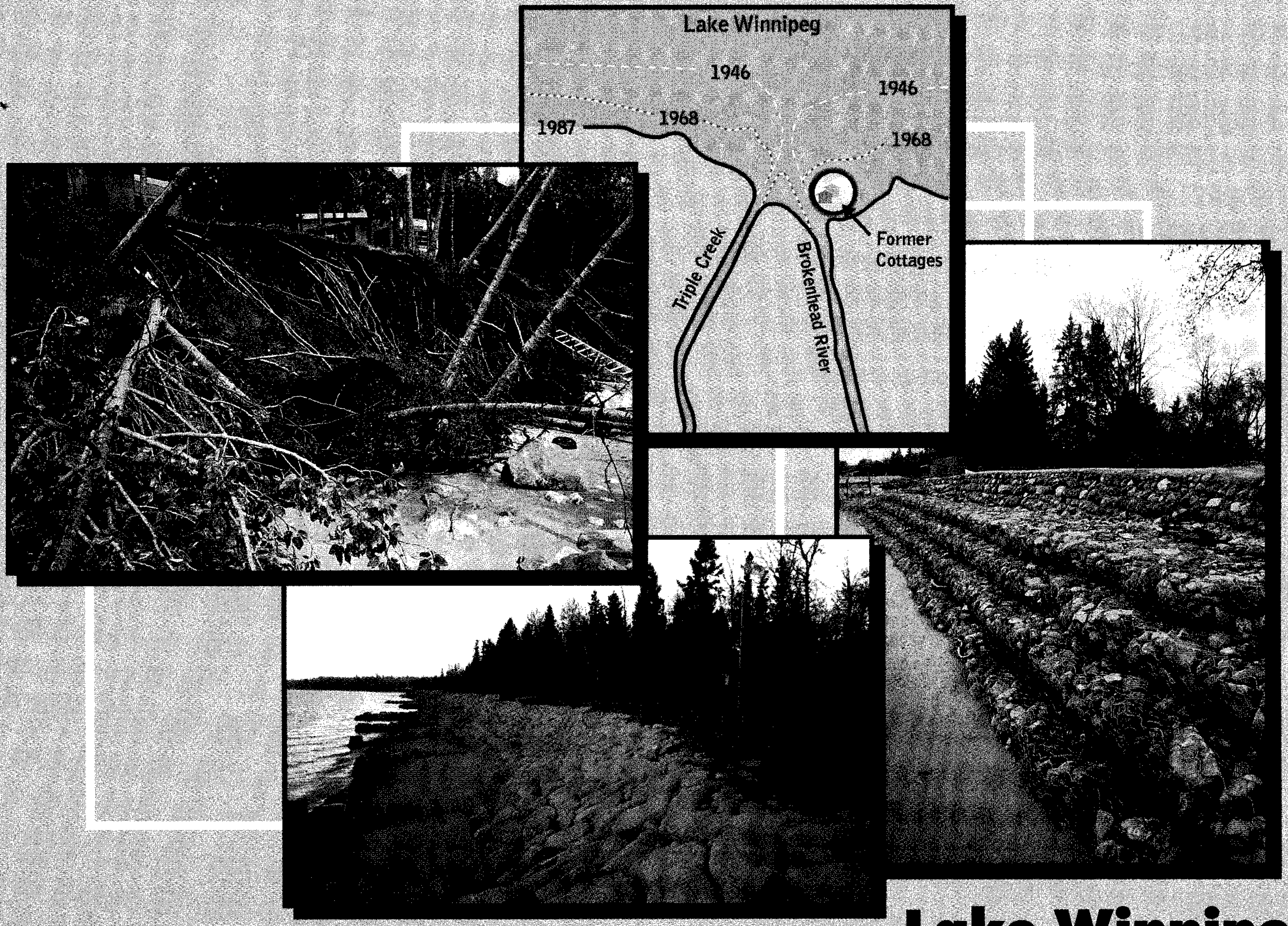
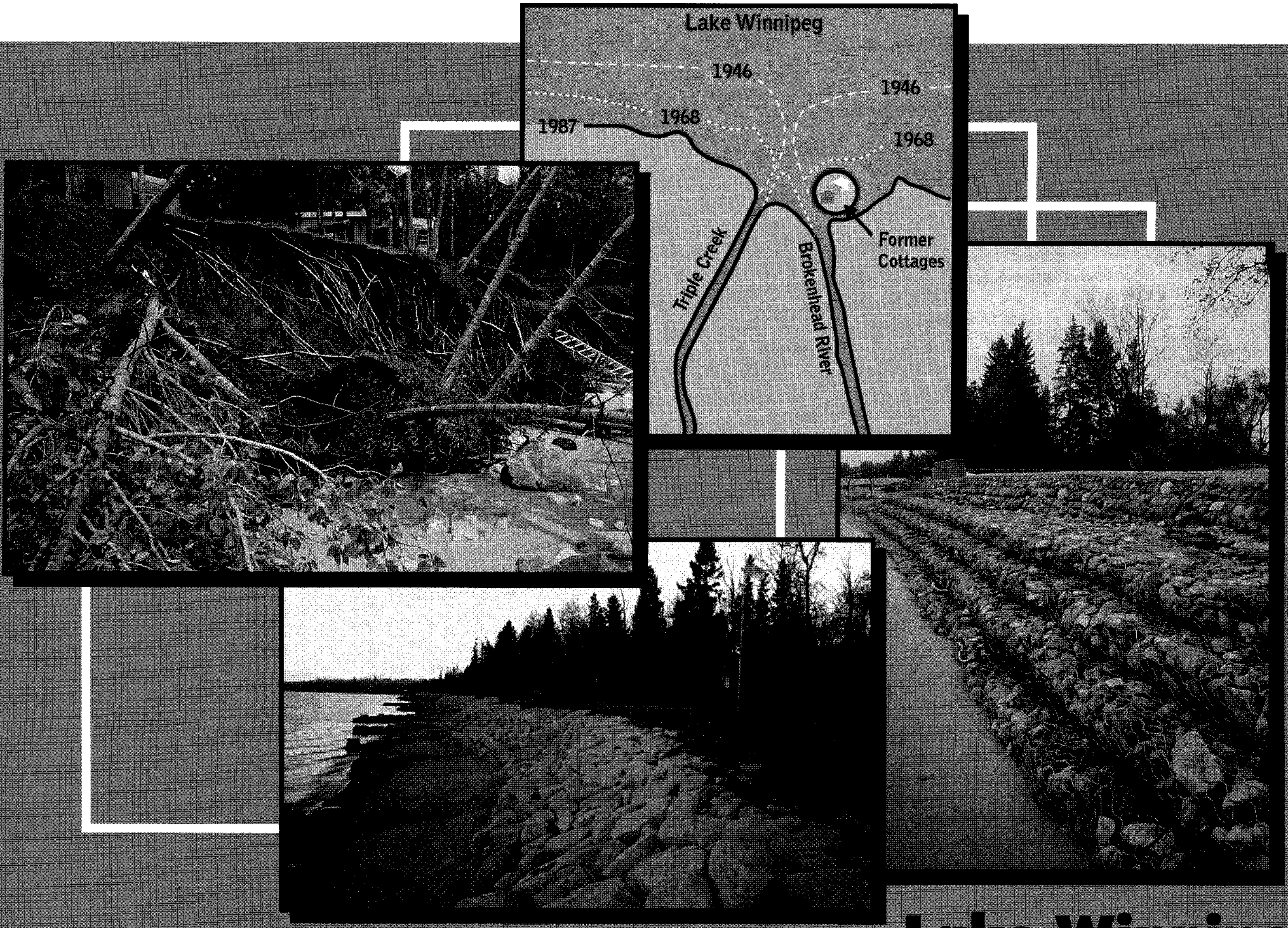


# Lake Winnipeg

## Shoreline Management Handbook

March 2001



# Lake Winnipeg

## Shoreline Management Handbook

# Contents

**APPENDICES**

# Acknowledgements

Much of the information in this handbook is a summary of the ***Lake Winnipeg Shoreline Erosion Study*** report prepared for the Lake Winnipeg Shoreline Erosion Advisory Group by W.F. Baird & Associates Coastal Engineers Ltd. and Stantec Consulting Ltd. September 2000. The following documents provided valuable information for the report:

***Lake Winnipeg Shoreline Erosion, Sand Movement, and Ice Effects Study***

Lake Winnipeg, Churchill and Nelson Rivers Study Board, 1974
F. Penner, P.Eng. and A. Swedlo, P.Eng.

***The Lake Winnipeg Shoreline Handbook: A Property Owner's Guide to Shoreline Processes and Erosion Protection Structures on the South Pool of Lake Winnipeg***

Department of Mines, Resources and Environmental Management, 1977
M. Young, P.Eng. and F. Penner, P.Eng.

The Manitoba government is taking action to preserve our shorelines by providing funding for the publication of this report.

Government also supports the Shorelines Erosion Technical Committee and its efforts to advise landowners about building effective shoreline protection structures

More information about preventing shoreline erosion is available from Manitoba Water Stewardship at manitoba.ca/waterstewardship or by calling 204-945-6398.

# SECTION 1 – Introduction

Significant portions of the shoreline around the south basin of Lake Winnipeg are eroding and transgressing landward. In addition, low-lying areas adjacent to the shoreline are prone to flooding due to various high combinations of mean water levels and wind set-up. In response to these flooding and erosion hazards, many shore property owners have attempted to construct their own shoreline protection structures. Sometimes they were successful, but frequently they found that after spending considerable time and money, their structures were ineffective and/or caused negative impacts elsewhere.

W.F. Baird & Associates Coastal Engineers Ltd. and Stantec Consulting were retained by the Lake Winnipeg Shoreline Advisory Group to review the shoreline erosion factors around the south basin of Lake Winnipeg (see Figure 1.1) and to identify appropriate shoreline management and protection options. The results were presented in a report to the advisory group titled *LAKE WINNIPEG SHORELINE EROSION STUDY* and are summarized in this handbook.

Section 2 of this handbook discusses shoreline processes including controlling substrate, water levels, waves, recession rates, sediment transport, ice, ground water and vegetation. It is intended to give the reader at least a basic insight into the factors that affect shoreline flooding and erosion.

Section 3 presents a range of preventative, nonstructural and structural shoreline management options and discusses the advantages and disadvantages of each approach. The reader is provided with the steps to selecting which shoreline management approach is best suited for his or her individual requirements. In many cases, a careful review of long-term erosion rates, the impact of protection

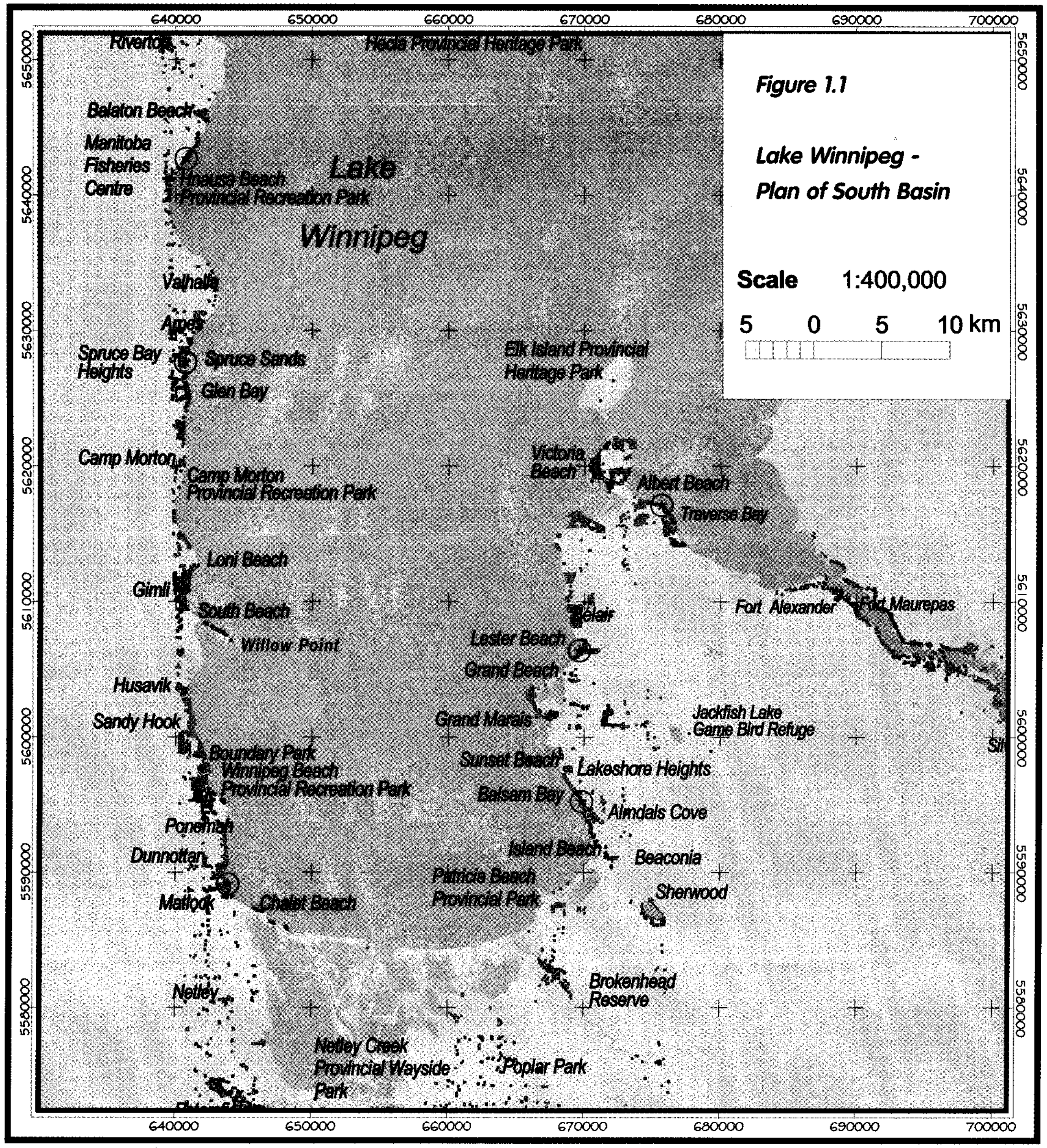


*Figure 1.1*

*Lake Winnipeg - Plan of South Basin*

structures on beaches, and the total cost of a proper protection structure relative to the value of the property, will indicate that the best course of action may be to allow the erosion to occur. For those situations where structural works are warranted, the reader is provided with the design basics of various flooding and erosion protection structures.

**Caution**. This handbook is not intended as a substitute for professional engineering services that are needed to properly design shore protection works. The services of a competent coastal engineer should be retained to carry out shoreline protection design specific to the site being protected in order to reduce the risk of failure and to evaluate any effects on neighbouring properties.

# SECTION 2 –
# Understanding Shore Flooding and Erosion

## 2.1 Lake Winnipeg Shoreline

### 2.1.1 Geological Setting

The present day shoreline of Lake Winnipeg has formed as a result of geomorphological processes such as the action of glaciers, water level changes and erosion by waves, which have occurred over many thousands of years. A glacial ice advance, to the present day position of the eastern shore of Lake Winnipeg, deposited a till material over most of the area. Till is a diverse mixture of soil particle sizes (i.e., clay, silt, sand, gravel, cobble and boulder). As the glacial ice retreated, large quantities of sandy outwash material were deposited in the lake, over the till, in the area of the present eastern shore. With the ice barrier to the north, meltwater from the glacier ponded, forming glacial Lake Agassiz, which was a much larger lake than present day Lake Winnipeg. During the Lake Agassiz phase, varying depths of clays and silts were deposited over the tills. These lacustrine clays and silts are generally free of stones and relatively unconsolidated. Compared to the cobble/boulder till, the silts and clays are highly erodible.

## 2.1.2 Shoreline Classification

Based on the geological setting, the south basin of Lake Winnipeg can be divided into three basic shoreline groups:

- lacustrine clays underlain by till along the west shore;
- sandy boulder tills along most of the east shore; and
- wind and water sorted sand deposits along the south shore and at a number of locations on the east shore.

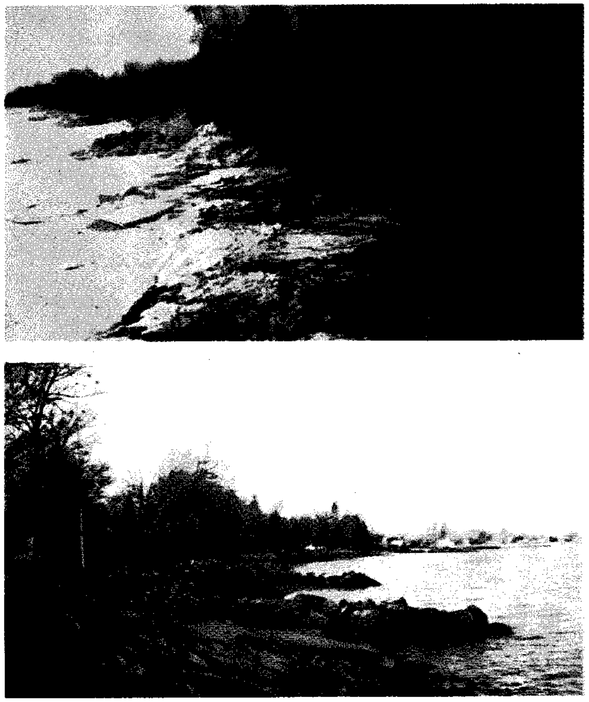
These three groups are briefly described in the following paragraphs in the context of the west, east and south shores. The three basic groups can be subdivided into twelve shoreline types. The distribution and description of the twelve different types is provided in Appendix I.

### West Shore

The west shore consists of low sand and mixed sand-gravel beaches in the north, giving way southward to extensive low cliffs fronted by narrow sand and gravel beaches. Willow Point, the most prominent littoral feature along the west side of the south basin, is formed by a boulder-lag platform. On the north side of the Point, a transgressive sandy barrier is moving onshore over the back barrier marsh. South of Willow Point, the shore is heavily developed and extensively modified by shore protection structures.

*West Shore Beach*

The soil profile at the shore generally consists of a shallow depth (1 to 20 ft, or 0.3 to 6 m) of lacustrine clay underlain by clay till (see Figure 2.1). A further description of the distribution of the soil profiles along the shore is presented in Appendix I. The lacustrine clay is relatively stone free and highly erodible. The underlying till contains significant quantities of coarse particles - sand, gravel, cobbles and boulders. The quantity of coarse particles remaining after the fine grained particles - silt and clay – have washed away varies along the shore but is typically only 15% to 20%. The remaining sand deposits are typically concentrated in a narrow band adjacent to the shoreline where they may be 1.5 to 4 feet deep (0.45 m to 1.2 m). The sand layer is normally only 0.5 ft deep 100 ft offshore and gets progressively thinner further offshore. Between elevation 713 ft and 718 ft the beach has a slope of about 1:10. Offshore of elevation 713 ft, the slope is relatively gradual, ranging from 0.3% to 1.1% with an average of approximately 0.7%.



***Photographs show bluff erosion north of Gimli (above) and protection south of Gimli (left)***

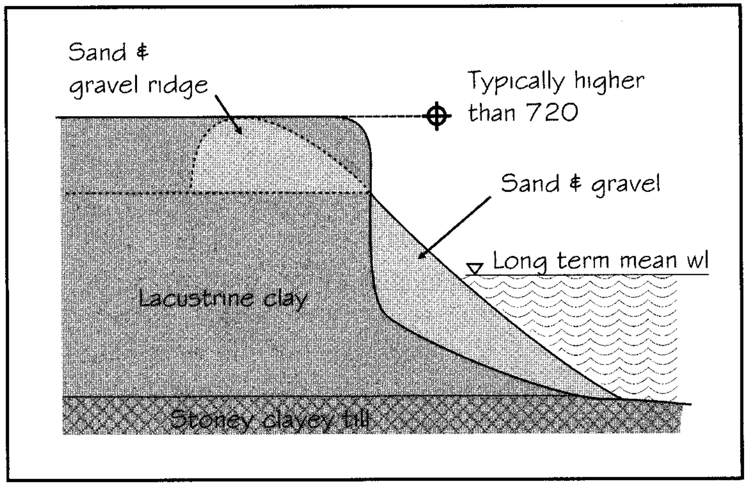


***Figure 2.1***
***Example of soil profile along west shore***

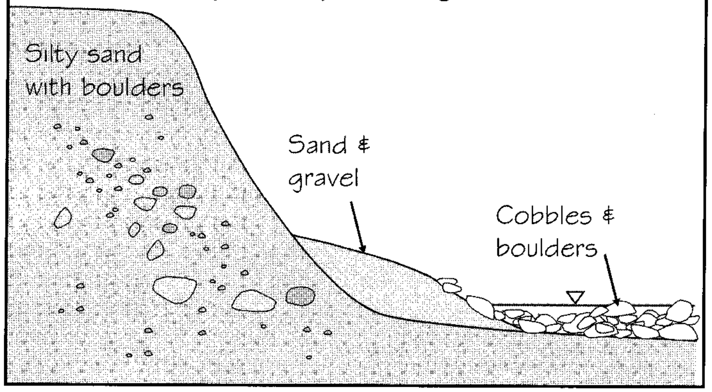
## East Shore

Cobble Beach at Halcyon

Shorelines along the east shore are more variable and complex and are generally higher than the west shore. They include glacial outwash deposits consisting mainly of sands, lacustrine clays and silts, and boulder-rich clay till (see Figure 2.2). The beach profile between elevation 713 ft and 718 ft has a slope that generally varies from 1:20 to 1:40. Offshore profiles are variable with some armoured by cobbles and boulders. The eastern shoreline material is approximately 90% to 95% coarse-grained. Erosion of the fine-grained material from the boulder rich till material leaves a significant lag deposit of cobbles and boulders, forming armoured headlands.

North of the Winnipeg River, the east shore of the south basin is relatively low and characterized by a succession of shallow embayments between rock or boulder-lag headlands. Mixed sand and gravel beaches and low erosional scarps fringe the embayment shores. Shallow gravelly washover veneers are present at some headland locations. Vegetation extends down across the upper beach in some places implying a period of reduced wave runup. Colonizing vegetation also commonly extends into the water on gravel shoal platforms and headlands.

***Figure 2.2 – Example of soil profile along east shore***



Black River is located approximately midway along the east shore of the south basin. The river edges are low-lying with predominant areas of marsh vegetation and some bedrock outcrops. Local observations indicate that the width of the river has increased over time and adjacent areas have become submerged. Areas that were once hay fields have now become wetlands. Houses and a school building close to the river were reportedly abandoned decades ago due to increasing water levels.

Coastal dunes have developed on sandy barriers at Beaconia (Patricia Beach), Grand Beach and Hillside Beach. The gravel spit and barrier island at Grand Marais appear to be transgressive. Resistant points or headlands at Stoney Point, Grand Marais Point, Ironwood Point, Hillside Point, Volks Point and Elk Island anchor the barriers. These sand deposits along the eastern shore are more extensive than the western shore. The largest sand deposits occur at Beaconia Beach, Grand Beach, Hillside Beach, Victoria Beach and from Elk Island to Albert Beach.

## South Shore

The south shore of Lake Winnipeg consists of barrier islands except for the bedrock outcroppings at Stoney Point. During severe storms at high water levels, some sediment is transported into the marshes through inlets or by overwash and some sediment is eroded from the foreshore and transported off into deeper water. As discussed in Section 2.2.2, the lake level in the southern basin is rising due to isostatic tilting of the northern outlet of the lake and possibly some influence of climatic fluctuations during the last few centuries. As a result, the south shore barrier beaches and bay-mouth bars are migrating southwards as evidenced by outcroppings of silt and clay sediments, organic muck and subfossil wood initially deposited in the marsh. Figure 2.3 shows the nature of the landward migration. It is estimated that the south shoreline has transgressed landward (to the south) 200 ft to 300 ft (60 to 100 m) since about 1650 AD.

**Figure 2.3 – Landward migration of Barrier Island due to rising water levels**

Generalized profile of the beach and nearshore zones and the terminology describing the various features of a barrier island.
after Nielsen & Conley, 1994.

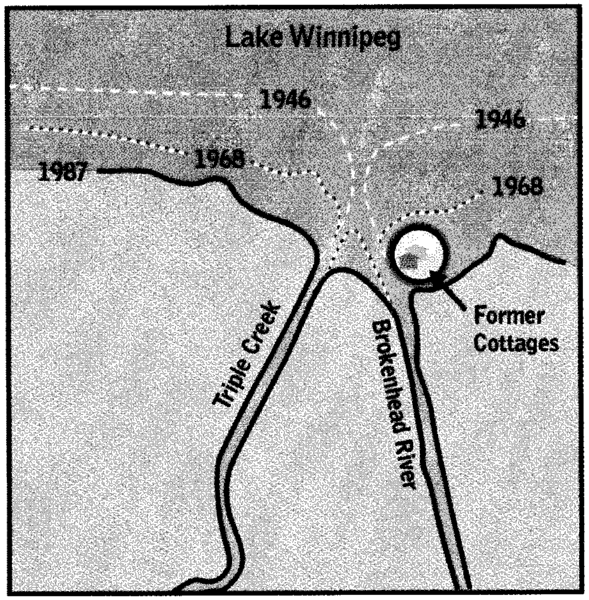


*Figure 2.4 – Lake Winnipeg Shoreline at Brokenhead River and Triple Creek*

The transgression of the shoreline and the effects of wind setup result in long-term and short-term flooding of the shoreline areas. For example, in the vicinity of the Brokenhead River, the barrier island shoreline is generally less than about 3 ft (1 m) in height but varies between 80 ft (25 m) to more than 300 ft (100 m) in width. It has experienced historic shoreline recession rates of 10 ft/yr to 24 ft/yr (3 m/yr to 7.3 m/yr). Airphotos from 1946, 1968 and 1987 show that the mouth of the Brokenhead River had retreated inland in the order of 650 to 1000 ft (200 to 300 m) (see Figure 2.4). Triple Creek now flows directly into Lake Winnipeg. Cottages visible in the 1946 airphoto are no longer present and their foundations are now under water.

East of Pruden Bay, the shoreline has undergone significant changes due to long-term increases in the water level. Airphotos from 1929 show hay fields south of the barrier island. By 1946 the hay fields appeared to be gone and by 1996 they had given way to marsh and open water.

***Location of former cottages, mouth of Brokenhead River***

## 2.2 Shoreline Processes

The primary factors that govern shoreline processes are "controlling substrate", water levels, waves, recession rates, sand movement and ice. These factors are discussed in the following subsections.

### 2.2.1 Controlling Substrate

The controlling substrate is the dominant lakebed material in the nearshore area. This dominant substrate material controls the erosion and shoreline processes. There are four general classes of controlling substrate:

- bedrock shorelines;
- cohesive shorelines;
- dynamic beaches; and
- muddy shores (soft sediments with vegetation; e.g., silts and organics).

**Bedrock Shorelines**

Bedrock shorelines are relatively resistant to the forces of wave erosion. Some additional factors causing bedrock erosion are repeated cycles of wetting and drying and freezing and thawing. Bedrock was not observed along the western and southern shorelines except at Stoney Point. Bedrock outcrops were observed at sites along the northerly portion of the east shore of the south basin (e.g., at Black River, Manigotagan and Hollow Water).

***Cohesive Shorelines***

The controlling substrate of a "cohesive shoreline" consists of a consolidated clay matrix of some form (e.g., glacial till or a lacustrine deposit; refer to Section 2.1.1) in the nearshore. The visible shoreline bluff above the water may consist of different materials and/or there may even be a thin deposit of beach sand, gravel, or cobbles. However, there is not enough of these beach materials to protect the underlying cohesive material from erosion by waves.

In the nearshore area, lakeward of the water's edge, wave action reaches down to the lakebed, breaks apart the cohesive material and erodes the lakebed downward (see Figure 2.5). The very small particles of silt and clay are set loose but are too small to remain in the high energy breaking wave zone at the shoreline and are washed into deeper water offshore where they settle to the bottom. It was noted in Section 2.1.2, that along the west shore the clay and silt particles accounted for 80 to 85 percent of the soil at the shoreline. In this manner, the downward erosion or downcutting of the cohesive shoreline is irreversible; the silt and clay particles cannot be "stuck back together" – the shoreline cannot accrete (i.e., move lakeward). The remaining limited volume of sand material is moved along the shore by waves (see Section 2.2.6).

The downcutting is greatest in the shallow water at the shoreline and diminishes as you go into deeper water offshore. It is estimated that erosion of the nearshore profile in Lake Winnipeg's south basin extends out to depths of about 8 ft to 12 ft (2.4 m to 3.7 m) below the long-term mean water level. As the downcutting continues, the toe of the bluff at the shoreline is undercut. The bluff slope becomes over-steepened and collapses resulting in recession of the crest. The slumped material is removed by wave action.

***West shore, exposed cohesive shoreline***

If the cohesive material has a high content of cobbles and boulders (e.g., glacial till along the east shore), the very small clay and silt particles are washed away leaving behind a "lag deposit" of cobbles and boulders. This lag deposit slows the downcutting process and reduces recession of the shoreline. Stripping or removal of the cobbles and boulders to "tidy" the beach or for the construction of groynes or revetments, will accelerate erosion of the nearshore.

The amount of sand and gravel in the nearshore can also affect the downcutting rate. A limited amount of sand acts as an abrasive agent as it is moved across the cohesive material. A large amount of sand will cover and protect the underlying cohesive material.

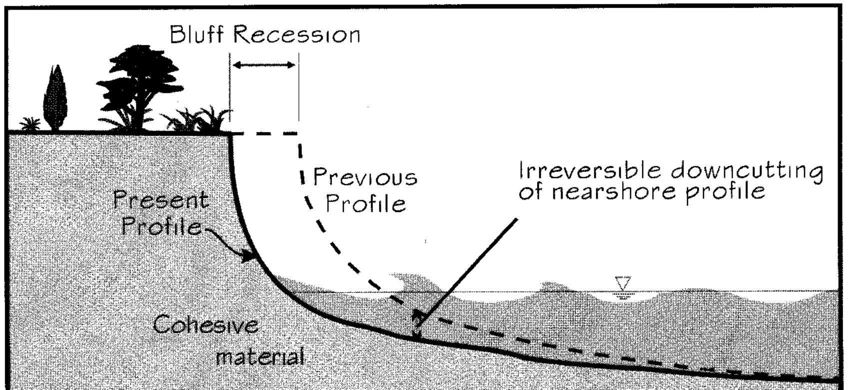
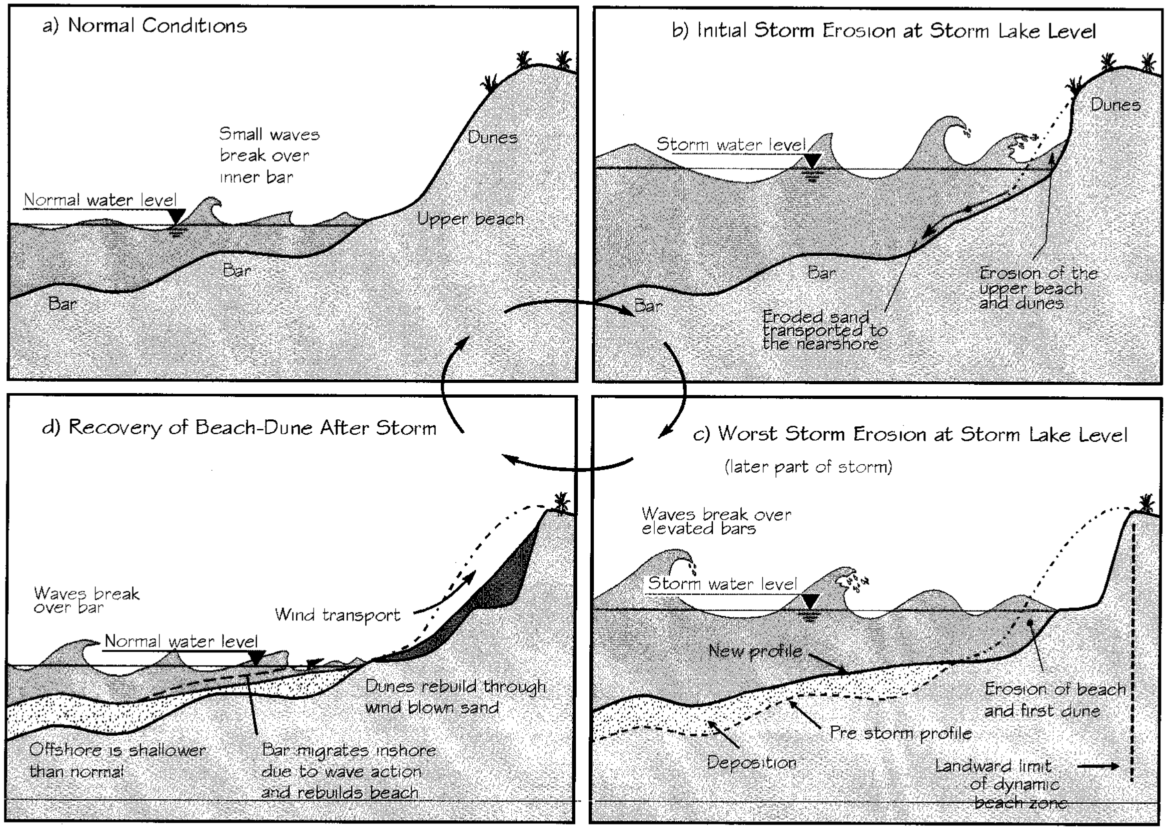


**Figure 2.5 – Downcutting of Cohesive Nearshore Profile**

## Dynamic Beach Shorelines

Beach shorelines are simply extensive deposits of cohesionless materials, such as sand, gravel and cobbles, that have been transported and deposited by waves, currents and wind. "Dynamic beach" shorelines are those beach shorelines that have enough sand and gravel such that any underlying substrates are not exposed to erosion. Much of the south shore and parts of the east shore consist of dynamic beach shorelines (see Section 2.1.2).


a) Normal Conditions

b) Initial Storm Erosion at Storm Lake Level

c) Worst Storm Erosion at Storm Lake Level (later part of storm)

d) Recovery of Beach-Dune After Storm

*Figure 2.6 – Dynamic Beach - Dune System - Cross-Shore Transport*

As shown in Figure 2.6, dynamic beach shorelines can alternately recede and accrete (i.e., cross-shore transport) over the short-term due to changes in the wave climate and water levels. In these instances, beach material is temporarily eroded from the beach and deposited in the nearshore and will be returned to the beach over time. This dynamic aspect of beaches can be considered separately from the long-term erosional effects. Generally, long-term erosion of a beach occurs when the volume of beach sediment being supplied to the area by alongshore transport is less than the volume of sediment being removed from the area by alongshore transport. These long-term changes are generally the result of a reduction in the updrift sediment supply. Alongshore transport is the movement of beach sediment, parallel to the shoreline, by waves and currents and is discussed further in Section 2.2.6.

### Muddy Shores

Muddy shores are usually associated with sheltered embayments with minimal wave and current action. They are often characterized by the presence of organic material and emergent vegetation.

## 2.2.2 Water Levels

### Long-Term Water Level Changes

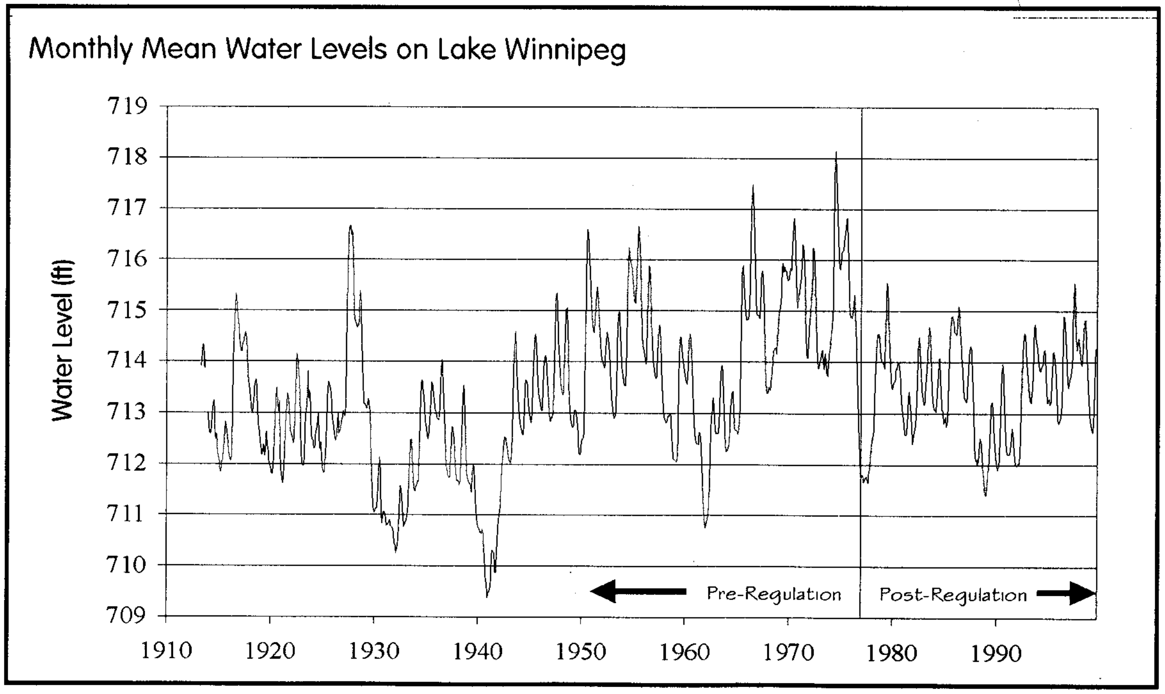
Long-term changes – months to seasons to years – in Lake Winnipeg water levels result from variations in the amount of precipitation, evaporation, inflow to and outflow from the lake, including the effects of regulation. The historical variation in the mean monthly level is shown in Figure 2.7, both prior to and after regulation. Mean monthly water level is used to represent lake wide conditions because the level of the lake at any given time varies from location to location due to short-term effects such as wind setup. The effects of wave setup and wave runup at the shoreline are in addition to the effects of mean lake level and wind setup.

Manitoba Hydro's license for regulation of the lake since 1976 requires that the "wind-eliminated" lake level be maintained between elevations 711 ft and 715 ft (216.7 m and 217.9 m) insofar as possible. Since regulation, the *wind-eliminated* level has not been below the lower target level and has seldom exceeded 715.0 ft and only twice has it exceeded 715.5 ft. Following regulation, the variation of the mean monthly lake level has been reduced - peak levels have been lowered and the lowest levels have been increased.

Natural seasonal changes follow an annual cycle with peaks in the late spring or early summer, due to spring runoff, and lows in the late fall or winter. In any given year, the difference between the highest monthly mean and the lowest monthly mean for that year typically ranges between 1 ft to 2 ft but has been higher than 4 ft (prior to regulation) and as low as 0.5 ft.

Due to isostatic rebound over the last 7,700 years, the northern outlet of Lake Winnipeg is rising at a quicker rate relative to the southern end. Isostatic rebound is the action of the earth surface springing back up following the removal of the immense weight of the glacial ice sheet. With the upwards tilting of the north end, the water level in the south end increases and the water body transgresses southward over the land. Estimates based on radiocarbon dating of peat deposits and trees suggest the mean water level in the south basin has been rising approximately 8 inches per century (20 cm/century) over the last three hundred years.

***Figure 2.7***



## Wind Setup

Short-term lake level fluctuations are primarily the result of strong winds. When the wind blows over the lake in one direction for a number of hours, the water level at the downwind shoreline is pushed up. This increase above the normal still water level is called "wind setup" (see Figure 2.8). In a similar manner, "wind setdown" is produced at the upwind end of the lake. Wind setup does not include the effects of wave action. Wave setup and wave runup and overtopping further elevate the water level effects at the shoreline. Wind setup tends to be more severe in the fall.

Wind setup events calculated at Winnipeg Beach/Gimli by subtracting the wind-eliminated water level from the daily water level are presented in Table 2.1.

Wind setup values calculated by subtracting the wind-eliminated elevation from the hourly water levels would result in slightly higher setup values.

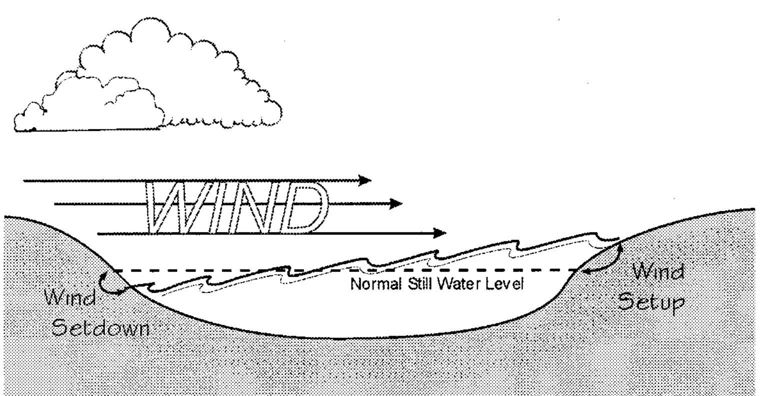


*Figure 2.8 Wind Setup*

**Table 2.1: Top 10 Wind Setup Events: Winnipeg Beach/Gimli ***

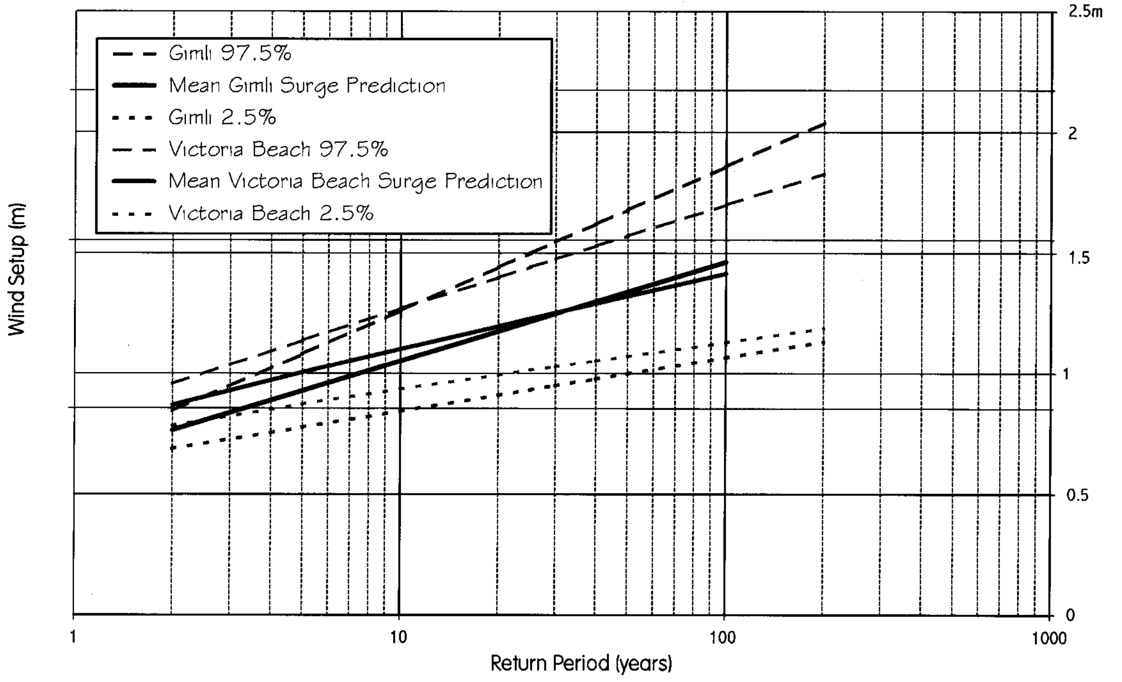
| Rank | Date | Set up *(ft)* | Wind-Eliminated Water Level *(ft)* | Total Daily Water Level *(ft)* |
|---|---|---|---|---|
| 1 | Nov. 11, 1932 | 3.7 | 710.8 | 714.5 |
| 2 | Oct. 18, 1930 | 3.6 | 710.7 | 714.3 |
| 3 | Nov. 12, 1940 | 3.3 | 709.8 | 713.1 |
| 4 | Jul. 2, 1917 | 3.2 | 714.6 | 717.8 |
| 5 | Oct. 8, 1956 | 3.1 | 715.0 | 718.1 |
| 6 | Nov. 2, 1997 | 3.1 | 714.4 | 717.5 |
| 7 | Oct. 24, 1994 | 3.0 | 713.5 | 716.5 |
| 8 | Aug. 31, 1944 | 3.0 | 713.7 | 716.7 |
| 9 | Oct. 14, 1943 | 3.0 | 714.0 | 717.0 |
| 10 | Oct. 29, 1993 | 2.8 | 714.5 | 717.3 |

* calculated at Winnipeg Beach/Gimli by subtracting the wind-eliminated water level from the daily water level

Wind setup values were estimated from recorded data for Gimli and Victoria Beach by subtracting recorded hourly water levels from the daily wind-eliminated water levels for the period 1991 to 1999. The estimated wind setup values (also known as storm surge) and return periods for Gimli and Victoria Beach are presented in Figure 2.9. It can be seen from this figure, that the wind setup values at Gimli and Victoria Beach are similar. The 10-year and 100-year return period wind setup values are about 3.5 ft (1.1 m) and 4.5 ft (1.4 m) respectively. There is a 93% risk that a 10-year return period event will be equaled or exceeded at least once over a period of 25 years. A 100-year return period event has a risk of 22% of being equaled or exceeded at least once over a period of 25 years.

At other locations around the south basin, the magnitude of the wind setup values relative to the values for Gimli and Victoria Beach will vary due to local conditions. At sites on the western shore, north of Gimli,

***Figure 2.9 Wind Setup (Storm Surge) Return Periods at Gimli and Victoria Beach (1991 to 1999)***



setup values are about 10% less than the values for Gimli for a strong northerly wind. South of Gimli, setup values are about 10% greater than the setup at Gimli. Along the eastern shore, the setup values are estimated to be 17% greater at Beaconia than the setup value at Victoria Beach, 6% greater at Lester Beach and 9% greater at Traverse Bay.

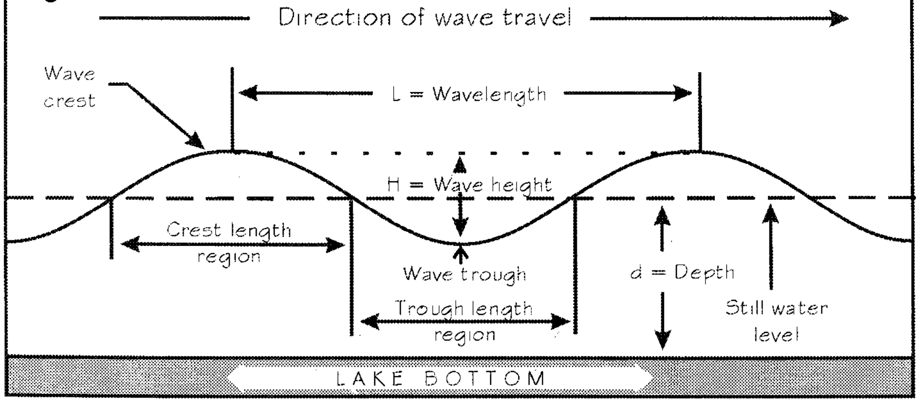
## 2.2.3 Waves

### Characteristics of Waves

The action of wind-generated waves is one of the most important factors in shoreline erosion and in the transport of sand along a shoreline. Waves generated by wind are primarily a function of the wind speed, the duration of the wind (i.e., how long does it blow) and the distance over the water which the wind blows (i.e., the "fetch"). The common terms used to describe waves, such as height and length are presented in Figure 2.10. Wave period is the time it takes for successive wave crests to pass a given point, and is expressed in seconds.

Since wind speed and direction are not constant and since the wind continues to generate new waves over the whole length of the fetch, waves of many heights, lengths and periods are generated, resulting in what is commonly called irregular waves. In other words, in a given series of waves, the wave heights are irregular (i.e., the wave heights are not regular or uniform). The "significant wave height" is defined as the average height of the highest one-third of all the waves in a given series of waves. The maximum wave height in the series can be 1.5 to 2 times greater than the significant wave height.

*Figure 2.10 Wave Characteristics*



### Deepwater Wave Hindcast

Using historical wind records and measured fetch lengths, it is possible to hindcast (i.e., the opposite of forecast) a wave climate for a point in deep water just offshore of any given location or stretch of shoreline. Based on wind records from April 1978 to August 1999, a deepwater wave hindcast estimated that the maximum significant wave heights around the south basin are approximately 6 to 7 ft. (1.8 m to 2.1 m) with peak periods of 5 to 6 seconds.

### Nearshore Waves

For those contemplating shoreline protection, the wave conditions at the shoreline are of greater interest than the deepwater waves. As the offshore waves move from the deepwater to the nearshore, the water depth gets shallower and the waves will begin to be affected by the lake bottom. Thus, the nearshore wave conditions will vary from the offshore waves due to the effects of shoaling, friction and refraction.

Generally, shoaling decreases the length and velocity of the wave but increases the wave height. In shallow water, some of the increase may be offset as a result of energy losses caused by friction with the lake bottom. Friction becomes more significant on gently sloping shorelines where the distance over which the wave shoals is long.

By comparison, the process of wave refraction occurs as waves move from deep water into a shallower shoreline region, changing their direction as the wave crests attempt to align themselves parallel to the underwater depth contours. The degree of wave refraction depends on the wave length, water depth and nearshore bathymetry. In addition to changes in the wave direction and alignment to the shoreline, refraction may increase or decrease the wave height at shoreline locations through the concentration or spreading of wave energy. The maximum significant wave heights in the nearshore are typically 3 to 4 ft (1 to 1.2 m).

A graphic description of the process of wave refraction, for explanatory purposes, is provided in Figure 2.11. Within this graphic, wave "rays", or "orthogonals", are shown as lines drawn perpendicular to the wave crest at all points. In deep water the wave orthogonals are equally spaced and thus the wave energy between the orthogonals is also equal. As waves approach the shoreline and the wave crests bend to conform more closely to the underwater contours, the orthogonals are concentrated on headland areas and spread out in the bays. Therefore it can be seen that wave energy, and hence wave height, is greatest at the headlands and smallest in the bays.

The depth at which a wave breaks, and the form of the breaking wave, are determined by the wave height and period, the water depth and the slope of the lake bottom. For example, in deep water, waves break (i.e., white-capping) when the wave height becomes too large relative to the wavelength (i.e., the wave becomes "too steep"). In shallow water, waves break as a result of the limiting water depth. For preliminary purposes, the maximum significant breaking wave height in shallow water can be estimated as 0.8 times the water depth.

## 2.2.4 Wave Runup and Overtopping

As the waves reach the shoreline, they will runup or uprush onto the beach, bluff or protection structure. Wave runup is defined as the vertical distance reached by the uprushing wave above the stillwater level or flood level (see Figure 2.12). The stillwater level is the level the water would assume in the absence of wave action.

When the height of the natural shoreline, or of the protection works, above the stillwater level is less than the limit of runup, wave overtopping occurs (see Figure 2.12). The phenomena of wave overtopping can result in backshore flooding and can potentially threaten the structural stability of the overtopped protection works.

As noted in Section 2.2.3, wave heights are irregular. For preliminary purposes, it is typically assumed that wave runup is proportional to the wave height and therefore wave runup will also be irregular. The "significant" wave runup value is the average of the highest one-third of all the wave runup values.

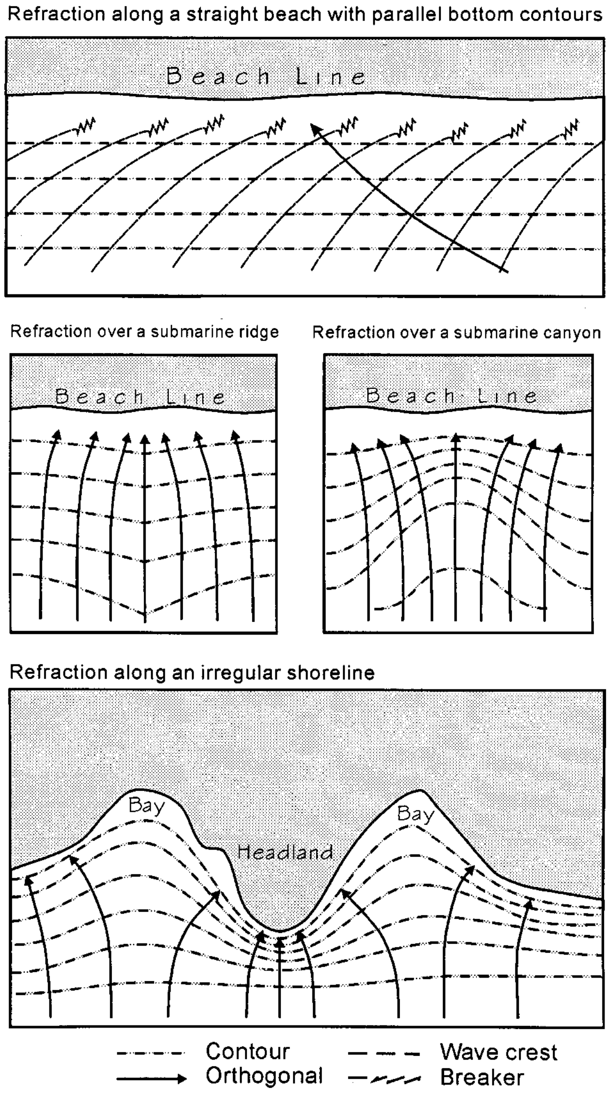


***Figure 2.11***

***Wave Refraction of Simple and Complex Shorelines***

Therefore, some waves will runup more than the significant wave runup. A reasonable approximation of the limit of wave runup is about 1.4 times the significant wave runup value and may be marked by the limit of wave debris (e.g., driftwood) and vegetation along the shoreline. Typical significant wave runup values for various shore structures are shown in Figure 2.13.

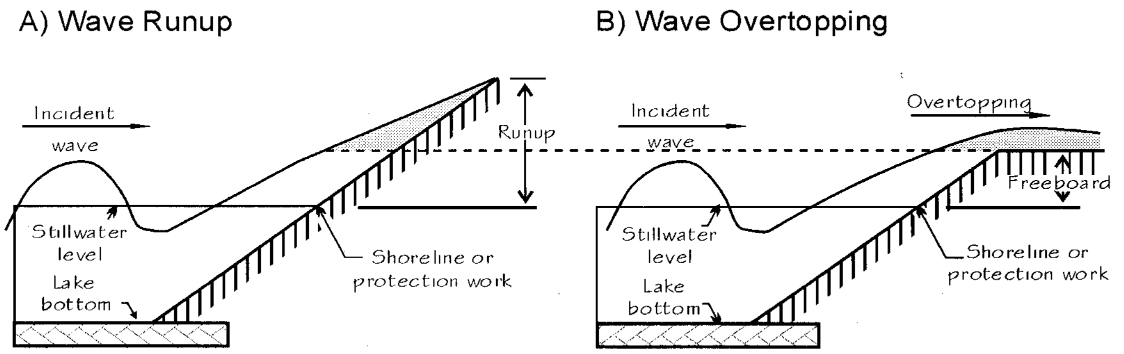
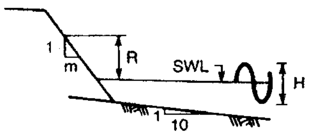
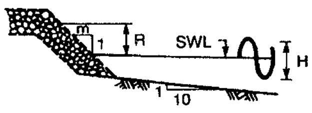


*Figure 2.12 – Wave runup and overtopping*



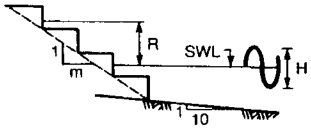
| Slope (m) | Runup (R) |
|---|---|
| 1.5 | 2.25 H |
| 2.5 | 1.75 H |
| 4.0 | 1.50 H |

**Smooth Face (beach or earth)**



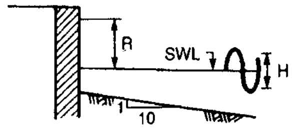
| Slope (m) | Runup (R) |
|---|---|
| 1.5 | 1.25 H |
| 2.5 | 1.00 H |
| 4.0 | 0.75 H |

**Rough Face (rip rap or gabions)**



| Slope (m) | Runup (R) |
|---|---|
| 1.5 | 2.00 H |

**Stepped Face (concrete or armour stone)**



| Slope (m) | Runup (R) |
|---|---|
| – | 2.00 H |

**Vertical Face**

*Figure 2.13 – Wave Runup on various structures*

## 2.2.5 Historic Shoreline Recession Rates

Comparison of the shoreline positions over various time periods indicated typical shoreline recession rates of 1 ft/yr to 2 ft/yr (0.3 m/yr to 0.6 m/yr) with extremes of 0 ft/yr and 25 ft/yr (0 m/yr and 8 m/yr). Shoreline recession rates for the south basin of Lake Winnipeg are shown in Appendix II.

It is important to note that erosion rates can vary widely from year to year. Lake shorelines can often show little change for many years and then will erode rapidly under conditions of severe wave action and/or high levels.

## 2.2.6 Sand Movement

Movement of sand and gravel at the shoreline can be parallel to the shore (i.e. "alongshore transport") and perpendicular to the shore (i.e., "cross-shore transport"). Sediments are set in motion at the lakebed by the oscillatory motion associated with the passage of each wave, by turbulence associated with wave breaking and by the action of swash and backwash on the beach. Sediments are then transported alongshore when waves approach at an angle to the shoreline and a portion of the momentum of the breaking waves is directed alongshore resulting in the generation of alongshore currents in the direction of wave approach (see Figure 2.14). These alongshore currents, together with beach drifting on the swash slope, are the primary influences responsible for the transport of sediment alongshore. As discussed in Section 2.2.1, sediment can also be transported onshore-offshore.

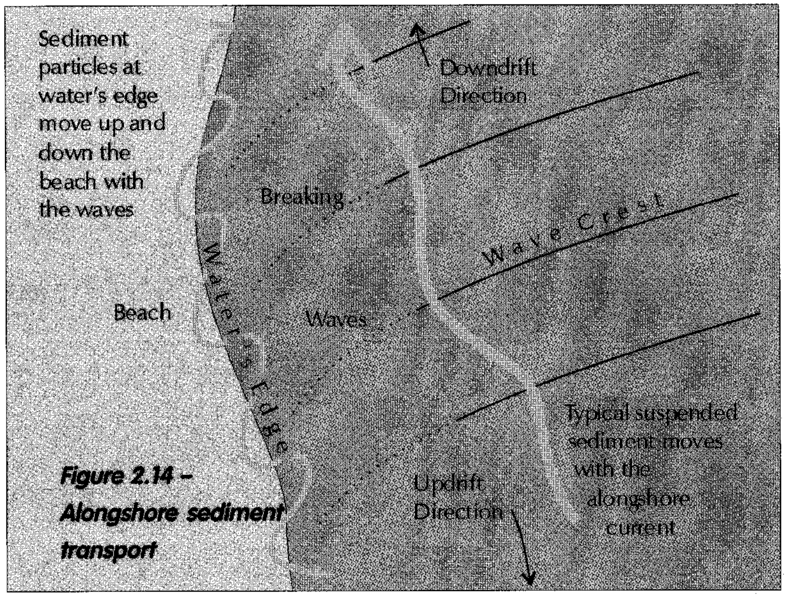


**Figure 2.14 – Alongshore sediment transport**

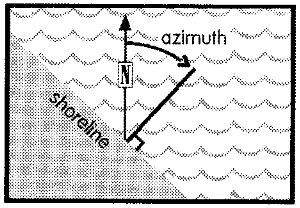
Erosion of the shoreline bluffs and the nearshore area provides the supply, or source of the sand and gravel found along the shoreline. On a shore profile with a sufficient depth of sand and gravel cover (i.e., a "dynamic beach" shoreline; see Section 2.2.1), the movement of material is limited to the top layer of the sand and gravel. On a cohesive shoreline (see Section 2.2.1), erosion of the insitu soil material provides the sand and gravel. The type of soil eroded determines the size and quantity of beach material generated.

The alongshore sediment transport at six sites on Lake Winnipeg was estimated using a computer model. Table 2.2 presents the average annual transport to the south and to the north at each of the six sites along with the net average annual transport rate and direction. The net transport is the difference between transport in each alongshore direction. At two of the sites, two different shoreline orientations were considered.

Alongshore transport at the west shore is limited because of the minimal amount of sand and gravel at the shoreline. As pointed out in Section 2.1.2, the sand is normally only 6" deep 100 ft offshore. Although the sand deposits are thicker along the south and east shorelines, the sand and gravel is also concentrated near the shore.

***Table 2.2 - Average Annual Alongshore Transport***

| Site | Site Name | Shore Azimuth | Grain Size $D_{50}$ (mm) | Transport North ($m^3$/yr) | Transport South ($m^3$/yr) | Net Transport ($m^3$/yr) | Net Transport Direction |
|---|---|---|---|---|---|---|---|
| 1 | Traverse Bay | *20 | 0.18 | 4,000 | 6,000 | 2,000 | South |
| 2 | Lester Beach | 318 | 0.3 | 8,100 | 12,100 | 4,000 | South |
| 3 | Halcyon | 260 | 0.2 | 2,600 | 16,000 | 13,400 | South |
| 4 | Matlock | 71 | 0.17 | 300 | 3,800 | 3,500 | South |
|  |  | 53 | 0.17 | 500 | 3,600 | 3,100 | South |
| 5 | Spruce Sands | 102 | 0.25 | 2,000 | 1,700 | 300 | North |
|  |  | 94 | 0.25 | 1,600 | 2,000 | 400 | South |
| 6 | Hnausa | 120 | 0.5 | 1,400 | 900 | 500 | North |



* Azimuth is the angle measured from north clockwise to a line perpendicular to the shoreline

## 2.2.7 Ice Conditions

The formation of ice during winter months affects shoreline processes in two ways. The formation of shorefast ice, in combination with an "ice foot", protects the shoreline area, landward of the ice, from wave action even when the main body of the lake is ice-free. However, local scouring can result from waves breaking directly against the ice foot, and sediments incorporated in the ice may be transported and deposited offshore. The second factor is that ice formed within the greater water body has the effect of reducing wave generation during the winter months and as such, reduces the potential erosion and the volume of sediment transport. Lake Winnipeg is generally ice-free from about early May to late November.

Ice can become detached from the shoreline (i.e., ice floe) and may be further broken up by the actions of winds and currents. When the ice floes encounter appreciable resistance due to bottom friction or the presence of a structure, the ice piles up into a mound. This mound first builds in height and then in width. Ice detached from the shoreline or lake ice that is piled up by wind action against the shoreline can often scour sections of the beach and nearshore as well as damage and destroy structures close to shoreline. It can also remove boulders from the shallow areas, reducing their protective effect, particularly along cohesive bluff shorelines.

In the spring break-up period, when the snow cover has melted and there is still a competent ice cover, temperature fluctuations produce thermal expansion and contraction of the ice sheet. Maximum onshore ice thrusts usually occur during this period as the temperature of the ice cover rises and buckling of the ice is suppressed by the greater thickness of the ice at this time of year.

Generally, ice is not considered an important factor for changing the Lake Winnipeg shoreline. Estimates of the potential expansion of the ice sheet towards the shoreline in December are 50 ft at the south shore, 30 ft at Hnausa and Black River, and 20 ft at Gimli and Grand Beach. These are also distances required beyond the ice level if no damage to vegetation or shore structures is to result. The potential ice shove distances noted rarely develop because the ice typically grounds out in shallow water offshore and offshore pressure ridges are formed. Generally, there also is adequate room along the shoreline to allow for ice expansion. As a result ice shove damage is only a threat to lightly constructed offshore structures. Minor, localized ice-push features can be seen, but lasting effects such as ice-pushed ridges and scarred or bulldozed trees are rare.

*Above left: Groundwater flowing out of toe of bluff at Lester Beach, Above: Slope instability, Traverse Bay Left: Slope failure at Halcyon Cove*

## 2.2.8 Other Erosion Factors

### Groundwater

In bluff areas, the presence and movement of groundwater can be a major factor in the erosion processes. Many bluffs consist of layers of different types of material of varying thickness and permeability. The ability of surface water to flow or infiltrate vertically downward through the bluff structure depends on the types of material from which it is composed. For example, water passes quickly and easily through a layer of sand, but if the sand is underlain by a layer of impervious clay, then the vertical movement of groundwater is halted and the groundwater then moves horizontally along the sand-clay boundary to the bluff face. The groundwater then exits through the face of the bluff at the sand-clay boundary and runs down the bluff face causing erosion of the sand layer and the bluff face, and over time, leads to the landward recession of the bluff.

The presence of groundwater in a bluff reduces its ability to resist collapse or bluff failure. This is due to the lubricating effect that a high water content has on the soil. A collapse or bluff failure of this type is most likely to occur when the soil is saturated with water. Soil saturation may be caused by natural influences such as the spring snowmelt or a heavy rain, or by human-related structures or activities, such as faulty septic systems and leaking swimming pools.

### Surface Water

The flow of surface water down the face of a bluff can lead to erosion of a bluff face and ultimately to varying degrees of bluff failure or collapse. Frequently, concentration of surface water flows on a given shoreline bluff feature leads to the formation of gullies along the bluff face. As a gully grows, it may become the route for surface water drainage from an increasing tableland area, thereby increasing both the volume of water flow and the rates of gully growth. The creation of tableland water drainage networks, such as field tiles or drainage ditches, are typically the forms of surface water concentration that have led to the formation and growth of shoreline gullies.

## Vegetation

Vegetation cover on a slope is the primary defence against soil erosion and is very important to long-term erosion protection (see Figure 2.15). Vegetation protects against surface erosion and shallow translation slope slides by:

- holding, binding, or reinforcing the soil with a root system;
- removing water from the soil by uptake and transpiration;
- reducing runoff flow velocity;
- reducing frost penetration; and/or
- the buttressing or reinforcing action of large tree roots.

By reducing surface erosion, the likelihood of shallow instability is also decreased. Vegetation also improves the visual aesthetics of a shoreline slope and is a vital part of the ecosystem. Slope stability can be decreased by the removal of stabilizing shore vegetation. This may be of particular importance where tree roots, especially the smaller and more numerous tree roots which provide a binding strength for any sedimentary layers they enter, may have been removed. By the cutting of trees in these areas, the naturally cohesive strength and anchoring force may be lost.

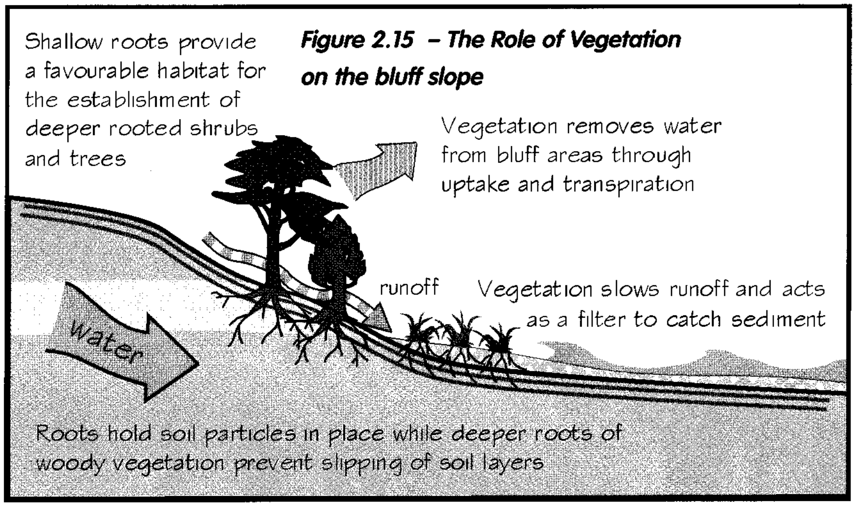


***Figure 2.15 – The Role of Vegetation on the bluff slope***

# SECTION 3
# Selecting a Shoreline Management Approach

## 3.1 Deciding on a Response

Alternative shoreline management approaches are simply the means we use or don't use to deal with shoreline flooding and erosion hazards. We can: choose to ignore the hazard and take our chances; control building within the hazardous area; move away from the hazardous area; construct shoreline protection or take measures to reduce damage when it occurs. There is almost always a combination of possible alternatives. The tendency, however, is to think of only a single course of action or to repeat what was done in the past. This section provides an introduction to alternative shoreline management approaches.

Shoreline management approaches can be classified in a number of ways. For the purpose of this handbook, approaches are grouped as follows:

### Prevention and Relocation

#### Nonstructural

- Bluff Slope Grading, Vegetation and Drainage Improvements
- Dune Enhancement

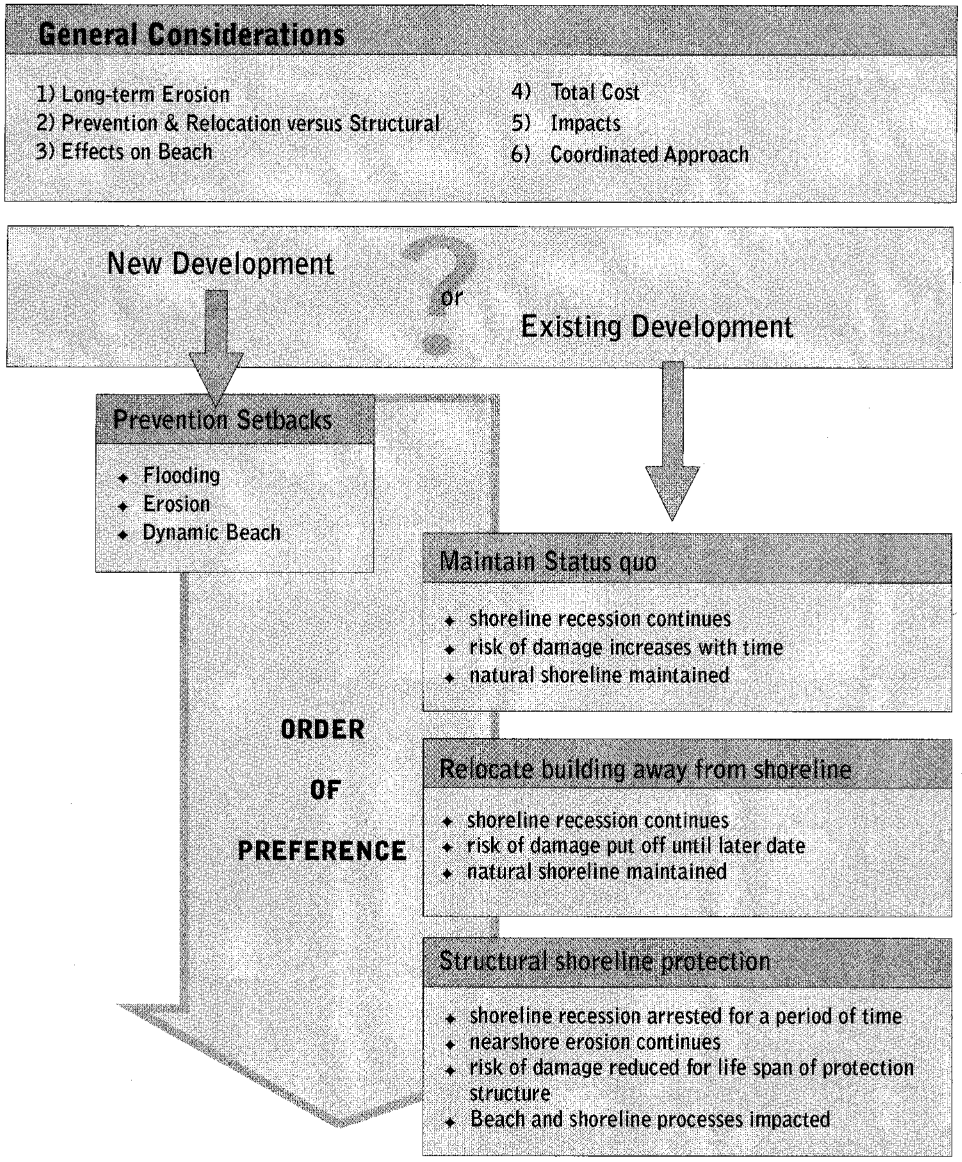
#### Structural

- Replicate the natural processes (beach nourishment, lakebed armouring)

- Work with the natural processes (groynes, artificial headlands, detached breakwaters)
- Oppose the natural processes – armour the shoreline
    - Heavy protection structures (e.g., heavy stone revetments, concrete and steel sheet pile seawalls)
    - Light protection structures (e.g., light stone revetments, timber cribs and bulkheads, gabion walls).

The steps to selecting the most appropriate shoreline management approach are outlined in Figure 3.1 and further described in this section.

## Selection of a Shoreline Management Approach



**General Considerations**

1) Long-term Erosion
2) Prevention & Relocation versus Structural
3) Effects on Beach
4) Total Cost
5) Impacts
6) Coordinated Approach

New Development or Existing Development

**Prevention Setbacks**

- Flooding
- Erosion
- Dynamic Beach

**ORDER OF PREFERENCE**

**Maintain Status quo**

- shoreline recession continues
- risk of damage increases with time
- natural shoreline maintained

**Relocate building away from shoreline**

- shoreline recession continues
- risk of damage put off until later date
- natural shoreline maintained

**Structural shoreline protection**

- shoreline recession arrested for a period of time
- nearshore erosion continues
- risk of damage reduced for life span of protection structure
- Beach and shoreline processes impacted

*Figure 3.1*

## 3.2 General Considerations

Prior to determining which shoreline management approach is best suited for a given site, it is appropriate to review some general considerations.

### *Consider the Long-Term Average Erosion Rate*

Consider the total amount of shoreline erosion that is likely to occur over the next 20 to 50 years. The rate of erosion may vary greatly from year to year. Do not consider short time periods of minimal or no erosion as an indication of the real extent of the erosion risk. On the other hand, significant and alarming erosion often occurs during storms at high water levels. Average annual recession rates are outlined in Appendix II.

### *Consider Prevention and Relocation*

Where possible, the preferred shoreline management approach is prevention; namely, locating development landward of the shoreline hazards. Structural protection is not necessary for development that is located landward of the hazardous lands since the development will be reasonably safe from the flooding, erosion and dynamic beach hazards. In areas of existing development, relocation should be given serious consideration. The advantages of prevention and relocation over structural protection works are:

- greatly reduced construction, maintenance and replacement costs;
- no negative impacts to the environment or downdrift shorelines;
- natural aesthetics and amenities of the beach at the shoreline are preserved; and
- no need for approvals.

### *Consider the Effect of the Structure on the Beach*

For many, the "beach" is a significant part of the attraction of shorefront property. When the landward movement of an eroding shoreline is arrested by a structure, the unprotected area in the front of the structure continues to erode and to deepen. On an eroding shoreline, any beach in front of an armoured shoreline will normally diminish in width over time, as the nearshore profile erodes, and the beach will eventually disappear. The beach loss may be accelerated by wave reflection from the structure.

### *Consider the Total Cost*

Shoreline owners often construct protection structures with little or no consideration of the total cost of maintaining, repairing and replacing the structure for the full life of the development. Owners should critically evaluate the total costs and benefits of proposed erosion protection structures. The direct cost of shore protection is often not justified by the direct benefit of the value of shoreline property protected from erosion. Many individual property owners invest such large amounts in protection, including time, materials, construction, and future maintenance, that they essentially "rebuy" their house and land and in most cases their land continues to erode.

### *Consider the Impacts*

Structural protection works are most commonly associated with effects on the physical shoreline environment (i.e., reducing sediment supply by stopping bluff erosion, trapping and/or deflecting alongshore sediment transport). Changes in the physical processes due to structural protection works may also result in a range of potential impacts on the terrestrial and aquatic environment.

Proposed shoreline protection works should be accompanied by an evaluation, to demonstrate that flooding, erosion, and dynamic beach hazards are not aggravated at updrift and downdrift properties. For example, it may not be appropriate to place protection works in areas where the continued, active erosion of the site provides an essential sediment source for downdrift beach environments. The assessment of the proposed protection works should also identify that no adverse environmental impacts will result. A shoreline owner who installs shore protection works that result in damages to other properties may be held liable.

### *Consider Coordinated Efforts with Adjacent Properties*

To be most effective, shoreline protection works must be coordinated with the adjacent properties (see Figure 3.2). The lack of, or the level and type of protection at adjacent properties must be considered. It is of little value to provide wave runup protection along the lakeside of a site if the properties adjacent to the site have little or no flood protection. Water that floods the properties adjacent to the site could easily flow to the site from the sides. Also, erosion protection along a single, narrow lot may be of little value, even if flank protection is provided, if the adjacent properties are not protected. Through coordinated construction, overhead costs, material prices and the actual amounts of construction can be reduced.

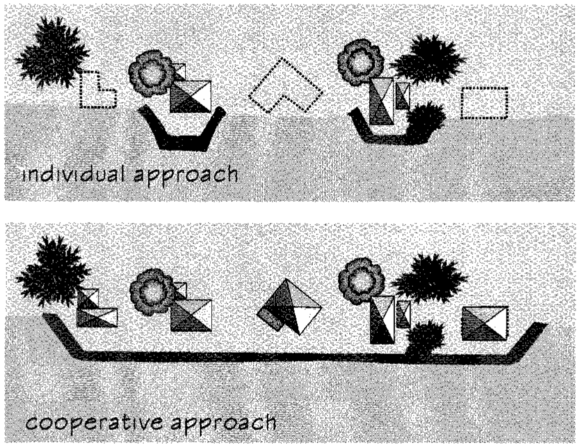


***Figure 3.2 Importance of a Coordinated Approach***

## 3.3 New Development - Prevention of Hazards

Shorelines along Lake Winnipeg are subject to the natural processes of flooding (including high water levels, wind setup and wave runup), erosion and dynamic beaches. These are ongoing shoreline processes that become "hazards" when we attempt to locate our development (e.g., houses, cottages) too close to the shoreline. Hazards can be defined as natural events, which present a danger to life or result in significant property damage. By identifying the limits of the flooding, erosion and dynamic beach hazards, development could be directed to areas safely landward of shoreline hazards.

The "prevention" shoreline management approach is the orderly planning of land use and the regulation of development in hazardous areas through the use of such controls as flood and erosion setbacks and specified minimum elevations for flood protection. A setback is a distance from the shoreline to a house or other building that is intended to provide a safe separation between the shoreline hazard and the development. The setback should be the furthest landward of the flooding, erosion or dynamic beach hazard limits.

### 3.3.1 Flooding Hazard Limit

Determining the flooding hazard limit involves the calculation of the total impact of the flood level and an allowance for wave uprush and other water related hazards including ice action (see Section 2.2.7). The flood level is a combination of the mean monthly water level and the wind setup that has a reasonably low probability of occurrence. The flood level is represented by a contour line or elevation on the shoreline mapping. The flood allowance for wave runup is a specified horizontal distance measured landward from the flood level (see Figure 3.3). The flood level is not the final floodproofing level to which buildings should be safely constructed.

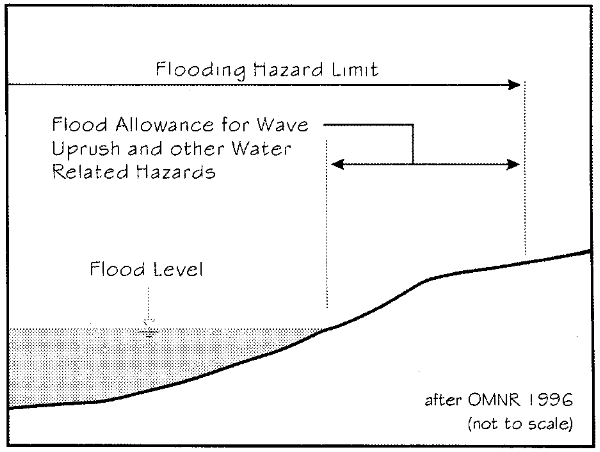


*Figure 3.3 Flooding Hazard Limit*

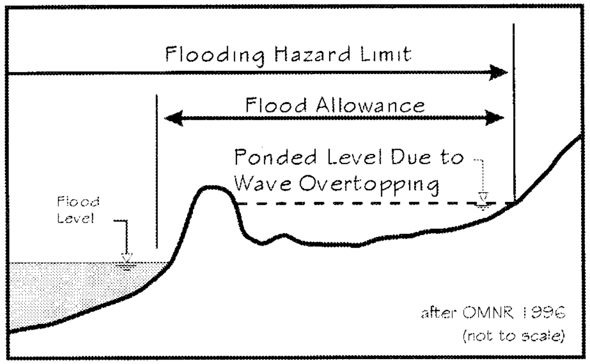


*Figure 3.4 – Flooding Hazard*

In Section 2.2.2, it was noted that the mean level for Lake Winnipeg has exceeded 715.5 ft only twice since regulation and that wind setup greater than 3.5 ft is rare. Combining these values of mean lake level and wind setup results in an estimated flood level of 719 ft.

In addition, for shorelines where flooding and/or wave action overtops a natural bank or protection works, causing ponding landward of the flood level, the flood allowance for wave runup and other water related hazards must be determined (see Figure 3.4) by means of an appropriate analysis.

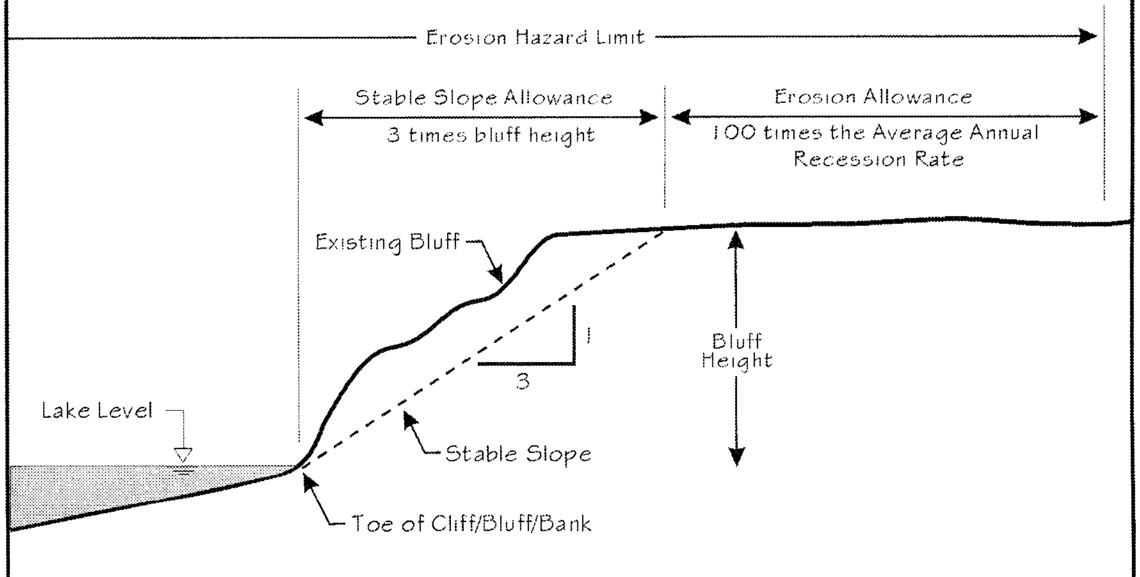
## 3.3.2 Erosion Hazard Limit

Estimating the limit of the erosion hazard involves the calculation of the sum of the allowance for a stable slope plus an allowance for erosion based on the long-term average annual recession rate (see Figure 3.5).

Stable slope was discussed in Section 2.2.8 and involves consideration of the soil material and layers in the bluff, the bluff height, the presence of ground water and other factors. For preliminary purposes, a slope of 1:3 (i.e., for every 1 ft you go vertical, you go 3 ft horizontal) could be considered as a safe estimate of the stable slope. The actual stable slope at a site may be steeper or flatter but it will depend on the site conditions and should be assessed by a geotechnical engineer.

The erosion allowance provides for the ongoing erosion of the shoreline over a given time period, say a planning horizon of 100 years. The long-term average annual recession rate (see Section 2.2.5) is determined based on calculations of the long-term shoreline erosion (without protection in place) for the area in question, excluding the effects of shoreline protection, over a sufficient period of time to provide a reasonably representative and reliable rate.

**Figure 3.5 Erosion Hazard Limit: Stable Slope Allowance plus 100 times the Average Annual Recession Rate**



(after OMNR 1996)

### 3.3.3 Dynamic Beach Hazard Limit

The dynamic beach hazard is concerned with the natural response of the beach and dune system to high water levels and storm waves as discussed in Section 2.2.1. The dynamic beach hazard is defined as the landward limit of the flooding hazard (flood level plus a flood allowance for wave runup and other water related hazards) plus a dynamic beach allowance that would generally extend to the landside base of the first main foredune plus an erosion allowance (see Figure 3.6). The erosion allowance is particularly important for transgressive shorelines (see Section 2.1.2).

The dynamic beach hazard is only applied where there is sufficient beach material for the shoreline to respond as a dynamic beach. If it is not a dynamic beach, it should be treated as a cohesive shore. As a guide, the dynamic beach hazard should not be considered in situations where: beach or dune deposits do not exist landward of the water line (e.g., land/water interface); beach or dune deposits overlying bedrock or cohesive material are less 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 less than 5 km and in other areas of restricted wave action where wave related processes are too slight to alter the beach profile landward of the waterline.

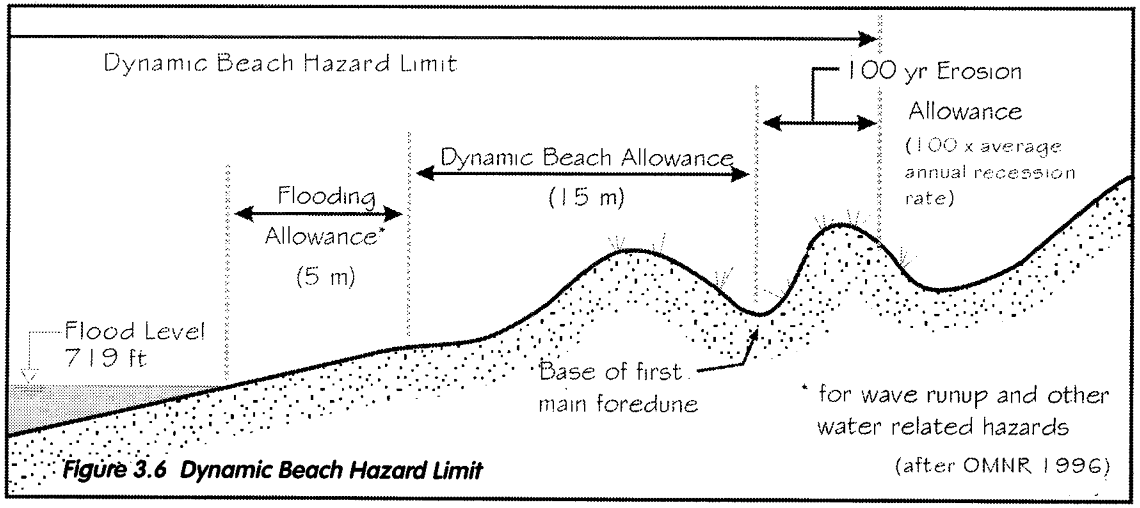


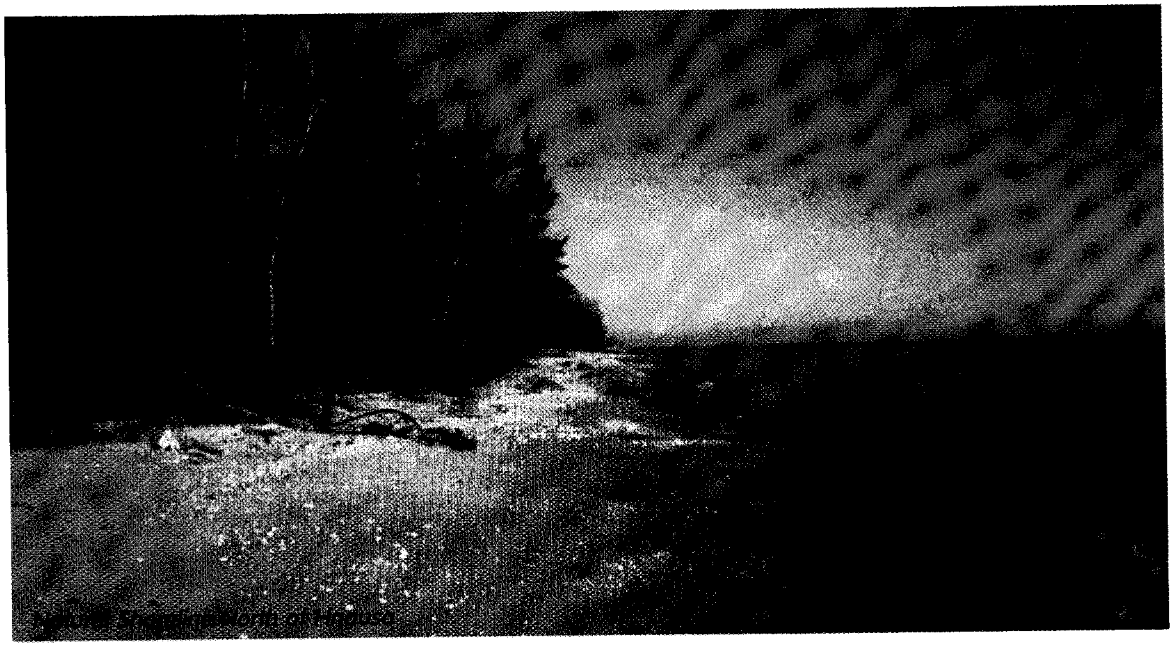
*Figure 3.6 Dynamic Beach Hazard Limit*

(after OMNR 1996)

## 3.4 Existing Development - Maintain the Status Quo

In areas of existing development, establishing suitable flood, erosion and dynamic beach setbacks may not be possible. In these instances, it may be more appropriate to consider another range of options: maintain the status quo; relocation; and structural protection. Where relocation or structural options are considered, they should be accompanied by the maximum setbacks possible to address the flooding, erosion and dynamic beach hazards.

In many cases a careful review of long-term erosion rates, the impact of protection structures on beaches, and the total cost of the structure relative to the land will indicate that the best course of action is to maintain the status quo, do nothing and allow the natural erosion to occur. Obviously shoreline recession will continue and the risk of damage to property and buildings will increase with time. Advantages of this approach are that it costs nothing to build and the natural shoreline is maintained.



Natural Shoreline North of [illegible]

## 3.5 Existing Development – Nonstructural Improvements

### 3.5.1 Bluff Slope Grading, Vegetation & Drainage Improvements

Grading the bluff slope, planting stabilizing vegetation on the bluff slope and/or controlling drainage of surface runoff and groundwater flow are considered nonstructural shoreline management options. On their own, these measures are insufficient to address an erosion hazard on a shoreline that is eroding primarily due to wave action except possibly in very low wave energy environments.

In situations of bluff instability, a professional engineer qualified in geotechnical engineering should be consulted. When applying bluff measures, other sources of water that need to be controlled (e.g., not freely discharged down the slope face) include lawn sprinkling, downspouts, swimming pool drainage and leaks and possibly septic systems.

A brief outline of some of the various bluff measures include:

Vegetation and bioengineering: Vegetation can be used to help stabilize soil on the face of a slope by anchoring the soil with the root mass and by reducing the velocity of the surface runoff flow. It can improve the visual quality of a shoreline area and provide wildlife habitat. Bioengineering combines structural measures (e.g., timber cribbing) with live plant materials in order to stabilize the slope face. Native plant species, which are compatible with the local flora, should be used.

Surface drainage: The erosive effects of surface drainage on a slope can be reduced by directing water away from the slope or by providing an erosion resistant swale or channel which conveys the water down the slope face in a controlled manner.

Internal drainage improvements: Where internal drainage (groundwater) is causing bluff erosion and instability, the drainage can be improved by interceptor drains, french drains or tile drains.

Grading slope: Where the existing bluff is oversteep and unstable, the bluff can be graded to a flatter slope. Grading is often accompanied by drainage improvements and revegetation.

### 3.5.2 Dune Enhancement

Sand dunes are fragile features of the shore and as such are easily altered by the actions of people (i.e., pedestrian and vehicular traffic). If the natural vegetation, which stabilizes the dunes, is lost, the sand can more easily be blown away. Dune enhancement involves measures to protect and enhance vegetation and dune growth. These measures include restricted or controlled access points and the re-establishment of dune vegetation. Driftwood and fallen trees help protect dunes and should not be removed.

## 3.6 Existing Development - Relocation

Relocation is the moving of a building or service (e.g., roadway, utility) to a different site further inland or to a more landward location within the existing site. Relocation is an effective practice to mitigating flooding, erosion and dynamic beach hazards for existing buildings. Relocation often proves to be less costly than protection, especially in areas of high to severe erosion.

Relocated buildings should be landward of the flooding, erosion or dynamic beach hazards.

The major limitations to relocating a house or cottage are the size and construction style of the building (and therefore the actual feasibility of moving) and the availability of a site for relocation. The actual moving costs for a typical single family dwelling can be relatively small in comparison to providing effective protection works. Generally, the width and height of the house are the limiting factors. The width must be less than the clearance along the roadways (i.e., between trees, hydro poles) and the height lower than the overhead clearance (i.e., under overhead wires, bridges). Houses with slab foundations, concrete block walls, extensive brick or stone work, or large unusual shapes may be impracticable to move. The greatest costs associated with relocation may be in acquiring an additional parcel of land if setbacks requirements do not permit relocation on the same property.

# 3.7 Existing Development - Structural Protection Works

## 3.7.1 Overview

Where flooding or erosion seriously threatens valuable buildings or land, and nonstructural shoreline management alternatives are truly not feasible, it may be necessary to consider structural shoreline protection works. Structural protection works involve the construction and/or placement of significant additional structures and/or materials at the shoreline.

Where structural protection approaches are considered, assessments on a reach-by-reach basis (i.e., areas of similar shoreline types) are more likely to lead to an overall protection strategy that is in keeping with the shoreline processes. It should also be noted that shoreline processes do not recognize individual property boundaries, and as such, protection works should be coordinated with the adjacent properties.

At sites with low recession rates (say less than 1 ft/yr), addressing the hazard over the long-term may be viable by implementing suitable structural protection works accompanied by a stable slope allowance plus other setbacks, or hazard allowances that may be deemed to appropriate. Attention should be given to landside erosion considerations, as these may be a factor in the shoreline recession. The protection works must be properly engineered taking into consideration all the appropriate design factors.

In areas of moderate recession rates (say 1 to 2 ft/yr), protection works become less viable both in terms of functional performance and costs and benefits. Downcutting of the cohesive shore becomes an increasingly important factor in the lifespan of the structure. Practical construction practices (e.g., depth of water, slumping of excavated trench sides, access) limit the depth to which the toe of a structure can be excavated to provide a sufficient base elevation for protection against downcutting.

Along cohesive shorelines with high (say 2 to 4 ft/yr) to severe (say greater than 4 ft/yr) average annual recession rates, structural protection works that safely reduce the erosion hazard over the long-term will be relatively large and costly. Potential undermining of the structure due to downcutting of the nearshore is a serious concern.

Structural erosion protection should be accompanied by stable slope and hazard allowances and may be accompanied by other measures such as bluff measures and dune enhancement. Floodproofing may be required to address flooding hazards. Prior to installing structural protection, the proponent should clearly establish ownership of the land where the protection works are to be located. Required permits and approval must be obtained.

As previously noted, structural options can be grouped into three categories: those that try to replicate, or copy the natural shoreline processes (e.g., beach nourishment, lakebed armouring); those that work with the natural processes (e.g., groynes, artificial headlands, detached breakwaters); and is those that oppose the natural processes (e.g., revetments and seawalls).

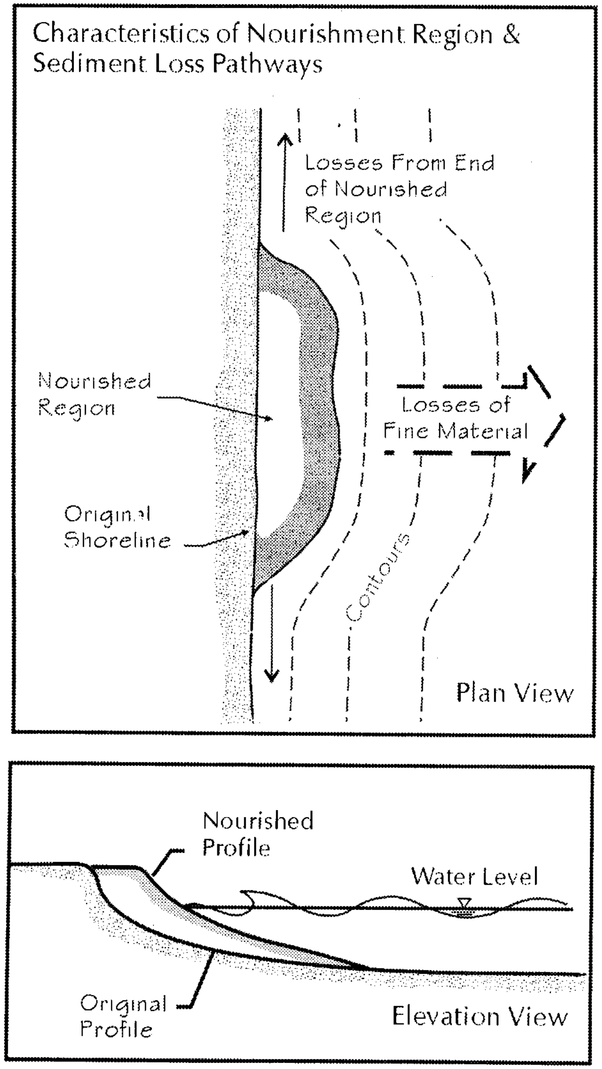
### 3.7.2 Stable Slope and Hazard Allowances

The construction of structural protection works should also be combined with an allowance for stable slope plus an additional hazard allowance. The additional hazard allowance provides a "safety factor" and is in recognition of several factors including, but not limited to the following:

- uncertainties in recession rate data, nearshore downcutting processes, wave data, shoreline processes;
- limited design life of protection works (i.e., undermining and durability of materials);
- wave runup, overtopping and spray;
- inability to ensure long-term maintenance requirements;
- some uncertainty with respect to structure performance (i.e., armour stability, wave overtopping, toe scour);
- condition and effectiveness of any adjoining protection works;
- provision of an environmental buffer strip along the shoreline; and
- provision for maintenance access.

## 3.7.3 Beach Nourishment and Lakebed Armouring (Replicate the Shoreline Processes)

The best approach to arrest shoreline erosion is to replicate, or copy the natural shoreline protection provided by beaches and cobble/boulder lag deposits through beach nourishment and lakebed armouring respectively. These two options require significant further study to determine their viability as long-term, cost-effective shoreline management options for shoreline property owners on Lake Winnipeg. If feasible, they would typically be applied on a much larger scale than one individual property owner and would require specialized coastal engineering study and design.



### Beach Nourishment

Beach nourishment is the artificial placement of suitable, imported beach material on an eroding or sediment deficient beach area in order to replenish, maintain and/or enhance the beach width. The grain size diameter of the imported beach sediment generally should be the same or larger than the native material to reduce the rate of erosion of the imported material after placement. The beach material would typically be imported from an inland source. In most cases, beach nourishment will have to be periodically replaced as it is moved downdrift and/or offshore by wave action (Figure 3.7). Without the retaining structures, maintaining the placed beach material would be very difficult in areas of rapid erosion (i.e., fine-grained cohesive shores) or where no previous beach existed (i.e., bedrock shores).

*Figure 3.7* ***Beach Nourishment***

***Lakebed Armouring***

Conceptually, lakebed armouring involves protecting the nearshore profile against further downcutting by trying to replicate the lag deposit nearshore profile that develops in erosion resistant cohesive material (i.e., cobble/boulder till; see Figure 3.8). Layers of coarse material (e.g., cobble to boulder size) would be dumped to blanket the lake bottom. The nearshore armouring would have to be carried out on a large scale, involving many properties and likely would only be part of a long-term strategy for shoreline management.

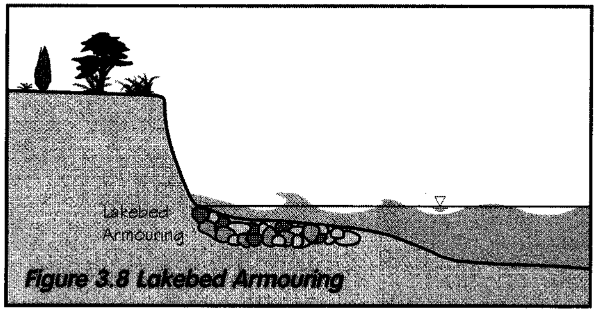


*Figure 3.8 Lakebed Armouring*

## 3.7.4 Groynes, Detached Breakwaters and Artificial Headlands (Work With Natural Processes)

***Groynes***

A groyne is a narrow structure projecting from the shoreline into the nearshore, at approximately a right angle (i.e., perpendicular to the shore). A groyne system, or groyne 'field', is made up of a number of individual groynes, usually of similar length and installed at regular intervals along the shoreline (see Figure 3.9). If there is a sufficient alongshore transport of beach material (see Section 2.2.6), the intent of a groyne is to trap some or all of the beach material, which would otherwise move past the site. The beach material would be trapped on the updrift side of the groyne where it would help protect the nearshore and the backshore from wave attack and erosion.

Groynes will not work if there is minimal or no natural alongshore transport of suitable beach material now or in the future, as is the case along many cohesive shorelines. Groynes do not

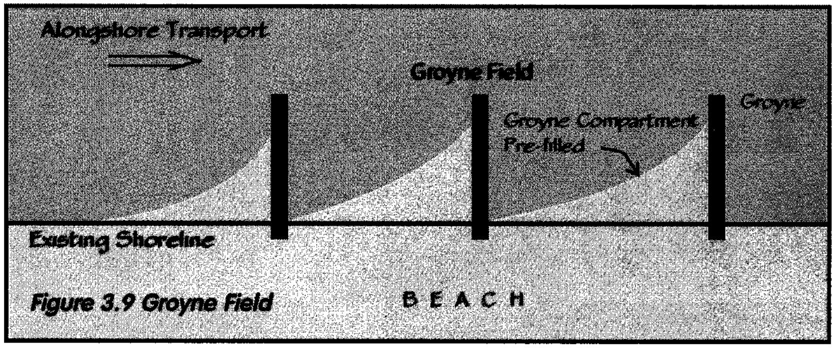


*Figure 3.9 Groyne Field*

"attract" beach material that does not exist. This can be a substantial concern in areas where increasing shoreline protection further decreases an already limited sediment supply. Groynes, including prefilled groynes, are easily emptied of the protective beach material at times of rising water levels when cross-shore transport during storm events moves the material offshore beyond the end of the groyne. Material moved offshore beyond the end of the groyne will be quickly carried away as alongshore transport. To effectively protect the nearshore profile of the cohesive Lake Winnipeg shoreline from downcutting, groynes would typically have to extend beyond a depth of about 8 to 12 ft (2.4 m to 3.7 m) below mean lake level which is several hundred feet offshore. Groynes of such length are not likely; many of the groynes on Lake Winnipeg are much less than 50 ft to 100 ft (15 to 30 m) long. Therefore it is expected that groynes would generally not be considered as long-term solutions along the cohesive shores of Lake Winnipeg.

As noted, groynes are intended to trap alongshore beach material, if it exists. Trapping results in less beach sediments at the downdrift shorelines. The trapping will continue until the compartments of a groyne field are filled. Once the structure is "full", bypassing of sediments will occur. To mitigate the downdrift effects, groynes should be pre-filled with imported beach material and then refilled with additional imported material when they are "emptied" by storm activity.

Structures placed in the nearshore, such as groynes and artificial headlands and detached breakwaters, may result in currents that deflect the coarser fraction of the alongshore littoral transport from near the shoreline to the nearest nearshore bar in deeper water (see Figure 3.10). In deeper water, it is more difficult for the waves to move the coarser materials back to the shoreline. Thus the material is moved along the bar, past the immediate downdrift property, and is only slowly returned to the shoreline further downdrift. The offshore diversion of the littoral material results in a deficit of material immediately downdrift. The

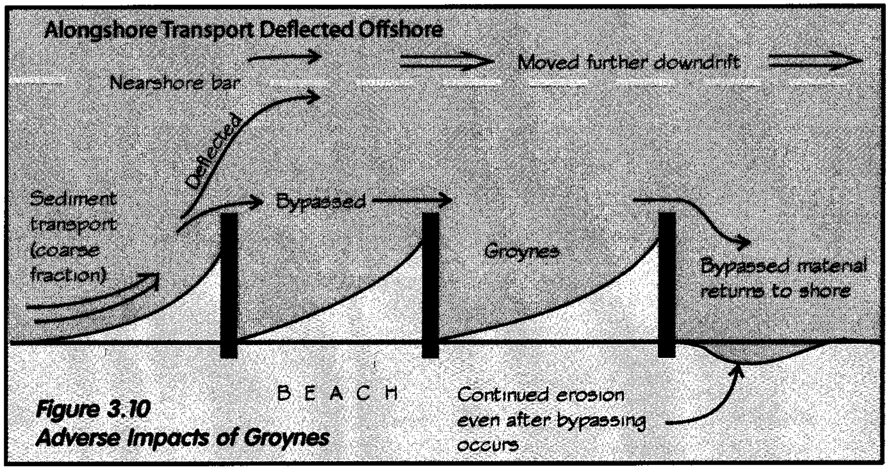


**Figure 3.10**
**Adverse Impacts of Groynes**

immediate downdrift properties will experience an on-going sediment deficit even after bypassing around the updrift structures occurs and even if the updrift structure is pre-filled. The diversion and the resulting sediment deficit will continue as long as the updrift structure is in place.

The impacts of the groynes will generally depend on the nature of the littoral system and the length, height and permeability of the groynes. High, long and impermeable groynes will typically have the greatest impacts while short, low and permeable groynes will have the lesser impacts. Groynes may impede pedestrian access along the shoreline.

The design of a groyne system is relatively complex, and beyond the scope of this handbook. The use of groynes involves the cooperation of many adjacent shoreline property owners. The design requires a specialized knowledge of coastal processes (i.e., nearshore waves, littoral transport, interaction with structures). The design of a groyne field should be undertaken on a site specific basis by a qualified coastal engineer. Additional details, which may require attention, include the potential for outflanking of the groynes, the potential for damage to the groynes due to wave forces, ice forces and soil loading conditions, and the potential for downdrift impacts, which may lead to permitting difficulties and mitigation requirements.

***Figure 3.11 – Detached Breakwaters***

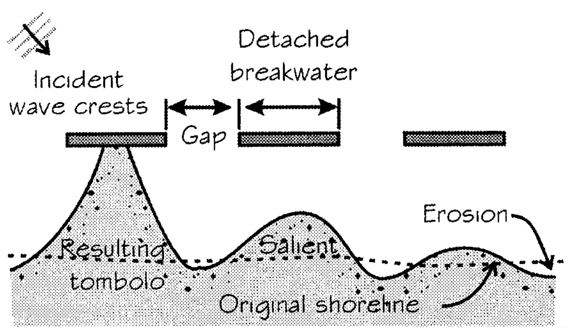
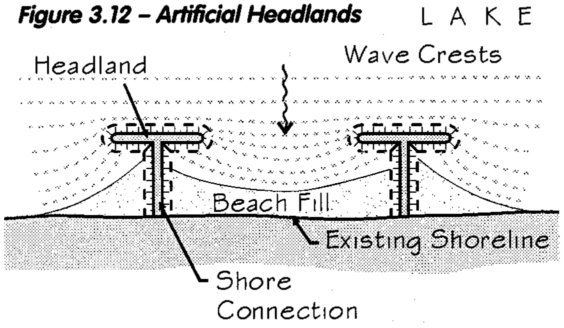


***Figure 3.12 – Artificial Headlands***



### *Detached Breakwaters and Artificial Headlands*

Detached breakwaters are shore parallel structures constructed a significant distance offshore and are not connected to the shore by any sand-retaining structure (i.e., they are "detached" from the shore; see Figure 3.11). Artificial headlands (see Figure 3.12) are designed to combine some of the aspects of groynes (i.e., the shore perpendicular connections trap alongshore transport) and some aspects of detached breakwaters (i.e., the shore parallel "headlands" alter incoming waves through wave diffraction). They have also been referred to as headland breakwaters, headland-bay breakwaters and pocket beach breakwaters. As with beach nourishment and groynes, artificial headlands and detached breakwaters typically require a cooperative approach of many adjacent properties and an intensive design effort.

## 3.7.5 Armour the Shoreline (Oppose Natural Processes)

Structural options that armour the shoreline, such as revetments and seawalls, form a physical barrier, or "last line of defence" between the natural shoreline processes and the onshore property. These structures directly oppose the natural processes.

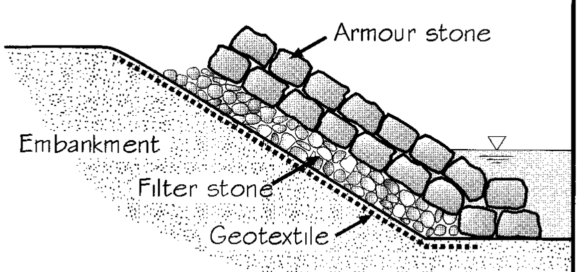
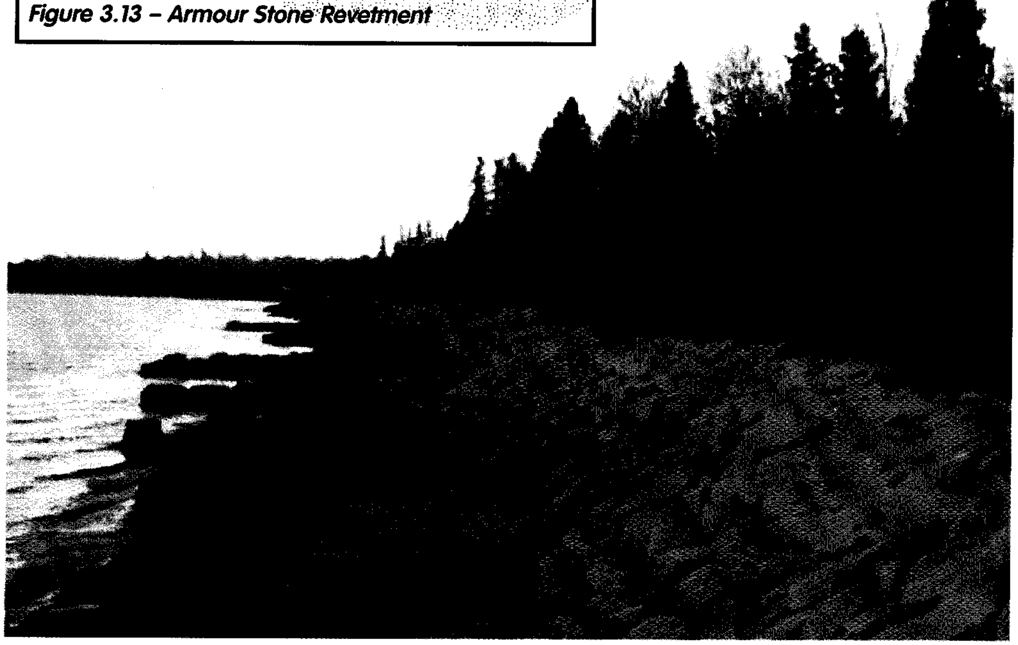


*Figure 3.13 – Armour Stone Revetment*

Revetments are sloped shore parallel structures that are built to prevent the direct attack of waves at the toe of a bluff. The outer protective layer typically consists of large "armour" stones (see Figure 3.13). Revetments rely on the mass of the armour stones to withstand the forces of the waves. As waves impact the structure, energy is dissipated as the water moves over the rough, permeable sloped face of the structure, and through the voids between the armour stones. The land behind the structure is thus protected from wave attack.



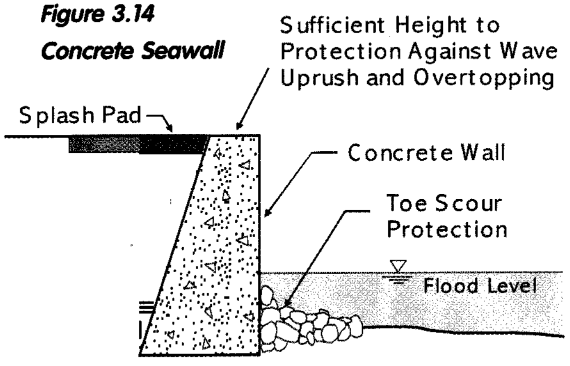
***Armour Stone Revetment at Spruce Sands***

Seawalls are vertical, or near vertical shore parallel walls that function in a very similar manner to a revetment. To block wave action from reaching the land, seawalls tend to be rather massive structures constructed of concrete (see Figure 3.14) or steel sheet pile.

Revetments and seawalls are primarily intended to control the erosion of the backshore (i.e., the land behind the structure) due to direct wave attack. This will result in a decrease in the natural sediment supply to the littoral zone. A reduction in the sediment supply may result in increased long-term erosion to downdrift shorelines.

Revetments and seawalls do not protect the nearshore zone and natural downward erosion of the lakebed will continue unabated. As nearshore downcutting progresses, the increased depth in front of the revetment or seawall will permit larger waves to attack the

***Figure 3.14***
***Concrete Seawall***



***Steel Sheet Pile Seawall at Traverse Bay***

structure, thereby putting the stability of the structure at risk. If downward erosion of the nearshore is significant, the onshore structure will eventually be undermined (see Figure 3.15). This is of particular concern along cohesive shorelines with moderate to severe recession rates.

When the retreat of a cohesive shoreline bluff is stopped for a period of time by the construction of a protection structure, the downcutting of the nearshore profile lakeward of the revetment/seawall continues unabated. The lakeward profile continues to erode and to deepen and any beach that was present will gradually diminish in width and likely will disappear altogether.

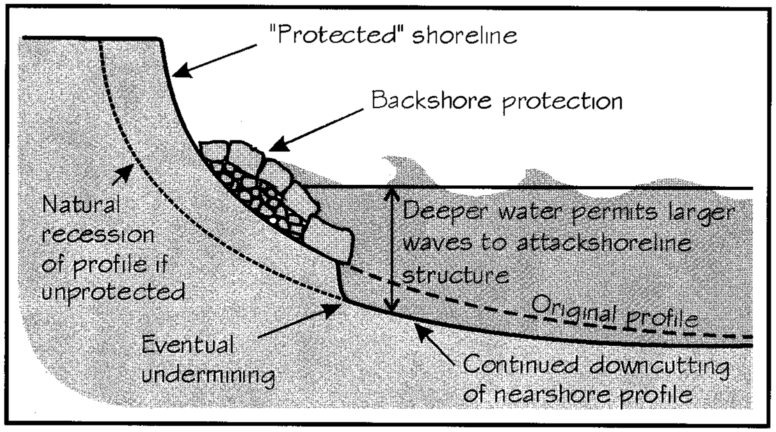


***Figure 3.15 Undermining of Shore Protection***

***Shoreline protection and loss of beach***

Along the toe of the revetment or seawall, local scouring which results from wave reflection may increase the natural erosion. At the alongshore ends of a revetment or seawall, the adjacent shoreline may be subject to some localized scour or erosion (in addition to any ongoing erosion of the shoreline). Scour along the toe of a structure can undermine the structure, resulting in its collapse (see Figure 3.16). Wave reflection will vary depending on the slope and permeability of the shoreline or protection work. Steeper, smoother and less permeable features result in more reflection than flatter, rougher and more permeable features. A guide to the reflection coefficient (ratio of reflected wave height to incoming wave height) is given as follows:

| Shoreline or Structure Type | Reflection Coefficient |
|---|---|
| Smooth, impermeable vertical wall | 0.9 to 1.0 |
| Vertical wall with crest above water | 0.7 to 1.0 |
| Vertical wall with submerged crest | 0.5 to 0.7 |
| Slope of rubble stones (slope of 1 on 2 to 3) | 0.3 to 0.6 |
| Natural beach | 0.05 to 0.2 |

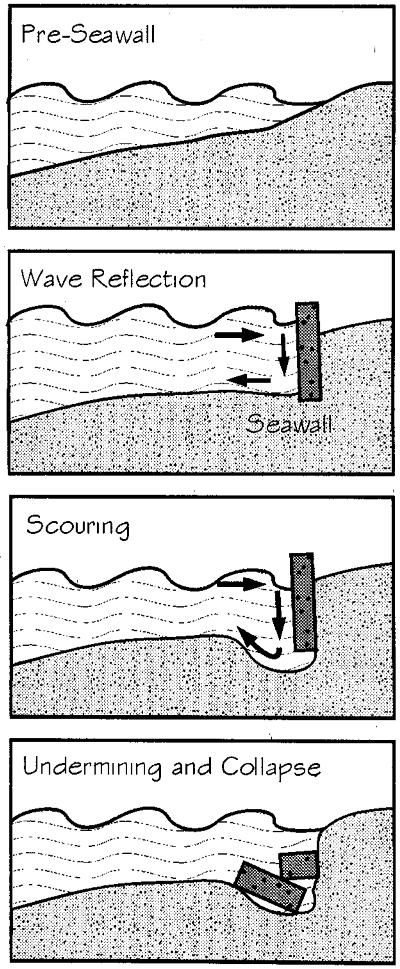


*Figure 3.16 Scour*

For example, a smooth, impermeable vertical wall (such as a steel sheet pile wall) will be more reflective than a sloping stone revetment.

## 3.8 Caution with Structures on a Dynamic Beach

On dynamic beaches (see Section 2.2.1), wave action and other water related hazards such as wave spray and ice action could impinge directly on buildings, roads, and other facilities, or indirectly affect structures by removing beach material, which supports foundations, footings and piles. The simplest, most effective and most desirable approach to addressing the hazard is to setback all permanent construction such as buildings, roads, and parking lots, landward of the dynamic beach hazard limit (i.e., landward of the area that will be affected by wave action and other natural beach processes; see Section 3.3.3). The reason for this is simply that dynamic beaches adjust to changing wave and water level conditions and that the natural beach itself provides the best protection against wave action. If permanent structures are located landward of the limit of the natural dynamic beach profile adjustment, they will be protected from wave-related hazards. At sites where there is a measurable recession rate or evidence of long-term shoreline recession, an additional setback of 100 times the average annual recession rate should be used (see Figure 3.6).

If a building is located within the dynamic beach hazard limit, it will be within the zone exposed to wave action at some time as well as being subject to removal of supporting beach material. Thus the building itself, or any structure designed to protect it, will not only be subject to the hazard, but it will also interfere with the ability of the beach to adjust to natural processes. This in turn will impair the ability of the beach to offer protection to the area behind it, as well as having the potential to affect adjacent sections of the beach.

The preferred order to addressing the hazard on dynamic beach shorelines is outlined in the following paragraphs.

1. Relocate buildings, roads, and other facilities to a position landward of the dynamic beach hazard limit. This in turn will permit removal of retaining walls and shore protection structures such as revetments and groynes completely from the dynamic beach hazard limit.
2. Where existing buildings, roads and other facilities can not be relocated and are located near the landward margin of the dynamic beach hazard limit and are subject to wave action only

infrequently (i.e. less than once about every 10 years) they may be protected by changes to the structure itself to minimize the impact of wave action and to reduce interference with the natural processes. Such changes could include raising the structure on stilts or removing porches and windows at low levels.

3. Protection in the form of a revetment or seawall may be used to reduce the risk of wave action from reaching a building. However, the protection structure should be placed next to the primary building itself and as far away from the beach as possible in order to minimize the impact on the normal beach processes. Seawalls, revetments and other protection works positioned for the protection of non-essential structures (e.g., gazebos, sheds etc.), lawns and/or other landscaping features, and which extend into the dynamic beach hazard, are not recommended.
4. Where existing buildings, road and other facilities are located so close to the beach that they are subject to wave action more than once every ten years, then a greater degree of protection than set out in 3 above will be required. If relocation (see Section 3.6) is not a viable option, it is likely that some form of revetment or seawall close to the building may be necessary. The protective structure should be designed to minimize impact on the beach in front of the property and on adjacent beaches. *However, it should be recognized that it is impossible to build a structure within this zone without having a significant impact on the beach environment.* Alternative approaches that involve either the building out of the beach, through trapping of sand in groynes, or behind detached breakwaters, may have an even greater impact on downdrift areas and may therefore be even less desirable.

Where one of the first three approaches is taken, the protection afforded by the beach and associated dunes on a sandy beach can be enhanced by promotion of dune development through protection of the natural dune vegetation and through measures designed to minimize the impact of activities on the vegetation and the dune form.

On an erosional dynamic beach shoreline (see section 3.3.3) it should be recognized that the frequency and magnitude of the hazard will increase through time as the shoreline position recedes, and the structure becomes located closer and closer to the water's edge. The effectiveness of the approach chosen will decrease and ultimately, as the shoreline recedes, the shoreline will reach the building or other facility. Thus, measures 2, 3, and 4 outlined above, will not provide a permanent solution on an eroding beach and their longevity will need to be assessed carefully, along with their possible environmental impacts.

# SECTION 4 – Armouring the Shoreline

## preliminary designs

Preliminary shoreline protection structure designs are presented in this section with cost estimates. Guidelines for selecting a structure suited to your needs are discussed. The various factors that determine the success or failure of a protective structure are also discussed.

Two levels of protection are considered here: heavy protection and light protection. The heavy protective structures are intended to withstand the worst conditions likely to be expected on the lake. Unfortunately they are very costly and can take up most of the beach, but they require less maintenance and will last longer. The light protection can be on the beach or above the beach further from the waterline. They are less costly but are more easily damaged by natural forces.

Actual costs may vary substantially from the estimates indicated, depending on site specific conditions and the costs of materials, labour and equipment. The costs indicated are per lineal foot of shoreline. Protection works should be coordinated with the adjacent properties.

The preliminary designs presented here are for planning purposes only and are not intended as substitutes for final designs prepared by qualified professional engineers.

# 4.1 Heavy Protection Structures

## 4.1.1 Armour Stone and Boulder Revetments - Preferred Structural Alternative

Armour stone or boulder revetments have advantages over many other forms of shore protection, because they can be designed to provide a high level of protection to a bluff under most conditions encountered on Lake Winnipeg. In most instances the use of larger armour stones or boulders (not to be taken from the lake bed) and a high crest elevation will provide a stable structure, which protects the backshore from erosion and storm wave runup damage for a period of time. This type of structure can also be designed to accommodate some of the ongoing downcutting of the lake bottom, thus providing relatively long-term protection to the backshore. However, this will have a significant impact on the capital construction cost, although annual maintenance cost will be reduced.

### *Advantages of Rock*

Shoreline protection structures built of and/or armoured with rock have a number of advantages when compared with other materials and forms of construction including:

- durability - quality rock withstands wear and attrition well and is ideally suited to the coastal environment;
- as coastal rock structures are porous and generally have shallow sloping faces, they readily absorb wave energy and reduce adverse scour;
- rock structures are readily modified to take into account changing environmental conditions;
- even with limited equipment, resources and professional skills, rock structures can be built that function successfully;
- rock structures are flexible, and can adjust to settlements. If design conditions are exceeded, damage is typically progressive;
- repairs are relatively easy and generally do not require very specialized equipment. If properly designed, damage may be small and repairs may only involve work to reset displaced stones;

- revetments typically extend only a minimal distance into the lake and do not significantly block longshore transport.

### *Disadvantages of Revetments*

Revetments, like any other shore protection structure, have a number of disadvantages that must be considered. Revetments do not encourage beach development, and may in fact accelerate the loss of beach due to increased wave reflection and scour. Construction of a revetment requires access to the shoreline for large construction equipment. Revetments may severely limit access to the beach and water, and do nothing to increase the amount of recreation space. Beach or water access must often be provided by staircases or ramps located intermittently along the shoreline. Finally, armour stone or boulder revetments may be relatively expensive, depending on the exposure of the site, the selected design life of the structure, and the availability of suitable quarried stone material or boulders.

### *Key Revetment Design Features*

The key design features of a revetment are:

- armour stone size – must be sufficient to resist the waves which reach the structure. Stone revetments built along the Lake Winnipeg shoreline may use different sizes of armour, depending on the wave exposure, the slope of the structure and the type of stone (e.g., quarried stone or natural boulders);
- stone quality – must be dense, durable and resistant to freeze/thaw cycles;
- crest elevation and width – high enough and wide enough to control the level of wave runup and overtopping. A higher structure is less prone to overtopping by waves, meaning that the area behind the structure is more protected. If excessive overtopping occurs, the structure and/or the backshore may be damaged;
- scour protection and toe elevation – must consider scour of loose sediments in front of the structure as well as the long-term erosion of the nearshore lake bottom. "Toe protection" typically takes the form of extending an apron of stone in front of the structure and/or digging the base of the structure into the lakebed; and

- filter layer and geotextile – to prevent fine soil material in the embankment from being washed out through the voids in the armour layer. This is done through the use of various layers of smaller rock and a geotextile filter fabric.

The design and installation of protection works must allow for access to the protection works for appropriate equipment and machinery for regular maintenance and/or repair purposes. Typically, the width for access should be in the order of 5 m and should extend both along and to the shoreline. Quality control must be exercised during construction; the designer should review construction. The completed protection works should be monitored periodically to ensure that any problems are detected in a timely manner, and corrective action is taken.

### *Revetment Design Life*

The design life of revetment structures is typically governed by the stability of the toe of the structure (i.e., downcutting and scour) and the durability of the armour stone or boulders. It has been assumed that if the construction and materials are of good quality and the structure is properly maintained, the limiting factor will be the downcutting of the lakebed in front of the revetment. It is estimated that a properly designed, constructed and maintained armour stone revetment could have a design life in the order of 20 to 50 years.

### *Preliminary Design of Revetments*

As noted earlier, a revetment structure can be designed to accommodate the effects of erosion of the nearshore lake bottom. To illustrate the impact of this process on the magnitude and cost of revetment structures, preliminary designs have been prepared with design lives of 15 to 20 years and 25 to 50 years for nearshore wave heights of approximately 5.0 ft and 5.5 ft respectively. Nearshore downcutting was estimated assuming a typical nearshore profile and bluff recession rate of 3 ft/yr. Cross-sections for the structures are shown in Figure 4.1.

The preliminary design information presented here is based on standard procedures and does not consider site specific details nor the availability of suitable quarried stone materials. Final designs are beyond the scope of this handbook, and should be prepared by a qualified coastal engineer for shoreline protection at any specific site.

It is difficult to assess the annual maintenance requirements of shoreline structures. As a simple preliminary guide, a factor of 1.5% of the initial capital cost could be used to include repairs and replacement costs in the annual maintenance allowance. It is anticipated that the maintenance work would be required periodically, say every 5 to 10 years on average, and after severe storms.

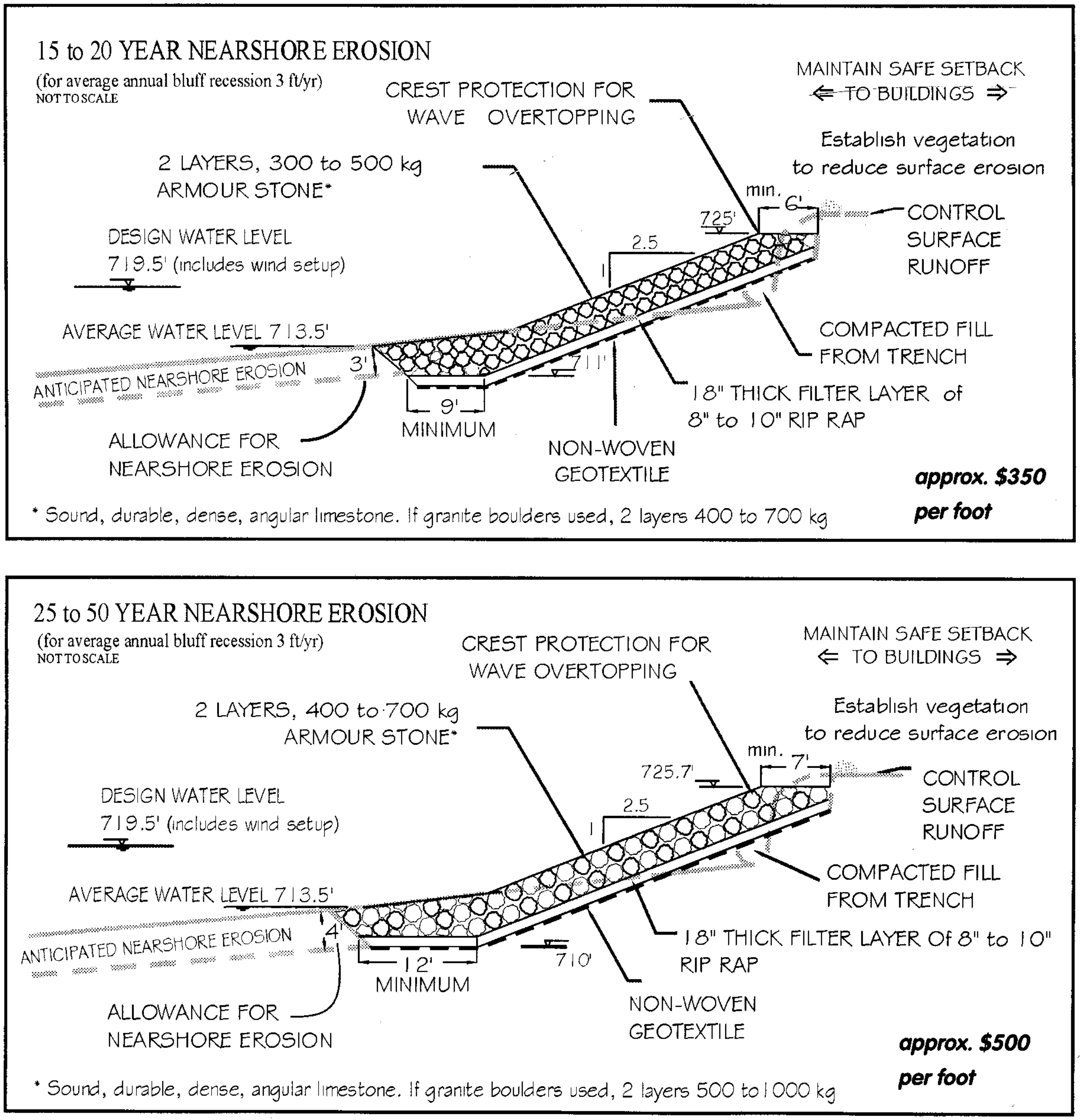


*Figure 4.1 – Stone Revetment: Preliminary Designs*

### 4.1.2 Seawalls

As discussed earlier, seawalls are vertical, or near vertical shore parallel walls. To block wave action from reaching the land, seawalls tend to be rather massive structures that require proper scour protection at the toe and wave overtopping protection at the crest. Typically, seawalls are constructed from concrete or steel sheet pile (see Figure 4.2).

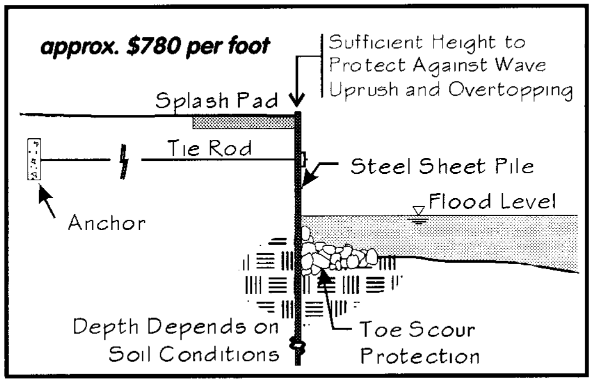


*Figure 4.2 – Steel Sheet Pile Seawall*

A steel sheet pile structure depends on the penetration into the lakebed and the tiebacks for its stability. Steel sheet piles can be driven into cohesive material as well as noncohesive material (i.e., sand). A high content of cobble and boulders in cohesive material increases the difficulty of driving steel sheet piles. The structural design of steel sheet piling is specialized and not subject to standard plans. For this reason, the service of a qualified engineer is essential. Key design considerations are foundation conditions, penetration of the piling, height and alignment, length and spacing of tie rods and scour protection. Sufficient access must be available for pile-driving equipment. Advantages include relatively low maintenance costs and readily available materials.

Rigid, poured concrete seawalls require a sound foundation with sufficient bearing capacity and minimal settlement. Reinforcing steel and concrete quality are important factors that should be designed by a qualified engineer.

Seawalls tend to require less width than a revetment, possibly making construction feasible in some areas with a steep backshore and where a sloped structure might require large amounts of earth moving. Seawalls, due to their steep (often vertical), impermeable and generally smooth face, cause more wave reflection, resulting in increased erosion in front of the structure and more problems with scour and undermining at the toe of the structure. Because of this, seawalls may fail catastrophically if proper design is not used. Seawalls also require higher crests than revetments if overtopping is to be reduced. Finally, the cost of a seawall may be less than or greater than that for a revetment depending on the site conditions, materials used and the required design life of the structure. Large seawalls can be very complicated to build, requiring anchoring of the walls to prevent overturning and/or very deep penetration depths for pile structures.

Based on the preceding discussion, in particular the possibility of increased nearshore erosion due to wave reflections, it is recommended that revetments be constructed rather than seawalls. This recommendation applies to both long-term erosion protection, as well as to storm wave runup protection (i.e., "light" protection).

## 4.2 Light Protection Structures

Light protection structures do not provide long-term shoreline protection. Light protection structures on the beach are similar to the heavy structures described above but they have less resistance to severe wave attack. They are slightly less costly but have a reduced design life and maintenance is required more frequently. They may also take up most of the beach.

Light protection structures above the beach may be utilized for protection against storm wave runup as long as they are located sufficiently landward of the water's edge so they are not exposed to direct wave attack. These structures have the advantages of being less costly, generally, than the other types of structures and of leaving more of the beach for recreational purposes. However, their design life is significantly less than heavy structures and they are much more susceptible to damage. Maintenance is necessary more often and toe erosion in particular could be a significant problem.

### 4.2.1 Light Revetments

*Stone Revetment*: Stone revetments are sloped structures built with layers of stone. They are the preferred method when armouring the shoreline is necessary as the last resort and when stone is available in sufficient size and quantity. Stone revetments are effective structures for absorbing wave energy. Their naturally rough surface reduces wave runup and they can be constructed in stages. Because they are flexible, slight movements don't weaken them. If damaged, they are usually readily repaired. Where access is limited they are difficult to construct because heavy equipment is required. They may limit the use of the beach.

The key design considerations are the dimensions, stone size and filter. Construction is not complicated and no special equipment, other than a backhoe and trucks are needed. Riprap slopes should not be steeper than three horizontal to one vertical for the sake of stability. An above-the-beach light riprap revetment is shown in Figure 4.3. Futher details of the toe apron and riprap size are provided in Sections 4.2.4 and 4.2.5.

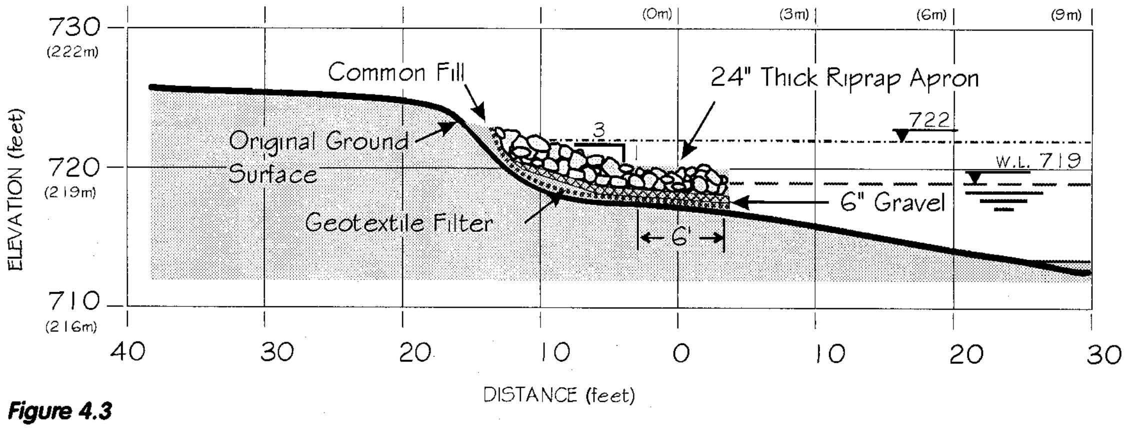


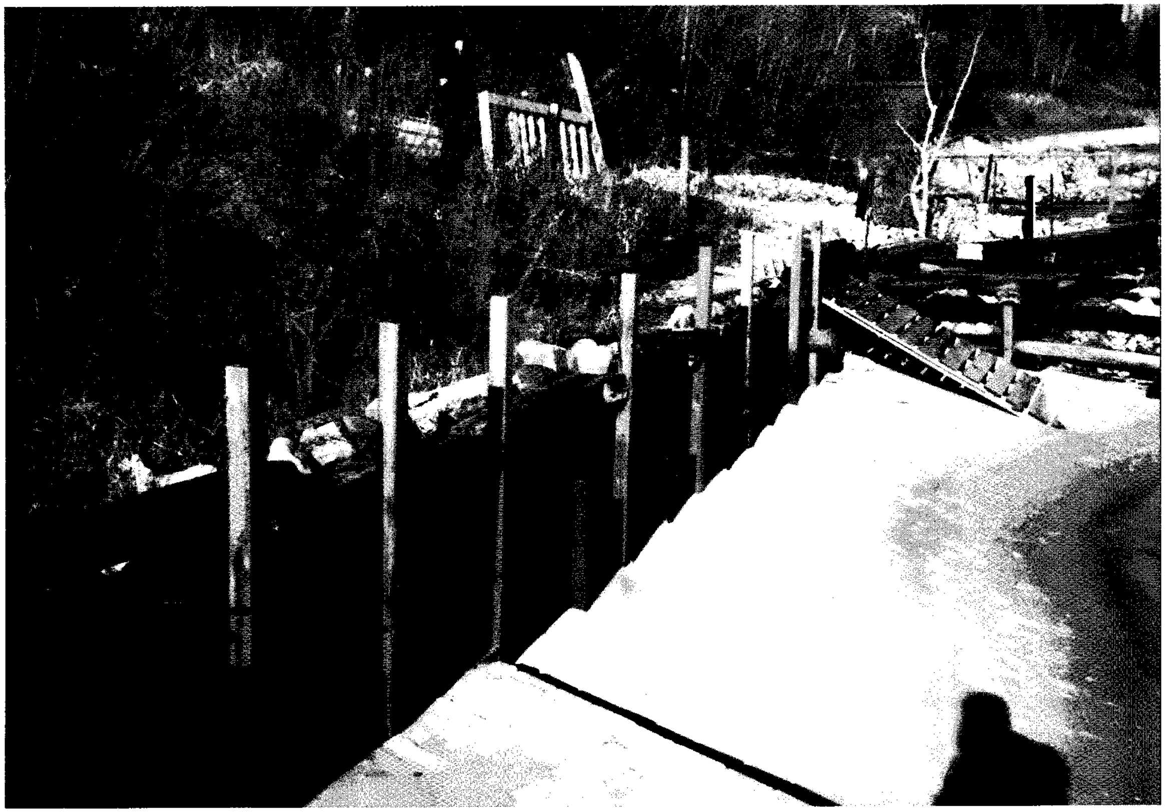
**Figure 4.3**

**Light Protection: Riprap Revetment Above Beach** **approximate cost: $50 per foot**

Gabion Mat Revetment: Gabion mats are commercially available wire mesh baskets filled with four-to nine-inch diameter rocks. Gabion mat revetments serve the same purposes as riprap slopes and may be used in their place where riprap of the proper size cannot be obtained. No special construction equipment is required and so they rate as a good "do-it-yourself" type of protection. The manufacturer's instructions should be followed closely. They are flexible and not damaged by slight movement. Potential damage by ice is a significant concern. Repair work may be difficult if baskets are displaced or submerged. Additionally, ends of broken wires are a hazard to bare feet. Gabion mats are subject to rusting and deterioration. Use of the beach is limited and maintenance costs are moderate.

### 4.2.2 Bulkheads

A bulkhead differs from a seawall in that, while it also separates the land and water, it is not intended to be subject to the full impact of the waves. Bulkheads tend to be of lighter construction than seawalls and are typically constructed from light steel sheet piles or timber. Bulkheads are mostly constructed with little consideration of the wave forces and as such are generally not recommended for use along shorelines exposed to direct wave attack.

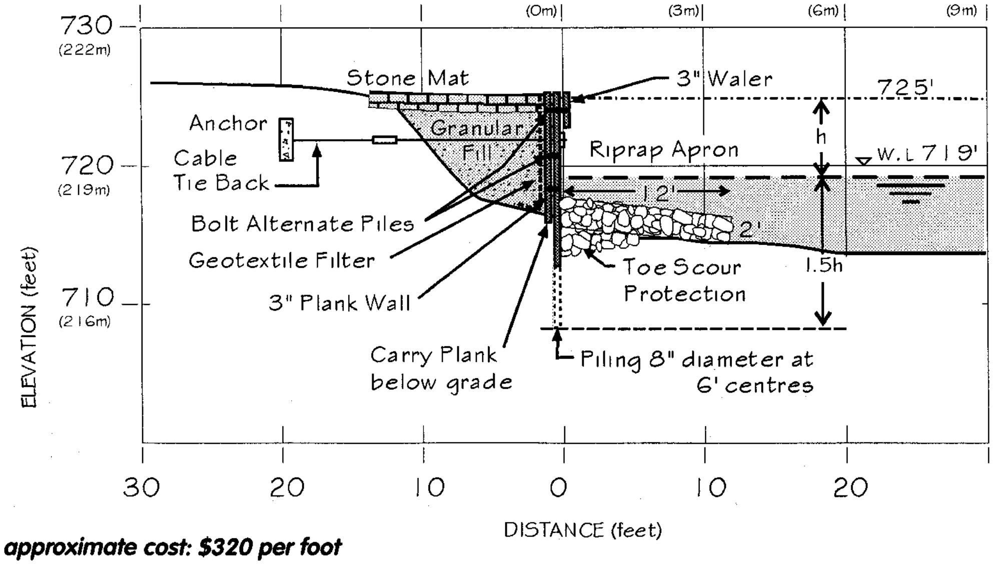


***Timber Bulkhead***

Steel Sheet Pile Bulkhead: A steel sheet pile bulkhead serves to armour the bank. The face must be designed to absorb all the wave energy. Severe scour occurs where the bulkhead intersects with the lakebed or beach. The sheeting depends on the penetration and tiebacks for its stability (see Figure 4.2). The structural design of sheet piling is specialized and not subject to standard plans. For this reason, the service of a qualified engineer is essential. Key design considerations are foundation conditions, penetration of the piling, height and alignment, and scour protection. Sufficient access must be available for pile-driving equipment. Advantages include relatively low maintenance costs and readily available materials.

Timber Wall Bulkhead: Timber walls are constructed of horizontal plank sheeting attached to vertical timber piles (see Figure 4.4). They must be tied back to anchor piling. A common cause of failure of timber bulkheads is undermining of material from the bottom of the toe of the structure, resulting in inadequate penetration of piling. The pressure of the soil and water on the backside can then push over the structure. The tiebacks and anchors provide additional strength to resist this force. Details of the tieback spacing and length should be determined by an engineer. Timber bulkheads also require positive toe protection. As with the steel sheet pile option, the service of a qualified engineer is recommended.

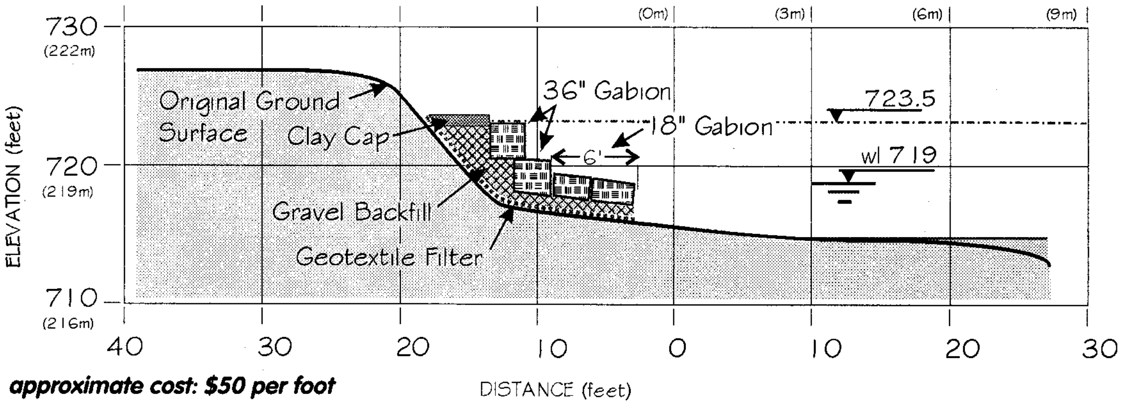
***Figure 4.4 – Light Protection: Timber Wall Bulkhead***



***approximate cost: $320 per foot***

Gabion Bulkhead: A gabion bulkhead is constructed by stacking gabion baskets on top of one another, wiring them together and filling them with stone. Gabions are commercially available wire mesh baskets filled with four to nine inch diameter rocks. Figure 4.5 illustrates a gabion bulkhead above the beach. Gabion walls are advantageous where space limitations do not permit sloped structures. They can be constructed without special equipment, and are flexible. No special construction equipment is required and so they rate as a good "do-it-yourself" type of protection. The manufacturer's instructions should be followed closely. They are flexible and not damaged by slight movement. Potential damage by ice is a significant concern. If a lower gabion basket is ruptured and loses its rock fill, overlying baskets may sag or collapse, making any repairs difficult. Access to and use of the beach is limited. The baskets are subject to rusting. Maintenance costs are moderate.

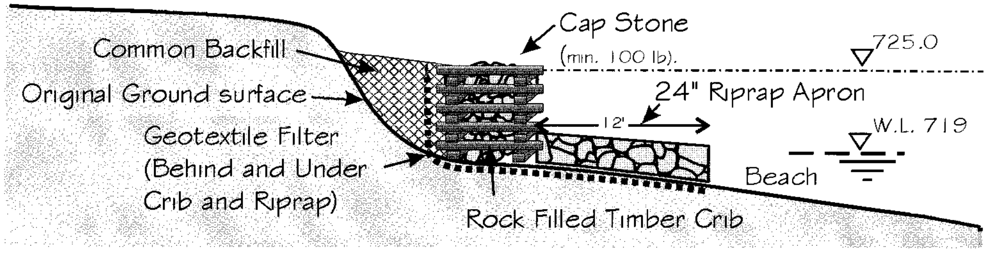
***Figure 4.5 – Light Protection: Gabion Wall Above Beach***



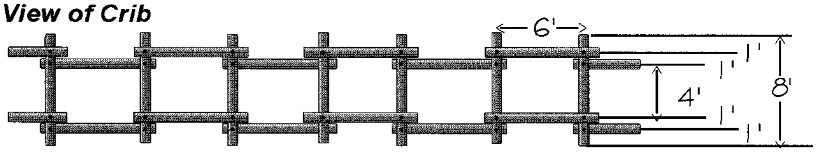
***approximate cost: $50 per foot***

Rock-filled Timber Cribs: As their name implies, rock-filled timber cribs are structures made by building timber frameworks and filling them with rock. The intent is to build them back from the waterline against the bluff. Figure 4.6 shows a rock-filled timber crib. Timber cribs are advantageous because they are easily constructed of readily available material and are relatively inexpensive. They lend themselves to staged construction and the protection of short reaches. Maintenance work is easily accomplished. If the timber used in construction is untreated it will eventually rot, limiting the structure life. The vertical walls induce scour at the base making adequate toe protection crucial.

**Figure 4.6**
**Light Protection – Rock Filled Timber Crib Above Beach**



**Plan View of Crib**



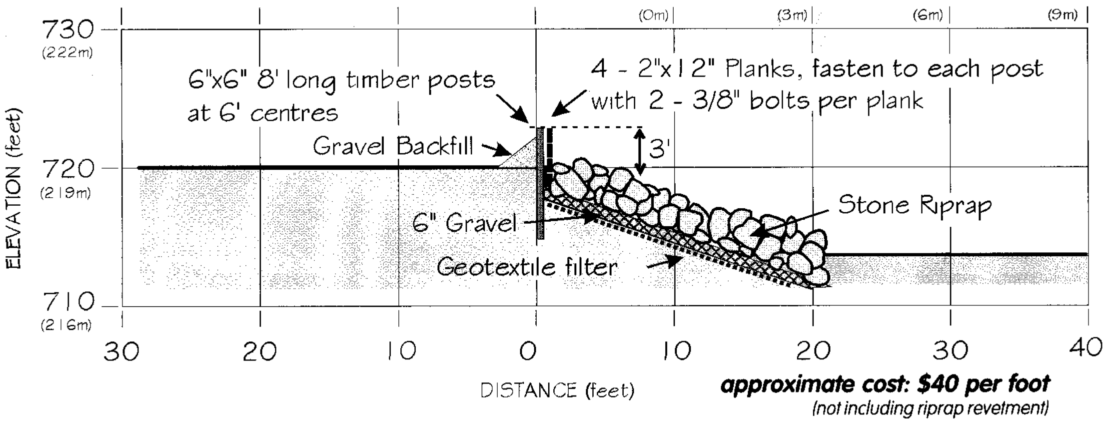
All logs 6" to 12" in diameter, 8' long. Drill 1" diameter holes in logs as shown. Assemble logs as shown, joining logs with 3/4" diameter steel rod with washer and nut at top and bottom.
Note: a gabion apron measuring 6' x 18" can be used instead of riprap apron.

***approximate cost: $90 per foot***

<u>Concrete Walls</u>: Concrete walls are intended to be built level from the waterline against the cliff. Concrete walls take up less room than most structures. Details of the dimensions, drainage, reinforcing steel and concrete quality are important factors that should be designed by a qualified engineer. Construction is relatively simple and maintenance costs are low. Concrete walls are rigid and can not tolerate any movement without cracking. They are particularly subject to toe erosion making adequate protection at the base essential.

Timber Wall Wave Screens: Timber wall wave screens are intended to be used in conjunction with another structure. They provide a relatively inexpensive way to increase the degree of wave overtopping protection offered at the top of a structure. Figure 4.7 illustrates a 3 ft high timber wave screen.

***Figure 4.7***
***Three Foot High Timber Wave Screen***



***approximate cost: $40 per foot***
*(not including riprap revetment)*

## 4.2.3 Selection of Light Protection Structure Option

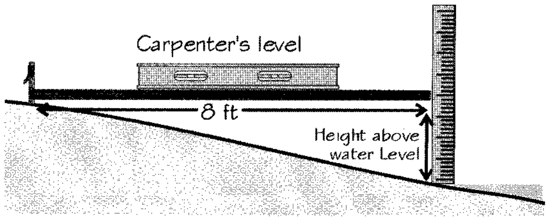
### *Determining Lake Level and Land Elevations*

In determining which type of structure is best suited for your needs, the first step is to sketch a profile of your property showing the bluff, the beach, the waterline and the underwater slope. To determine the elevation of the waterline, drive a stake into the ground at the water's edge on the morning of a calm day and request the lake level for that day for the gauge closest to your property from the Manitoba Water Resources Branch in Winnipeg (Telephone 204-945-6398).

The shore profile can be determined with sufficient accuracy by measuring the rise in land over horizontal distances with an 8 ft long board and a carpenter's level, as shown on Figure 4.8. The underwater portion of the profile can be surveyed by measuring the depth of the water at intervals of 8 feet horizontally to a depth of about four feet. This profile should then be plotted on squared paper along with the design high water level of 719 ft and the stable slope allowance (3 horizontal to 1 vertical) from the toe of slope (see Section 3.3.2).

### Sketch and Consider Alternatives

Sketch in several of the structures to see if there any space limitations. Of the structures that could be built on your property, decide how much you are willing or able to spend on erosion protection. Will the structure be suitable for long-term erosion protection? The long-term average erosion rates can be determined from Appendix II. Are the materials necessary for construction available? Eliminate the ones that are too expensive or that require materials that are not readily available.



Example:

Ground level at 'A' =713.5 ft (water level)

Ground level at 'B' = 'A' + 0.6 ft = 714.1 ft

Ground level at 'C' = 'B' + 1.0 ft = 715.1 ft

Ground level at 'D' = 'C' + 0.8 ft = 715.9 ft

Ground level at 'E' = 'D' + 4.0 ft = 719.9 ft

Lakebed level at 'F' = 'A' - 0.5 ft = 713.0 ft

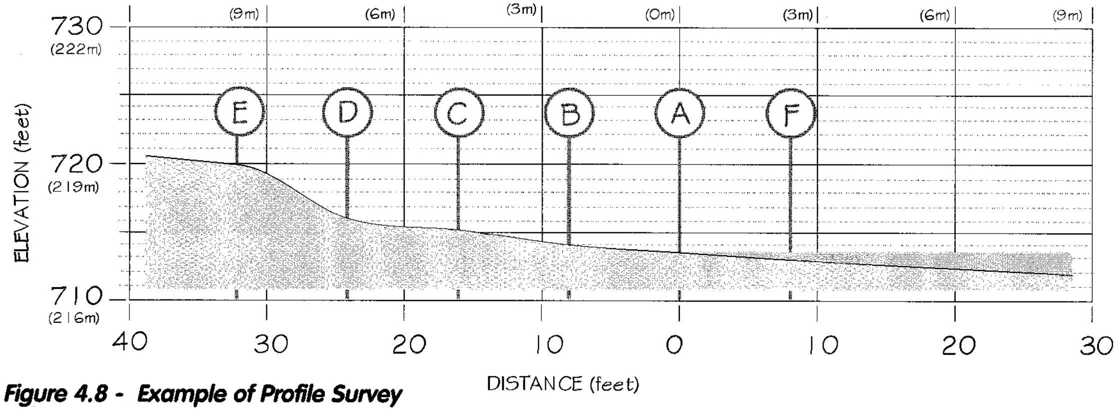


Figure 4.8 - Example of Profile Survey

Consider how the remaining structures will affect your property. Will it take up too much of the beach? What will happen to the beach over time? Will you find it unsightly? How will the structure be coordinated with the neighbours? Will the structure have any negative impacts? Will maintenance costs be high? Is there adequate access to facilitate construction and future maintenace?

### *Professional Engineering Services*

After weighing the pros and cons of each structure choose one that is best suited to your needs. Consult a qualified engineer to prepare the final design.

### *Approvals and Licenses*

Before constructing any structures along the shoreline, the ownership of the land on which the structure is to be built should be determined. This can only be done by examining the Certificate of Title for a property to determine the limits of the property and by establishing the limits of the property in the field. In many cases it will be found that a strip of land generally 99 ft wide called a Crown Reservation or Public Reserve exists between the waterside boundary of a cottage lot and the shoreline. The Reserve may belong to the Province, a Rural Municipality, a Local Government District or Town, which may establish bylaws governing the use of the Reserve. The significance of the matter is that the owner of the property adjacent to the Reserve has no right to construct works on the Reserve or to do anything which might interfere with the use of the Reserve by others unless such rights are granted by the authority having jurisdiction over the Reserve. For this reason approval should be sought from the appropriate authority before constructing any structures on land not owned by the builder.

The builder should check with the local government authority to determine whether a building permit is required for the proposed construction.

Where the proposed structure extends into the water or where it may interfere with navigation the builder should check with the Canadian Coast Guard to determine whether a permit or exemption is required under the Navigable Waters Protection Act. Under the federal Fisheries Act, it is an offence to cause a harmful alteration, disruption or destruction of fish habitat. Additionally the builder should determine the ownership of the underwater portion of the land required for the structure and obtain any necessary easements.

## 4.2.4 General Design Considerations for Light Protection Structures

If an erosion protection structure is to last for a long period of time, it must be designed to withstand the worst conditions it is likely to experience and take into consideration the nearshore downcutting. Unfortunately structures designed on this basis are generally quite expensive. Less costly, "lighter" structures offer reduced protection, have shorter lifespans and must be repaired more frequently. The types of conditions which a structure must be able to tolerate before it is damaged, dictate the design parameters of the structure.

Following is a discussion of the general considerations implicit in the design of light protection structures.

1. Adequate Toe Protection: The failure of many structures is the result of undermining at their base. Adding an "apron" at the toe of the structure to resist the wave energy deflected downward by the structure can reduce the risk of scour.

On Lake Winnipeg much of the wave energy is expended above elevation 713 ft. Therefore, for long-term protection, the toe elevation of a structure should be 713 ft, or lower. However, this has a serious disadvantage in that a structure with a toe elevation of 713 ft will likely take up most of the beach. Structures built further from the waterline at approximately elevation 718 ft (not including toe apron) may be more susceptible to toe erosion but they leave the beach free for recreational use. Table 4.1 summarizes the apron dimensions for various structures.

**TABLE 4.1**
**Preliminary Dimensions of Toe Aprons for Light Protection Structures**

| | Riprap Apron Dimensions | | | Gabion Apron Dimensions | | |
|---|---|---|---|---|---|---|
| Type of Structure | Vertical Walls | 3:1 Slopes | Stepped Walls | Vertical Walls | 3:1 Slopes | Stepped Walls |
| Protection on beach | - | 8'x32" | 12'x32" | - | 6'x18" | 6'x18" |
| Protection above beach | 12'x24" | 6'x24" | 9'x24" | 6'x18" | 3'x18" | 6'x18" |

2. Adequate Height: It is important that a structure is built high enough so that wave overtopping is reduced thereby reducing the risk of erosion behind the structure. To determine how high a structure should be built, three factors are considered: the design lake level, the design wind setup, and the design wave runup.

The design lake level is the maximum lake level the structure is designed to tolerate. With regulation, the mean level of Lake Winnipeg is to be kept below 715 ft in so far as possible and has seldom exceeded a level of 715.5 ft. The design wind setup is the maximum wind set-up a structure is built to tolerate. Relatively few wind setup events exceeded 3 ft while a wind setup of 3.5 feet is seldom exceeded. Table 4.2 includes the design lake levels for various structures.

The maximum wave runup a structure is designed to tolerate is the design wave runup. Table 4.2 shows the design wave runups for different structures. The top elevation of a structure is found by summing the design mean lake level, the design wind setup, and the design wave runup. The top elevations of different structures are shown in Table 4.2.

**TABLE 4.2**
**Preliminary Design Parameters for Light Protection Structures**

| | Type of Light Structure | |
|---|---|---|
| | Protection on Beach | Protection above Beach |
| Bottom Elevation<br>(not including toe apron) | 713.0 ft | 718.0 ft |
| Design Mean Lake Level | 715.0 ft | 715.5 ft |
| Design Wind Set-up | 3.0 ft | 3.5 ft |
| Design Wave Height | 4 ft | 3 ft |
| Design Wave Runup | | |
| Vertical Walls | - | 6 ft |
| 3:1 Riprap Slopes | 4 ft | 3 ft |
| Stepped Walls | - | 4.5 ft |
| Top Elevation | | |
| Vertical Walls | - | 725.0 ft |
| 3:1 Riprap Slopes | 722.0 ft | 722.0 ft |
| Stepped Walls | - | 723.5 ft |

The recommended elevations for the top of shoreline protection given in this table are generally acceptable for the South Basin. However, for the most southerly portions, where the effects of setups are most extreme, the addition of up to one foot may be advisable.

3. Adequate Material Size: Erosion protection structures must be constructed of material that is heavy and dense enough so that individual elements of the structure are not moved by waves. Relationships between the design wave height (the largest wave that a structure is designed to withstand) and the size of an element have been established from standard published methods. The use of smaller sizes in construction will substantially decrease the chances that the structure will behave as anticipated. The estimated design wave heights for the structures are included in Table 4.2.

4. Adequate Care Taken to Insure Underlying Material is Not Washed Out: Often the voids left between individual elements are large enough for water to wash out the fine underlying material and cause the structure to fail unless special precautions are taken. For this reason it is necessary to place a geotextile filter under and behind all structures. The geotextile filter is a commercially available product that allows water to pass freely but keeps the fine underlying material in place.

5. Adequate Care Taken to Protect the Structure Against Flanking: Erosion will continue unabated past the ends of erosion protection structures (see Figure 3.2). If no precautions are taken, the erosion will occur around the ends of the structure in behind it. This process is called flanking. Structures must be turned back into the bank to prevent flanking. The sides of the structure will need to be extended back as necessary as the adjoining unprotected property continues to erode.

6. Adequate Foundation Conditions: Soft foundation material could result in excessive settlement or sliding of the structure. As a general rule, if the existing bank is stable and the height and steepness of the structure do not exceed that of the bank, the structure should be stable.

7. Adequate Inspection and Maintenance: Structures must be inspected regularly, particularly after every storm. Any damage must be repaired immediately if further damage is to be avoided.

*Please note that all of the above seven guidelines must be followed or the failure of the structures after construction is a virtual certainty.*

## 4.2.5 Materials and Construction

Following is a brief discussion on material and construction specifications.

1. <u>Riprap</u>: The riprap should be dense, durable rock that is not subject to excessive weathering. Table 4.3 specifies riprap sizes for various structures.

**TABLE 4.3**
**RIPRAP SPECIFICATIONS**

| Type of Structure | Riprap Size | | |
|---|---|---|---|
| | $D_{max}$ | $D_{50}$ | $D_{min}$ |
| Light riprap slope on beach | 26" | 16" | 8" |
| Riprap slope above beach | 20" | 12" | 6" |

Note:

1. *$D_{50}$ is the diameter of rock such that 50% by weight of the rocks are larger and 50% by weight are smaller.*
2. *$D_{max}$ is the maximum rock diameter and $D_{min}$ is the minimum diameter.*
3. *The thickness of the riprap layer is 2 times $D_{50}$. Care should be taken to insure that there are no areas with a lesser thickness.*
4. *For field control purposes, 15% of the rock by count should be between $D_{max}$ and $D_{50}$ and 85% of the rock should be between $D_{50}$ and $D_{min}$.*

2. <u>Gabions</u>: Gabions are available commercially from several sources. To be effective gabions must be assembled and attached to one another according to the manufacturer's recommendations. The rocks used to fill gabions must be durable and not subject to excessive weathering. Gabions must be tightly packed. The more angular the rock, the better it will pack. As has been noted, gabion baskets will eventually rust because abrasion by sand and friction with the rock fill wears off galvanizing or other protective coatings. Ice action can severely damage gabions so they should not be placed where ice is likely to reach them.

3. Geotextile Filter: Geotextile filter is a synthetic heavy cloth and is an essential part of all the structures described here. There are several brands on the market of varying quality. The basic functions of the geotextile are filtration and separation – to prevent the washing out of the underlying soil particles while allowing the water to pass and to separate layers of different size.

4. Gravel Backfill and Bedding: A six-inch bedding layer is required under the geotextile filter. This can be a pit run gravel, the largest stones being smaller than four inches in diameter. This size of gravel is also adequate for beachfill material when it is required behind structures. Clean gravel can be placed in freezing conditions and need only be compacted by handling equipment.

5. Common Backfill: Clayey and silty backfill should be placed in an unfrozen condition and must be well compacted.

6. Timber: Treated timber can have a life of about 15 to 30 years. Timber that has been seasoned but is untreated may last about 10 to 20 years. Unseasoned and untreated timber may only endure approximately 10 years.

# SECTION 5 – Summary

Significant portions of the shoreline of Lake Winnipeg are eroding and transgressing because of the cohesive nature of the shoreline material, the action of the waves and the influence of the water levels and ice. Transgression of the shoreline occurs as a result of long-term increases in the mean water level. Flooding of low-lying areas adjacent to the shoreline is a result of various high combinations of mean water levels and short-term water level fluctuations. In most instances, erosion, flooding and dynamic beach changes at the shoreline are to a large extent, the result of naturally occurring processes. Man-made alterations to the natural lake systems may, but typically to a lesser extent than the natural processes, affect the erosion, flooding and dynamic beach changes.

Cohesive shores are those shores that feature a thin layer of sand over clay or glacial till in the nearshore. The erosion of the cohesive nearshore profile is ongoing and irreversible – once eroded the clay and silts are transported into deep water and are never returned to shore. This process is the natural progression of a glacial lake such as Lake Winnipeg.

Mean water levels on Lake Winnipeg are primarily governed by climatic factors such as precipitation, evaporation, inflow and outflow. The outflow has been regulated since 1976, which has had the effect of reducing the variability of the monthly mean water levels to within a range of about 4 ft. Over the longer term, the effect of isostatic rebound is increasing water levels in the south basin of Lake Winnipeg at an estimated rate of 8 inches per century. Short-term water level fluctuations are caused by wind setup. A wind setup of 1 ft is common and it has reached 3.7 ft at Gimli/Winnipeg Beach.

Development practices should adapt to the shoreline processes and be setback from the shoreline beyond the limit of flooding, erosion and dynamic beach hazards. Relocating an individual house or cottage at risk should be considered as a viable alternative when feasible.

Structural protection works that attempt to replicate the natural processes (i.e., beach nourishment and lakebed armouring) and structural works that attempt to work with the natural processes (i.e., detached breakwaters, artificial headlands and groynes) require detailed study and would typically be applied on a much larger scale than one individual property owner. Many of the groynes constructed on Lake Winnipeg are ineffective because they are too short to trap enough sand to protect the cohesive nearshore profile and/or there is not enough beach material available in the littoral system. Along shorelines with sufficient littoral transport, groynes negatively impact downdrift areas by trapping material and reducing the sediment supply and by deflecting littoral material into deeper offshore water.

A properly designed, constructed and maintained revetment structure can effectively stop erosion at the water's edge for a period of time. Application of this approach requires careful consideration of the lake bottom erosion. A revetment can also be used to protect shorelines from storm wave runup damage, and can be designed to provide this protection even under extreme conditions. However, a revetment will not provide any recreational benefit to the shoreline, and may in fact reduce access and result in a reduction of existing beach deposits. Armouring the shoreline with a revetment or seawall will arrest the bluff recession for a period of time but it does not reduce the erosion of the nearshore profile. Eventually, the structure will be undermined. The toe of a shoreline structure must be sufficiently embedded to allow for nearshore downcutting.

On an eroding shoreline, the beach in front of an armoured shoreline will normally diminish in width over time, as the nearshore profile erodes, and the beach will eventually disappear. Beach loss may be accelerated by wave reflection from the structure. Sloping stone revetments result in less wave reflection than smooth, impermeable, vertical seawalls. Protecting shorelines from erosion reduces the supply of sediment that helps to form the beaches.

# glossary

**Accretion**

A volumetric addition of shoreland by natural deposition.

**Alongshore**

Parallel to and near the shore usually within the littoral zone (also longshore).

**Artificial Nourishment**

(also called beach nourishment) - The process of replenishing a beach with material (usually sand) obtained from another location.

**Average High Water Level**

The average of the highest monthly mean level of each year over a period of time.

**Average Low Water Level**

The average of the lowest monthly mean level of each year over a period of time.

**Average Annual Monthly Water Level**

The average of monthly mean water levels over the year.

**Backfill**

The material used to refill a ditch or other excavation, or the process of doing so.

**Backrush**

The lakeward return of the water following the uprush of waves.

**Backshore**

The part of the shore or beach that is usually dry extending from the limit of wave uprush at the average annual high water level to either: the place where there is marked change in material or physiographic form; or the line of permanent vegetation (usually the effective limit of storm waves); or the high water mark.

**Bathymetry**

The topography of the lake bottom.

**Beach Nourishments:**

The act of artificially supplying an eroding shoreline with new sediment, from inland sources or the offshore, to replace, enhance or maintain a beach for recreational purposes and shoreline protection.

**Bluff**

A steep slope or bank in either glacial sediment or rock, usually facing the lake.

**Breaking Point**

The point at which a wave begins to break.

**Bulkhead**

A steep or vertical structure supporting a natural or artificial embankment.

**Celerity**

Velocity of a moving wave.

**Cliff**

Same as bluff.

**Contour**
A line drawn on a map connecting points of the same elevation.

**Current**
A flow of water.

**Current, Longshore**
The current in the breaker zone moving essentially parallel to the shore generated by waves breaking at an angle to the shoreline.

**Downdrift**
The direction of predominant movement of littoral materials.

**Downrush**
See BACKRUSH.

**Dunes**
Ridges or mounds of loose, wind-blown material, usually sand.

**Duration, Minimum**
The minimum time necessary for steady-state wave conditions to develop for a given wind velocity over a given fetch length.

**Erosion**
A volumetric reduction of shoreland by natural processes.

**Erosion Rate**

The net loss of shorelands normally located above the lake surface elevation over a specific period of time.

**Fetch**

The distance across the lake that a water wave has traveled from its initiation to the shoreline.

**Fillet Beach**

A sand or gravel deposit that accumulates along the shoreline against a coastal structure, such as a groyne or a natural feature such as a headland.

**Filter**

A layer of well graded rock or a synthetic material between protection works and backfill soil to prevent extrusion of the soil through the protection works.

**Freeboard**

The additional height of a structure above a design water level used as a safety factor to prevent overflowing.

**G.S.C.**

Geodetic Survey of Canada.

**Groyne**

A shore protection structure built out at an angle from a shore to trap sand and to protect the shore from erosion by currents and waves by making a beach.

**Groyne Field**

A series of groynes acting together to protect a section of shore; (groyne system).

**Glacial Till**

The sediment which is deposited directly from a glacier, and which exhibits a wide range of particle sizes, from fine clay, silt and sand to rock fragments and boulders.

**Headland**

An erosion resistant promontory, either natural or man made, extending into the lake; embayments often form between adjacent headlands.

**Inundation**

The temporary submergence of shorelands normally located above lake levels.

**Jetty**

An elongate artificial obstruction projecting into the lake from shore to control shoaling and scour by deflection of currents and waves.

**Lacustrine**

Pertaining to the processes of, or sediments within, lakes.

**Land Use**

The human use of a planning area.

**Limestone**

A general term for a sedimentary rock which consists mainly of calcium carbonate.

**Linear Refraction**

For waves that approach at an oblique angle to the shoreline, the bending of the wave crest towards the general alignment of the nearshore contours and shoreline.

### Littoral Barrier

An object, manmade or natural, that interrupts the natural longshore transport of littoral drift.

### Littoral Cell

Areas under the continuous influence of specific longshore currents.

### Littoral Drift

Sediment, ranging in particle size from fine sand to coarse gravel that is transported in the littoral zone under the influence of wind generated waves and currents.

### Littoral Sediment

Same as littoral drift.

### Littoral Transport

The movement of littoral drift in the littoral zone by waves and currents including movement parallel to the shore (longshore transport) and perpendicular to the shore (onshore-offshore transport).

### Monthly Mean Level

The average water level occurring during a month computed from the hourly or daily readings in each month.

### Nearshore

An indefinite zone extending lakeward from the average annual water level to beyond the breaker zone defining the area of nearshore currents formed primarily by wave action.

### 100 Year Erosion Limit

In bluff areas the 100 year erosion limit is taken as the average annual recession rate extended 100 years from the eroding edge of the bluff plus an allowance to achieve a stable slope. In non-bluff areas the 100 year erosion limit is taken as the average annual shoreline recession rate extended 100 years from the shoreline position at average annual water level.

### 100-Year Flood Level

The 100-year flood level is defined as the water level due to the combined occurrences of mean monthly lake levels and wind setup having a total probability of being equalled or exceeded during any year of 1%.

### Overtopping

Passage of water over the top of a structure as a result of wave runup or wind.

### Pier

A structure, usually of open construction, extending out into the water from the shore to serve as a landing place, a recreational facility or other use.

### Pile

A long, heavy timber or slender section of concrete or metal to be driven into the ground or lakebed to provide support or protection.

### Profile

A side view or cross section (2 dimensional representation) of the lakebed elevation and slope conditions, normally measured in a perpendicular direction to the general shoreline orientation.

### Recession

A landward retreat of the shoreline by shore processes.

### Revetment

A facing of stone, concrete, etc.

### Riprap

A layer, facing, or protective mound of stones randomly placed to prevent erosion, scour or sloughing of a structure or embankment; also the stone so used.

### Rubble

Rough, irregular fragments of broken rock.

### Rubble-Mound

A mound of random-shaped and random-placed stones protected with a cover layer of selected stone or specially shaped concrete units.

### Rocky Shore

The shoreline geology, including the cliffs and lake bed, is dominated by sedimentary (such as limestone) or igneous rocks (such as granite).

### Sand Spit

A narrow, sandy shoal or deposit that projects into a body of water from the general shore orientation.

### Sandy Shore

The shoreline sediments consist primarily of sand-sized particles. The nearshore and beach can be extremely dynamic zones.

### Scour

Removal of material by waves and currents, especially at the base or toe of a shore structure or bluff.

### Seepage

Water escaping through or emerging along an extensive line or surface; the slow movement of water through soil by gravity.

**Seiche**

An oscillatory motion resulting in alternate high and low levels at each end of a lake that continues after the orginating force has ceased.

**Sedimentary Rock**

A soft rock composed of fine sediments, generally with a layered appearance such as limestone or shale.

**Setback Requirement**

A distance measured, inland from an edge of bluff, where construction is prohibited except for the purpose of erosion or flood control.

**Sheet Pile**

A pile with a generally slender flat cross-section to be driven into the ground or lakebed and linked or interlocked with like members to form a vertical wall or bulkhead.

**Shoal**

To become shallow gradually, cause to become shallow or to proceed from a greater to a lesser depth of water.

**Slump**

A failure of a bluff slope with a mass movement along a failure plane.

**Stillwater Level**

The elevation a water surface would assume if all wave action were absent.

**Storm Surge**

See WIND SETUP

**Surf Zone**

The area between the outermost breaker or where wave characteristics significantly alter due to decreased depth of water and the limit of wave uprush.

**Snell's Law**

An analytical method to account for wave refraction assuming a straight shoreline and nearshore contours.

**Toe Erosion**

The erosion which occurs at the toe of bluffs largely as a result of the continuous removal of earthen material by waves and currents.

**Transgression**

An extension of the lake over the land because of a rise in lake level or subsidence of the land.

**Undercut**

Undermining, erosion of the lower part of a steep bank so as to reduce the stability of the upper part.

**Updrift**

The direction opposite that of the predominant movement of littoral materials.

**Wave**

A ridge, deformation, or undulation of the surface of water.

**Wave Crest**

The highest part of a wave.

**Wave Direction**

The direction from which a wave approaches.

**Wave Hindcasting**

The use of historic wind data to calculate wave characteristics that probably occurred in the past.

**Wavelength**

The horizontal distance between similar points on two successive waves measured perpendicular to the wave crest

**Wave Period**

The time for two successive wave crests to pass a fixed point.

**Wave Rose**

The presentation of the incoming wave energy or wave heights at a specified nearshore point based on directional sectors or ranges (i.e. 22.5 or 45 degree sectors).

**Wave Runup**

The rush of water up onto the beach or shore following the breaking of a wave; for any given water level the limit of runrup is the point of farthest uprush.

**Wind Setup**

The vertical rise above normal water level on the leeward side of a body of water caused by wind stresses on the surface of the water.

# Appendix I – Shoreline Classification

## Shoreline Classification

Penner and Swedlo[1] divided the south basin of Lake Winnipeg into three distinct shoreline groups:

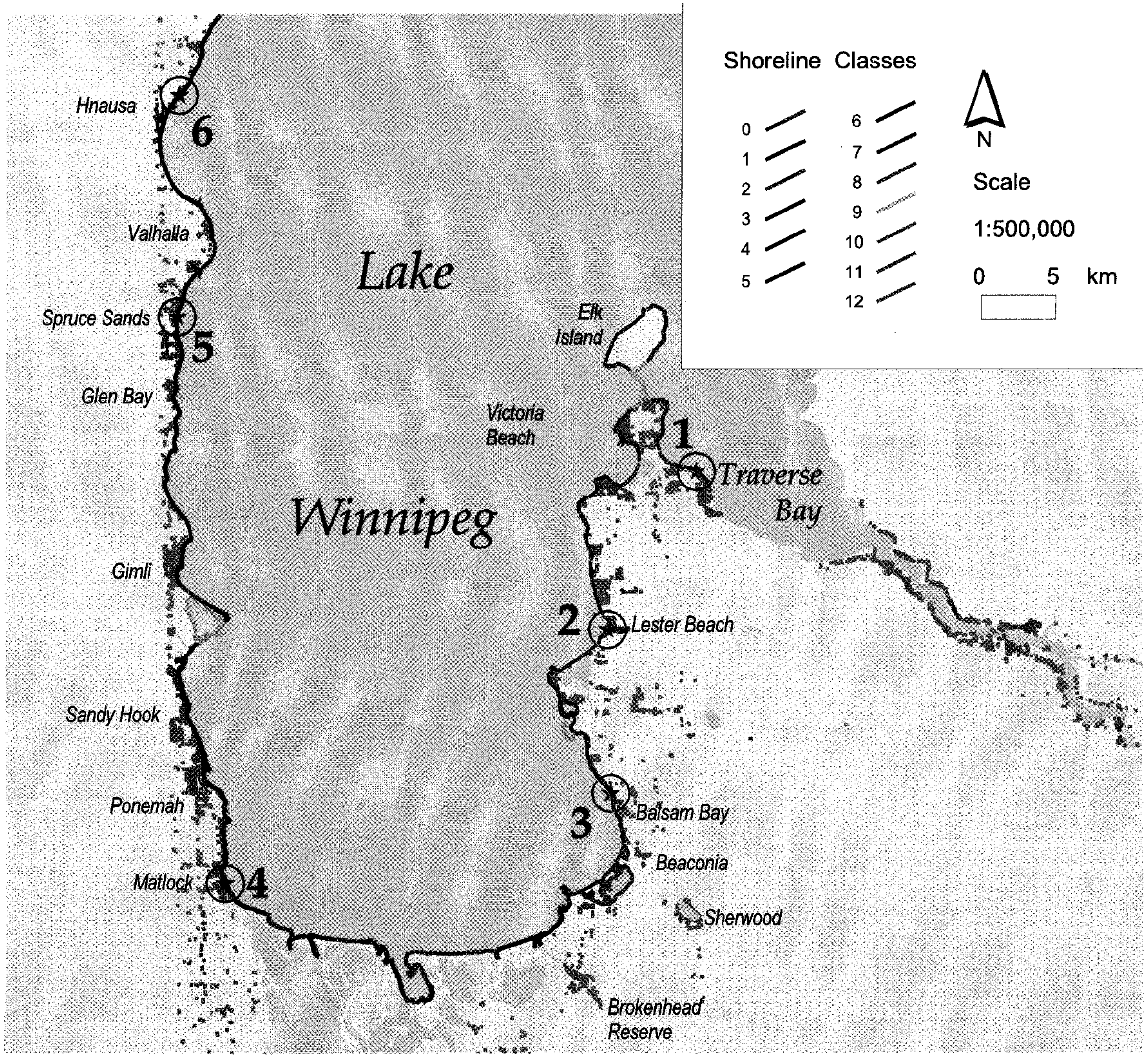
- lacustrine clays underlain by till along the west shore;
- wind and water sorted granular deposits along the south shore and at a number of locations on the east shore; and
- sandy boulder tills along most of the east shore.

These were subdivided into twelve shoreline types. The distribution of the different types is shown on the map.

[1] *Lake Winnipeg Shoreline Erosion, Sand Movement, and Ice Effects Study*

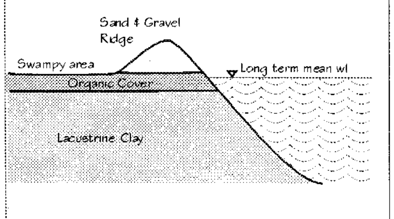
Lake Winnipeg, Churchill and Nelson Rivers Study Board, 1974
F. Penner, P.Eng. and A. Swedlo, P.Eng.

# APPENDIX I – shoreline classifications



## LACUSTRINE CLAYS UNDERLAIN BY TILL ALONG THE WEST SHORE

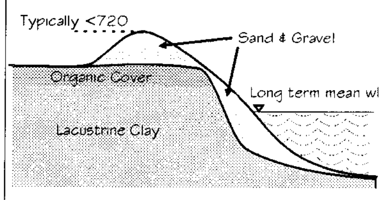
### Type 1



CLASSIFICATION TYPE 1

- shore material is organic cover underlain by a lacustrine clay
- backshore is generally a marsh and lower than 718 ft with ridge of sand and gravel deposited by wave action
- beach slope is stripped of granular cover material
- found in areas of high alongshore transport and no littoral barriers
- occurs in southwest and southeast portions of the lake
- typical erosion rate 10 to 15 ft/yr

### Type 2

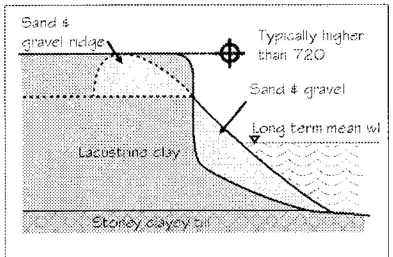


CLASSIFICATION TYPE 2

- similar to Type 1
- additionally has a cover of 1.5 ft of sand and gravel on the beach slope
- erosion rate 4 ft/yr
- along with Types 3 and 4, constitutes most of the western shore

---

## Type 3

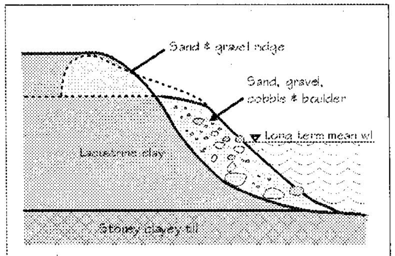


CLASSIFICATION TYPE 3

- shore material is lacustrine clay over stoney clay till
- top of bank normally at elevation 720 ft or higher (if lower, has a sand and gravel ridge)
- beach material consists of a mixture of sand and gravel with trace of cobbles and the occasional boulder
- thickness of granular material normally 1.5 ft
- typical erosion rate is 1 to 3 ft/yr, with rates up to 8 ft/yr
- Type 3 is the predominant shoreline type on the west shore

---

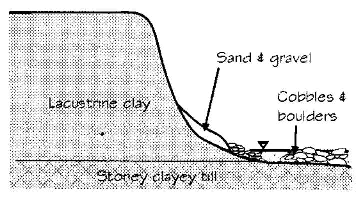
## Type 4



CLASSIFICATION TYPE 4

- shore material is lacustrine clay over stoney clay till
- top of bank normally at elevation 720 ft or higher
- granular material on beach slope consists of sand, gravel, cobbles and boulders
- more sand and gravel than cobbles and boulders
- maximum depth of granular material on the beach slope is 2 to 3 ft
- erosion 1 to 3 ft/yr
- this type occurs at several locations along the west shore

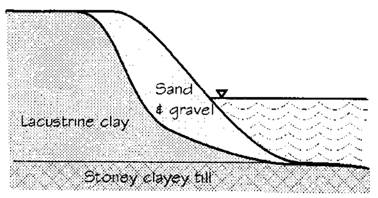
## Type 5



CLASSIFICATION TYPE 5

- shore material is lacustrine clay over stoney clay till
- top of bank higher than elevation 720 ft
- beach material is sand, gravel, cobbles and boulders but only small quantity of sand and gravel
- generally beach slope is paved with cobbles and boulders with a small wedge of sand and gravel at the bank face
- erosion is 0 to 3 ft/yr
- occurs at several locations on the west shore

## Type 6



CLASSIFICATION TYPE 6

- shore material is lacustrine clay over stoney clay till
- top of bank generally higher than elevation 720 ft
- beach consists of sand and gravel in sufficient quantity to prevent erosion
- depth of granular is 10 ft
- occurs in areas of accretion and is found only at Gimli and Winnipeg Beach

## GRANULAR DEPOSITS ALONG THE SOUTH SHORE AND AT SOME LOCATIONS ON THE EAST SHORE

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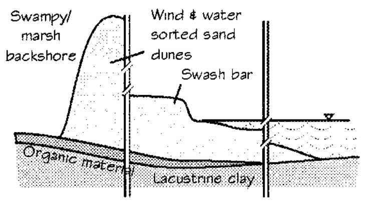
### Type 7

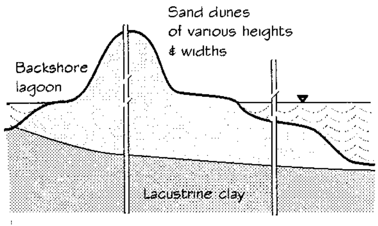


CLASSIFICATION TYPE 7

- shore material is lacustrine clay under an organic cover and wind and water sorted sand dunes over organic material
- backshore is generally a marsh area
- the beach material is wind and water deposited sand with the depth of sand at the waterline being about 10 ft
- occurs only along south shore

---

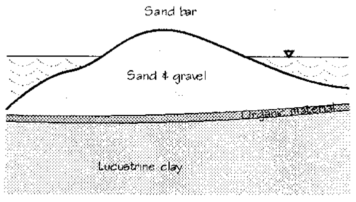
### Type 8



CLASSIFICATION TYPE 8

- wind and water deposited sand over lacustrine clay
- sand dunes are variable both in height and width
- a lake lagoon is present behind the dunes
- granular material on the beach is sand with a depth of 10 ft to 15 ft at the waterline
- found only at Patricia Beach, Grand Beach and Hillside Beach

## Type 9

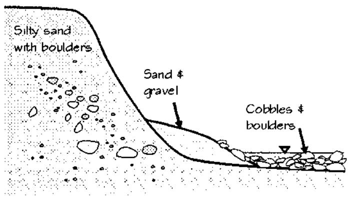


CLASSIFICATION TYPE 9

- water deposited sand from lake processes (sand spits and sand bars)
- these features are very dynamic
- found south of Willow Island on the west shore and south of Grand Marais and between Elk Island and Victoria Beach on the east shore
- the beach material is sand with a depth of approximately 15 ft

## SANDY BOULDER TILLS ALONG MOST OF THE EAST SHORE

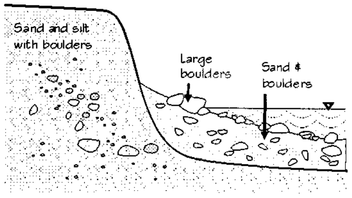
### Type 10



CLASSIFICATION TYPE 10

- shore material consists of silty sand with boulders
- top of bank typically higher than elevation 720 ft
- the beach has some sand and gravel (approximately 1 to 2 ft thick) with considerable coverage of boulders and cobbles
- erosion rate generally 2 to 4 ft/yr
- Types 10, 11 and 12 constitute most of the east shore

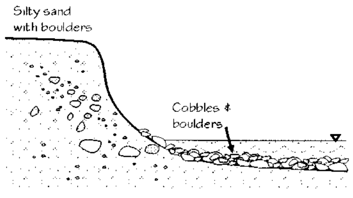
### Type 11



CLASSIFICATION TYPE 11

- shore material is sandy silt with boulders
- top of bank higher than elevation 720 ft
- beach material is mixture of sand, gravel, cobbles and boulders but sand and gravel is more predominant
- depth of granular at water line varies from a few ft to 30 ft
- typical erosion rate is 0 to 3 ft/yr
- predominant shore type at Victoria Beach and Elk Island

## Type 12



CLASSIFICATION TYPE 12

- shoreline material consists of sandy silt with boulders
- top of bank is typically higher than elevation 720 ft
- beach material is composed of cobbles and boulders to the extent that the erosion is virtually stopped
- found at several headlands along the east shore
- Types 10, 11 and 12 constitute most of the east shore

# Appendix II –

# Historic Shoreline Recession Rates

Shoreline recession rates for the south basin of Lake Winnipeg were determined by Penner and Swedlo (1974). They prepared a base plan to a scale of "1=200" based on aerial photographs and horizontal ground control obtained in the fall of 1971. Vertical ground control was taken from earlier surveys. Aerial photographs from 1946 to 1967 were used prepare a second shoreline for comparison with the base plan. A third shoreline was derived from land subdivision surveys and railway surveys dated 1874 to 1934. Comparison of the shoreline positions over the various time periods indicated typical shoreline recession rates of 1 ft/yr to 2 ft/yr (0.3 m/yr to 0.6 m/yr) with extremes of 0 m/yr and 25 ft/yr (0 m/yr and 8 m/yr).

From reference[1] *Lake Winnipeg Shoreline Erosion, Sand Movement, and Ice Effects Study*

Lake Winnipeg, Churchill and Nelson Rivers Study Board, 1974
F. Penner, P.Eng. and A. Swedlo, P.Eng.

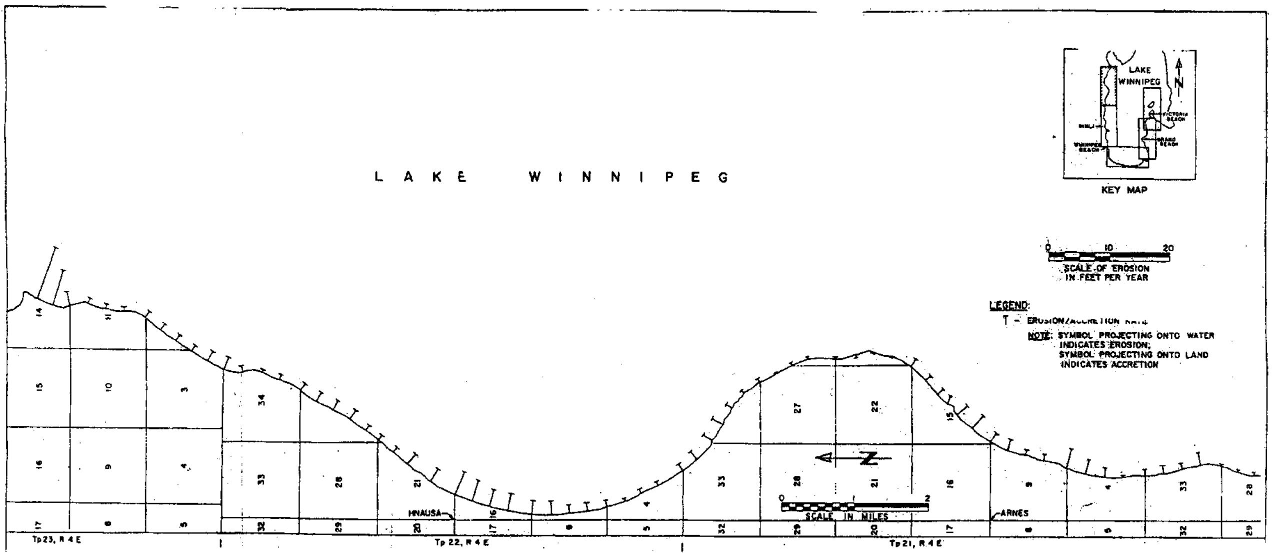


FIG. II-1

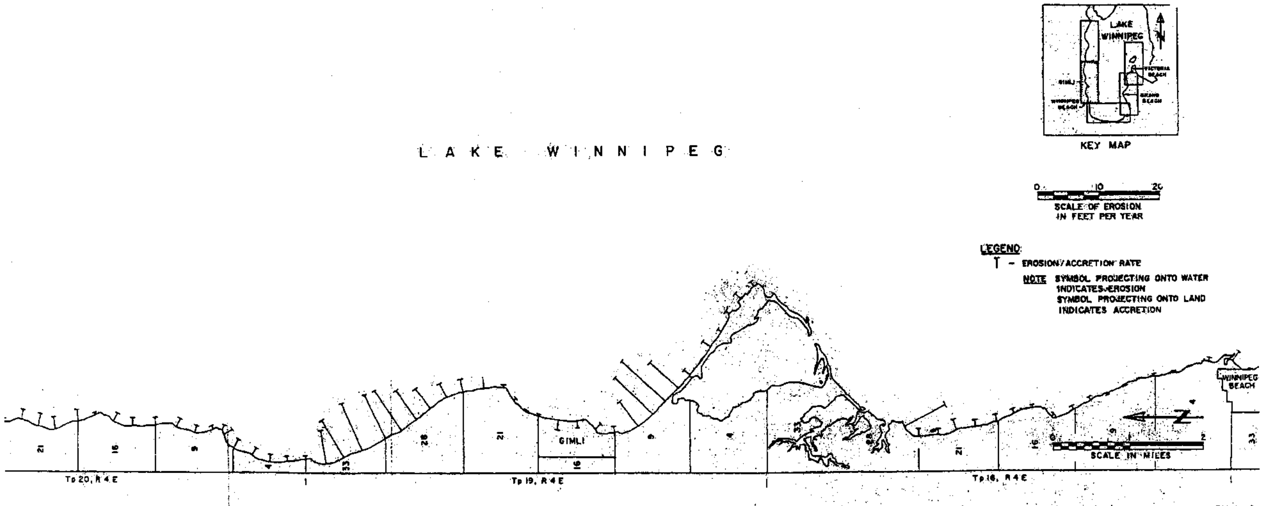


FIG. II-2

PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH

CANADA - MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD
LAKE WINNIPEG SHORELINE STUDY
HISTORIC SHORELINE RECESSION RATES

SCALE AS SHOWN | FILE NO. 39-2-1256

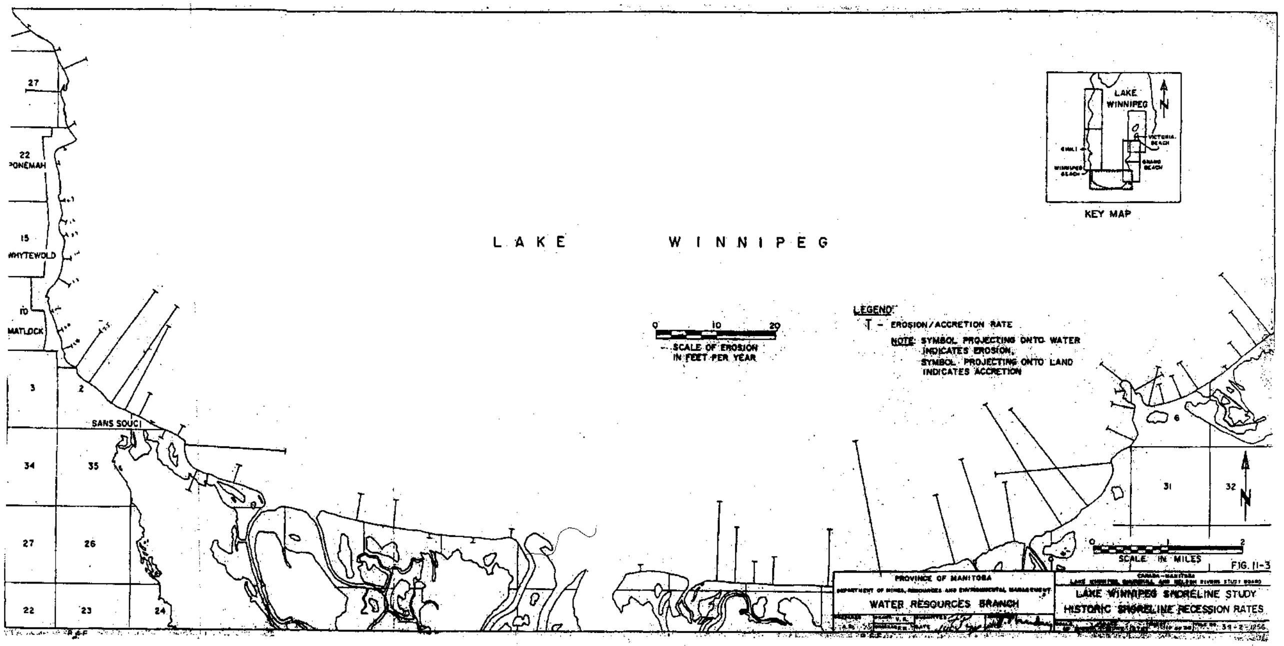


FIG. II-3

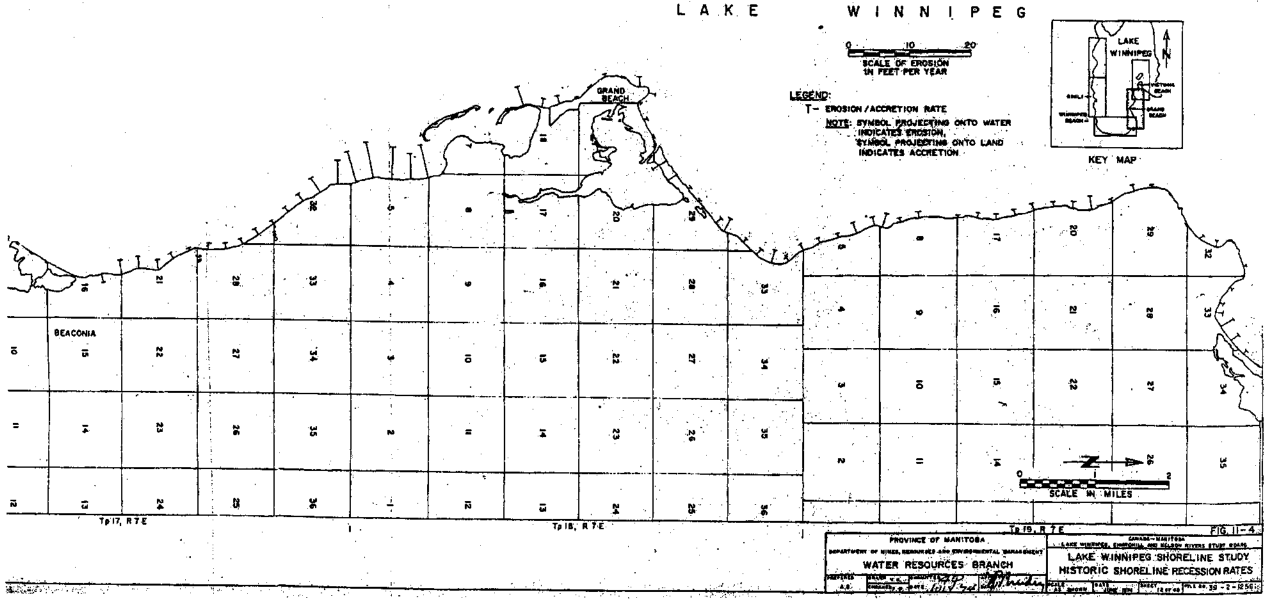
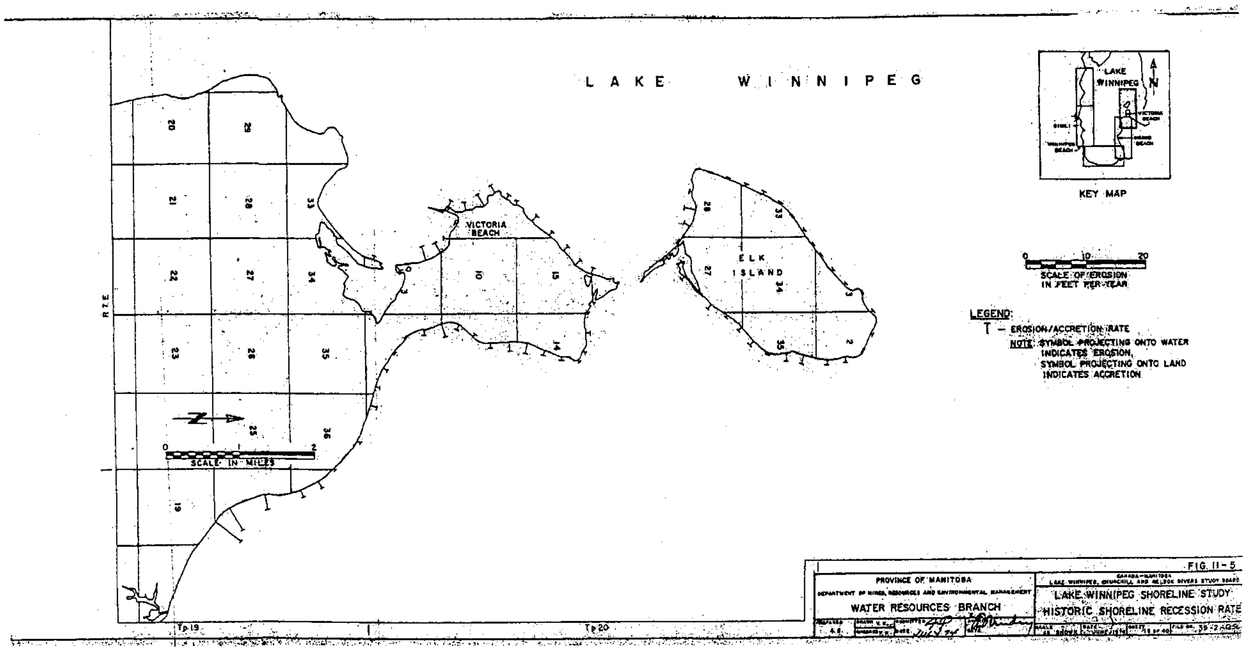


FIG. II-4


LAKE WINNIPEG
VICTORIA BEACH
ELK ISLAND
R.7.E.
Tp.19
Tp.20
20
21
22
23
19
29
28
27
26
25
33
34
35
36
10
15
14
3
28
33
27
34
35
2
3
0 1 2
SCALE IN MILES
N
LAKE WINNIPEG
N
GIMLI
WINNIPEG BEACH
VICTORIA BEACH
GRAND BEACH
KEY MAP
0 10 20
SCALE OF EROSION IN FEET PER YEAR
LEGEND:
T – EROSION/ACCRETION RATE
NOTE: SYMBOL PROJECTING ONTO WATER INDICATES EROSION, SYMBOL PROJECTING ONTO LAND INDICATES ACCRETION
FIG. II-5
PROVINCE OF MANITOBA
DEPARTMENT OF MINES, RESOURCES AND ENVIRONMENTAL MANAGEMENT
WATER RESOURCES BRANCH
CANADA–MANITOBA
LAKE WINNIPEG, CHURCHILL AND NELSON RIVERS STUDY BOARD
LAKE WINNIPEG SHORELINE STUDY
HISTORIC SHORELINE RECESSION RATE
PREPARED A.B.
DRAWN
CHECKED
SUBMITTED
DATE July 74
SCALE AS SHOWN
DATE JUNE 1974
SHEET 18 OF 40
FILE NO. 39-2-A25