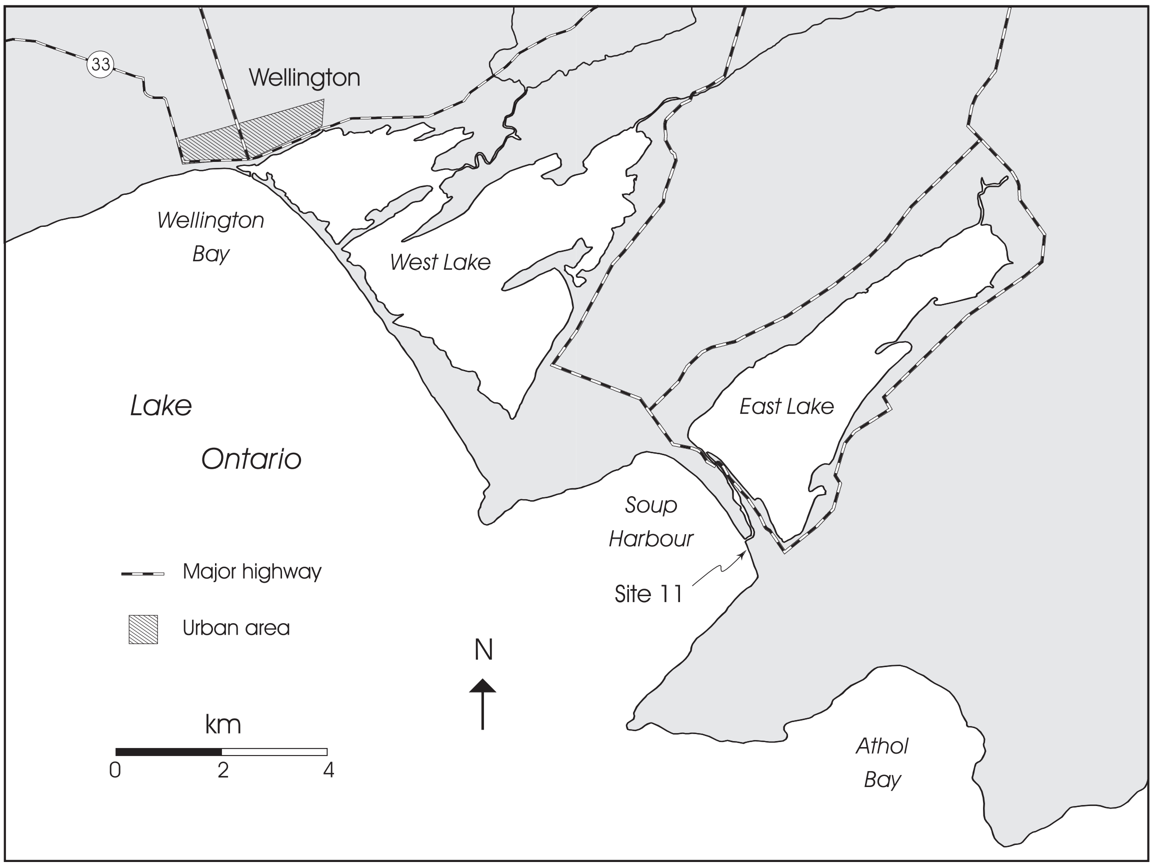


Figure A5.1.45: Aerial Photograph of Sandbanks Provincial Park (3-1-3)

Box represents approximate location of profile and photograph

Figure A5.1.46: Generalized Profile of Sandbanks Provincial Park (3-1-3)

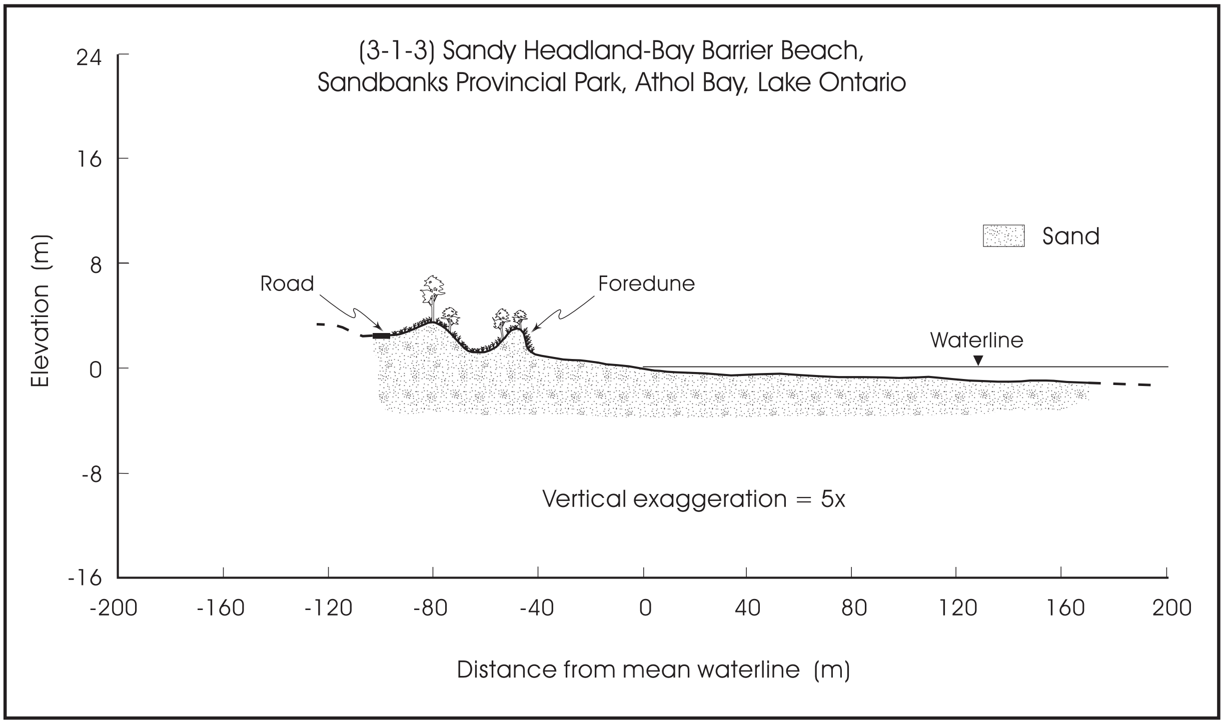
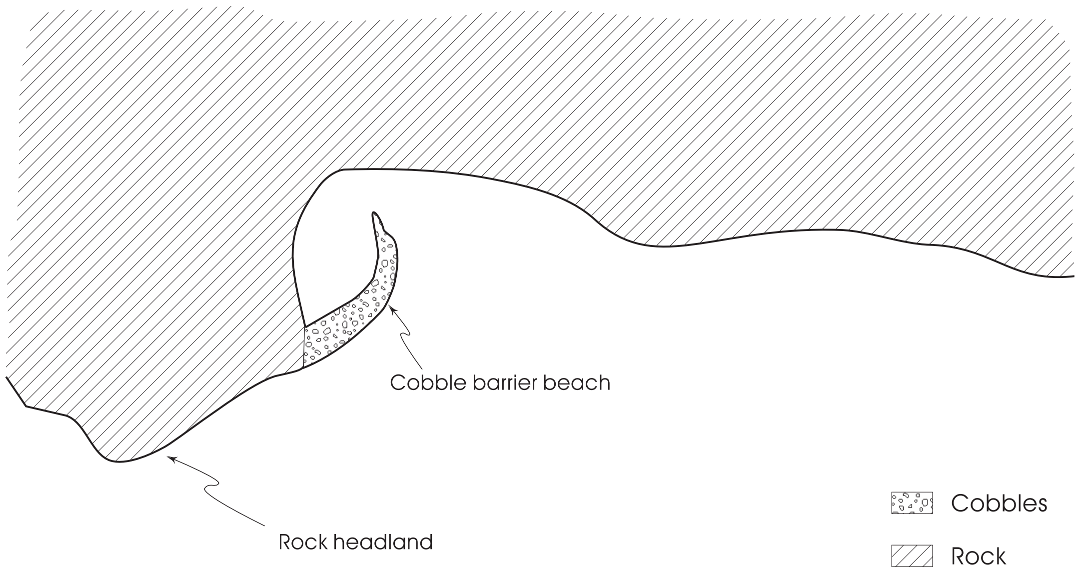
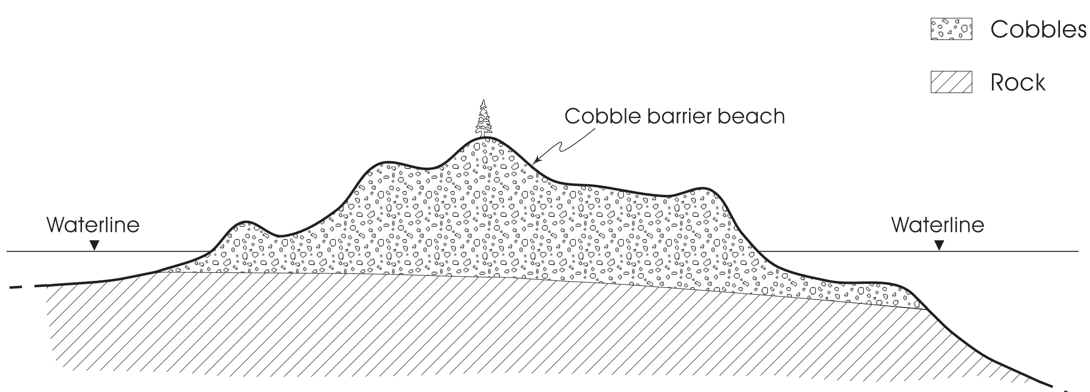


Figure A5.1.47: Photograph of Sandbanks Provincial Park (3-1-3)

Figure A5.1.48: Cobble Partial Headland Barrier Beach (3-2-1)

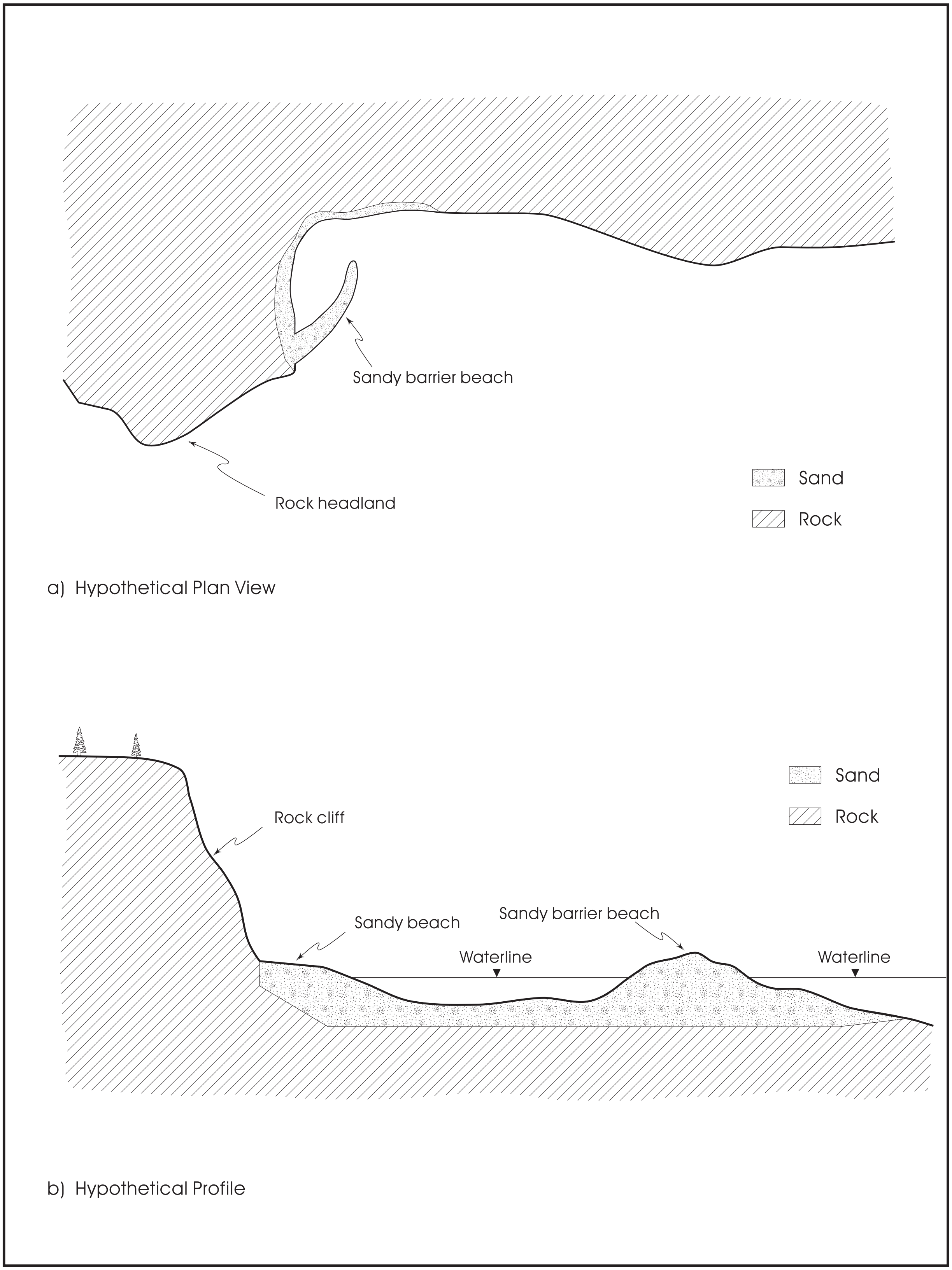


a) Hypothetical Plan View



b) Hypothetical Profile

Figure A5.1.49: Sandy Partial Headland Barrier Beach (3-2-3)



c) Exposed Beaches

This grouping of beach environments includes the following dynamic beach sub-classifications:

- **3-3-1 Cobble Exposed Barrier Beach**
- **3-3-3 Sandy Exposed Barrier Beach**

Typical factors to be considered when dealing within these dynamic beach sub-classifications include the following:

- Since waves can reach exposed beach shorelines from a wide range of directions, exposed beaches tend to experience a greater number of days impacted by high waves than is normally experienced on other shorelines. As such, changes in beach topography may occur more frequently on exposed beaches. In addition, exposed beaches tend to have a higher total (i.e., gross) sediment transport rate than other shorelines. Most exposed shorelines, where there is sediment available, are best evaluated within the framework of a littoral cell. The long-term stability of exposed beaches is dependent on whether the reach is located within the updrift (i.e., erosional) end of the cell or the downdrift (i.e., depositional) end of the littoral cell. In either case, the stability of the shoreline is sensitive to changes in the supply of sediment from updrift.

- Barrier beaches are the most dynamic of all beach types as they are prone to overwash and inlet formation. Exposed barrier beaches occur generally as spits or as baymouth barriers built across embayments or small estuaries. Sediments are supplied from the erosion of updrift cliffs and bluffs, and from the re-working of glacial and post-glacial sediments. Many now recognize and support the position that the sediment supply to many barrier beaches in the Great Lakes is now much lower that it was when the barriers were initiated. As such, the barrier beaches are now more sensitive to interruptions in the modern sediment supply. Where the barrier beach is low (i.e., less than 4 m) and narrow (i.e., less than 100 m) the whole barrier beach should be defined as part of the *dynamic beach hazard*.

- Many cobble barrier beaches found in northern Lake Huron and on Lake Superior may have been formed as a result of the isostatic uplift raising part of the barrier beach well above the reach of modern wave action. This may be evidenced in two ways: 1) by the height of the back barrier being above the modern lake level; and 2) by the development of forest vegetation. In these cases, there will generally not be a need to extend the landward limit of the dynamic beach beyond that defined through the application of the *dynamic beach hazard*.

- The stability of exposed sandy barriers is dependent on the sediment budget and on the evolution of the barrier feature through time. On barrier spits, the updrift (i.e., proximal) end usually develops a negative sediment budget resulting in erosion of the barrier over the long-term. This long-term erosion usually takes the form of barrier overwash and extensive dune cliffing. Development should not be permitted in these areas. As an additional measure, consideration should be given to removing any existing development located on the barrier. Where sandy barriers are forming across a bay, as a natural occurring process in the development of the shore barrier feature, the stability and long-term maintenance of the barrier is dependent on the local sediment (i.e., the continuous supply of sediment) and the lake level history. Due to their inherent instability, in most cases development should not be permitted on these barrier features.

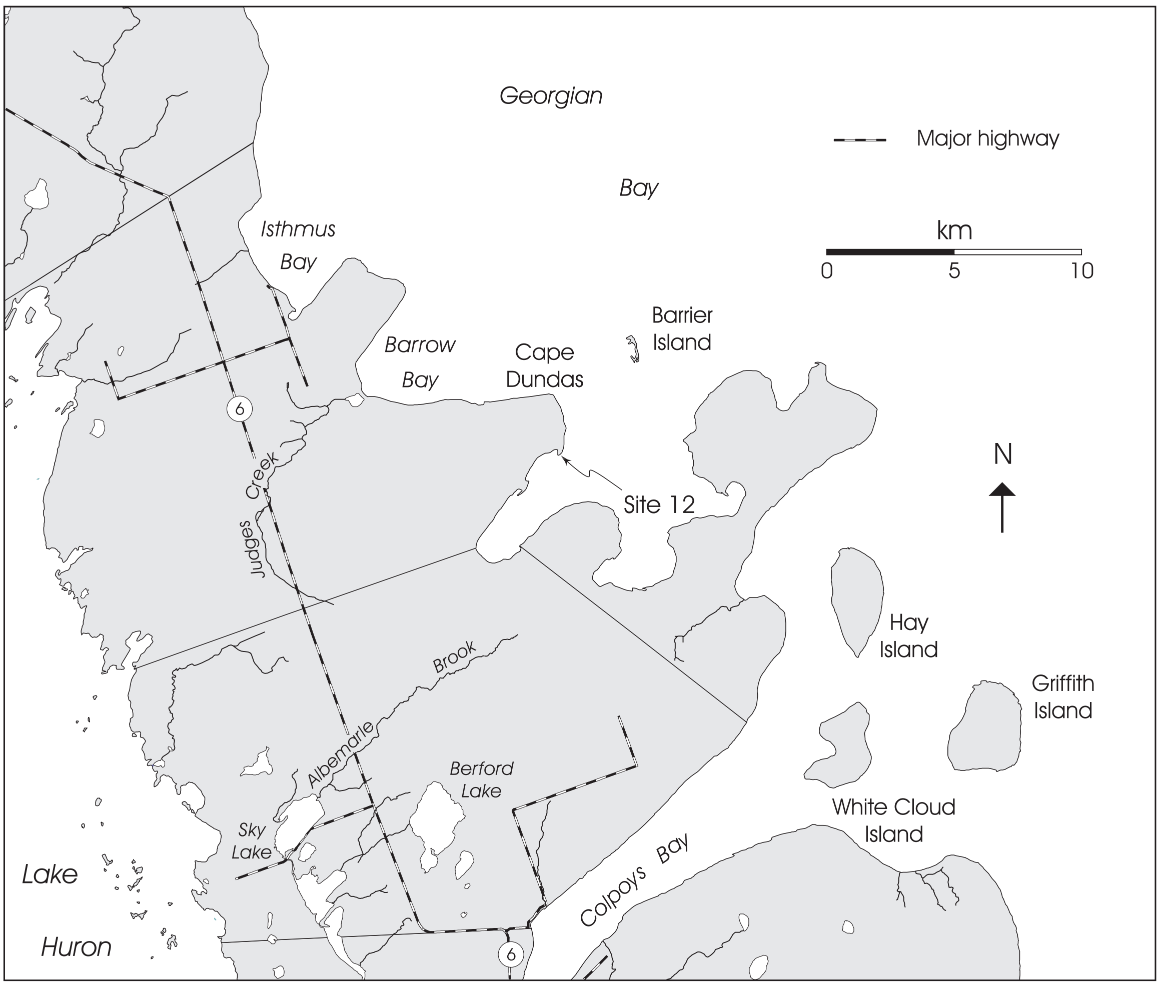
The following provides an example of each of these dynamic beach sub-classifications.

<u>3-3-1 Cobble Exposed Barrier Beach</u>

Example Location: Cape Dundas Spit, Georgian Bay, Lake Huron (site 12 on Figure A5.1.1)

Cape Dundas Spit is a cobble exposed barrier beach on the west shore of Georgian Bay, Lake Huron (Figure A5.1.50). The beach is comprised entirely of cobbles. The active beach is quite narrow (i.e., 10 to 20 m) and steep. Isostatic uplift has raised older beach deposits well above the modern lake level. Most of the cobble material was

Figure A5.1.50: Location Plan of Cape Dundas Spit (3-3-1)



probably derived from the reworking of post-glacial sediments with some limited supply of talus supplied to the bases of the cliffs north of the spit. New sediment input from updrift is now very limited. Figure A5.1.51 shows an aerial view of the site. A generalized profile of the beach is illustrated in Figure A5.1.52 and Figure A5.1.53 is a photograph of the site.

3-3-3 Sandy Exposed Barrier Beach

Example Location: 1) Frenchman's Bay, Lake Ontario (site 13 on Figure A5.1.1)

The barrier beach that encloses Frenchman's Bay is a good example of a small-scale sandy exposed barrier beach. Figure A5.1.54 shows the location of the site. The subaerial portion of the barrier is only 50 to 60 m wide and at its highest parts are only 2 to 2.5 m above mean lake level. Sediment is being supplied to the barrier beach by erosion of the bluffs to the east of the barrier. The barrier beach is comprised entirely of sand and has the potential to be very dynamic. Figure A5.1.55 shows an aerial view of the site. A generalized profile of the beach is illustrated in Figure A5.1.56. Figure A5.1.57 is a photograph of the site.

Example Location: 2) Long Point, Lake Erie (site 14 on Figure A5.1.1)

The Long Point barrier spit on the north shore of Lake Erie (Figure A5.1.58) is a good example of a large-scale sandy exposed barrier beach. The subaerial portion of the barrier is up to 5000 m wide at the progradational distal end, and its highest dunes are 10 to 15 m above the mean lake level. Substantial volumes of sediment are being supplied to the barrier by erosion of the extensive bluffs to the west of the barrier. The barrier is comprised entirely of sand and is very dynamic especially at the erosional proximal end. Figure A5.1.59 shows an aerial view of the site. A generalized profile of the beach is illustrated in Figure A5.1.60. Figure A5.1.61 is a photograph of the site.

Figure A5.1.51: Aerial Photograph of Cape Dundas Spit (3-3-1)

Box represents approximate location of profile and photograph

Figure A5.1.52: Generalized Profile of Cape Dundas Spit (3-3-1)

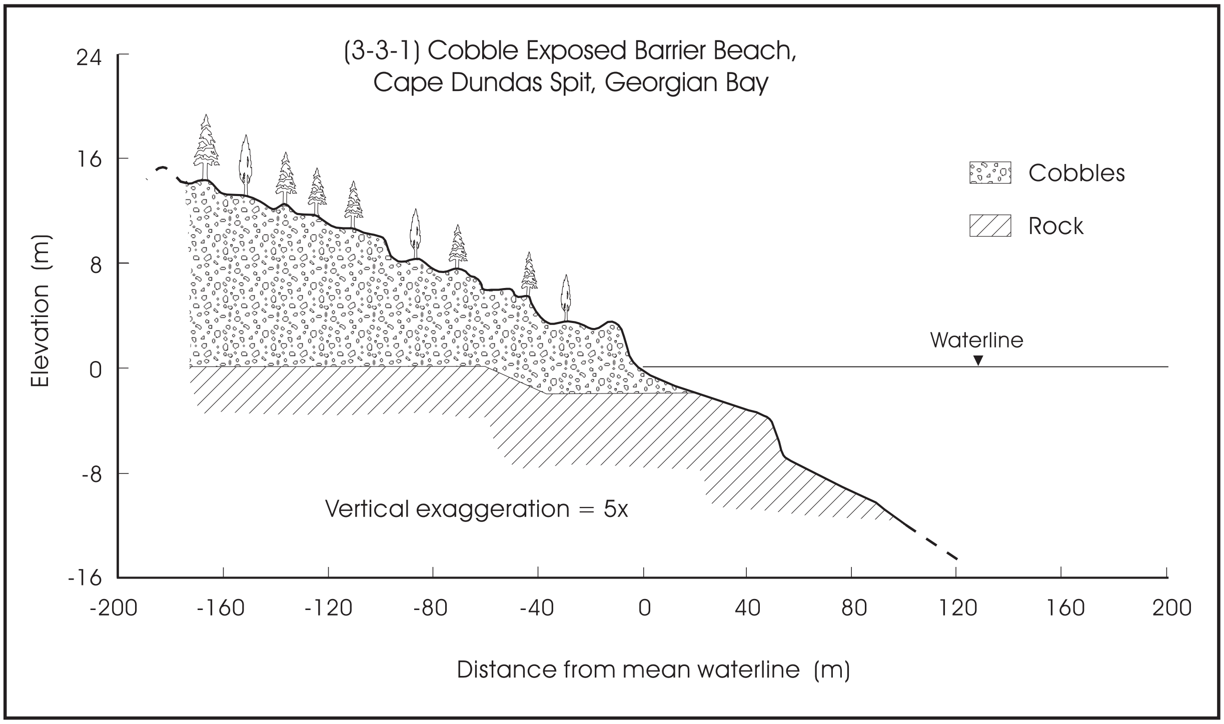


Figure A5.1.53: Photograph of Cape Dundas Spit (3-3-1)

Figure A5.1.54: Location Plan of Frenchman's Bay (3-3-3)

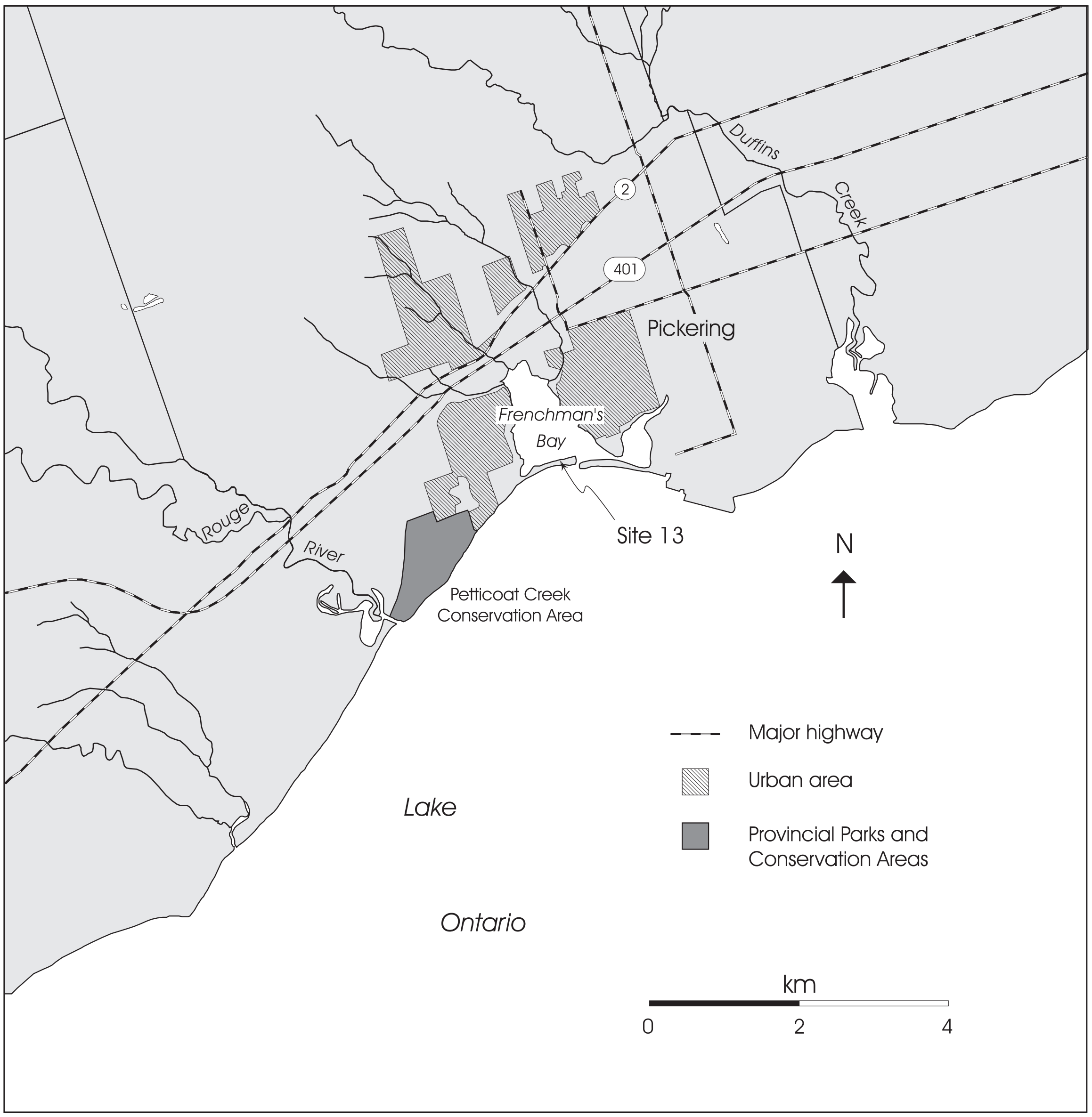


Figure A5.1.55: Aerial Photograph of Frenchman's Bay (3-3-3)

Box represents approximate location of profile and photograph

Figure A5.1.56: Generalized Profile of Frenchman's Bay (3-3-3)

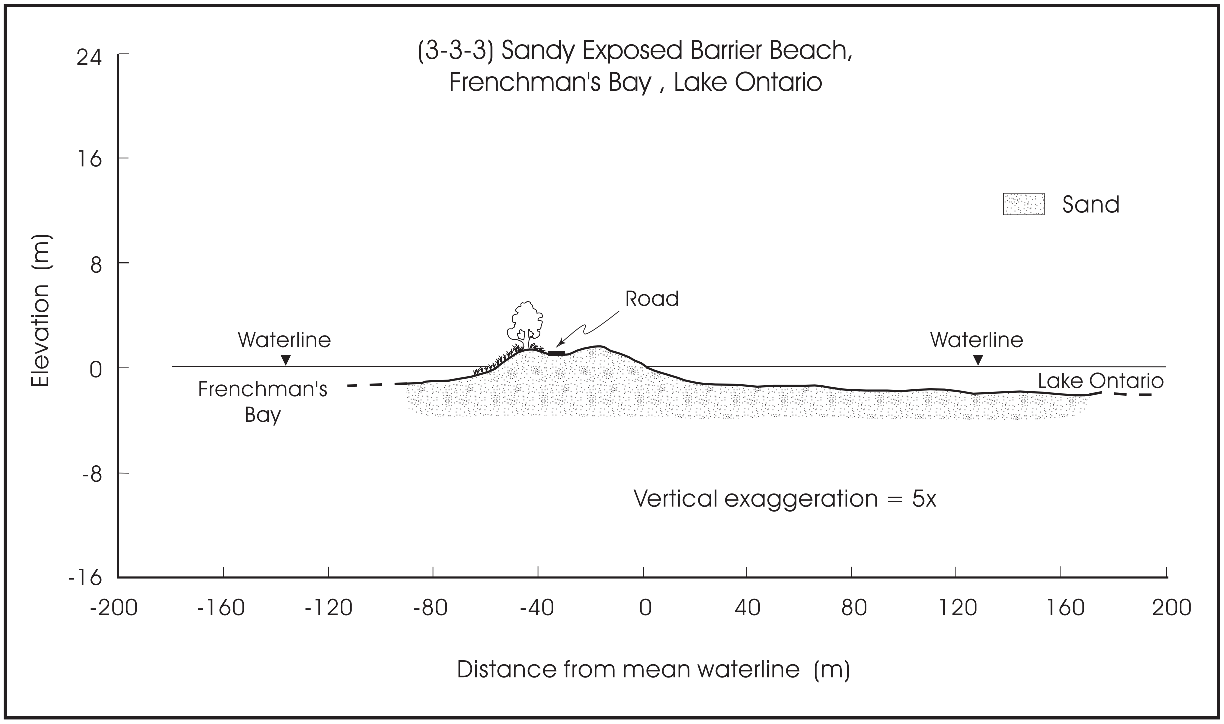


Figure A5.1.57: Photograph of Frenchman's Bay (3-3-3)

Figure A5.1.58: Location Plan of Long Point (3-3-3)

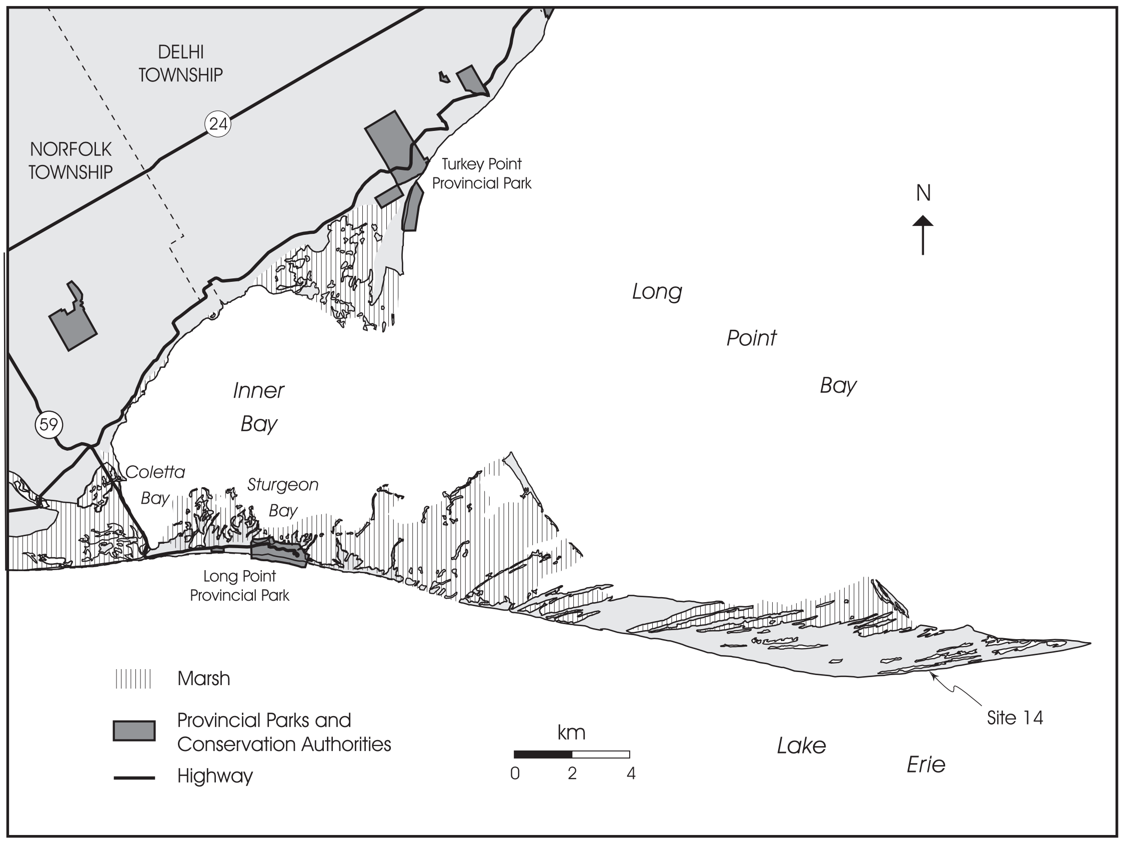
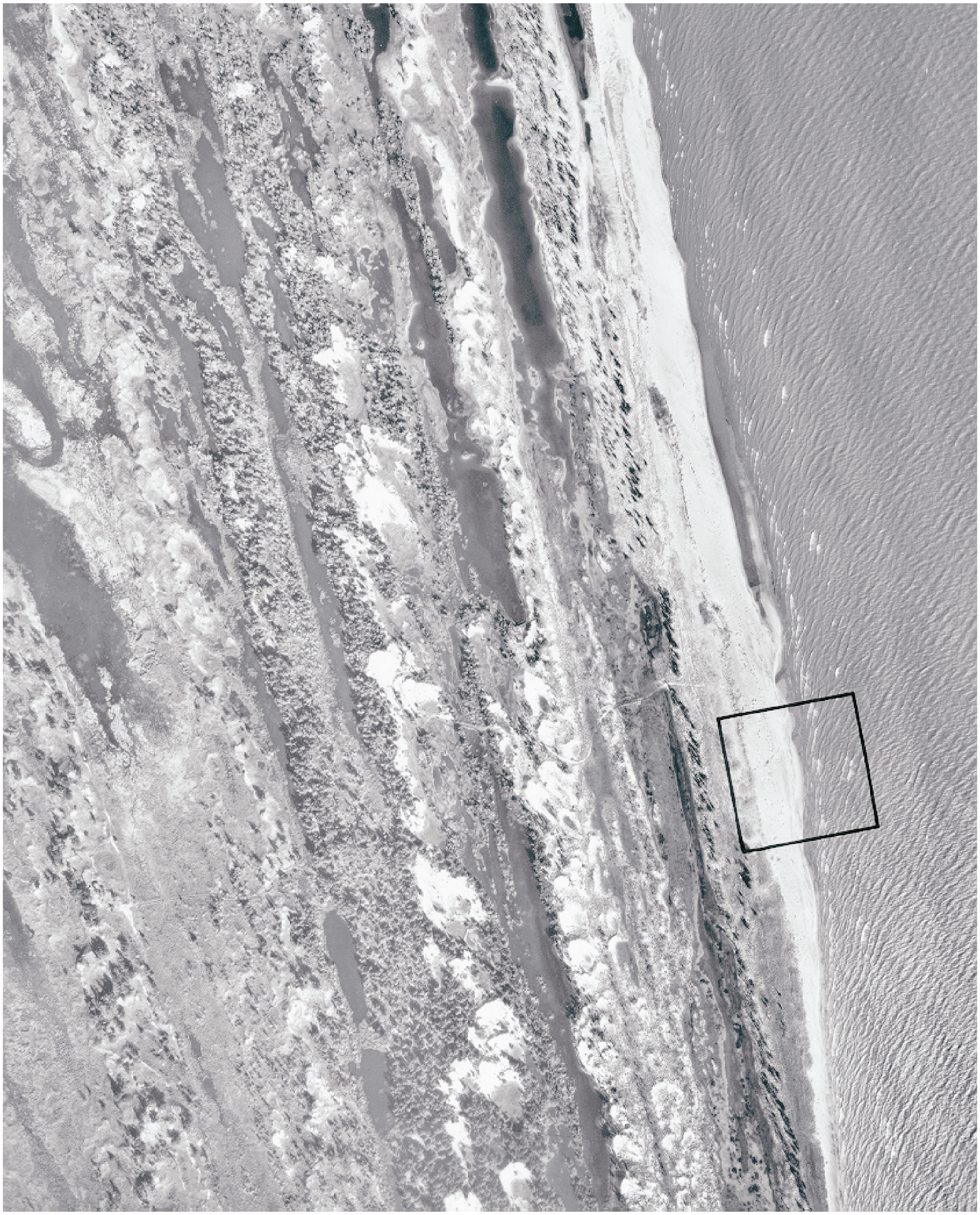


Figure A5.1.59: Aerial Photograph of Long Point (3-3-3)



Box represents approximate location of profile and photograph

Figure A5.1.60: Generalized Profile of Long Point (3-3-3)

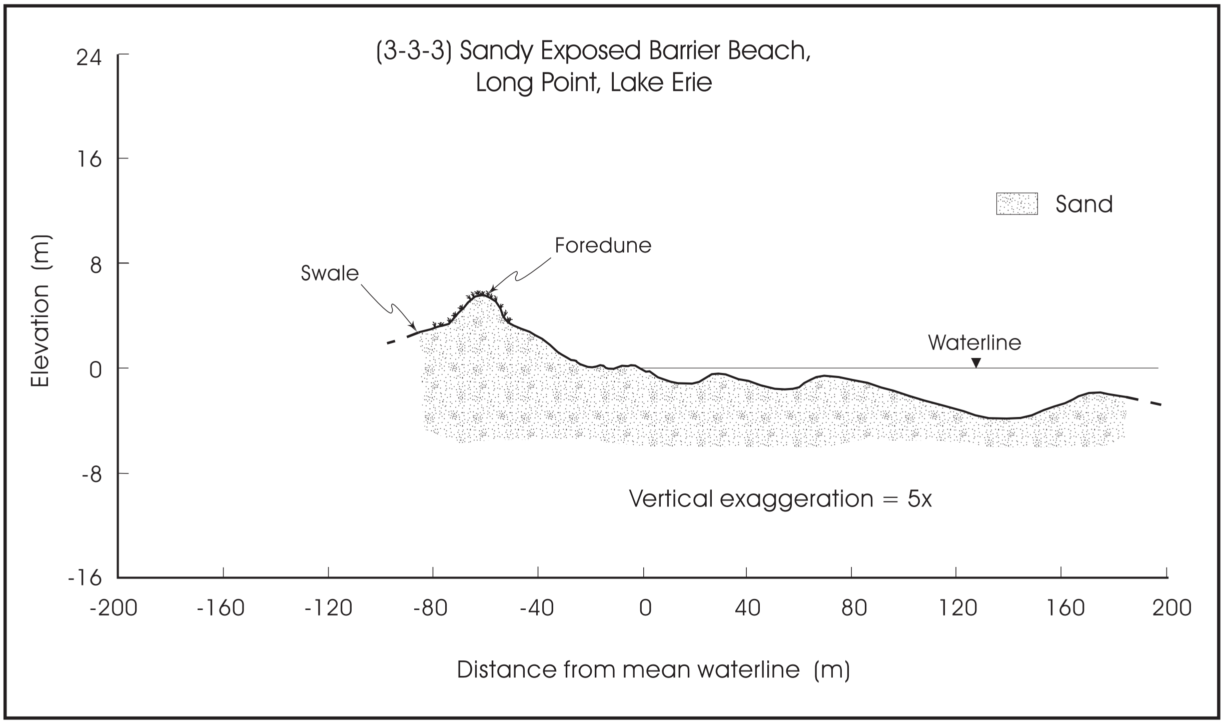


Figure A5.1.61: Photograph of Long Point (3-3-3)

TECHNICAL GUIDE FOR
GREAT LAKES - ST. LAWRENCE RIVER SHORELINES

APPENDIX A5.2

CLASSIFICATION AND ALONGSHORE BOUNDARIES

OF DYNAMIC BEACHES

CLASSIFICATION AND ALONGSHORE BOUNDARIES OF DYNAMIC BEACHES

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A5.2 CLASSIFICATION AND ALONGSHORE BOUNDARIES OF DYNAMIC BEACHES

This appendix will present a procedure for determining the proper classification for a particular beach form using the recommended dynamic beach sub-classification scheme (outlined in **Part 5: Dynamic Beach Hazard**, Section 5.4). The recommended dynamic beach sub-classification scheme forms part of the larger process of identification, classification and mapping of shoreline types and reaches initially outlined in **Part 2: Recommended Shoreline Classification Scheme for Determining Shoreline Reaches** of this Technical Guide.

Prior to following the procedures outlined in this appendix for classifying dynamic beaches, one must first ensure that the following initial steps have been completed, including:

- that a preliminary identification and classification of the shoreline using the procedures described in Part 2 of this Technical Guide has confirmed that the subject shoreline is a dynamic beach form;

- that the person carrying out the classification and initial mapping procedure is familiar with the classification scheme for shorelines (outlined in Part 2, of this Technical Guide) and with the information presented in Part 5, Section 5.4 of this Technical Guide; and

- that all the available relevant background information such as maps, consultants reports, aerial photographs, and shoreline videos, have been assembled.

The ultimate objective of classifying dynamic beaches is to properly divide the shoreline into reaches with relatively uniform characteristics. After having segmented the shoreline into unique shoreline reaches, a determination of the classification of the dynamic beach reach can be achieved by following the provided flow chart. The flow chart describes the information on the beach required for each step and eventually permits the assignment of the beach to one of the 18 sub-classes in the recommended dynamic beach sub-classification scheme.

Should additional information on the typical characteristics of each of the 18 sub-classes be required, including descriptions, illustrative photographs and typical cross-sections, the summaries presented in Appendix A5.1 should be consulted. Cross-referencing of the selected dynamic beach sub-classification for a subject reach with the information provided in Part 5 Section 5.4 should ensure the proper selection of the appropriate classification. Further, it will enable the identification of any special features associated with the dynamic nature of the identified dynamic beach type, and finally, enable the proper determination, mapping and staking of the landward limit of the *dynamic beach hazard.*

Determining the alongshore extent of individual shoreline reaches sometimes becomes difficult, particularly in areas of transition between one shore reach type and another. In addition to providing a step-by-step procedure for classifying individual reaches of dynamic beach, this appendix also provides the procedures for determination of the alongshore boundaries of shoreline reaches. Repetition of this process of first identifying the dynamic beach classification for each general reach along a subject shoreline, followed by the determination of alongshore boundaries of each reach will ultimately enable the proper classification and delineation of unique reaches of dynamic beaches along a given stretch of shoreline.

For the purposes of this Technical Guide, the recommended dynamic beach sub-classification scheme divides dynamic beaches into 18 different shore types based on three criteria:

1) Beach Profile Type
   - **1) cliff/bluff**
   - **2) low plain**
   - **3) barrier**

2) Beach Planform and Exposure

- **1) headland-bay**
- **2) partial headland**
- **3) exposed**

3) Beach Materials

- **1) gravel, cobble or boulders**
- **3) sand**

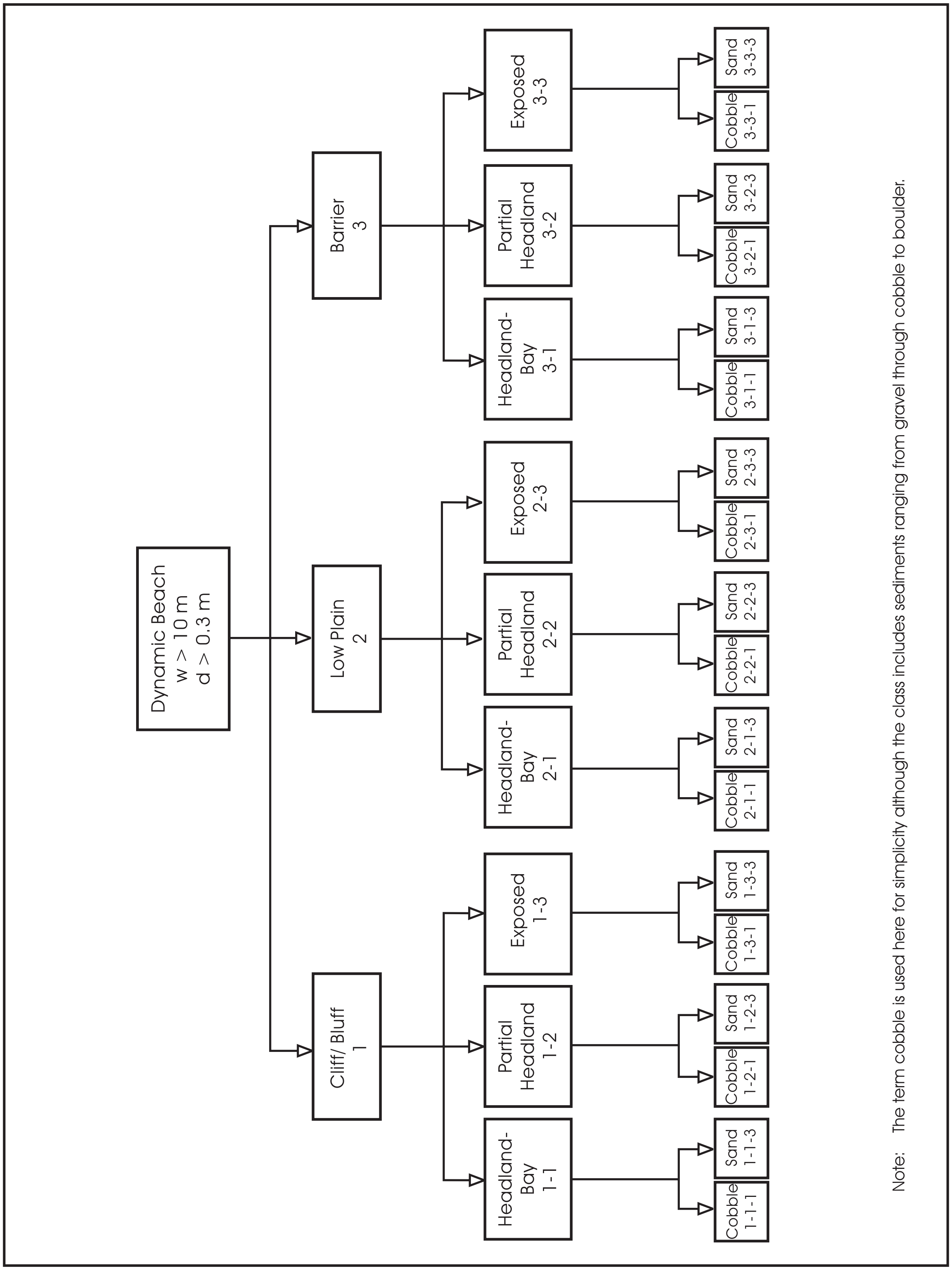
For the purpose of clarification, the 18 primary dynamic beach sub-classifications are organized and presented in a flowchart (Figure A5.2.1). After a particular shoreline has been identified as a dynamic beach and the required background information has been collected, the flowchart is entered from the top and the information on the shoreline reach is used to determine the route through the flow chart to one of the 18 sub-classes at the bottom of the chart. Based on which of the 18 dynamic beach sub-classes is identified, a number and descriptive terms unique to the identified dynamic beach class is assigned (see Table A5.2.1). For instance, where an exposed low plain sandy dynamic beach is identified, the classification number 2-3-3 is assigned.

Table A5.2.1
Dynamic Beach Sub-Classifications

PROFILE TYPE	PLANFORM AND EXPOSURE	MATERIALS *	SUB-CLASS #
CLIFF/BLUFF	Headland-Bay	cobble sand	1-1-1 1-1-3
	Partial Headland	cobble sand	1-2-1 1-2-3
	Exposed	cobble sand	1-3-1 1-3-3
LOW PLAIN (MAINLAND BEACH AND DUNE)	Headland-Bay	cobble sand	2-1-1 2-1-3
	Partial Headland	cobble sand	2-2-1 2-2-3
	Exposed	cobble sand	2-3-1 2-3-3
BARRIER	Headland-Bay	cobble sand	3-1-1 3-1-3
	Partial Headland	cobble sand	3-2-1 3-1-3
	Exposed	cobble sand	3-3-1 3-3-3

* The term cobble is used here for simplicity although the class includes sediments ranging from gravel through cobble to boulder.

Figure A5.2.1: Dynamic Beach Sub-Classifications



A5.2.1 Classification Procedure

To ensure consistency and future cross-referencing of information developed through the completion of the following procedure, it is assumed that the supporting background information for each shoreline reach has been collated and recorded in a systematic manner. To assist in the collation and recording process, a standard form may be developed by the reviewer or the sample form provided at the end of this appendix may be used. This form is retained and updated or amended as new information becomes available (e.g., from field investigation and staking activities).

- **Step 1** Select the Shoreline Segment

  Select one of the shoreline segments identified as a "dynamic beach". Begin with a point near the middle of the selected shoreline segment and away from any obvious boundaries for the selected segment such as a headland or river mouth.

- **Step 2** Determine the Beach Profile Classification

  Using the 1:2,000 FDRP or 1:10,000 OBM topographic maps as a base and any additional information provided by hydrographic charts, aerial photographs, etc., sketch a cross-section of the shoreline at that location beginning, where possible, 100 to 200 metres offshore and extending inland for 200 to 300 metres. Additional measurements landward may be required if there is a feature such as a marsh or bay behind the actual dynamic beach shoreline.

  On the basis of the cross-section and on an analysis of supporting background information, assign the selected shoreline segment to one of the three profile classifications:

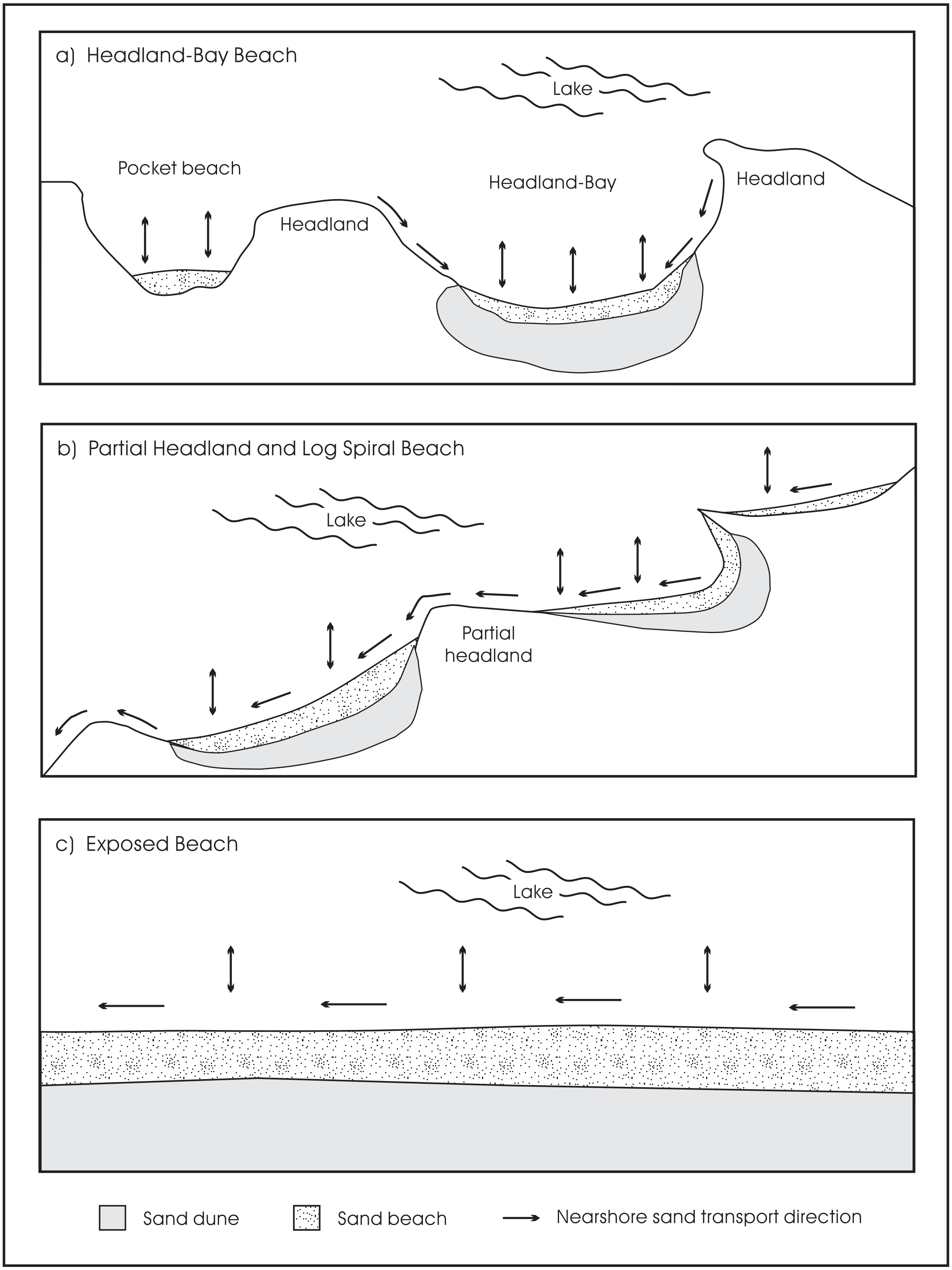
  - **cliff/bluff,**
  - **low plain, or**
  - **barrier**

  A cliff or bluff profile will show up as closely spaced contour lines immediately landward of the shoreline. This determination should also be evident in the collated aerial photographs. Based on aerial photographs, reports and personal experience, determine whether the material in which the slope is formed is bedrock (i.e., cliff) or cohesive sediments (i.e., bluff). Where large sand dunes are present, the dune features may also show up on the contour maps as high areas with steep slopes facing to the beach. In these instances, aerial photographs and field information should be consulted to distinguish the large sand dune features from cliff/bluff features. Where dunes are present, the shoreline is to be classified as low plain, except where the dunes develop only in a narrow band between the shoreline and a bedrock cliff or cohesive bluff.

  A low plain will show up as widely spaced contours on the topographic map. The area landward of the shoreline should be flat or slope gently upwards as the feature extends landward, and should be 2 metres or less in height close to the shoreline.

  Barriers should consist of a bay, estuary or marsh behind the shoreline, with at least some areas of open water. The area of land separating the open lake from the bay, estuary or wetland should be formed primarily in beach and dune sediments. In many instances there will be a channel or channels connecting the bay, estuary or marsh to the open lake and there may be evidence of wave action reaching the bay/estuary/marsh in the form of washovers. This will be evident particularly on aerial photographs taken during or immediately after the high water periods of 1985-86 and 1972-73.

Figure A5.2.2: Beach Classification Based on Planform



· **Step 3 Determine the Beach Planform and Exposure Classification**

Using a map with a scale of 1:50,000 or even 1:100,000 as a base, examine the shoreline planform for a distance of 10 to 20 kilometres on either side of the point of interest to determine the extent to which the beach is exposed to waves from a wide range of directions.

Where there are headlands on both sides of the beach which restrict wave action to about 45^o on either side of a line perpendicular to the shoreline, the beach should be classified as Headland-Bay Beach (Figure A5.2.2a).

Partial Headland Beaches have headlands that are much shorter than the Headland-Bay class and as such, offer much less protection from wave action. Often the shoreline exhibits a tight curvature downdrift of each headland, giving a characteristic log-spiral form (Figure A5.2.2b).

Exposed Beaches are nearly straight shoreline features extending over a long distance and may be exposed to waves over angles greater than 75^o on either side of shore perpendicular (Figure A5.2.2c).

· **Step 4 Determine the Beach Material Size Classification**

This step is intended to distinguish between coarse sediment beaches and sand beaches on the basis of the average size of the sediment particles on the beach.

Coarse sediment beaches are made up primarily of sediments that are greater than 2 millimetres in diameter, and consist of gravel, cobble, boulders, or some combination of each. For simplification, the term cobble is used at times although the class includes sediments ranging from gravel through cobble to boulders.

Sand beaches are made up of sediments smaller than 2 millimetres in diameter. The distinction between the coarse sediment and sand beaches is designed to be made qualitatively. In general, it is not necessary to carry out a detailed analysis of the beach sediments to make this distinction in particle size. In many instances the identification can be made from a simple visual inspection of aerial photographs, shoreline videos or a site visit. This information may also be available from reports and papers describing the particular shoreline area under investigation.

On aerial photographs and shoreline videos, sand beaches generally appear to be light in colour when compared to coarse sediment beaches. The existence of dunes behind the beach is a second indicator that the beach is composed of sand. Where sand is abundant in the nearshore, sand bars are nearly always present and show up as light patches in shallow water forming a distinct linear pattern parallel to the beach. The bars may be straight or crescentic shaped.

Coarse sediment beaches are nearly always associated with a nearby source of bedrock from which the material is eroded. Wherever bedrock cliffs or outcrops are present within the selected shoreline or within adjacent shoreline segments, and there are no indications that sand is present (e.g., the visual indicators discussed above), then it is likely that the sediments within the selected shoreline are gravel or cobble.

Field inspection of the selected shoreline segment should make it readily apparent whether most of the sediment is sand or coarser material. If the beach consists of a mixture of sands and coarse material, the assignment of beach classification (i.e., cobble or sand) should be based on an assessment of whether sand is present in the form of dunes or whether bedrock outcrops are common within and adjacent to the selected segment of shoreline.

· **Step 5 Determine the Dynamic Beach Type Sub-Classification**

Based on the information determined from Steps 2, 3 and 4, the selected segment of shoreline can then be placed in one of the 18 dynamic beach sub-classifications outlined in Table A5.2.1. This can be done by entering the flow chart Figure A5.2.1 with the information determined in Steps 2, 3 and 4.

At this stage it may be useful to confirm the correct sub-classification of the beach by comparing the attributes of the shoreline to those previously described for the each dynamic beach sub-classification in Appendix A5.1. Where there are inconsistencies between the description provided in Appendix A5.1 and the shoreline segment under consideration, these should be resolved at this step, or immediately following the completion of Step 6.

A5.2.2 Alongshore Boundaries of Dynamic Beach Reaches

· **Step 6 Determine the Alongshore Boundaries of the Dynamic Beach Sub-Classification**

Steps 6 and 7 form a two-stage procedure for dividing the shoreline into reaches. In Step 6, the alongshore boundaries of the dynamic beach sub-classifications identified in Step 5 are determined.

The boundaries are established simply by working along the shoreline first in one direction and then in the other direction starting from the approximate mid-point within the selected segment of shoreline.

The reach boundary is placed where there is a transition from one dynamic beach type to another dynamic beach type (e.g., from an exposed sandy beach backed by a bluff (1-3-3) to an exposed sandy barrier (3-3-3)), or a transition to a different shoreline type altogether (e.g. from an exposed sandy beach backed by a bluff to a bluff shoreline where the beach is less than 10 metres wide).

In many instances these transitions will be abrupt and readily apparent on maps and aerial photographs. In some locations, however, there may be a more gradual transition from one shoreline type to another. For example, along some sections of shoreline underlain by bedrock, narrow sand or gravel beaches may develop, often with small patches of bedrock outcropping (e.g., along much of the shoreline of the Penetang Peninsula in Georgian Bay). In other areas, narrow sandy beaches may exist in front of eroding cohesive bluffs during low water periods and then may be absent in the spring or during years of high lake levels. In all such situations, an assessment must be made to determine whether there is sufficient sediment present along the stretch of shoreline to act as a dynamic beach or whether the bedrock or bluffs essentially act to constrain any profile adjustment.

When endeavouring to determine a classification for an area of transition between shoreline types, the general guideline in identifying a "beach" is that sediment thickness should exceed 0.3 metres and that the beach form above the waterline should be greater than 10 metres in width. One should further note that these "guidelines" are minimum values and that they are intended to be applied as an average over a length of shoreline exceeding 100 metres. One should accept that some degree of judgement will have to be exercised in the precise placement of the dynamic beach classification boundary and that in some instances a field inspection may be warranted.

- **Step 7 Determination of Alongshore Reach Boundaries**

An **alongshore reach boundary** can be determined in **three different situations**:

- defining **a change from one dynamic beach sub-classification to another**
- defining **a change from one shoreline type to another**
- defining **changes within a single dynamic beach sub-classification**

Changes identified between different dynamic beach sub-classifications and different shoreline types must automatically be marked by a reach boundary.

Within a single dynamic beach sub-classifications there may be several unique reaches. In general, reaches should not be less than 0.5 kilometres in length and are usually not more than 20 kilometres in length.

Within a single dynamic beach sub-classification, individual reach boundaries may be drawn on the basis of a significant change in one of several criteria:

- where there is a change in shoreline orientation;
- where there is a break in beach continuity at a river mouth or inlet entrance;
- where there is a change in the height or composition of the cliff/bluff or some other relevant feature landward of the beach; or
- where there is some change in beach stability (e.g., from erosional to depositional).

As a result, reach boundaries are drawn by examining the shoreline within the boundaries drawn for the individual dynamic beach sub-classification for any significant change in one of the factors noted above. Once the reach boundaries have been established, they can be placed on shoreline maps at the appropriate scale.

- **Step 8 Confirmation of Dynamic Beach Sub-Classification**

The final step in the classification procedure is to review the information collected and to confirm that the shoreline reaches meet all the requirements of a dynamic beach.

As was discussed in Part 5, a **"dynamic beach"** does not exist or is not applied where:

- beach or dune deposits do not exist landward of the mean waterline, or where such deposits, overlying bedrock or cohesive material, are generally less than 0.3 metres in thickness, 10 metres in width and 100 metres in length

OR

- in embayments, connecting channels and other areas of restricted wave action, such that wave-related processes are too slight to significantly alter the profile landward of the waterline. This generally applies where the maximum fetch distance measured over an arc extending 60^{o} on either side of a line perpendicular to the shoreline is less than 5 kilometres

If these conditions are met then the dynamic beach sub-classification and reach boundaries, determined using the eight step procedures outline above, can be confirmed. In some areas, a field visit may be necessary to determine beach width and thickness.

A5.2.3 Field Verification of Dynamic Beach Sub-Classification and Alongshore Boundaries

The classification and boundary delineation process described previously is based primarily on an "in-office" assessment of background information, maps, aerial photographs, videos and field reports, and represents an appropriate level of investigation for those areas of shoreline not presently undergoing development. In areas where shoreline development is currently existing, intensifying, or proposed, field verification of the dynamic beach sub-classification and boundaries assigned to each reach is recommended.

For the majority of shorelines, the verification of dynamic beach sub-classifications and reach boundaries can simply be achieved through a single site inspection. In shorelines involving complex shore types or where a precise determination and delineation of the *dynamic beach hazard* is required, the verification procedure may involve more than one site visit to determine the final placement of the boundaries between reaches. This later process may also include the need to integrate information obtained from secondary sources with that obtained from the field inspections.

As a result, the verification process will often be an iterative one in which there are several stages of classification and revision until the boundaries of the shoreline units are finally confirmed. The actual process applied by any one individual or agency is likely to vary slightly from one region to another in response to differences in the length of shoreline reaches and shoreline complexities between regions.

The following step-by-step procedure is intended as a guide to assist in undertaking the verification process.

- **Step 1** Based on the information provided by the initial classification procedure, select a section of shoreline for field inspection centred on the area of interest. The selected section of shoreline should be between 10 to 50 kilometres in length and will likely contain several dynamic beach reaches. It is expected that the selected section of shoreline will be defined by clearly identifiable boundaries. Wherever appropriate, the selected section of shoreline should include all, or a major portion, of a littoral cell.

- **Step 2** Identify all the dynamic beach units within the selected shoreline section and ensure that the supporting background information used in making this determination has been transferred to the field sheet for each unit.

- **Step 3** To begin the field verification process, select a dynamic beach reach at one end of the section under investigation. The selected dynamic beach reach should be at the updrift end of the section of shoreline wherever a well-defined littoral transport direction exists.

- **Step 4** Examine the characteristics of the shoreline within the selected dynamic beach reach in the field, focusing on the central part of the dynamic beach reach rather than on the boundaries of the reach. Verify the initial information on the field sheet that will be used in the classification procedure, by:

    - establishing that the minimum criteria for classification as a beach, in terms of the width and thickness of beach sediments, are met;

    - confirming that the information on beach profile and planform are correct;

    - determining through visual inspection the average size of the beach sediment;

    - classifying the beach as sand or coarse sediment (i.e., gravel/ cobble/boulder); and

    - determining whether the sediments are thick enough for the profile to be fully-developed (i.e., sediments generally thicker than 1 metre over bedrock or cohesive materials) or whether bedrock or cohesive materials are close enough to the surface to restrict profile changes due to wave action and water level fluctuations.

- **Step 5** Based on the information obtained in the field:

    - confirm the original sub-classification of the dynamic beach reach (i.e., determined in the office through analysis of supporting background information); or

    - use the information collected and recorded during the field inspection process to re-classify the reach

- **Step 6** Work, in both directions, along the shore to determine the final placement of the boundaries of the reach. As was the case in the procedures described previously, the boundaries of the reach will be determined by:

    - a change in one of the factors that form the basis for the classification scheme (e.g., a change in sediment size class, or in the beach profile) so that a new dynamic beach unit occurs;

    - a change within a single dynamic beach sub-classification (e.g., significant change in shoreline orientation, height of landward feature, beach stability or beach continuity;

    - by a transition to a section of shoreline that no longer meets the requirement for dynamic beach (e.g., bedrock outcrops and sediments become too thin to form a beach).

    In this latter case, one needs to make the determination of whether there is sufficient sediment present along the stretch of shoreline to act as a dynamic beach. The general guideline in these areas is that sediment thickness should exceed 0.3 metres and that the beach above the water line should be greater than 10 metres in width. In applying this general guideline, one should note that these are minimum values and that they are intended to be applied as an average over a stretch of shoreline of greater than 100 metres in length.

- **Step 7** Move to the adjacent dynamic beach unit and repeat Steps 1 to 6. As the process is repeated, new dynamic beach units or reaches may be created where the field investigation indicates and confirms changes to a different dynamic beach type that were not evident in the preliminary classification (e.g., a change from cobble to sand which was not evident in the initial data collected for that shoreline section). Conversely, some of the preliminary units may be merged where field investigation confirms that the initial boundary determined through the preliminary classification process was incorrect.

A5.2.4 Dynamic Beach Sub-Classification Field Sheet

Background

Identification and location

1) Conservation Authority/MNR District

2) Dynamic Beach Unit #/Identification

3) Lake/connecting channel

4) Map sheet(s); Hydrographic chart(s)

5) Initial boundary locations/grid coordinates

Shoreline orientation and fetches

6) Shoreline orientation azimuth

7) Fetch window, range of wave directions to which the beach is exposed

8) Fetch lengths, measured in a straight line for shore perpendicular (i.e., 90 ^{o}) and at 22.5 ^{o} increments on either side:

   0.0 ^{o} 22.5 ^{o} 45.0 ^{o} 67.5 ^{o} 90.0 ^{o} 112.5 ^{o} 135.0 ^{o} 157.5 ^{o} 180.0 ^{o}

Wave climate and wind setup

9) Source of wave climate information

10) Wave height, period and direction for largest waves occurring 10 hours or more per year.

11) Estimated wind setup associated with 10-year return frequency storm (and source of information).

Beach planform and littoral drift pattern

12) Small-scale map showing unit within larger shoreline section/littoral cell - include generalized pattern of alongshore sediment transport directions.

13) Classification of dynamic beach on basis of planform.

14) Major sediment sources and sinks, identification and estimated volumes

15) Input and output volumes of littoral drift.

Beach profile

16) Sketch of profile perpendicular to shoreline based on topographic map and hydrographic chart plus photographs, etc.

17) Classification of beach by profile type.

Change in shoreline position

18) Average annual recession rate. Positive values indicate shoreline erosion/recession, negative values indicate accretion and progradation. Source of information for determination of recession rates.

19) Any other indicators of shoreline change, including isostatic uplift/water level change.

Field Data

Field Conditions

20) Date of visit, lake level, weather and wave conditions at time of visit; antecedent conditions.

Beach Characteristics

21) Classification of beach sediment size; description of characteristics of beach sediments.

22) Average beach width.

23) Average thickness of beach sediments over bedrock, cohesive substrate.

24) Classification of fully developed or partial profile.

Human intervention

25) Classification into natural or artificial beach.

26) Extent of shoreline protection structures, type, condition.

Determination of beach type

27) Classification criteria:

i) Beach sediment size (from 21) ____________________

ii) Beach profile type (from 17) ____________________

iii) Beach planform type (from 13) ____________________

iv) Beach profile development (from 24) ____________________

v) Natural or artificial beach (from 25) ____________________

28) Beach type based on above criteria from classification chart

29) Notes on special features of dynamic beach unit which may be of significance in application of Dynamic Beach Hazard.

Determination of boundaries of dynamic beach unit

30) Location of right boundary (when looking offshore):

i) reason for boundary change - change in which criterion

ii) classification of adjacent unit

iii) notes on nature of transition to adjacent unit

31) Location of left boundary (when looking offshore):

i) reason for boundary change

ii) classification of adjacent unit

iii) notes on nature of transition to adjacent unit

Verification of Dynamic Beach Hazard

32) Are there any special features of beach type in the sub-classification scheme or from observations in the field (29) that indicate a need to redefine the limit of the Dynamic Beach Hazard (e.g., dynamic beach backed by a cliff/bluff/bank, beach is eroding, beach exists on a narrow barrier system, or beach profile below 100 year flood level).

33) Establish the position of the Dynamic Beach Hazard at a number of locations in the field from the initial line drawn on the 1:2000 FDRP maps. Compare the position of the line with the field situation and determine whether it is appropriate or whether it should be adjusted based on the criteria (e.g., dynamic beach backed by a cliff/bluff/bank, beach is eroding, beach exists on a narrow barrier system, or beach profile below 100 year flood level).