The role of vegetation in shoreline management

A guide for Great Lakes shoreline property owners

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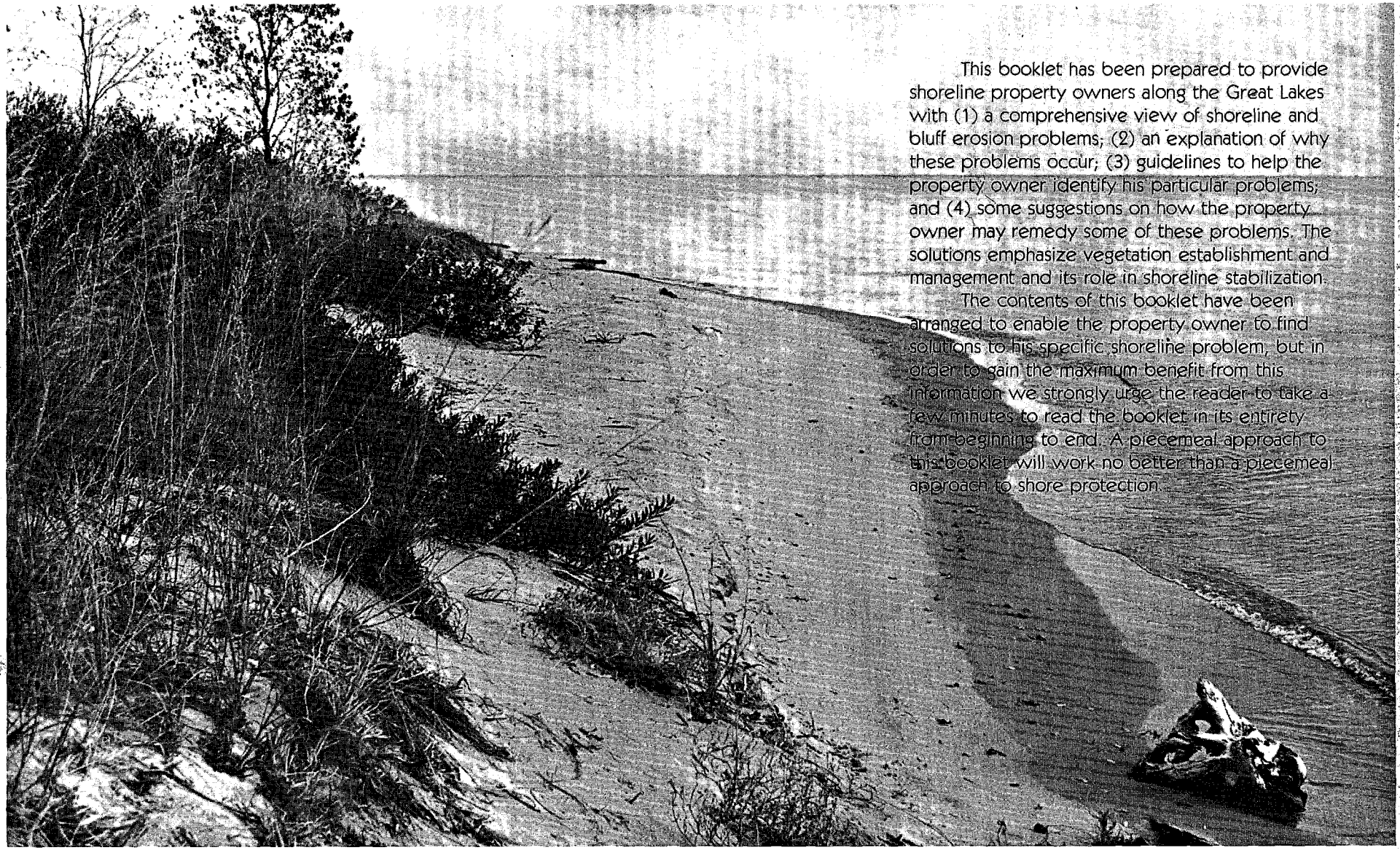

This booklet has been prepared to provide shoreline property owners along the Great Lakes with (1) a comprehensive view of shoreline and bluff erosion problems; (2) an explanation of why these problems occur; (3) guidelines to help the property owner identify his particular problems; and (4) some suggestions on how the property owner may remedy some of these problems. The solutions emphasize vegetation establishment and management and its role in shoreline stabilization.

The contents of this booklet have been arranged to enable the property owner to find solutions to his specific shoreline problem, but in order to gain the maximum benefit from this information we strongly urge the reader to take a few minutes to read the booklet in its entirety from beginning to end. A piecemeal approach to this booklet will work no better than a piecemeal approach to shore protection.

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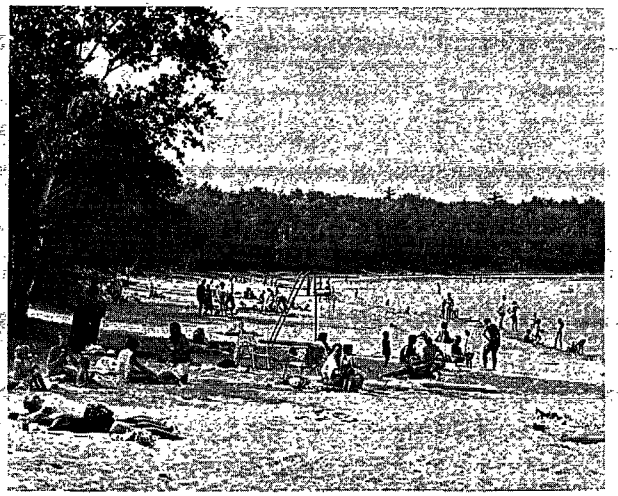
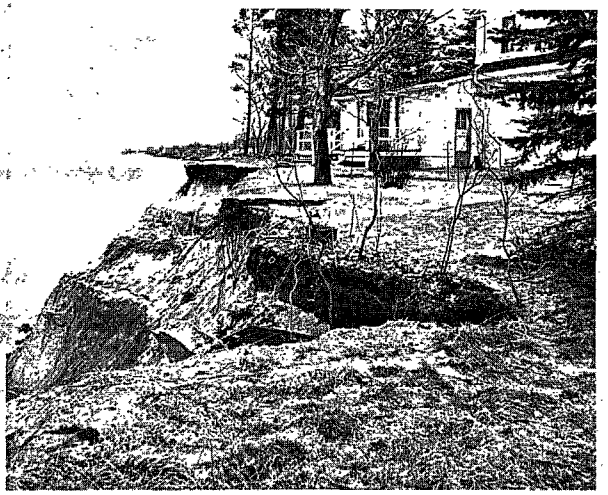
Preface





The Great Lakes shorelines have long been preferred as areas for both agricultural and urban development. The recreational potential of the Great Lakes beaches and waters and the economic potential related to transportation and commercial development of shoreline resources are just two of the reasons people have chosen to settle in the Great Lakes shore zone.

The Great Lakes shorelines vary in their topography and geology from rigid bedrock cliffs to periodically flooded wetlands. Significantly, more than 7,500 kilometers (4,630 miles) or approximately half the total Great Lakes shoreline is classified as erodible. Furthermore, 76% of this shoreline in Canada was privately owned in 1973 and the figure approaches 83% for the United States portion. Approximately half of the privately owned erodible shoreline of the Great Lakes is in residential use; in other words, **in your hands**.

Recent high lake levels combined with poorly planned shoreline development and inadequate shore protection have resulted in severe shore property losses due to flooding, beach erosion, and bluff retreat. Though shoreline property owners have resorted to a multitude of methods to stop or at least reduce this damage to their land and dwellings, in most cases they have met with only limited success. This is due, partly, to misinformation and a piecemeal approach to the solution of an extremely complex problem.

This booklet has been prepared to supply the shore property owner on the Great Lakes with some basic guidelines and information about shore stabilization techniques, emphasizing the role of vegetation in an overall shoreland management strategy. With the increasing costs of structural devices for shore protection (both for installation and maintenance), it is necessary and desirable to develop complementary, economical, shoreline stabilization techniques such as establishment of a vegetative cover. While not intending to be a cure-all for shoreline erosion ills, this guide does provide the information necessary for a general understanding of Great Lakes shoreline problems and suggests techniques to more adequately deal with them, especially when lake levels are expected to be lower than during the past several years.

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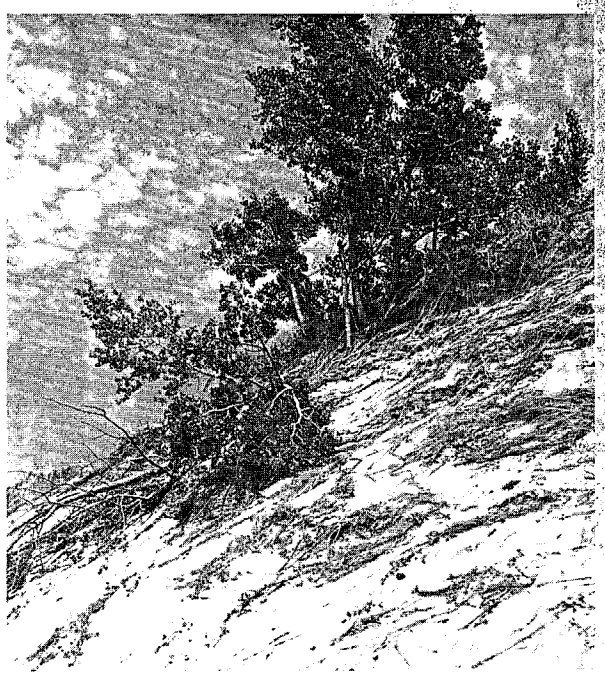
Introduction



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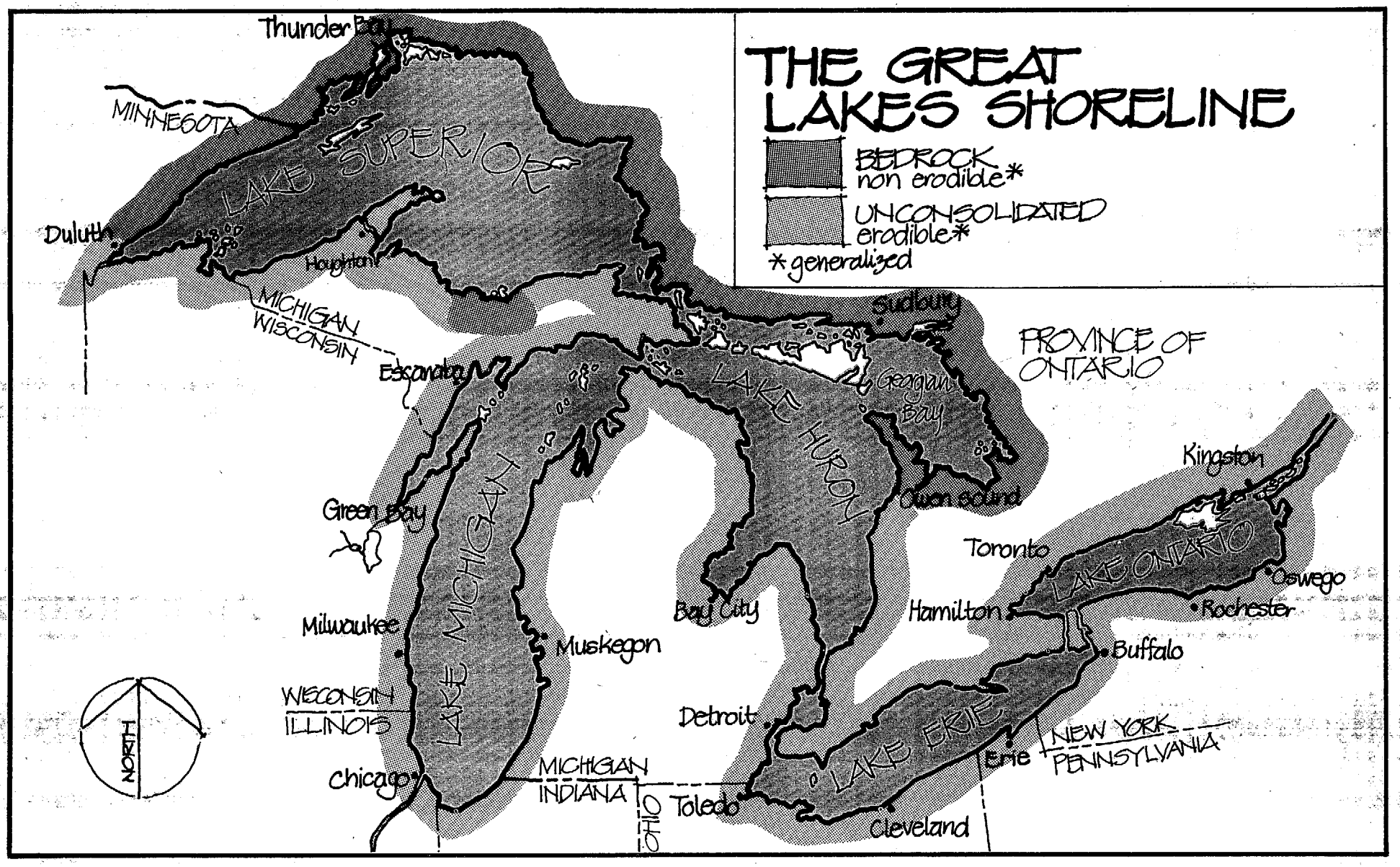
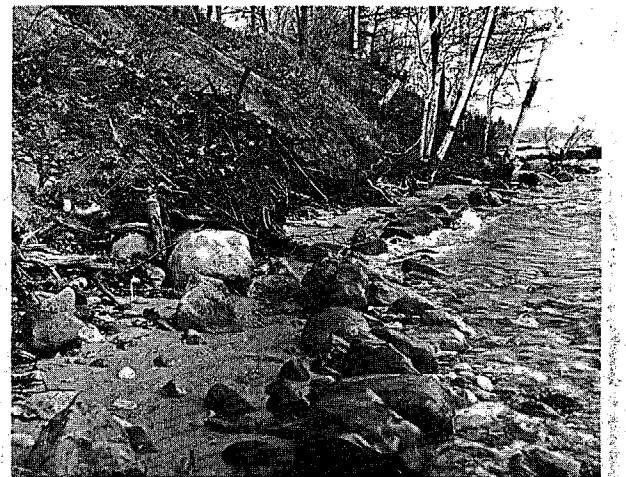

THE GREAT LAKES SHORELINE
BEDROCK non erodible*
UNCONSOLIDATED erodible*
*generalized
Thunder Bay
MINNESOTA
LAKE SUPERIOR
Duluth
Houghton
MICHIGAN WISCONSIN
Escanaba
Sudbury
PROVINCE OF ONTARIO
LAKE HURON
Georgian Bay
Owen Sound
Kingston
Green Bay
LAKE MICHIGAN
Toronto
LAKE ONTARIO
Oswego
Rochester
Bay City
Hamilton
Milwaukee
Muskegon
Buffalo
WISCONSIN ILLINOIS
Detroit
LAKE ERIE
NEW YORK PENNSYLVANIA
Erie
NORTH
Chicago
MICHIGAN INDIANA
OHIO
Toledo
Cleveland

The shores of the Great Lakes vary greatly in their composition. This makes the task of prescribing general shoreline treatments in a brief booklet rather difficult. Nevertheless, it is important to recognize the variety of shore types found within the Great Lakes if we are to understand, in a general sense, the erosion problems associated with each type and the appropriate solution(s).

This guide addresses only the unconsolidated, erodible portion of the Great Lakes shorelines. These erodible areas have been indicated on the map on page 4. The northern shores of Lake Superior and Georgian Bay are predominantly bedrock and do not suffer erosion problems such as those shores found to the south and east.

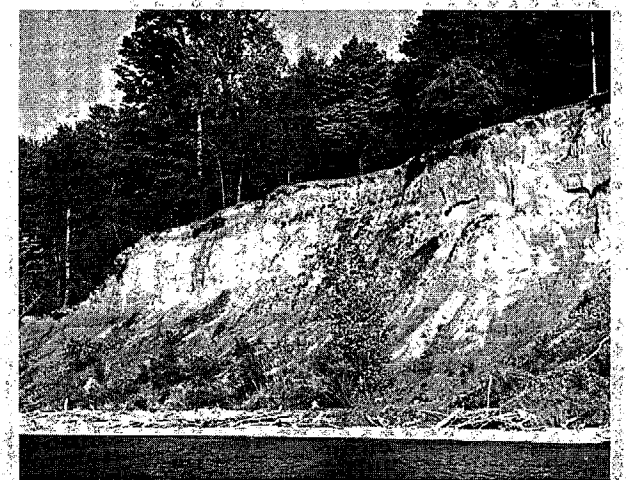
The series of ice lobes and larger ice sheets that carved out the present Great Lakes basin between 10,000 and 1,000,000 years ago are also responsible for the layers of glacial sediments which now cover the Great Lakes region and make up a large portion of the shorelines. These unconsolidated glacial deposits are made up of clays, silts, sands, gravels, and boulders which were eroded, transported, and deposited in many forms by the advancing and retreating glaciers. On the geologic time scale, this glacial activity is a relatively recent development. Thus, the shorelines, through the action of wind, waves, and rivers, are still changing, particularly in response to fluctuations in lake levels. What appears to be a recent problem to shoreline property owners, could be more accurately regarded as a natural process which has been occurring for several thousand years but which affects and is affected by the actions of man.



The major shore types that have evolved within the erodible portion of the Great Lakes shorelines include the following:

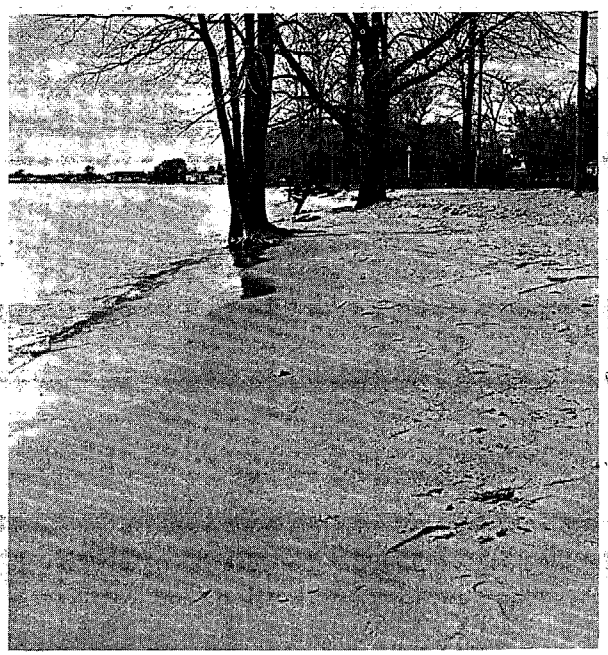
Low erodible bluffs range in height from 3 meters to 10 meters (approximately 9 feet to 30 feet) and are mainly composed of glacially derived gravels, sands, silts, and clays. They are found along all five of the Great Lakes, interspersed among the other shore types. Drainage and slope stability are problems commonly associated with this shore type.

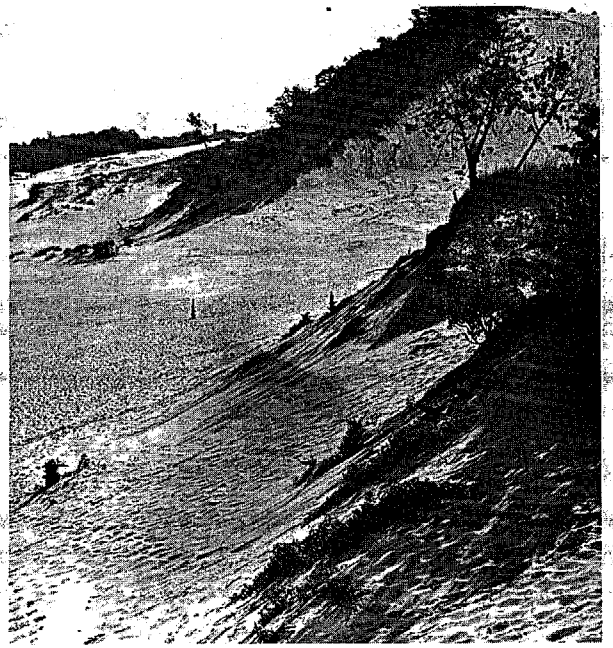
High erodible bluffs are those greater than 10 meters (approximately 30 feet) in height and composed of glacial materials. The Scarborough Bluffs near Toronto are among the highest of these, reaching 90 meters (295 feet) above Lake Ontario.



High erodible bluffs are found on all five lakes but are most prevalent along the Lake Michigan and Lake Erie shorelines. Drainage and slope stability are problems commonly associated with this shore type.

The Great Lakes shorelines

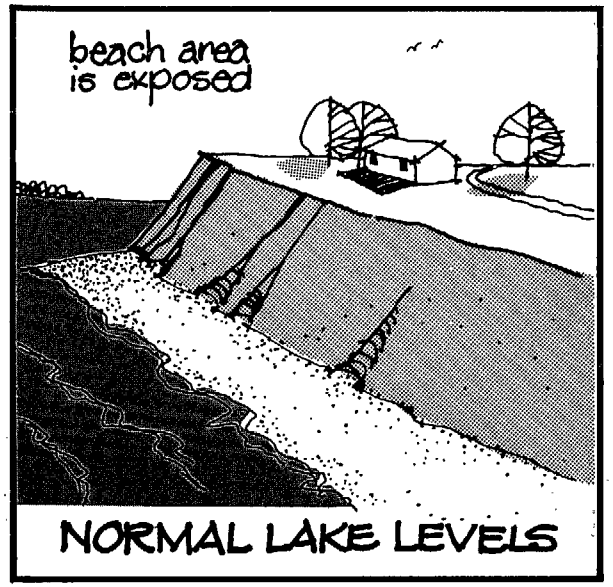




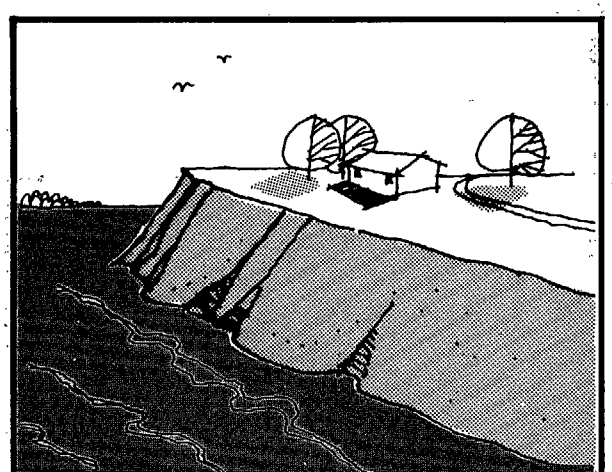
Low erodible plain refers to those unconsolidated stretches of shorelines less than 3 meters (approximately 9 feet) in height. They are found predominantly on the north shore of Lake Ontario and on the shore of Lake Michigan. They are commonly associated with wetland areas and are subject to erosion when exposed to wave attack. Flooding is a common problem.

Sand dunes make up roughly a sixth of the Great Lakes erodible shoreline and present special considerations for development and protection. Low dunes are found on all the lakes, but high dunes reaching over 137 meters (450 feet) are found primarily along the eastern Lake Michigan shoreline, where man's activity and wind erosion are the primary concerns.

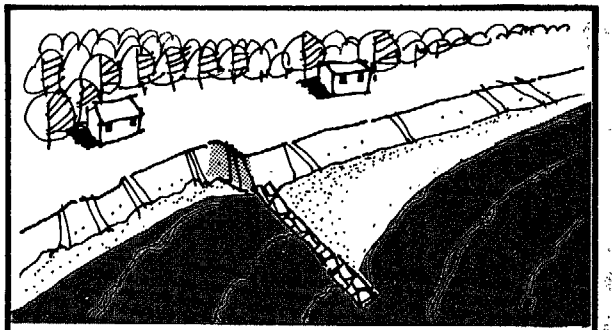
Wetlands make up almost one-fifth of the Great Lakes erodible shoreline but are primarily confined to large bays such as Green Bay and Saginaw Bay, and other shallow areas of the lakes such as Lake St. Clair and the western end of Lake Erie. Dredging and filling operations tend to reduce these wetlands and the shore protection they provide.



NORMAL LAKE LEVELS



THE SAME VIEW DURING HIGH LAKE LEVELS



SHORE PROTECTION STRUCTURES MAY CAUSE AS MANY PROBLEMS AS THEY SOLVE

The erodible shore types identified on the preceding pages are subject to three principal types of degradation: (1) wave action, (2) groundwater seepage and bluff slumping, and (3) surface runoff and wind erosion. These three factors of shore erosion may occur individually or in some combination. In order to arrive at a solution to your erosion problems, it is necessary to first understand the above three factors and to what degree each is contributing to your specific situation.

Wave Action

Waves generated by wind blowing over the Great Lakes are capable of moving material on, off, or along the beach depending on their height and direction. Waves breaking on the shore contain a considerable amount of energy, as property owners who have seen their shore protection efforts carried off in a storm will testify. As long as this energy is expended on a wide sloping beach and plenty of beach material is available to be moved along the shore, the system is in relative harmony.

However, in storm conditions, wave heights increase and lake levels may rise locally, inundating the existing beach and resulting in a net removal of beach materials. In extreme cases wave action may reach the normally stable back beach or bluff and remove material from the toe of the bluff itself.

These extremes have occurred almost continuously between 1972 and 1976 because of high seasonal lake levels which have submerged large portions of the Great Lakes beaches. Net erosion of protective beaches has allowed prolonged attack on the bluffs.

In addition, a constant supply of beach materials is not always available, resulting in possible sediment starvation of a beach. This may be caused by loss of materials to offshore areas or by trapping of materials along the shore at groins, jetties, breakwaters, and other structures. This trapping effect has resulted in local beach losses in many locations around the lakes, allowing further wave attack of unprotected bluffs.

The problems

Groundwater Seepage and Bluff Slumping

All too often, attention is directed solely to the problems presented by wave action, with complete disregard for the processes acting on the bank or bluff behind the beach. Because of the nature of the erodible shore types described earlier, special bank and bluff erosion problems are found on all of the Great Lakes. These problems result from a combination of high, steeply sloped bluffs, the action of groundwater within the bluffs, and finally, man's further alteration of factors which control the stability of the bluffs.

The bluffs which make up a large portion of the Great Lakes shorelines are composed of a wide variety of materials. These range from a mixture of clays, sands, and rock fragments called glacial till, to clay, silts, and sands deposited in separate layers thousands of years ago when the Great Lakes stood at much higher elevations. The most common result is a bluff which has a glacial till base (or in some areas bedrock), an overlying layer of clay which may include lenses of silts and sands, and finally a cap layer of silty sands. It is important to point out that **a specific bluff may be composed of only one of these units, or some different layering than portrayed here.**

The type of problems associated with the bluff will vary according to the material of which it is composed.

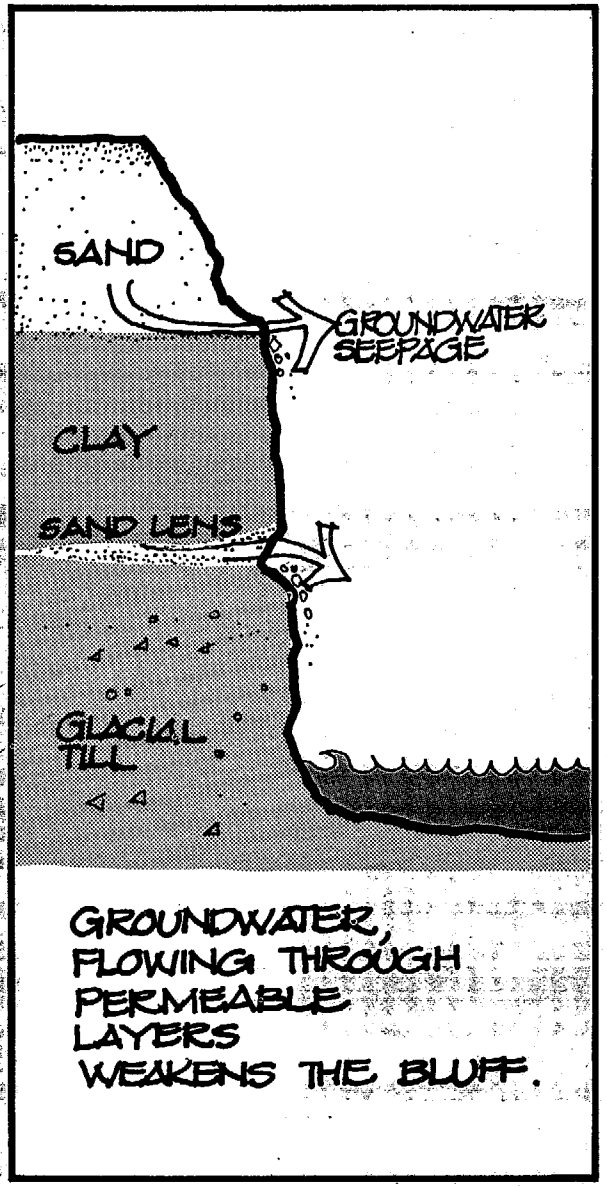
The action of groundwater within the bluff is often the most important factor affecting its stability. Water which is added to the bluff naturally by rainfall or artificially by sprinkler or septic systems, affects the bluff in three ways.

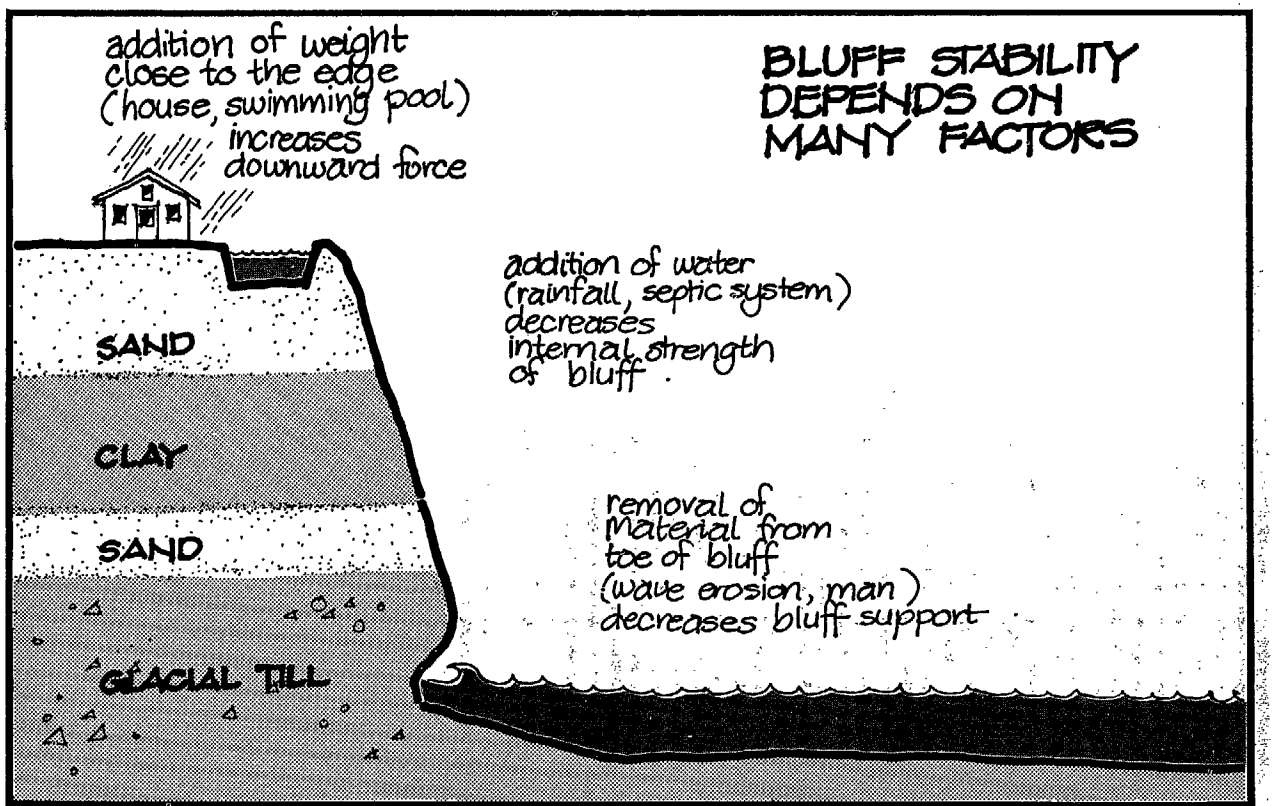
(a) It seeps down through the more permeable layers until it encounters a less permeable layer such as clay and often flows out toward the bluff face. Seep zones develop along the bluff face causing materials to be removed and increasing surface erosion.

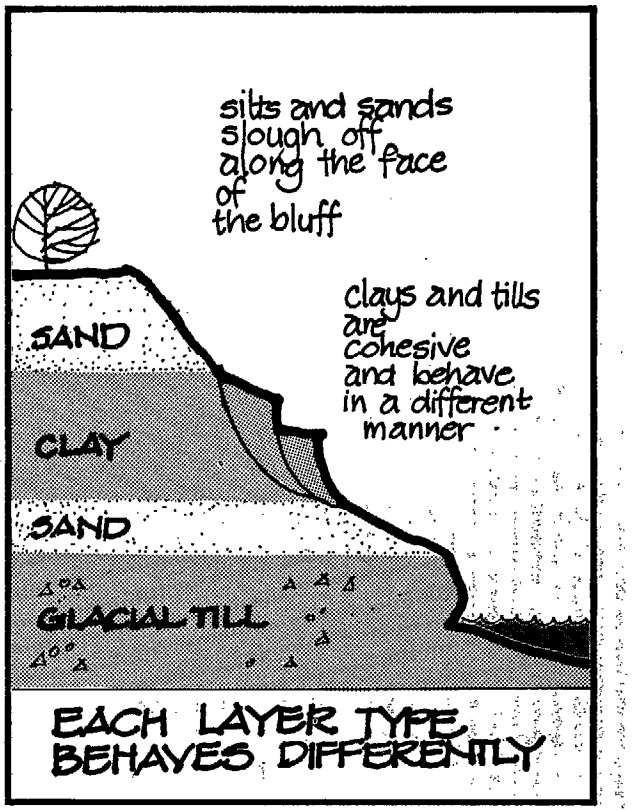
(b) Water added to the bluff may saturate the more permeable silt and sand layers at the top increasing the weight and creating an unstable situation.

(c) Added water increases the water pressure within the bluff materials. This increased pressure decreases the natural strength (cohesion) of the bluff materials and this in turn decreases stability or resistance to slumping and sliding.

Other factors in addition to the presence of water in the bluff can contribute to internal failure of the bluff materials. Weight added to the top of the bluff close to the edge in the form of buildings, swimming pools, and other structures decreases the stability of the bluff. Materials removed from the toe of the bluff by wave action or by man's excavation steepen the slope and remove the support at the base. With sufficient addition of water to the bluff, the internal strength of the bluff materials will decrease and an unstable situation is created which nature will seek to correct!







This is accomplished by a readjustment of the bluff slope by slumping and sliding. As indicated in the diagram, these processes vary according to the bluff composition. Silt and sand layers tend to slough off in shallow segments near the face of the bluff whereas cohesive materials such as clay and till tend to slide along deeper zones in the bluff.

In the case of a bluff composed of layers of several different materials, the overall failure and retreat of the bluff will reflect the differential erosion processes associated with each layer of materials in the bluff. In the case of a bluff composed of one massive unit of clay or till, large slump blocks tend to fail along deep-seated zones of weakness and establish a more stable slope by sliding downward, seeking a natural angle of repose.

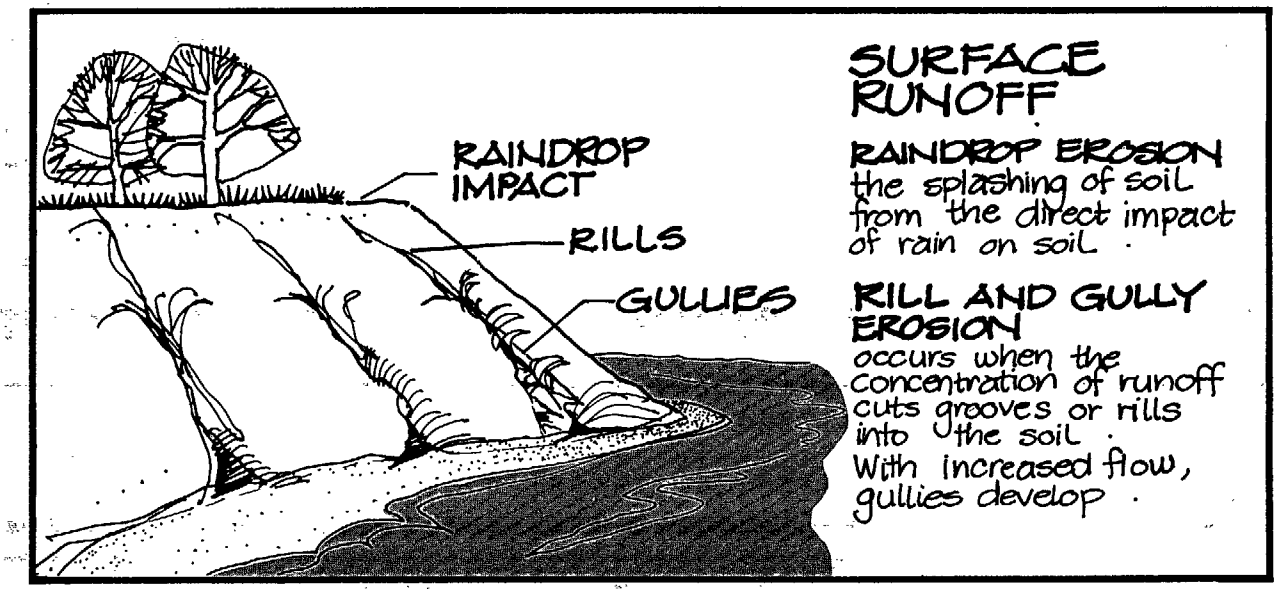
This is an oversimplified explanation of a process which can be very complex depending on the specific section of bluff one is examining. All of the factors discussed above contribute to the overall stability of a bluff but their relative degree of importance depends on the particular bluff in question.

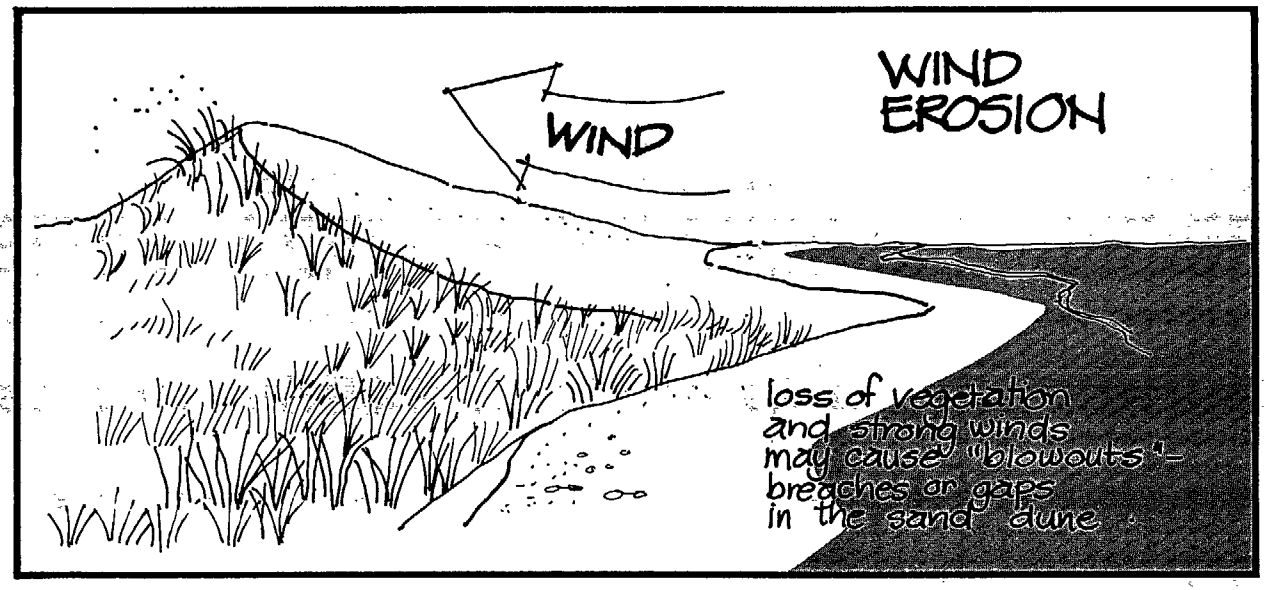
Surface Runoff and Wind Erosion

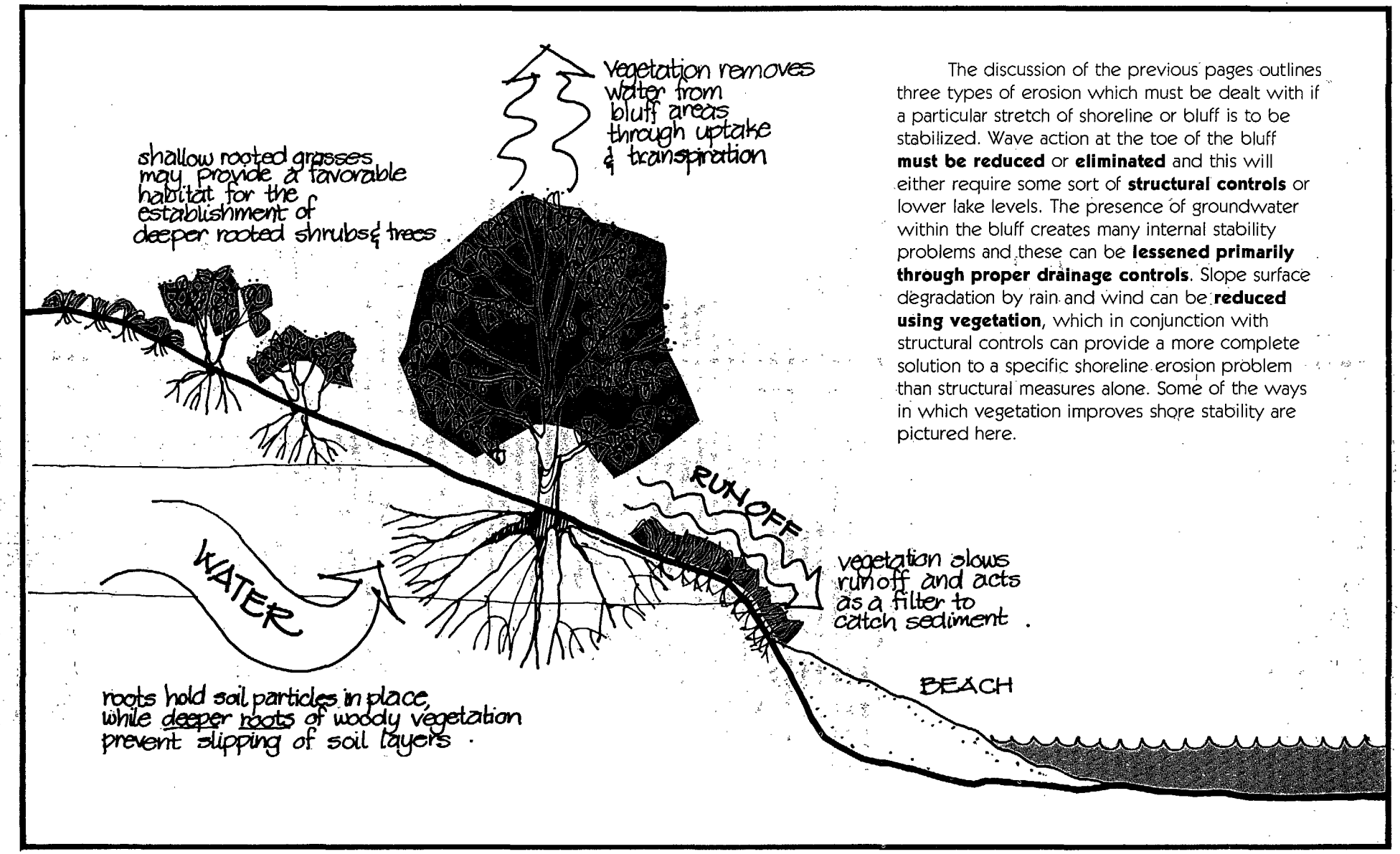
The third cause of Great Lakes shore retreat which this booklet considers are the processes contributing to the surface degradation of the lakeshore. **It is these processes which the use and proper management of vegetation can most easily control.**

The primary agents of slope surface erosion are rain, surface runoff, and wind. All of these are capable of removing sediment from unprotected slopes and unless they are controlled, can result in large losses of materials over an extended period of time.

The action of wind as an erosive agent is especially important in the sand dune areas of the Great Lakes. Wind is the force responsible for building the dunes and likewise, it is capable of shifting and/or removing the sand dunes when they are left unprotected. In dune areas where natural vegetation has been disturbed by development or traffic activity, winds have eroded the unprotected fine grained sands and transported them elsewhere.

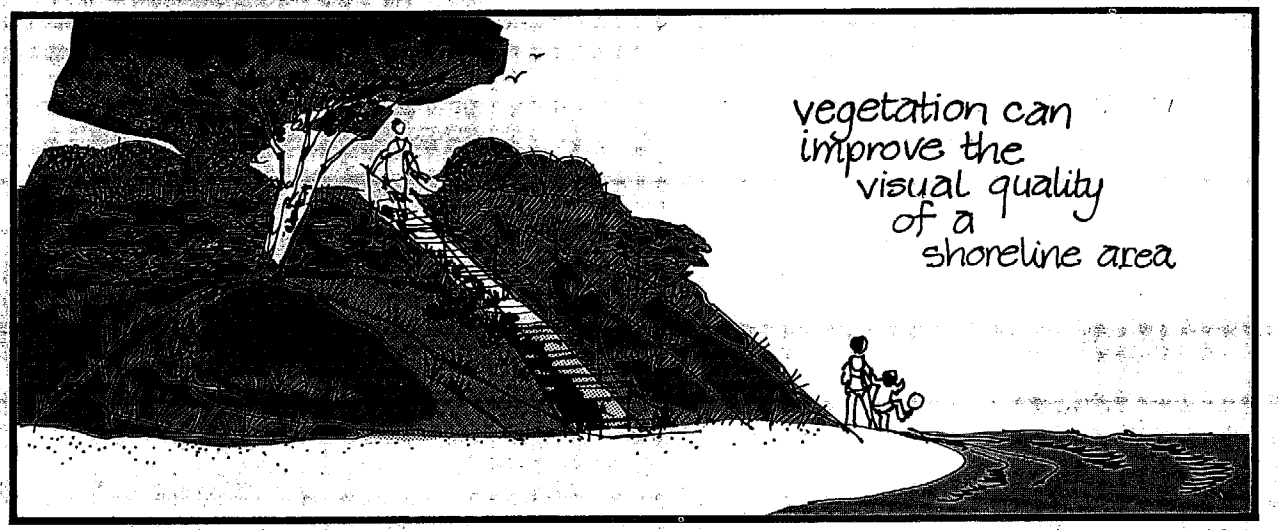


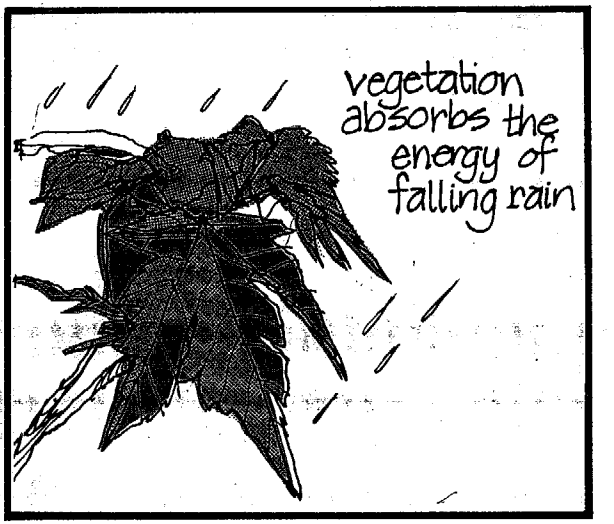


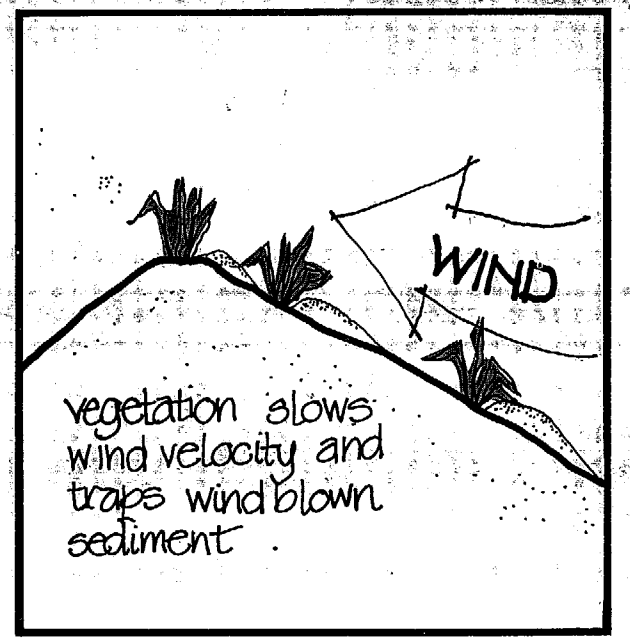


The discussion of the previous pages outlines three types of erosion which must be dealt with if a particular stretch of shoreline or bluff is to be stabilized. Wave action at the toe of the bluff **must be reduced** or **eliminated** and this will either require some sort of **structural controls** or lower lake levels. The presence of groundwater within the bluff creates many internal stability problems and these can be **lessened primarily through proper drainage controls**. Slope surface degradation by rain and wind can be **reduced using vegetation**, which in conjunction with structural controls can provide a more complete solution to a specific shoreline erosion problem than structural measures alone. Some of the ways in which vegetation improves shore stability are pictured here.

The role of vegetation

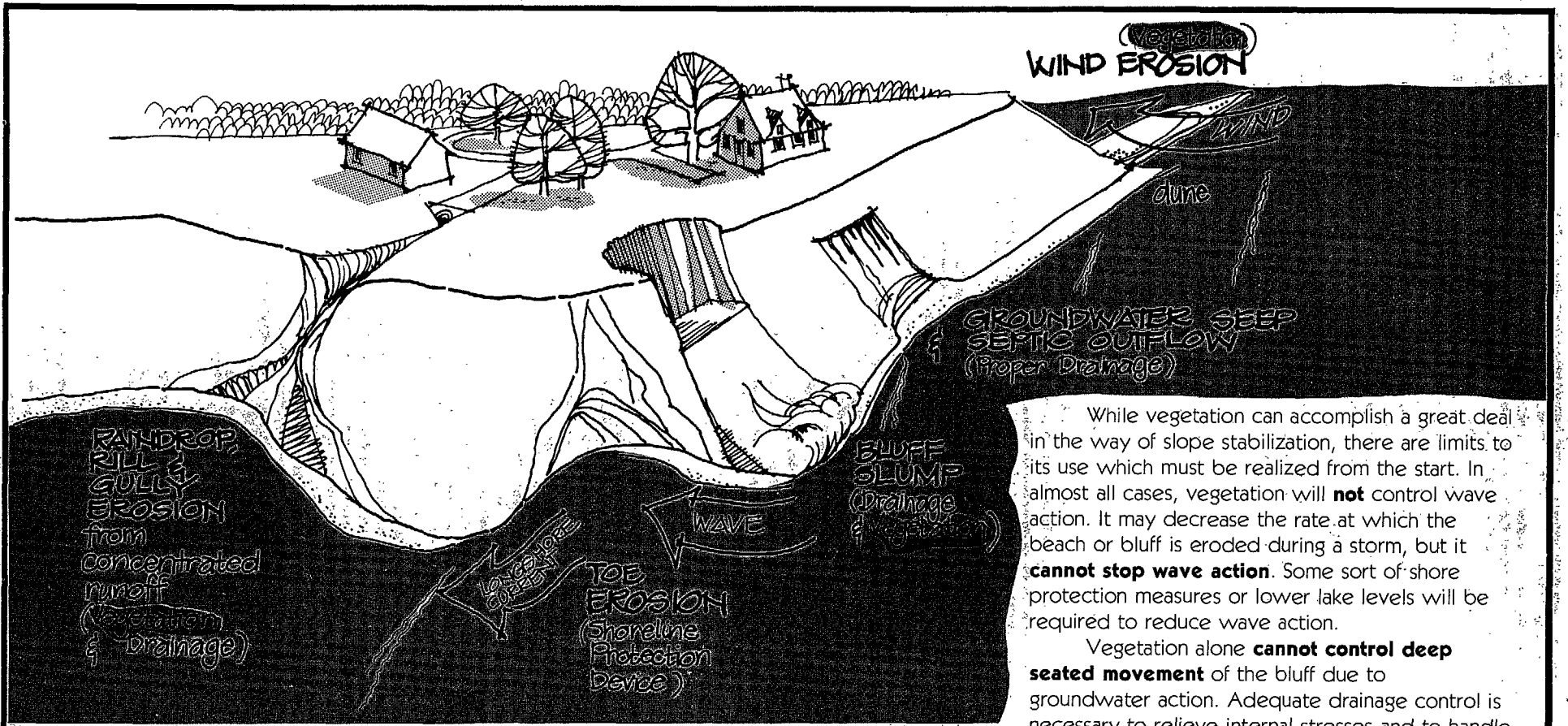






VEGETATION ALSO:

- helps to maintain absorptive capacity of the soil
- can reduce frost penetration
- provides wildlife habitat



EROSION PROBLEMS
and some possible solutions

While vegetation can accomplish a great deal in the way of slope stabilization, there are limits to its use which must be realized from the start. In almost all cases, vegetation will **not** control wave action. It may decrease the rate at which the beach or bluff is eroded during a storm, but it **cannot stop wave action**. Some sort of shore protection measures or lower lake levels will be required to reduce wave action.

Vegetation alone **cannot control deep seated movement** of the bluff due to groundwater action. Adequate drainage control is necessary to relieve internal stresses and to handle large volumes of surface runoff during storms.

The accompanying diagram summarizes the forces and processes acting on the shoreline area and identifies those which vegetation may control or reduce, and those for which drainage controls and shore protection structures may be required.

Before solutions to specific shoreline erosion problems can be found, it is very important to **identify** and diagnose the specific problems affecting **your** shoreline property. The background information provided in the previous pages discusses these problems on a general level. The accompanying "checklist" will assist you in defining your particular situation and identifying those problem areas which need further attention. The easiest way to go about this is to simply go out and familiarize yourself with your shore area, using the checklist as a guideline to identify present or potential problems. The page numbers listed next to the checklist items indicate sections of this booklet where solutions and other information may be found for those items.

Page #	**Shoreline Checklist**
	What Kind Of Shore Type Is Your Property Located On?
5	☐ 1. High Erodible Bluff (greater than 10m) (30 feet)
5	☐ 2. Low Erodible Bluff (3-10m) (10-30 feet)
6	☐ 3. Low Erodible Plain (less than 3m) (10 feet)
6	☐ 4. Sand Dune
6	☐ 5. Wetland
	Describe Your Shoreline Property
	____ 1. How high above water level is your house?
22	____ 2. What's the slope angle of the face of the bluff, dune and/or beach?
8–9	____ 3. What kind(s) of material is the bluff composed of?
	☐ a. Sand ☐ b. One layer of Clay or Till
	☐ c. One layer of Silt or Sand ☐ d. Bedrock
	☐ e. Mixed layers of Silt, Sand, Clay, and Till
17	____ 4. How wide is the beach (from water line to base of bluff)?
	5. What is it composed of?
	☐ a. Sand ☐ b. Sand and Gravel
	☐ c. Gravel and Rock Fragments
	What Are The Problems?
	Wave Action
17	____ 1. Are waves eroding the beach?
17	____ 2. Are waves eroding the toe of the bluff during storms?
17	____ 3. Are there presently any shore protection structures?
	____ a. On your property? ____ b. On your neighbor's?
	____ 4. If Yes, have they stabilized the shoreline and protected the toe of the bluff?
	____ 5. Is your property subject to flooding?

Guidelines for identifying your problems

Page #

Groundwater

19 ____ 1. Are there seep zones along the face of your bluff?
____ 2. Is active slumping (landslides) occurring?
____ 3. What are your contributions to the groundwater supply?
☐ a. Septic Tank ☐ b. Sprinkling or Irrigation
☐ c. Drain Pipes ☐ d. Swimming Pool

Surface Runoff and Wind Erosion

26 ____ 1. Are the effects of surface runoff visible?
☐ a. Raindrop Impact ☐ b. Rills
☐ c. Gullies
19 ____ 2. What are your contributions to surface runoff?
☐ a. Drain Pipes ☐ b. Sprinkling or Irrigation
27–28 ____ 3. Is sand being blown off the beach, or are dunes shifting?

Vegetation

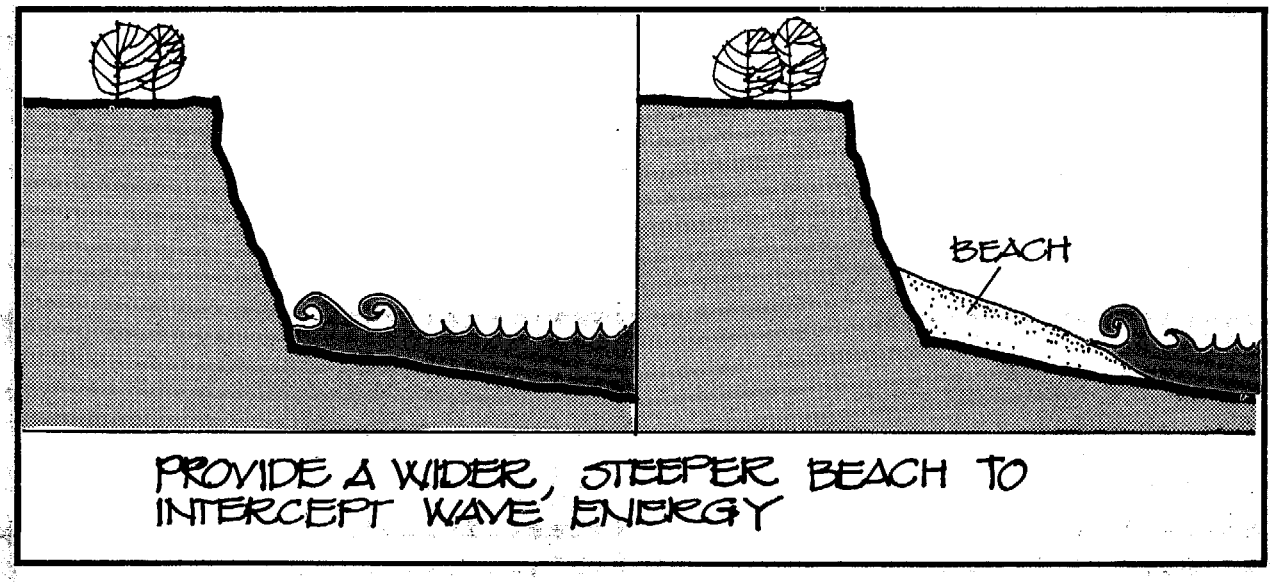
23–25 ____ 1. Is there any on the bluff top, face, or toe?
____ 2. Was there ever any? If so, what happened to it?
____ 3. What vegetation types (species if known) are (or were) found on the bluff top, face, and toe?

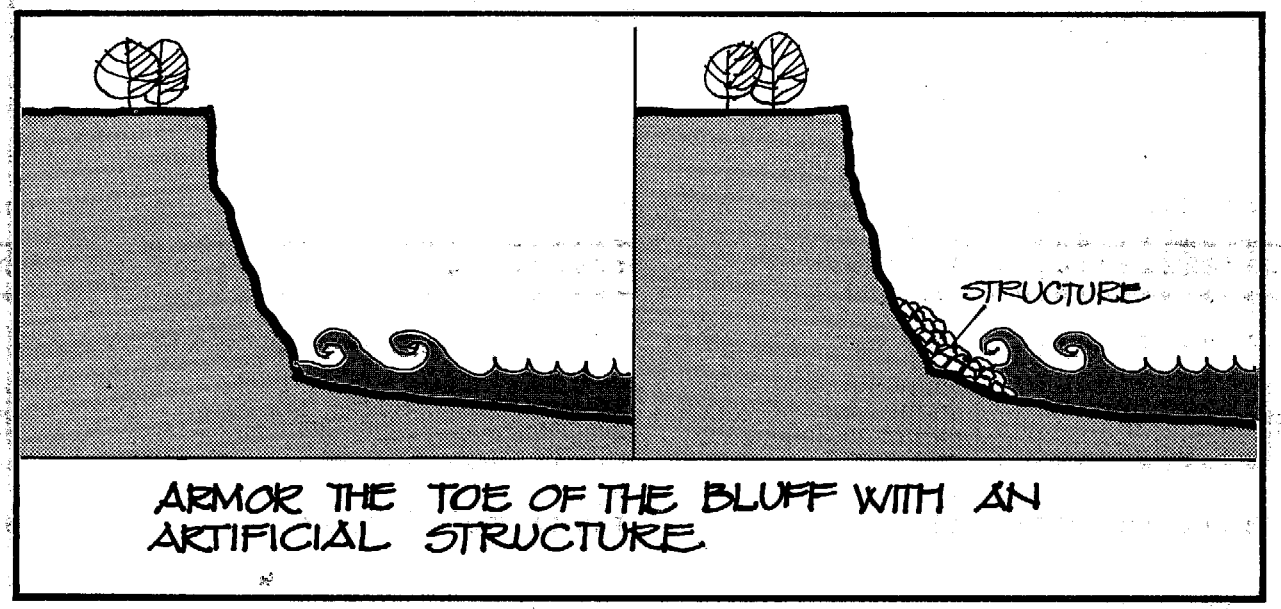
How Do You Use The Bluff Or Backshore Area?

20 1. Access to the Beach
☐ a. Foot Paths ☐ b. Stairs
☐ c. Vehicular Traffic
20 ☐ 2. A place from which to view the lake for aesthetic reasons
☐ 3. Site for building ☐ 4. Fill

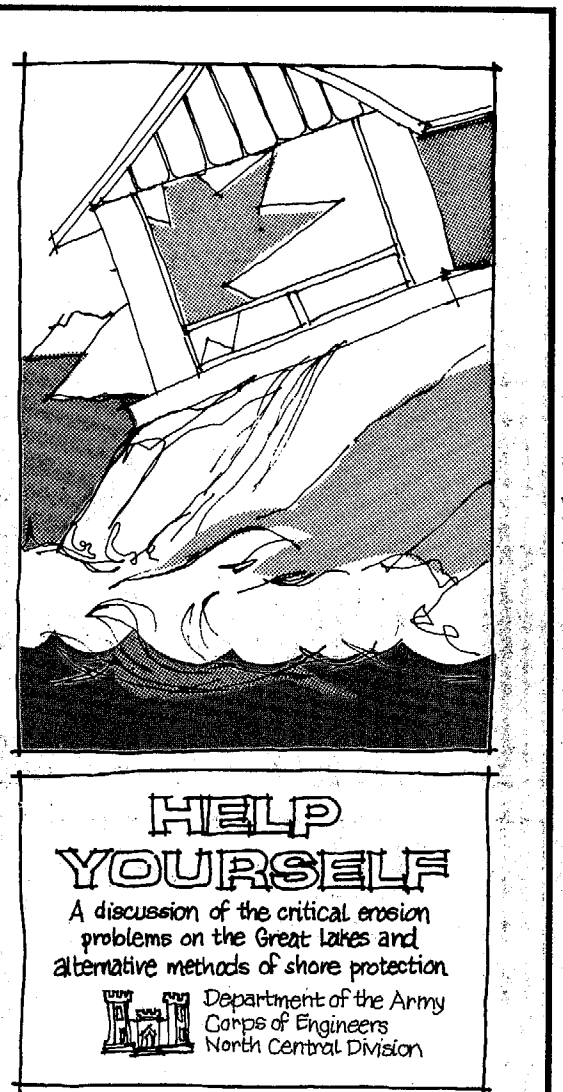
After you've "defined" your shore area and identified those problems which are particular to your property, the next step is to determine solutions to each of the problems you have identified. The listed page numbers on the checklist are keyed to some solutions suggested in this booklet. Throughout the following attempts to correct your property's shoreline problems, it is important to always remember that the system you are dealing with is extremely complex and that the natural forces which are causing your problems are going to have to be accommodated rather than combatted if you are to be successful.

It was emphasized at the beginning of this booklet that a piecemeal approach to solving shore erosion problems was the major cause of continued failure and consequent financial losses. If you are to be successful, you must consider and deal with the three causes of shore erosion equally and simultaneously. A groin or seawall which has been successful in protecting the beach area may ultimately fail because the groundwater seepage problems were ignored. A graded and well-drained slope may continue to recede if surface runoff is not abated through establishment of vegetation. A well-drained, thickly vegetated slope may continue to erode if waves are allowed to attack the toe of the bluff. Consequently, the importance of a comprehensive solution to all of the three problems cannot be overstated.





Considerations: shore protection/drainage



Beach Maintenance and Protection

To begin dealing with the problems of slope stability encountered on steep bluffs, it is **imperative to first establish a stable toe area**. If you have identified active wave erosion occurring on the beach and toe, this erosion must be corrected before anything is done with the bluff. Wave energy at the toe of the bluff should be reduced and this can be accomplished in two ways. (See drawing on page 16.)

In the first case, nature may provide a wider beach simply by the recurrence of lower lake levels. Indeed, if levels recede in the near future as projected, this may be an opportune time to deal with bluff problems, particularly in preparation for future high water years. Artificial beach nourishment by hauling in sand and gravel also can provide this necessary buffer area.

However, during storms and higher lake levels, wave action may continue to threaten the toe areas, and in these cases some sort of structural protection will be required to either trap beach materials or provide direct protection against wave action.

A pamphlet entitled, "Help Yourself" has been prepared by the U.S. Army Corps of Engineers to provide the Great Lakes shoreline property owner with a guide to alternative methods of shore protection. This pamphlet contains information on basic structural or coastal engineering solutions to shore erosion problems and explains the technical and financial considerations of various structures. Many methods of structural protection against shore erosion have been devised, and there are many agencies, institutions, and private contracting and consulting firms that can provide technical advice and services for coastal engineering problems in the Great Lakes area. A list of some of these has been provided at the back of this booklet.

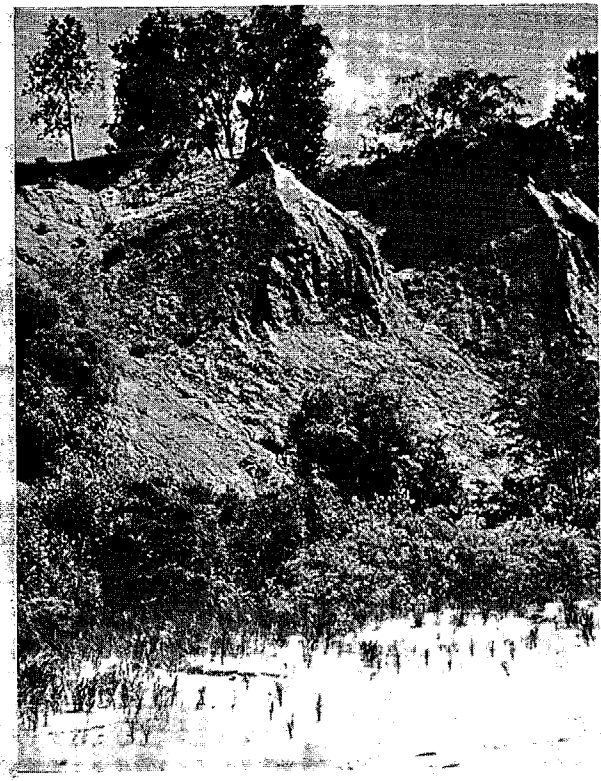
The property owner is urged to seek professional advice for his particular problem because structural solutions to shore erosion are very expensive and therefore should be well-planned before they are built. Furthermore, the cost and potential adverse effects of these structures on neighboring shorelines can be reduced significantly, simultaneously increasing the effectiveness, if property owners get together and consider **coordinated solutions** to their problems along longer stretches of shoreline.

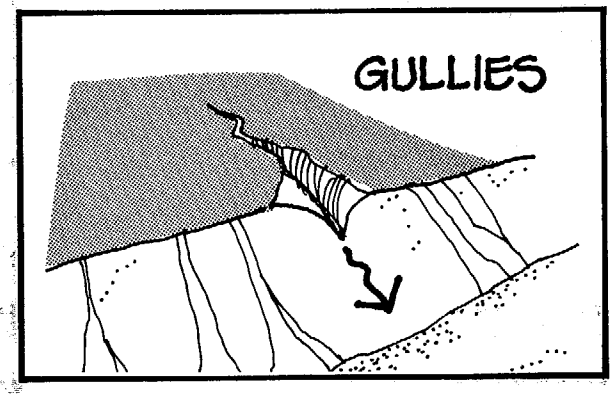
As part of a public awareness program, Fisheries and Environment Canada and the Ontario Ministry of Natural Resources are preparing a brochure series under the general theme "Coping with the Great Lakes." These will provide existing shore property owners, prospective buyers, and community planners with updated information and guidelines for shoreland management based on the recent Canada-Ontario Great Lakes Shore Damage Survey Technical Report and the follow-up programs.

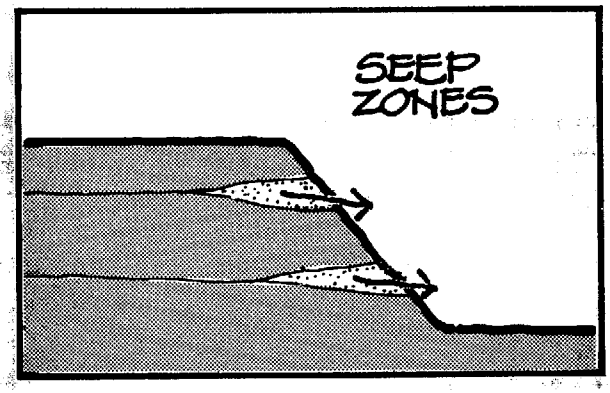
Drainage Controls

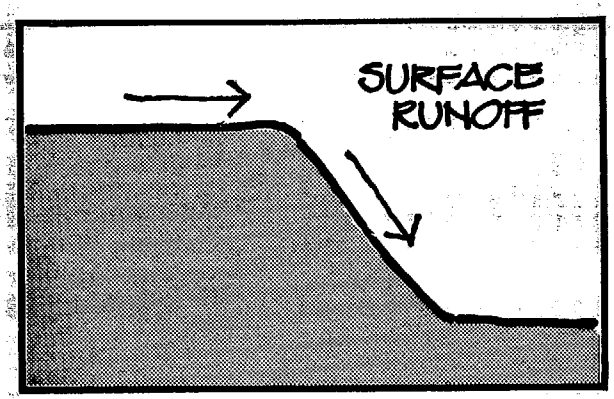
Landslides, gullies, seep zones, and denuded slopes are all evidence of surface runoff and groundwater action. As shown in the photograph, these processes can continue even though the toe area has been stabilized.

If vegetation is to be established successfully, the water which causes these runoff and mass-wasting problems must be controlled through proper drainage. General types of drainage controls which address some of the problems identified in the property owner's checklist are provided on these pages.





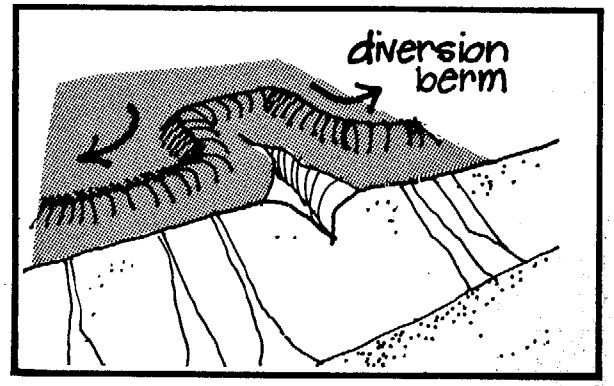


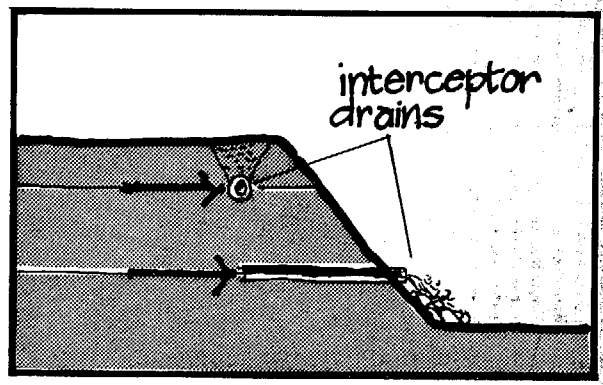


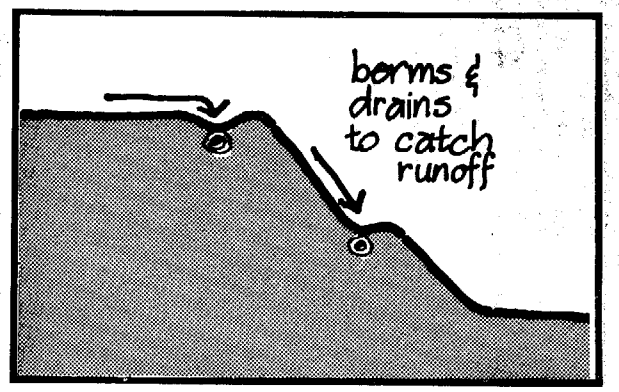
Gullies are formed when the flow of surface runoff is concentrated in one place along the bluff. Gullies will continue to develop and expand unless the water entering the gully is intercepted and diverted. A diversion berm along the top of the bluff will keep the water out of the gully and allow vegetation to re-establish. The intercepted water should then be diverted down the face of the bluff in a **controlled manner** through a flexible pipe or suitably lined (rip rap, filter mat) ditch.

Seep Zones occur where groundwater flows out of the bluff between differing layers of materials. Where possible this water should either be intercepted by drains or conducted out of the bluff by horizontal drains. As in the case of gully controls, the intercepted water should be led into a pipe or channel which carries it down to the lake.

Surface Runoff in general should be slowed or intercepted where possible. This can be accomplished by placement of a diversion ditch and drain along the top of the bluff and then a series of similar terraces and drains along the face of the bluff. The number of these necessary will depend on the height, composition, and slope of your bluff. The intercepted water should again be conducted to the bottom of the bluff.







In addition to natural surface runoff and groundwater flow, direct sources of water to the shore area such as sprinkling, downspouts, pool drainage, and possibly septic systems should be inventoried and reviewed. It should be possible that these man-made contributions be diverted or reduced.

Drainage control, particularly of groundwater, is a complicated subject which should not be undertaken without some professional observation and advice. The examples provided in the drawings are general solutions to general problems and should be considered only as guidelines. Drainage engineers and contractors and soils experts can provide you with a detailed assessment of drainage problems and the type and cost of solutions.

When caring for vegetation already existing or establishing new vegetation, there are several important considerations and principles which you will need to keep in mind.

Climate

The location of your property along the Great Lakes can make a great difference in what kind of trees, shrubs, or grasses will grow well in that area. There are at least four different zones of plant hardiness which correspond to average minimum temperatures in the Great Lakes region. It is important to select vegetation which will tolerate these temperatures. Before deciding on any vegetation, be sure to consult local nurserymen, garden centers, or county agricultural extension agents to obtain the best indication of local conditions and plants that will tolerate them.

Human Activity

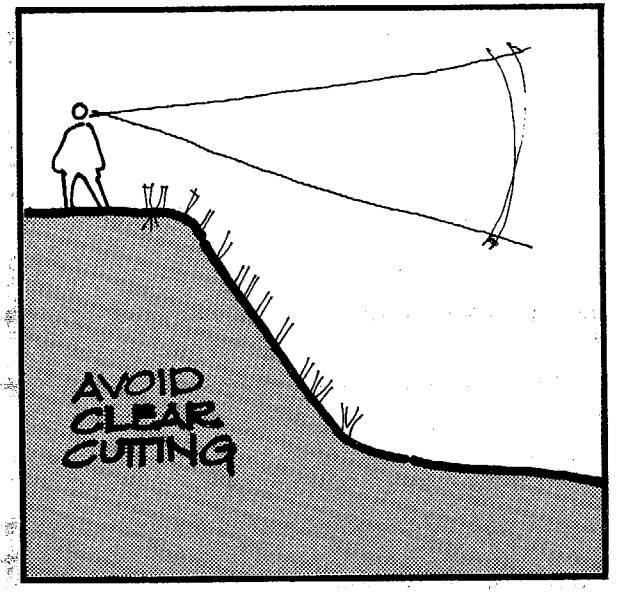
The success or failure of vegetation depends greatly on the types of human activity to which it is subjected. For this reason, it is important to choose plants that are appropriate for the anticipated use of an area. One should also consider which of those activities or uses of the shoreline area might be altered to allow vegetation to establish more easily and create a more stable bluff. This principle applies to existing vegetation as well as proposed or additional plantings. Selective pruning instead of clearcutting, stairways instead of footpaths are examples of how human activities can be altered to improve vegetative growth.

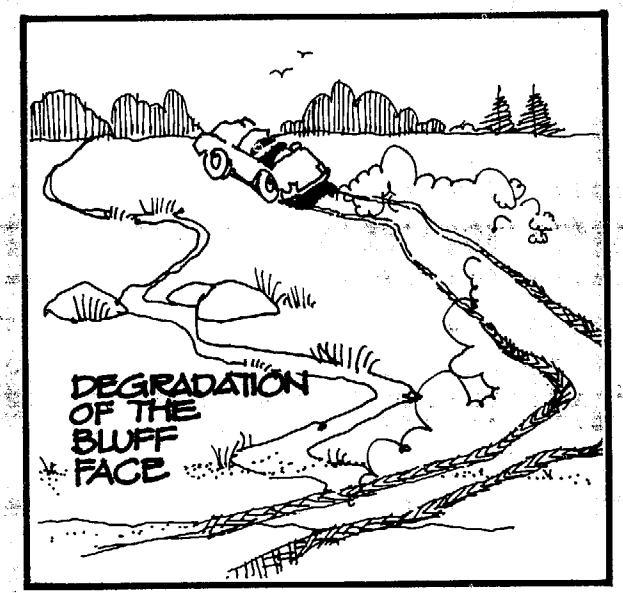
Species Selection

Deciding on what types of vegetation to plant depends on a great many factors that may be specific to your property only. These factors include:

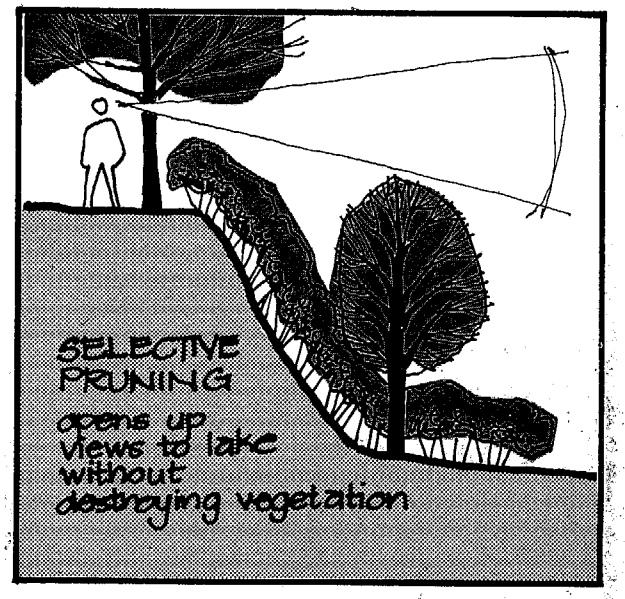
Soil limitations such as droughtiness, fine textures, claypan soils, wetness, alkalinity, acidity, shallow depth, toxicity, or nutrient imbalance. Consult your local soil experts for an analysis of your situation.

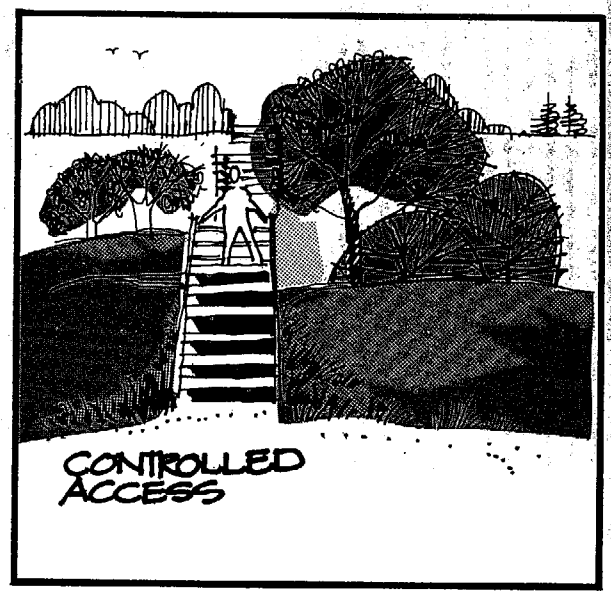
Slope or the degree of steepness of the bluff is an important consideration. This is discussed in more detail in the next section.





Considerations: vegetation





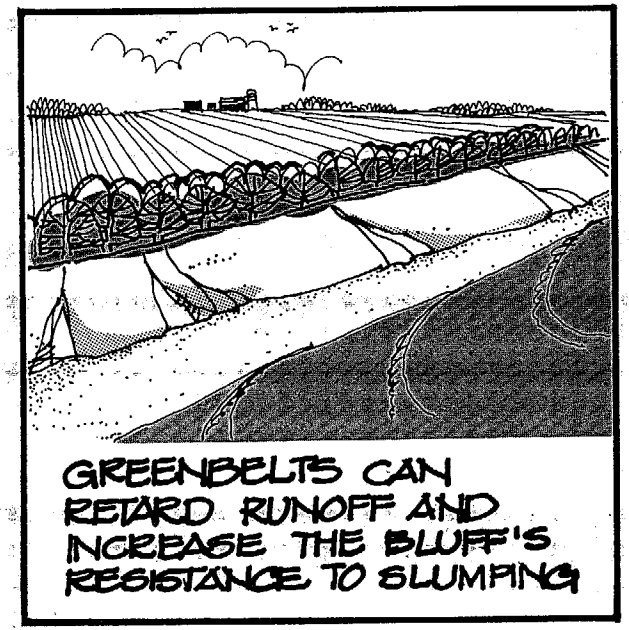
Availability of species is a limiting factor in those cases where commercial sources of seed or plants are sought. See the directory in the back pages of this booklet for possible sources within the Great Lakes basin.

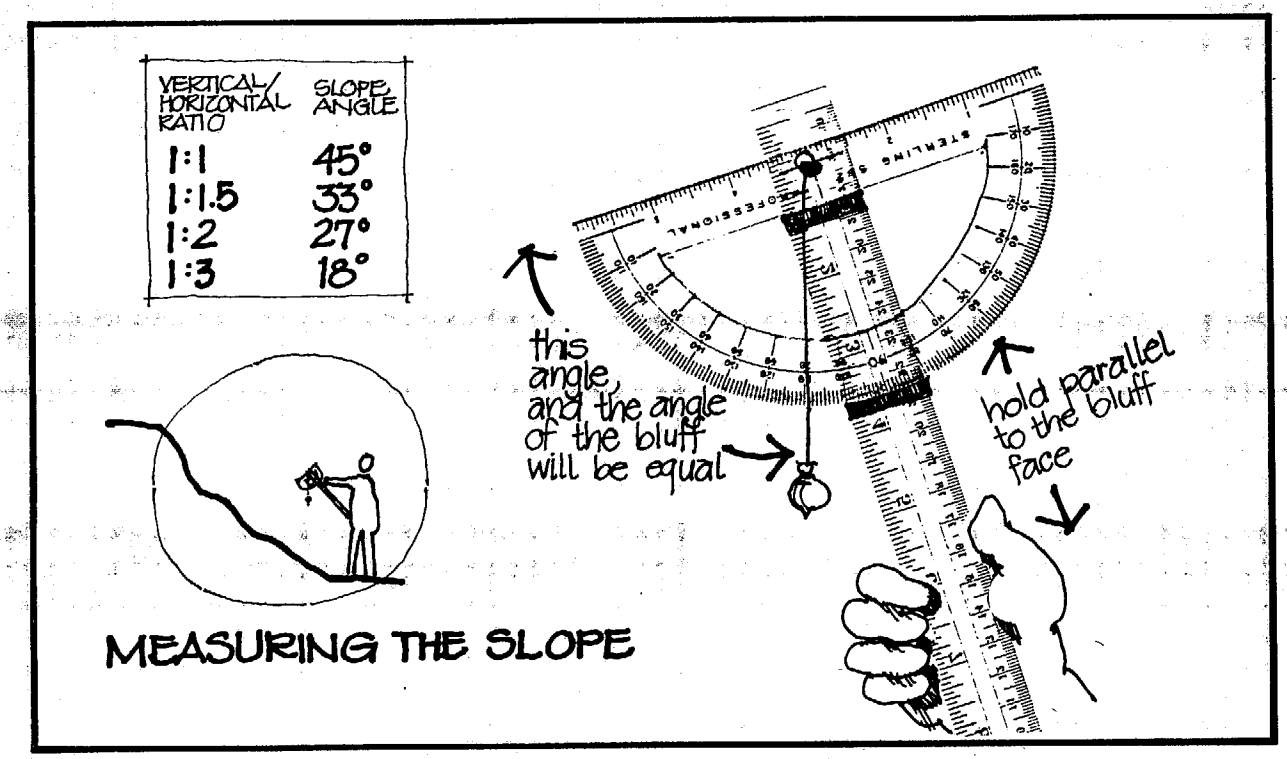
Aside from physical limitations, intuitive judgments about aesthetics and the intended functions of vegetation will guide the selection of plants.

Aesthetics refer to the visual amenities or "special features" of vegetation such as form, texture, and color. Vegetative cover can improve the attractiveness of shoreline areas as viewed from both lake and shore, and a variety of color and form can be achieved with imaginative selection of species.

Functional considerations of plant selection include choosing a plant which will produce a desired effect while considering the amount of maintenance a given species might require. Species should be compatible with existing vegetation and not conflict with intended use of the shoreline area. If view of the lake is desirable, height of a species at maturity should be a consideration in the selection process. Likewise, if top soil control is the goal, fast growing species with widespread root systems should be considered. If controlling traffic is desired, plants such as Rosa rugosa or brambles (Rubus spp.) might be very effective.

There are mixed opinions regarding the planting of species which are **native** to an area versus planting of **introduced** or exotic species of vegetation (often the types with which we are most familiar). The final decision generally depends upon commercial availability, species adaptability to a specific location, the effect of competition between native and introduced species, and desired effect. In further discussions in which we suggest species for specific areas, we will try to indicate, where possible, both native and introduced alternatives. Again, consultation with local plant experts will provide specific information for your area.



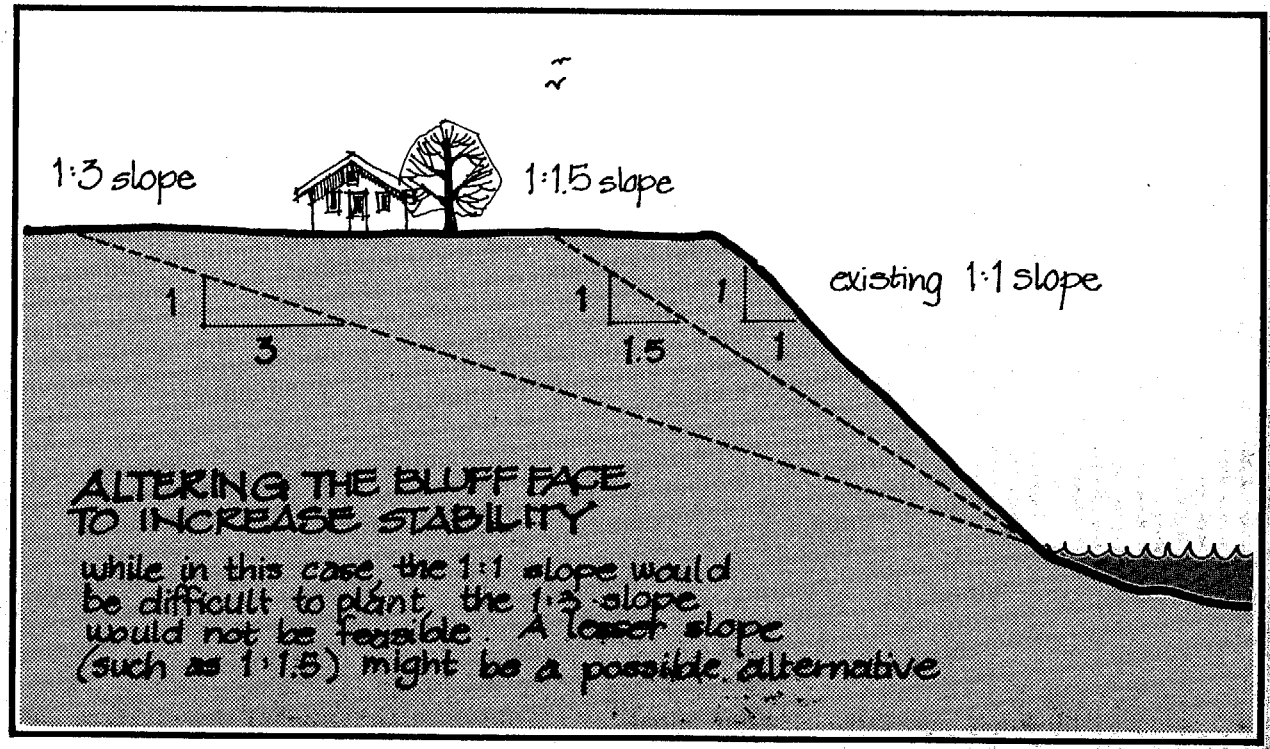


The Great Lakes shores can be divided into specific problem areas which may be considered individually or in various combinations depending on a given situation. These include the top of the bluff, the slopes or bluff faces (complete with gullies and seep zones), the toe of the bluff, and sand dune and beach areas. The following sections provide more detailed information on possible solutions to the problems found in these specific areas.

Top of the Bluff

The vegetation on top of the bluff serves as a protective buffer for the bluff face and should be maintained or re-established as a strip of undeveloped land known as a "greenbelt". This is particularly important in areas where bluffs are too steep and too high for economically feasible stabilization methods. Large shoreline reaches of high bluffs such as the edges of agricultural areas along Lake Erie and Lake Michigan would be too costly to attempt to stabilize. Therefore, farmers are advised to maintain a wide strip [100m (300 feet) is desirable, 300m (1,000 feet) is optimal] of dense natural vegetation along the bluff edge. A proportionately smaller greenbelt could be established on smaller properties. This strip precludes traffic too close to the bluff edge and retards surface runoff from plowed fields. Also, the roots of the vegetation strengthen the bluff's resistance to slumping. If the bluff edge is currently cleared, you should consider leaving a strip undisturbed so it can naturally re-establish itself or you can speed things up by planting grasses, trees, and shrubs.

Vegetating specific shore areas



Large trees growing at the edge of the bluff with their roots exposed should be cut down to reduce the weight on the bluff edge. Their stumps should be left in the ground however so the bluff may benefit from their root systems (see illustration on page 11).

Bluff Face

Vegetation should be established on patchy and barren bluff faces to protect them from erosion and improve their appearance. Whether or not this is possible depends greatly on the character of the bluff, particularly on the steepness of the slope. A slope ratio of 1:1.5 (see illustrations on page 22 and 23) can be considered the dividing line between a manageable slope and a slope so steep that vegetation would be difficult or impossible to establish without outside professional reclamation services.

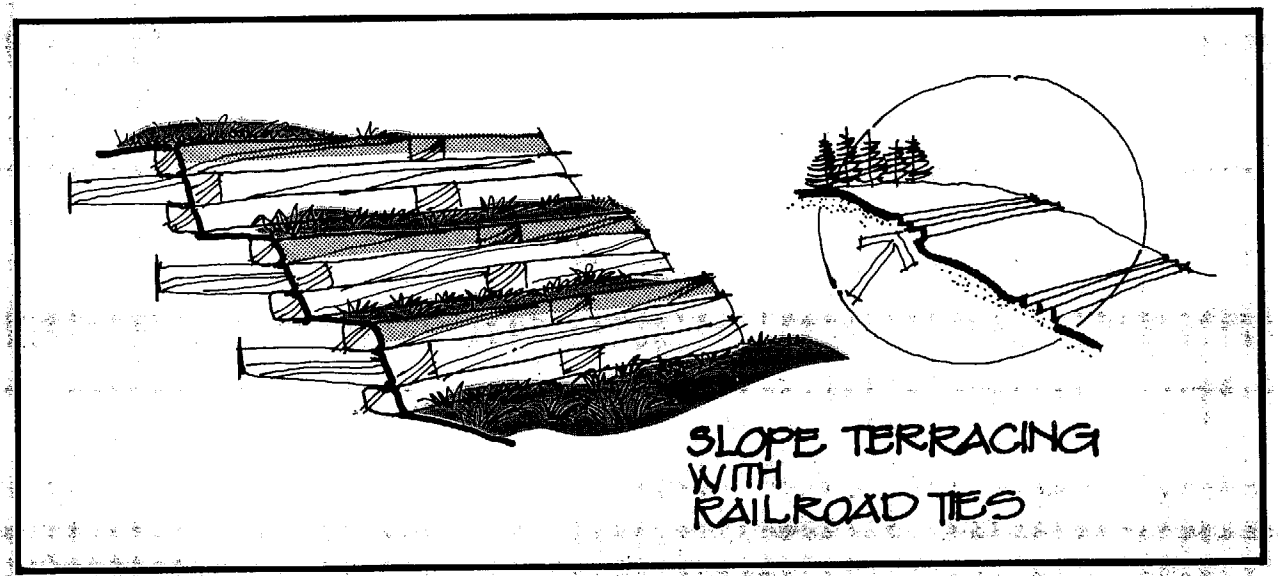
In determining the slope of your bluff, a method is suggested in the accompanying diagram. This is a simple device which can be constructed with a protractor and a yardstick. The protractor should be fastened securely to the yardstick as shown, with a string and weight attached accordingly. When the yardstick is held up and aligned with what appears to be the average slope of the bluff, the slope angle can be read directly from the protractor. This slope angle can then be converted to the appropriate vertical/horizontal ratio (see diagram on page 22).

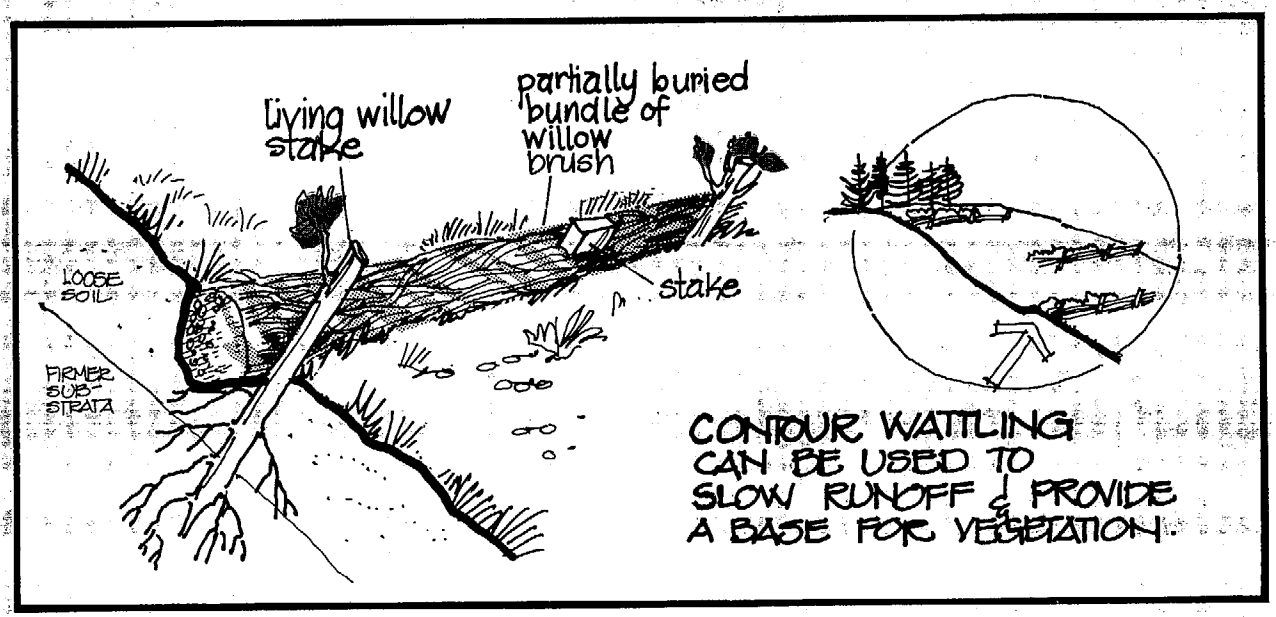
Where possible, steep slopes should be graded back to a more gentle configuration (1:3 or less is ideal because these slopes can be cultivated and planted with wheeled vehicles). However, in many cases along the Great Lakes, bluff areas are much steeper, and regrading may neither be economically feasible nor technically desirable for the individual property owner.

For those areas where regrading to a gentler slope is either costly or impractical, modifications to the existing slope may be made which will allow vegetation to establish. This can be accomplished by terracing, providing horizontal steps in which to plant vegetation; or the slope can be broken up by the addition of "contour wattles". These are bundles of live willow cuttings which are anchored with live willow stakes in trenches along the bluff face. They act as a base for vegetation growth and as a trap to slow surface runoff. Furthermore, the willow stakes and cuttings are capable of rooting in the bluff soil provided there is sufficient moisture.

What to Plant on the Bluff Face

For slopes and for the flatter areas created by terraces or contour wattles, there are a number of species and mixtures of species which can be planted and expected to succeed in this rather severe environment. These include seed mixtures of grasses and legumes and a range of shrubs and trees. The following lists provide a selection of both native and introduced species, and suggested seed mixtures. The soil moisture conditions and fertilizer requirements should be determined prior to any selection of vegetation. The Soil Conservation Service, Soil and Water Conservation Districts, or other soil experts could provide this information.





GRASS AND LEGUME SEED MIXTURES

Species	Lbs/Acre
Perennial Rye Grass* (Lolium perrene)	5
Redtop* (Agrostis alba)	4
Smooth Bromegrass* (Bromus inermis)	12
Orchard Grass* (Dactylus glomerata)	8
Canada Bluegrass (Poa compressa)	8
Sweet Clover (Melilotus alba)	4
Red Clover* (Trifolium pratense)	6
	47 lbs/acre

This mixture can be planted in well-drained soils.

Creeping Red Fescue* (Festuca rubra)	10
Kentucky Bluegrass* (Poa pratensis)	2
Redtop* (Agrostis alba)	1
Tall Fescue* (Festuca arundinacea)	20
Timothy* (Phleum pratense)	2
Birdsfoot Trefoil* (Lotus corniculatus)	10
	45 lbs/acre

This mixture can be planted in well-drained soils.

Reed Canarygrass (Phalaris arundinaceus)	15
Garrison Creeping Foxtail (Alopecurus arundinaceus)	5
Redtop* (Agrostis alba)	5
Birdsfoot Trefoil* (Lotus corniculatus)	10
	35 lbs/acre

This mixture can be planted in imperfectly drained soils.

SHRUBS

Species	Soil Moisture Types: Droughty	Well-Drained Good Moisture	Imperfectly Drained	Poorly Drained
Autumn olive* (Elaeagnus umbellata)	X	X		
Bearberry (Arctostaphylus uva-ursi)	X	X		
Chokecherry (Prunus virginiana)		X		
Gray Dogwood (Cornus racemosa)	X	X	X	
Red-Osier Dogwood (Cornus stolonifera)			X	X
Wild Grape (Vitis riparia)	X	X	X	
Common Juniper (Juniperus communis)	X	X		
Staghorn Sumac (Rhus typhina)	X	X		
Sandbar Willow (Salix interior)		X	X	X
Heartleaved Willow (Salix cordata)		X	X	X

TREES

Species				
Cottonwood (Populus deltoides)		X	X	
Black Locust (Robinia pseudo-acacia)		X		
Silver Maple (Acer saccharinum)		X	X	X
Willow (Salix spp.)			X	X
Red Maple (Acer rubrum)		X	X	
Box Elder (Acer negundo)		X	X	

*Indicates introduced species.

How to Plant

Proper **surface preparation** is essential to successful planting. Slope areas to be planted should be turned up and lime and fertilizer added according to specific vegetation requirements. (A soil test of the bluff should be conducted by an expert to provide this information.) The top edge of the bluff should be trimmed back and all rills and gullies should be smoothed over as much as possible prior to seeding. Much of this surface preparation may have to be done by hand on steeper slopes. All surface water draining on to the bluff face should be diverted (see "Drainage Controls" section, page 18). However, controlled sprinkling may be used during the initial planting period.

Seeding and **planting** of vegetation should be done carefully. In many cases, grass and legume seed mixtures will have to be seeded by hand scattering along the face of the bluff. The seed should then be covered with an appropriate mulch material. For large scale planting, on hard-to-reach areas, machines called hydroseeders which spray mixtures of seed, water, and mulch materials are recommended. These are generally used by the Soil Conservation Service.

Where broadcast seedings are made, time of seeding for grasses and legumes is very important. Seeding should be avoided in July and August wherever possible as extensive drought periods can occur. Legume-based mixtures should be seeded as early as possible but no later than mid-June. Grass-based mixtures can be seeded before and after July and August. It should be realized that healthy, vigorous grass stands will require annual fertilizer application to maintain this status.

Cottonwoods and willows can be planted as cuttings or saplings and are particularly good for seep zones and other wet areas of slope faces. However, avoid planting willows near artificial drains because their roots seek water and may eventually clog or disrupt the drains. When planting other shrubs and trees on slope areas, consult local nurserymen to determine appropriate species for your conditions.

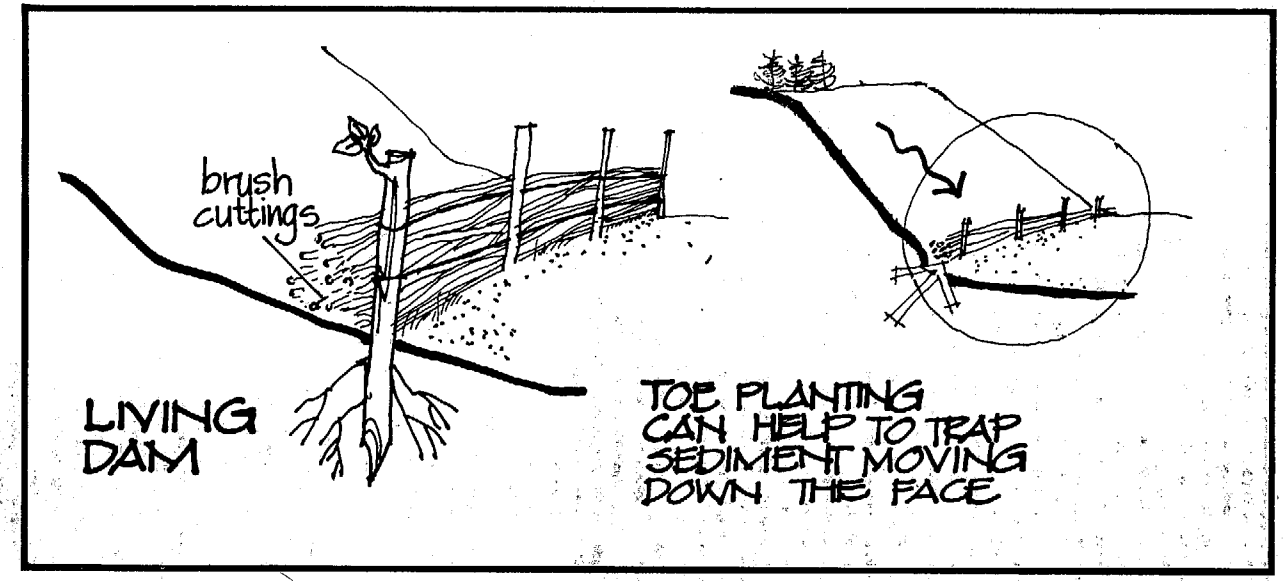
Mulching of seeded or planted areas is of particular importance to slope plantings. Mulch protects against rain and wind while seeds are germinating. It also reduces loss of soil moisture during extended dry periods. Because of the severe nature of most bluff areas, this mulch cover addition is necessary if vegetation is to be established from seed.

A wide variety of mulches can be used. These range from scattered straw to sprayed glass fiber. More common materials and methods of anchoring them are provided below.

Mulch Materials	Anchoring Method
Hay or Straw (1½-2 tons/acre)	— Peg and twine network — Punched into slope w/spade
Jute Netting	— Staked according to manufacturer's specifications
Plastic Netting	— Staked according to manufacturer's specifications
Manure or Compost	— Not necessary
Glass Fiber	— Follow manufacturing specifications

Check with your local Soil Conservation Service office, nurserymen, or garden and farm centers to get more information on local availability or suitability for your situation. The U.S. Environmental Protection Agency has also published a report entitled, "Guidelines for Erosion and Sediment Control Planning and Implementation", #EPA-R2-72-015, which provides details on mulches and anchoring methods.

One other anchoring method which has helped to stabilize slopes during vegetation establishment in some areas involves "nailing down" the bluff face with 1.6m (5 feet) metal fence posts. The posts are driven perpendicularly into the bluff face in a grid pattern with 3-5m (10-15 feet) spacings between them. The posts are cross-connected with heavy wire or cable which has the effect of tying the entire bluff face together from top to bottom and side to side. The posts should be driven almost all the way into the ground, wired, and then the slope should be seeded and mulched.



Toe of the Bluff

If a sufficiently wide beach exists in front of the bluff to dissipate wave energy, it is a good idea to increase bluff toe protection by planting vegetation in conjunction with structural support. This can be accomplished through the use of vegetation behind living dams (see illustration above), stone riprap, or railroad tie cribbing.

A living dam consists of live willow posts connected by wire fencing constructed along the toe of the bluff. Willow and poplar brush cuttings are then piled between the fencing and the bluff to act as a barrier to trap materials which are sliding down the face of the bluff. Because willows root in moist soil, the posts and cuttings become part of the vegetative growth and serve to anchor the toe and protect the base of the bluff.

Sand Dune Stabilization

Sand dunes, old or new, are very fragile features of the shore and as such are easily altered by the actions of man. The natural vegetation which grows on a sand dune is easily damaged by frequent pedestrian and/or vehicular traffic. When this happens, the stabilizing effect of the vegetation is lost and the sand is blown elsewhere by the wind.

If human activity and traffic are restricted or, at least, controlled, sand dune areas may in time restabilize naturally by the re-entry of native vegetation. Driftwood and fallen trees will help protect these areas, and should not be removed just for the sake of a "clean" beach.

Where more intensive stabilization is required, American Beachgrass (available from some sources listed on the back pages) can be planted in the Great Lakes area to stabilize old dunes or to trap blowing sand and build new dunes. Beachgrass also provides a favorable environment for the establishment of other native species of dune vegetation.

Planting Beachgrass

Where: (1) The most landward portion of the beach, (2) on and between existing dunes, or (3) immediately lakeward of an established duneline

When: Plant in early spring or fall when temperature is cool

What: Plant 2 to 3 culms (a single stem with roots attached) of American Beachgrass in holes 6-10'' deep.

How: Sand should be firm and moist around roots with no air pockets near base of plants Space clumps 18'' × 18'' where wind velocities and sand movement are high (about 20,000 clumps or 40,000-60,000 culms per acre) A spacing of 24'' × 24'' may be used in areas not directly exposed to strong winds (about 11,000 clumps or 22,000-33,000 culms per acre) Use a regular square or diamond pattern.

Fertilizer: Because of the sterile nature of sand, fertilizer is necessary 225 kg/0.4 ha (500 lbs/acre) of 12-12-12 or comparable fertilizer, or 360 kg/0 4 ha (800 lbs/acre) of 10-10-10 should be sufficient. Because of water quality concerns in the Great Lakes it is advised that this fertilizer be applied in 22 5 kg/0 4 ha (50 lb/acre) doses every two months starting in April rather than all at once Where possible, fertilizer high in nitrogen and low in phosphorus should be used dependent on soil needs

Other Vegetation: Once beachgrass is established, other vegetation such as trees may be planted. These include sand cherry (prunus pumila), cottonwood, scotch pine (pinus sylvestris), and black locust

Sound shoreland management requires a comprehensive view of one's shoreline property and the erosion problems that may occur on it. Vegetation management plays an important role in helping to prevent or minimize the kinds of shoreline erosion with which structural measures alone fail to deal. In this regard the shoreline property owner is urged to consider the use of vegetation to complement his shore protection efforts. Several levels of vegetation management may be used depending on the need of a given situation. A summary of these is provided below.

Minimal Management

This applies to shoreland areas which presently have good vegetative cover along the backshore or bluff, or have a stable beach. For example:

a) Bluffs which have good vegetative cover should be maintained and any bare patches along these bluffs should be planted with an appropriate plant material listed in this booklet.
b) Shoreland areas which have a good natural beach to serve as a buffer where wave action is dissipated but whose bluffs are too high [greater than 10m (30 ft)] **and** too steep [greater than 1:1.5 (33°)] to support vegetation without regrading, should at least be planted at the toe and on top of the bluff according to the suggestions provided in the previous "specific areas" section of this booklet.
c) All sand dunes and wetland areas are susceptible to damage from just minimal human disturbances, so it is important to maintain or re-establish the vegetation which these areas support. This maintenance will in turn preserve the important ecosystems associated with both sand dunes and wetlands.

Heavy Management

This applies to areas with stable shorelines but poor vegetative cover. It also includes those areas with gentler slopes [less than 1:1.5 (33°)] and those areas with successful manmade shoreline protection. Under these conditions, intensive planting and management of vegetation is both possible and strongly encouraged. For example:

a) Shoreland areas with good natural beaches for bluff toe protection and backshore or bluff areas with gradual slopes [less than 1:1.5 (33°)] should be planted in order to protect against surface erosion. Consult the "specific areas" section starting on page 22 of this booklet for techniques to establish this vegetative cover. Surface runoff should be controlled during this planting effort.
b) Shoreland areas with successful, structural protection against wave action (groins, breakwaters, or revetments) should be supplemented by establishing vegetation on the adjacent backshore or bluff areas. In those areas where the slopes are too steep [greater than 1:1.5 (33°)] but not too high [less than 10m (30 ft)], regrading to gentler slopes may be desirable. The "bluff face" section on page 23 discusses appropriate techniques.

Special Management

This applies to areas which presently have little or no natural beach, steep slopes, groundwater seepage problems, and poor vegetation. To adequately deal with these problems, combination of structural, drainage and vegetation controls is required. These may include structural toe protection, regrading of the slope, internal drainage of the bluff, and intensive planting on the slope face. This is the most effective method of dealing with the entire problem of shoreline erosion, but it is also the most expensive. These costs should be investigated thoroughly before such a project is undertaken.

Management summary

U.S. Army Corps of Engineers

North Central Division

Division Engineer
U S Army Engineer Div , North Central
536 South Clark Street
Chicago, IL 60605

District Offices

Buffalo District

District Engineer
U S Army Engineer District, Buffalo
1776 Niagara Street
Buffalo, NY 14207

Detroit District

District Engineer
U S Army Engineer District, Detroit
P O Box 1027
Detroit, MI 48231

Chicago District

District Engineer
U S Army Engineer District, Chicago
219 South Dearborn Street
Chicago, IL 60604

St. Paul District

District Engineer
U S Army Engineer District, St Paul
1210 U S Post Office and Custom House
St Paul, MN 55111

Minnesota

Coastal Zone Management Program
Minnesota State Planning Agency
100 Capitol Square Building
St Paul, MN 55101

Soil Conservation Service
200 Federal Bldg & U S Court House
316 North Robert Street
St Paul, MN 55101

Minnesota Soil and Water
Conservation Board
300 Centennial Building
St Paul, MN 55155

Minnesota Sea Grant Advisory Services
325 Administration Building
University of Minnesota — Duluth
Duluth, MN 55812

Wisconsin

Coastal Zone Management Program
State Office of Planning and Energy
1 West Wilson Street
Madison, WI 53702

Soil Conservation Service
4601 Hammersley Road
P O Box 4248
Madison, WI 53711

Wisconsin Board of Soil & Water
Conservation Districts
Room 346
1815 University Avenue
Madison, WI 53786

Wisconsin Sea Grant College Program
Advisory Services
1815 University Avenue
Madison, WI 53706

Sea Grant College Program
Advisory Services
Bayfield County Courthouse
Washburn, WI 54891

University of Wisconsin
Peninsular Experimental Farm
Route 2
Sturgeon Bay, WI 54235

Wisconsin Sea Grant College Program
Great Lakes Research Facility
600 East Greenfield Avenue
Milwaukee, WI 53201

Illinois

Coastal Zone Management Program
Department of Transportation
Marina City Office Building
300 North State St , Room 1010
Chicago, IL 60610

Soil Conservation Service
Federal Building
P O Box 678
Champaign, IL 61820

Bureau of Soil and Water Conservation
State Dept of Agriculture
Emerson Bldg , State Fair Grounds
Springfield, IL 62756

Indiana

Coastal Zone Management Program
State Planning Services Agency
143 West Market Street
Harrison Building
Indianapolis, IN 46204

Soil Conservation Service
Atkinson Square West
5610 Crawfordsville Road
Indianapolis, IN 46224

Indiana State Soil and Water
Conservation Committee
Room 7, Agriculture Administration Building
Purdue University
West Lafayette, IN 47907

Michigan

Shorelands Management Section
Division of Land Use
Michigan Dept of Natural Resources
Stevens T Mason Building
Lansing, MI 48926

Soil Conservation Service
U S Dept of Agriculture
1405 S Harrison Road
East Lansing, MI 48823

Michigan State Soil
Conservation Commission
Lewis Cass Building
P O Box 30017
Lansing, MI 48909

Michigan Sea Grant
Advisory Services
University of Michigan
2200 Bonisteel Blvd
Ann Arbor, MI 48109

County Drain Commission
County Extension Director

Ohio

Shoreland Management, Division of Water
Ohio Dept of Natural Resources
Building E , Fountain Square
Columbus, OH 43224

Soil Conservation Service
311 Old Federal Building
3rd & State Streets
Columbus, OH 43215

Ohio Soil and Water
Conservation Commission
Fountain Square, Building B
Columbus, OH 43224

Office of the Chief Engineer
Department of Natural Resources
Fountain Square
Columbus, OH 43224

Pennsylvania

Coastal Zone Management Program
Dept of Environmental Resources
Bureau of Resources Programming
Third & Reilly Streets
Harrisburg, PA 17120

Soil Conservation Service
Route 19
R D 5
Waterford, PA 16441

Agriculture Stabilization
and Conservation
County Committee
Route 19
R D 5
Waterford, PA 16441

Pennsylvania State University
Cooperative Extension Service
850 E Gore Road
Erie, PA 16509

New York

New York Coastal Zone
Management Program
Department of State
162 Washington Avenue
Albany, NY 12231

Soil Conservation Service
U S Courthouse & Federal Building
100 S Clinton Street
Syracuse, NY 13202

New York State Soil and Water
Conservation Committee
Box 2, 142 Emerson Hall
Cornell University
Ithaca, NY 14853

New York State Sea Grant
Advisory Service
SUNY College at Brockport
251 Hartwell Hall
Brockport, NY 14420

New York State Sea Grant
Advisory Service
SUNY College at Fredonia
375 Mason Hall Addition
Fredonia, NY 14063

Information directory

Canadian Federal

William S Haras
Shore Property Studies
Research and Development Division
Ocean and Aquatic Affairs
Central Region
Fisheries & Environment Canada
867 Lake Shore Rd
P O Box 5050
Burlington, Ontario L74 4A6
(416) 637 4338

Provincial

D L Strelchuk
Engineering Services Branch
Ontario Ministry of Natural Resources
Whitney Block, Room 5620A
Queen's Park
Toronto, Ontario M7A 1W3
(416) 965-1271

Also:

Ontario Ministry of Agriculture and Food

County	Agricultural Representatives	Soils & Crops Specialists
Essex	Essex (519) 776-7361	N C Laing (519) 674-5456 c/o R C A T, Ridgetown
Kent	Box 726, 435 Grand Ave W Chatham, Ont (519) 354 2150	
Lambton	Box 730, Petrolia (519) 882-0180	
Elgin	594 Talbot St St Thomas (519) 631-4700	David Norris (519) 674-5456 c/o R C A T Ridgetown
Wentworth	R R 1, Ancaster (416) 527 2995	Harvey Wright (519) 824-4120 Ext 2513 c/o Crop Science University of Guelph
Huron	Box 159, Clinton (519) 482-3428	Patrick Lynch (519) 271 8280 Box 398, 478 Huron St Stratford
Norfolk	19 Kent St S Simcoe (519) 426 0680	E B Pridham (519) 426 0680 19 Kent St St Simcoe
Haldimand	Cayuga (416) 772-3381	
Niagara, North Niagara, South	Vineland Station (416) 562-4142 574 South Pelham St Welland (416) 732-7552	
Bruce	Box 1330 Walkerton (519) 881 3301	R A Upford (519) 881-3301 Box 1330, Walkerton
Gray	181 Toronto St S Markdale (519) 986-2040	
Halton	181 Main St Milton (416) 453 9866	J P Fish (416) 895-4519 Newmarket Plaza
Peel	3 Elizabeth St S Brampton (416) 451-5474	
York	Newmarket (416) 895-4519	
Simcoe, North	Box 340, Elmvale (705) 322-2231	C H Kingsbury (705) 435-5521 Box 370, Alliston
Manitoulin	Box 326, Gore Bay (705) 282-2043	Walker Riley (705) 474-3050 222 McIntyre St W North Bay
Muskoka & Parry Sound	Box 130, Huntsville (705) 789-5491	
Sudbury	1414 LaSalle Blvd Sudbury (519) 566-1638	Walker Riley (705) 474-3505 222 McIntyre St W North Bay

County	Agricultural Representatives	Soils & Crops Specialists
Thunder Bay	Ontario Gvt Bldg 435 James St S Thunder Bay (897) 475 1631	
Durham	234 King St E Bowmanville (416) 623-3348	Neil Moore (705) 324-6125 322 Kent St W Lindsay
Northumberland	Box 820, Brighton (613) 395-3393	W E Hurst (613) 475 1630
Hastings	Box 340, Stirling (613) 395 3393	
Lennox & Addington	41 Dundas St Napanee (613) 354-3371	G J Smith (613) 476 3224
Prince Edward	Box 470, Picton (613) 476 3224	
Frontenac	Box 657, 1055 Princess St Kingston	
Leeds	Box 635, Brockville (613) 342 2124	J C Shelhaut (613) 258-3411 Box 2004, Kemptville
Grenville	Box 2004, Kemptville (613) 258-3411	
Dundas	Box 488, Winchester (613) 774-2313	
Stormont	Box 655, 109 11th St W (613) 933-1581 Cornwell	
Prescott	Box 110, Plantagenet (613) 673 5115	P E Beaudin (613) 673 5115 Box 110, Plantagenet
Glengarry	Box 579, Alexandria (613) 525-1046	

The following list of commercial suppliers is provided as **potential** sources of vegetation It does not in any way constitute a direct or implied recommendation of a particular company

Native Vegetation

Charles Klehm & Son Nurseries
Arlington Heights & Algonquin Roads
Arlington Heights, IL 60005

Midwest Flowers
c/o Leroy H Busker
Box 64
Rockton, IL 61072

Dutch Mountain Nursery
Route 1, Box 167
Augusta, MI 49012

Sunnybrook Farms Nursery
9448 Mayfield Road
Chesterland, OH 44026

High Meadow Farm
Tom & Molly Murray
Route 1, Box 215
Mt Horeb, WI 53711

Also Consult

Commercial listings in
Telephone Yellow Pages
Local Soil & Water Conservation
District office

Beachgrass

Manistee Soil Conservation District
Box 275
Onekama, MI 49443

Beach Grass not available in Canada

Other Canadian References

Dr E M Watkin
Department of Crop Science
University of Guelph
Guelph, Ontario N1G 2W1
(519) 824-4120 Local 3572

Consulting Engineers Directory
1027 Yonge St
Toronto, Ontario M4W 3ES
(416) 961-2457

Canada Seed Trade Association
Suite 210, 100 Dixie Plaza
Missauga, Ontario L5E 1V4

Developer's Handbook. Allen Carrol, State of Connecticut, Department of Environmental Protection. Coastal Area Management Program, 6 p

Evaluation of Potential Use of Vegetation for Erosion Abatement Along the Great Lakes Shoreline. June 1976. V L Hall, J D Ludwig, U S Army Corps of Engineers, Coastal Engineering Research Center Miscellaneous Paper No 7-75 35 p.

Great Lakes Vegetation Workshop Proceedings. 1977 Great Lakes Basin Commission, Ann Arbor, Michigan 113 p.

Guidelines for Erosion and Sediment Control Planning and Implementation. August, 1972 U S Environmental Protection Agency, Environmental Protection Technology Series, EPA-R2-72-015 228 p.

Help Yourself. "A Discussion of the Critical Erosion Problems on the Great Lakes and Alternative Methods of Shore Protection". Department of the Army, Corps of Engineers, North Central Division, Chicago, Illinois

Michigan Soil Erosion and Sedimentation Control Guidebook. 1975 Michigan Department of Natural Resources, Division of Land Resource Programs, Lansing, Michigan 108 p

Shore Erosion Study Technical Report. February 1977. Wisconsin Coastal Zone Management Program 199 p

Shore Protection Manual. Vol. 1-3 1973. Department of the Army, Corps of Engineers, Coastal Engineering Research Center, Ft. Belvoir, Virginia.

Shore Use and Erosion, Appendix #12, Great Lakes Basin Framework Study. 1975. Great Lakes Basin Commission, Ann Arbor, Michigan 111 p.

The Vegetation of the Great Lakes Canadian Shoreline: Its Role in Controlling Rates of Erosion. March 1976. Canada Centre for Inland Waters, Environment Canada 78 p.

References

Do's and don'ts

If you own shoreline property then . . . .

Do

- Plant vegetation on barren slopes if your beach and toe are stable
- Seek competent local advice on technical matters such as engineering, drainage, or soils
- Consult with your neighbors as to the best coordinated approach to solving shore erosion problems
- Take care of the trees, shrubs, and grasses already growing in your shoreline and bluff areas
- Consider carefully how your shore protection measures appear to and affect others

Don't

- Remove existing vegetation from the top, face, or toe of the bluff
- Throw rubbish such as old cars over the bluff
- Build structures on the beach without consulting your neighbors or seeking advice of experienced professionals
- Run drainage ditches or pipes over or through the bluff without any means of conducting the flow to the lake level
- Encourage activities which result in destruction of vegetation or increased erosion of bluff areas (i.e., pedestrian or vehicular traffic)

Before undertaking any major construction or slope regrading project, be sure to consult with local, state, provincial, and federal authorities in case permits are required for these types of activities.

Great Lakes Basin Commission

NOAA COASTAL SERVICES CENTER LIBRARY
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Fisheries and Environment Canada

Pêches et environnement Canada

Department of the Army
Corps of Engineers
North Central Division