Lakeshore Erosion Hazard Mapping

by

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ABSTRACT

Lakes offer opportunities for residential and recreational use. Shoreline developments, however, can negatively affect fish and fish habitat, the foreshore, and the very setting that makes them so attractive to people in the first place. This is particularly true for lakes that have fluctuating water levels.

The vulnerability of the lakeshore to erosion is varied, but erosion protection measures tend to be applied in a blanket approach—an approach that is neither cost effective, environmentally friendly nor typically required. This report presents a method for determining and mapping the shoreline erosion hazard around a lake and suggests appropriate protection measures. It is meant to help lakeshore owners and planners choose where to place their protection efforts, and offers alternatives that will help maintain the ecological integrity of the land-water interface, while protecting property and property owners. The first part of the report describes the methodology for determining and mapping lakeshore erosion hazards; the second is a conceptual tool kit for dealing with erosion where it occurs in a manner that retains some of the biological integrity of the lakeshore. The report does not specifically address individual concerns, nor is it meant to restrict the possibility of other innovative designs not considered in the tool kit.

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INTRODUCTION

Lakes are often considered ideal locations to live and play. They offer tremendous opportunities for recreation, and visitors or full- and part-time residents often feel more connected to the natural world. Many shoreline developments, however, negatively affect fish and fish habitat, the foreshore, and the very setting that makes them so attractive to people in the first place. This is particularly true for lakes that have fluctuating water levels—often small lakes with controlled outflows—and property owners must suddenly contend with potential erosion to their property and infrastructure.

Erosion protection measures, while often necessary, tend to be applied in a one-size-fits-all manner. In reality, the vulnerability of the lakeshore to erosion is varied, and the blanket approach is neither cost effective, environmentally friendly, nor typically required. This report presents a method for determining and mapping the shoreline erosion hazard around a lake and suggests appropriate protection measures. It is meant to help lakeshore owners and planners choose where to place their protection efforts, and offers alternatives that will help maintain the ecological integrity of the land–water interface, while protecting property and property owners. The first part of the report describes the methodology for determining and mapping lakeshore erosion hazards; the second is a conceptual tool kit for dealing with erosion where it occurs in a manner that retains some of the biological integrity of the lakeshore. The report does not specifically address individual concerns, nor is it meant to restrict the possibility of other innovative designs not considered in the tool kit.

PART 1
Determining the Shoreline Erosion Hazard (Small Lakes with Fluctuating Levels)

THE DESK STUDY

Geology and terrain mapping

Geological, terrain, and soils maps are available for many areas in B.C., typically at a scale of about 1:50 000. Although available information may not always be detailed, occasionally it is. These maps give key background information about sediment types, compactness, rock strength, and weathering characteristics that may be relevant to the study. They also help place the shoreline contextually when in the field.

Lake levels

An understanding of the limits on the lake level rise (and to a lesser extent, the drop) is critical information when considering the erosion hazard of a particular lake. Similarly, the frequency, cause and timing of extreme levels, as well as the rate at which the levels change are also important. Rapid drawdown of saturated and unconsolidated soil will cause substantial erosive damage, with or without the addition of wave action.

Air photograph analysis

Depending on the scale of mapping, analysis of air photographs forms an integral part of the mapping process. Stereo air photographs at 1:20 000 or better are standard in B.C. The air photograph interpretation will ideally provide an excellent base map for more detailed field investigations.

Climatological information

Any information regarding the annual hydrograph, prevailing wind direction(s) and other related data may be gathered in the desk study. Again, it will provide contextual data in the field. Anecdotal information may be considered cautiously here. Often a surprising amount of relevant knowledge is held by other lakeshore property owners.

THE FIELD STUDY

The following guide considers the type of data a mapper might typically acquire at each site along the foreshore. However, the real world may include items not on this list. In such an instance, consider the impact that variable is having on the erodibility of the foreshore, and provide a rationale for its consideration. Then, consider the criteria against which the strength of the variable around the lake will be measured.

The detailed field mapping exercise is conducted at a scale of about 1:5000. A qualified mapper (see below) walks the shoreline and assesses the erodibility along the way using the criteria described. The shoreline is broken up into units of similar characteristics such that the shoreline within a unit is self similar, but differs from neighbouring units. Stations can refer to boundary breaks along the shoreline, or to the unit itself, but the boundary breaks need to be correctly located in the field. An erosion hazard-rating is assigned to each unit and combined hazard ratings make up the map.

The shoreline characteristic criteria are given a traffic light style rating (low, moderate, high) related to erodibility. In principle, the different criteria can be combined to provide a more detailed hazard rating, however, the relative weighting of the criteria may vary from both lake to lake and site to site. Consequently, rating the criteria is meant to provide the mapper with a basis from which to define the erosion hazard at an individual site, reducing the likelihood of "instrument drift" as one works along the lake. The final erosion hazard rating incorporates a fair degree of judgement and experience, but should be consistent overall.

Beach stable angle

The slope profile of unconsolidated beach sediments eventually reaches a stable angle of repose as determined by the various geomorphological processes at work. The beach stable angle can be determined in the field through repeated measurements and by observing the grade at which the beach begins to reduce the slope. At Horne Lake on Vancouver Island, for example, the beach stable angle is about 17% (9.6 degrees). Steeper slopes were inevitably eroding, and shallower slopes were typically stable, often resulting in extended beaches. In some cases, compact or cemented soils (e.g., basal till) may make up significant portions of the beach; in such a case the beach angle will be higher, as if it has been armoured.

Prevailing wind direction

Table 1. Prevailing Wind Direction

Description	Hazard rating	Rationale
Shoreline perpendicular to prevailing wind direction	H	Shoreline faces consistent and continued inundation by wind and wave erosion at elevated water levels.
Shoreline 45° to prevailing wind direction	M	Shoreline faces continued wave and wind erosion at an angle. Longshore drift needs to be considered when constructing protection measures.
Shoreline parallel to wind direction	L	Longshore drift is an issue, but direct erosion from waves and wind in minimal.

Note: Some lakes may have several common wind directions, making these criteria inapplicable.

Wind exposure

Table 2. Wind Exposure

Description	Hazard rating	Rationale
Severe	H	Foreshore material and weathering patterns indicate severe and prolonged exposure to winc and wave erosion (this is measured relative to rest of the lake by the relative size of material in transport and being moved by waves, as well as evidence indicating unusually heavy weathering of the foreshore, despite material type).
Exposed	M	This is the typical case for a lake shoreline.
Sheltered	L	Relatively sheltered from wind and wave erosion (lee sides of nearby islands, enclosed coves and bays, etc.).

Note: Many lakes are exposed to wind from several directions, making the prevailing wind direction less useful. In this case, assess the relative exposure.

Soil composition

Table 3. Soil Composition

Description	Hazard rating	Rationale
Sandy, unconsolidated, exposed (free of vegetation) soil	H	Highly erodible
Moderately compacted soil and/or covered with vegetation	M	Moderately erodible
Cemented compact soil	L	Basal till, for example

Figure 1
Unconsolidated soil is highly vulnerable to both wave action and drawdown.

Backshore soil exposure

Much of the erosion concern on a controlled lake occurs where the backshore meets the water when the water level is high. Exposed banks are subject to all the forces of wind, water and drawdown when the water level drops.

Table 4. Backshore Soil Exposure

Description	Hazard rating	Rationale
Exposed bank >1 m high	H	Plan-form extent of erosion is high
Bank 0.5-1 m high	M	Plan-form extent of erosion is moderate
Bank <0.5 m high	L	Plan-form extent of erosion is limited by low height of backshore

Figure 2. *Exposed backshore is higher than 1 m. In this case, the sediment is non-cohesive but compact glaciofluvial sediments.*

Armouring

Determine size of material being (A) transported offsite, (B) rolled around but remaining onsite, and (C) resisting movement. When the foreshore slope is steeper than the stable angle for the beach, the following applies:

Table 5. Armouring

Description	Hazard rating	Rationale
A > B	H	Most of the material is being transported offsite
A < B > C	M	Material is providing some armouring, but is moving at higher energy levels; result is a net loss of sediment from the beach
A < B <= C	L	The shoreline has self-armoured and is not vulnerable to sediment loss

Note: A shoreline that has self-armoured has also effectively increased its own beach stable angle. In our pilot study, for example, we observed a secondary beach stable angle of about 24% (13.5°), where there was no sediment smaller than cobble sized (>64 mm).

Figure 3. *An example of beach armouring. Note that people have removed the stones and stockpiled them intermittently along the beach, probably for recreational use and access.*

Profiles

The lake profile is a combination of the processes at work and the criteria measured. Figures 4 to 11 illustrate typical shoreline profiles and their respective Erosion Hazard Ratings.

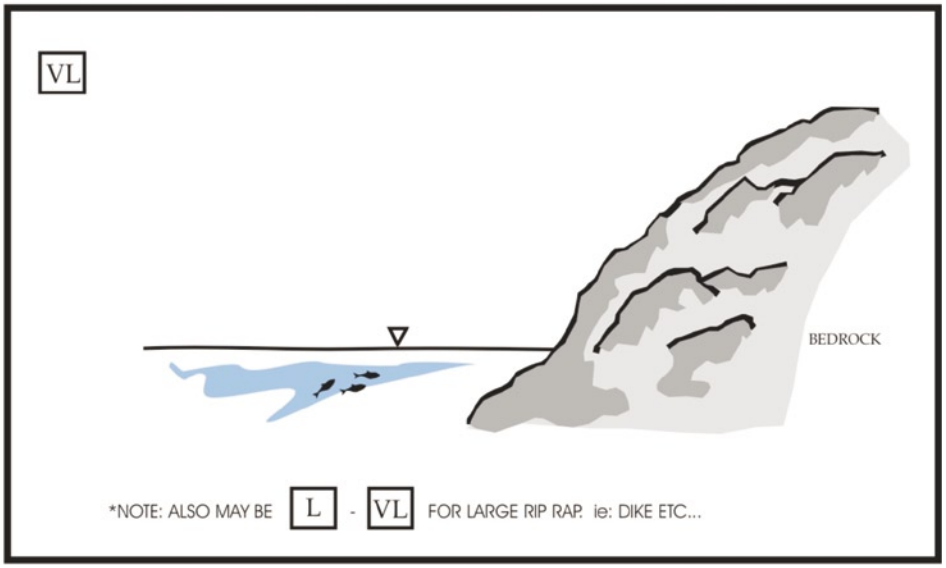

Figure 4. *Profile and typical photograph showing a bedrock shoreline. Erosion potential is typically Very Low.*

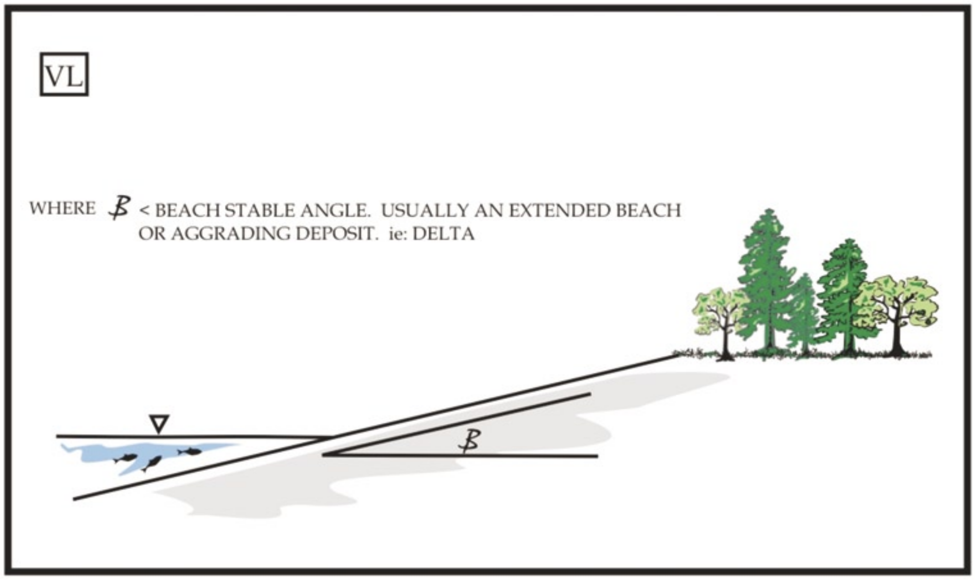

Figure 5. *Profile and typical shoreline for a broad, low-gradient (<10% in this case) beach. Erosion potential is typically Very Low.*

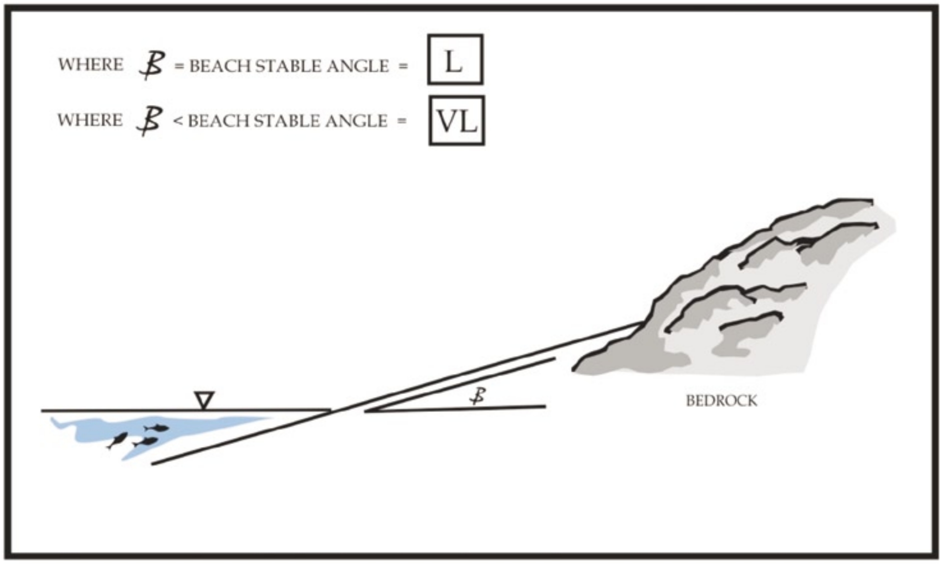

Figure 6. *Profile and typical shoreline for a beach with bedrock backshore. Hazard rating is typically Low to Very Low.*

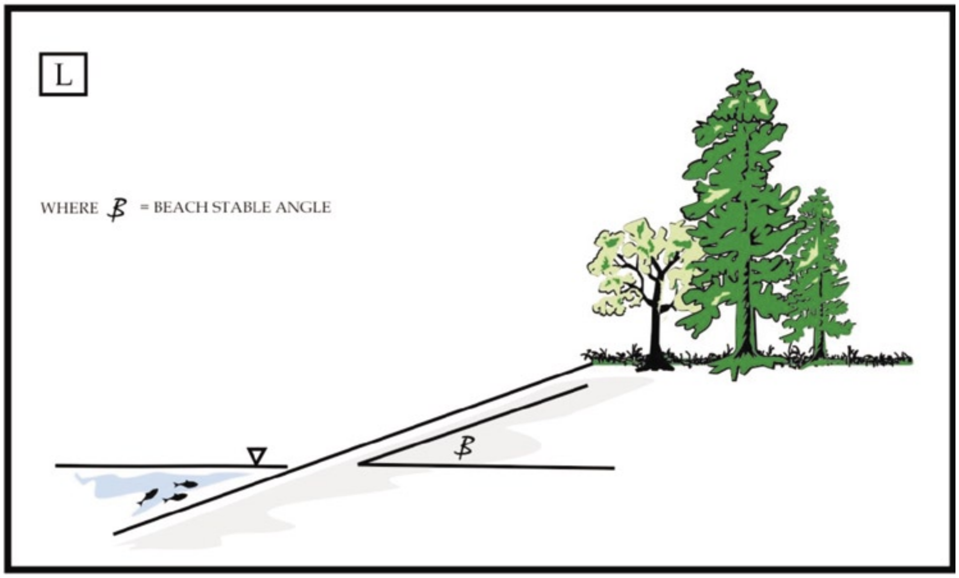

Figure 7. *Beach with a slope on or around the beach stable angle. Shoreline erosion hazard is typically Low.*

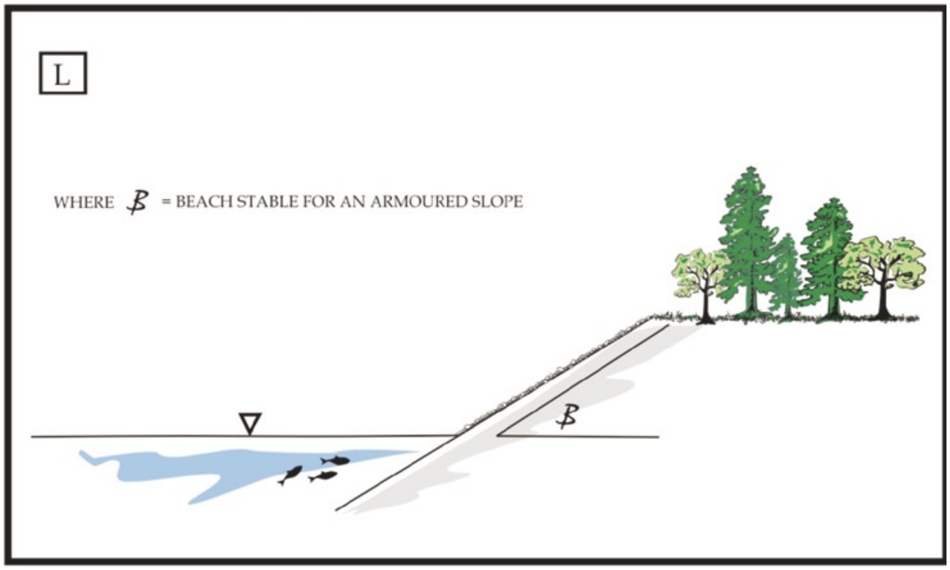

Figure 8. *Profile and photograph of a typical armoured beach. Based on this profile, the erosion hazard is typically Low.*

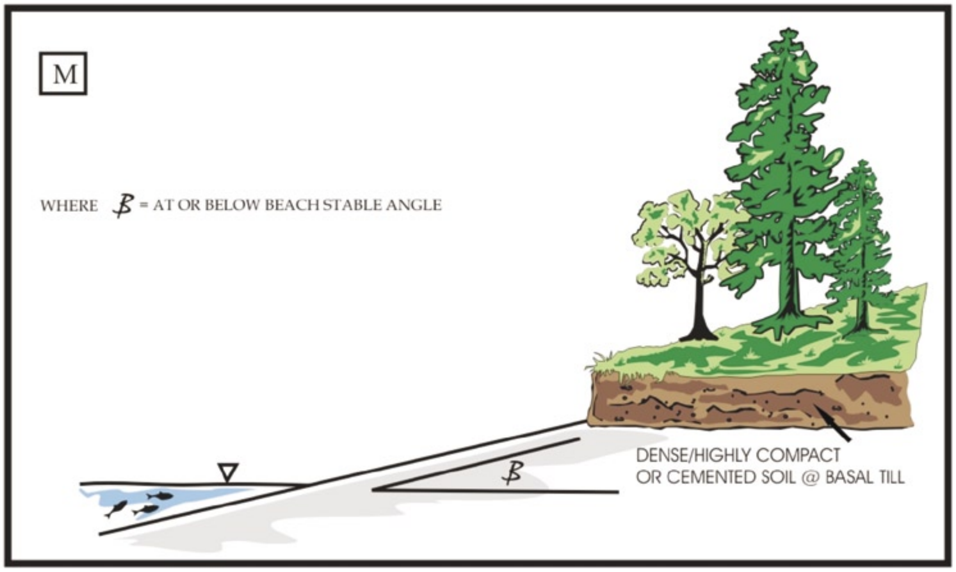

Figure 9. *Profile and photograph of a beach with exposed but cemented banks. In this case the basal till remains exposed and resists vegetation, but it is also more resistant to erosion, and the erosion hazard is typically classed as Moderate.*

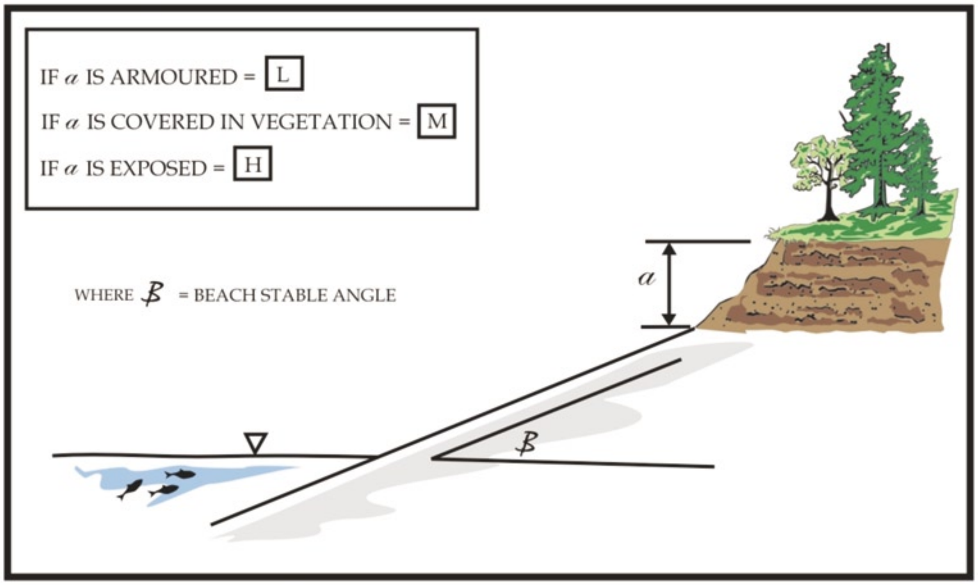

Figure 10. *Profile and photographs of a section of the backshore that is steeper than the general beach, but not an exposed vertical face. Erosion hazard depends on the material type and cover, as can be seen by the difference in erosion between (A) and (B).*

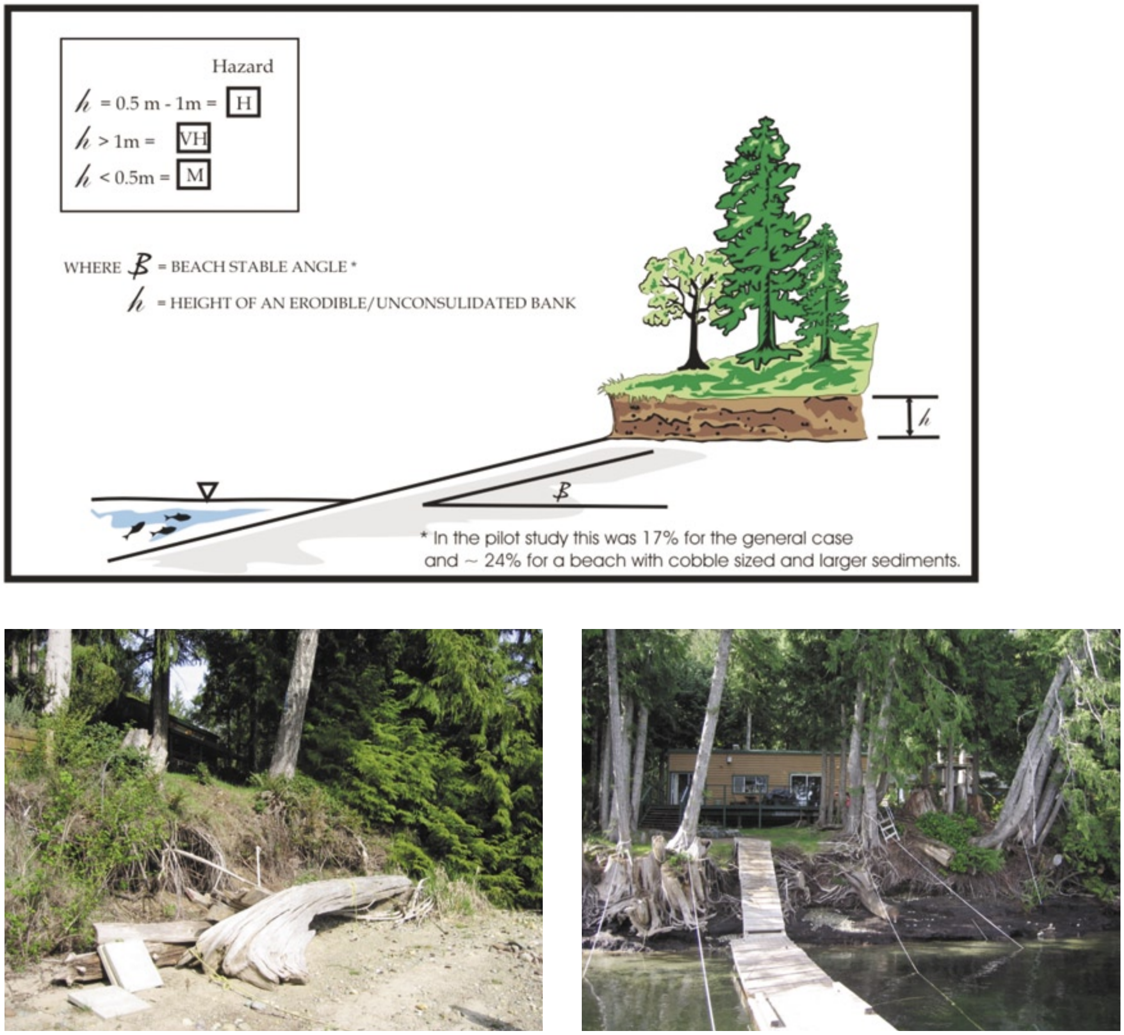

Figure 11. *Profile and photographs showing the erosion hazard associated with vertical and exposed backshores consisting of non-cohesive material. Erosion hazard is related to bank height (and implicitly related to amount of potential loss of bank back from the shoreline). The photographs show two examples of Very High erosion hazards, where the bank is well in excess of 1 m high.*

Combining two tables

The following is an example of how two tables might combine to produce the five-class erosion hazard scale. The relative rank of each category is combined to produce a new score. Two Lows, for example, combine to produce a Very Low score. In practice, some features will be more heavily weighted in the assessment, but are nonetheless often related. Judgement is required.

Table 6. Combining Two Tables – Five Class Erosion Scale

Soil Compaction/Backshore Soil Exposure	L	M	H
L	VL	L	M
M	L	M	H
H	M	H	VH

THE EROSION HAZARD RATING

The erosion hazard rating combines the factors from the field assessment, weighted according to the judgement of the mapper, and presents a five-class qualitative assessment of the hazard level. The profile drawings above, which tend to be a combination of the other factors, contain examples of typical hazard ratings from Very High (VH) to Very Low (VL). Implications for the ratings are given below:

Table 7. Implications of Erosion Hazard Rating

Ruling	Rationale	Solution
VL	Beach is depositional, aggrading or substantially below the beach stable angle. Even clearing and raking does not seem to reduce stability.	Plant trees where possible to provide biological value to the site. Complex sites are better than homogenous ones (cleared and raked).
L	Beach is at or near the beach stable angle, with no backshore cliff. Small terraces may develop on beach if water level maintains a constant high water mark, but erosion is easily contained by hand.	Placement of rocks where necessary, beach complexing and placing deadheads to create wave resistance and depositional areas.
M	Limited erosion is occurring, including around roots of trees, at high water mark on shoreline or against a till backshore cliff. Erosion is slow enough or limited enough that it can often (though not always) be solved by hand, however, toe protection added to treatments is probably necessary.	Beach complexing, bioengineering, buried deadheads, riprap.
H	Substantial erosion is occurring during high water, loss of trees and property and (where relevant) ultimately structures are likely without treatment.	Hard engineering solutions, designed bioengineering solutions, keyed-in structures are crucial.
VH	Imminent and substantial loss of property, vegetation, and (where relevant) structures at high and often moderate water levels. Typically differentiated from H by height of backshore cliff (relates to amount of potential erosion and site stability).	Hard engineering solutions, designed bioengineering solutions, keyed-in structures are crucial.

A WORD ABOUT SCALE

Map scale is an important limitation to understand in any assessment. The useable scale relates to the weakest link in the scale of mapping, not the accuracy of some of the components of the mapping. A mapper typically transcribes his or her observations on to a map of a set scale, for example, 1:5000. Location breaks and detailed notes may be exceedingly accurate, but the information that is available to the reader of the map is nonetheless limited by the scale and information that it has room to show. As a result, a 1:5000-scale map may be very detailed and give accurate information about the conditions of a certain area, but should not be mistaken for a 1:500 scale map, which may be the scale necessary to plan the accurate mitigative solution at a specific site. As a general rule, minimum mapped polygon size is 1 cm^2, regardless of scale. This is equivalent to 50 × 50 m at a scale of 1:5000.

Within a classification rank (mapped hazard rating), at a given scale, other classifications (higher or lower hazard ratings) may be below the mapped resolution.

A WORD ABOUT QUALIFICATIONS

Classification schemes (including mapping) attempt to order our understanding of processes, things, and events. It is the nature of most mapping projects that considerable judgement is required by the mapper on an ongoing basis. Mapping projects should be conducted by or under the direction of a professional geoscientist or engineer registered by the Association of Professional Engineers and Geoscientists in BC and specifically qualified by training and experience to engage in this type of work.

LIMITATIONS

The identification of hazards does not indicate a level of acceptance of those same hazards. The acceptable levels of hazard and related consequences are determined by individuals, by landowners, by designated agencies, by governments and by the courts, depending on the circumstances surrounding the assessment and the socio-economic and environmental factors considered important by the decision makers.

It is not uncommon for shoreline erosion hazards to be substantially increased by development practices. Overall, the impacts of development are difficult to separate from the natural shoreline erosion and are included in the hazard rating, but in some cases, the effects of development clearly differ from the natural erosion hazard. For example, a terrace built out onto the beach will be attacked by waves at higher water levels, whereas the beach is otherwise stable. The hazard rating could be substantially higher for that item than for the rest of the shoreline section.

Figure 12. *A terrace built out onto an otherwise stable beach. The shoreline erosion rating is Low, but the terrace itself presents a much higher erosion hazard, mitigated in this case by concrete lock-blocks.*

THE PRODUCT

In most cases, the primary product of shoreline erosion hazard mapping is a map. The map combines adjacent similarly scored shoreline units and distinguishes them from adjacent differently scored shoreline units, usually by a color scheme that is easy for the reader to understand. The major exception is where a detailed site survey is done and the map or diagram may include additional information not otherwise presented. Figures 13 and 14 show the method as applied to Horne Lake on Vancouver Island.

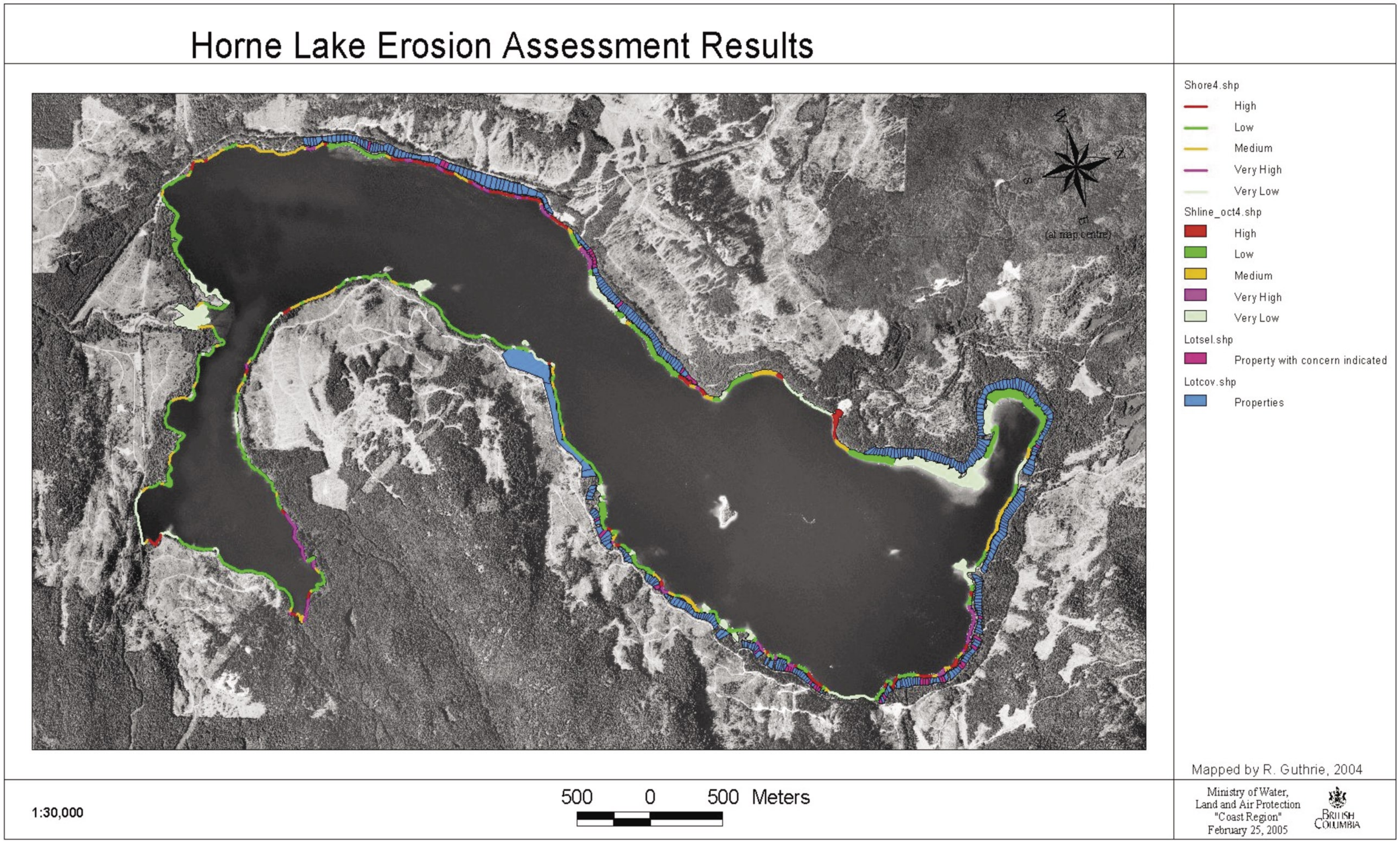

Figure 13. *An example of a shoreline hazard map around Horne Lake on Vancouver Island, BC. Blue parcels are properties and red parcels are properties that have applied for shoreline protection. Note that protection was not needed for all applicants. Hazard ranking: light green = VL, green = L, orange = M, red = H, and purple = VH. Original printed scale was 1:30 000.*

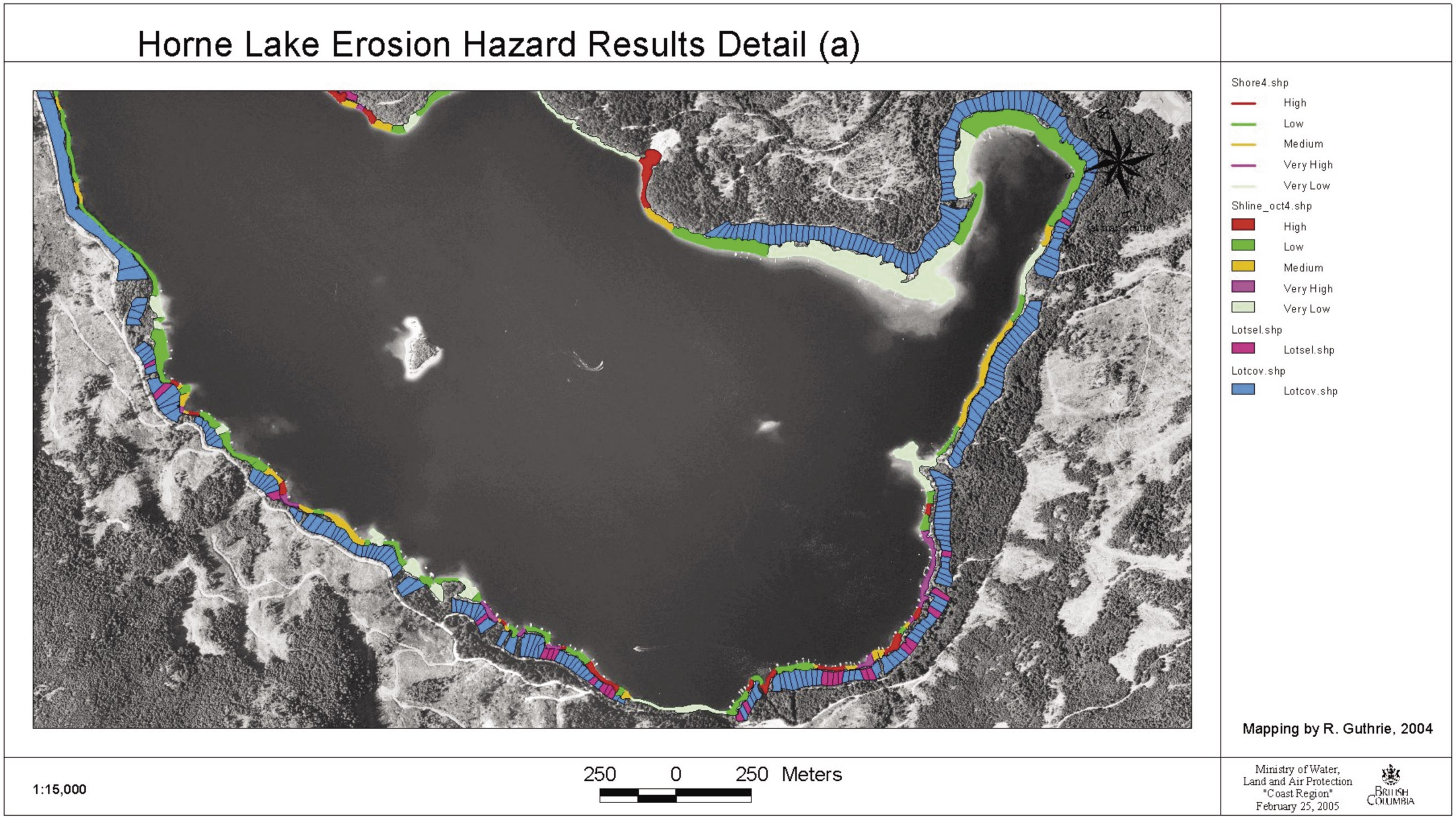

Figure 14. *Detail of shoreline erosion hazard mapping completed for Horne Lake on Vancouver Island, British Columbia. Blue parcels are properties and red parcels are properties that have applied for shoreline protection. Hazard ranking: light green = VL, green = L, orange = M, red = H, and purple = VH. Original printed scale was 1:15 000.*

PART 2
A Conceptual Tool Kit for Erosion Protection

Part II presents a conceptual tool kit for erosion protection structures and methods, and relates them to the appropriate hazard rating from Part I. This list is not exhaustive; for additional designs, see, among others, the US Department of Agriculture Engineering Field Handbook, Chapter 16, Streambank and Shoreline Protection: http://www.info.usda.gov/CED/ftp/CED/EFH-Ch16.pdf .

The comprehensive USDA manual forms the basis for designs in many other publications, and we have adapted several of these designs here.

Conceptual designs discussed in this section are placed generally in order of ability to resist erosion. Even a good design that is badly implemented in the field will often fail. It is particularly important to anchor, or key-in, the toe of the erosion protection.

In all cases, designs that require approval under the Water Act will also need a registered professional engineer's seal. Additional details, such as riprap sizing and construction limitations, will typically be assigned by the engineer on the basis of site-specific conditions. By providing the following conceptual diagrams, our intent is to offer alternatives that the landowner can ask the engineer to adapt to specific needs.

Designs should take advantage of native plant species normally expected around the lakeshore. This may require an assessment by a qualified professional familiar with Terrestrial Ecosystem Mapping in BC. For detailed information, see the Biogeoclimatic Ecosystem Classification and Terrestrial Ecosystem Mapping Websites: http://www.for.gov.bc.ca/hre/becweb/papermap/FieldMapsIndex.htm and http://srmwww.gov.bc.ca/ecology/tem/manuals.html .

HAZARD CLASSES HIGH AND VERY HIGH

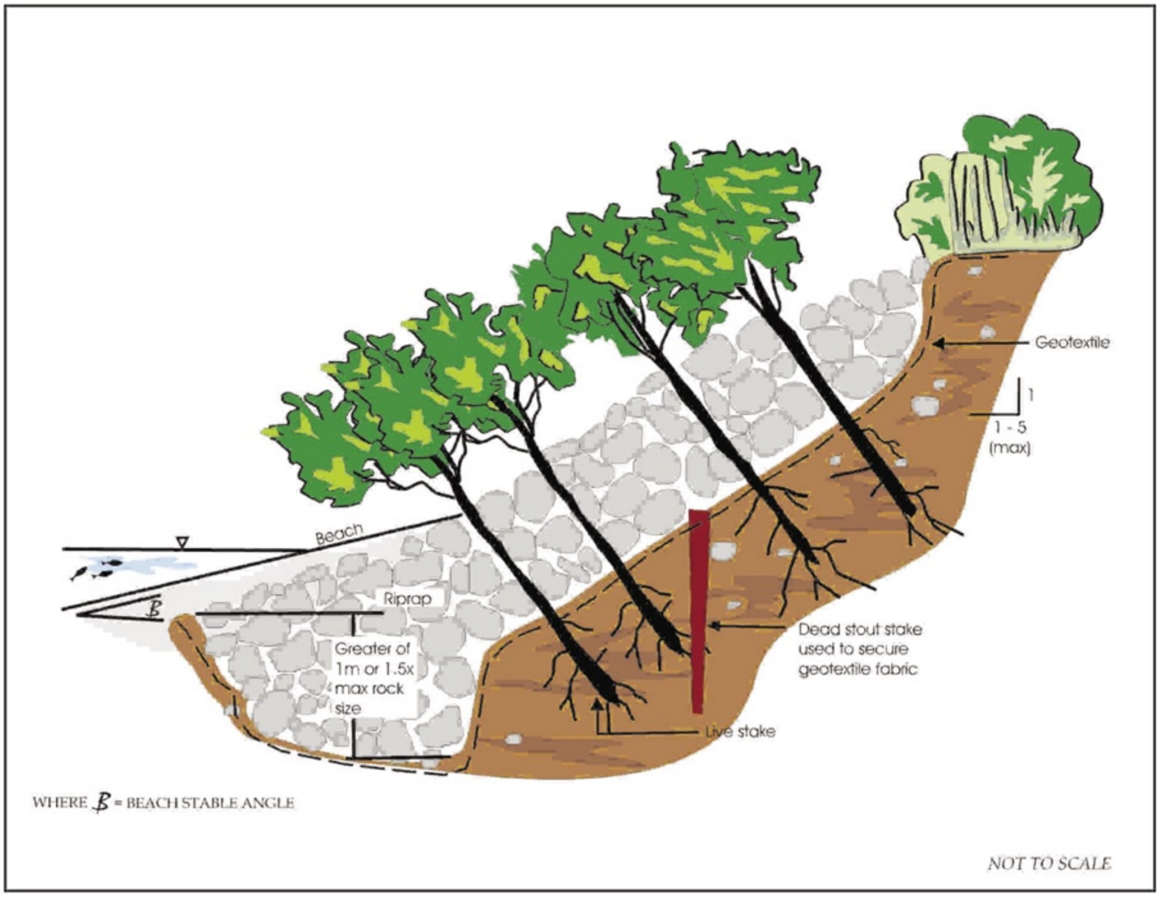

Figure 15. *Conceptual design to mitigate High and Very High lakeshore erosion hazard.*

Vegetation is added to the riprap in one of four ways:

1. Vegetation is placed in dirt as rocks are placed.
2. After the placement of rock, void spaces are filled with a gravely soil substrate by hand. Holes in the dirt-packed voids are created by forcing rebar into the dirt and then live cuttings are placed in the holes.
3. After the placement of rocks, live cuttings are placed into the void spaces and a soil slurry is poured in afterward.
4. PVC sheaths, overpacked with soil, are inserted as the riprap wall is placed, and supported by both the rocks and dirt (again in the void spaces). Rebar is forced into the sheaths creating a hole, followed by the cuttings, and finally removal of the sheaths themselves.

Note: The major weakness of planting in rip rap is that as the trees grow, they may loosen or displace the protective armour. Prudent maintenance of the trees as they grow will prevent most problems. This technique has been used successfully throughout North America.

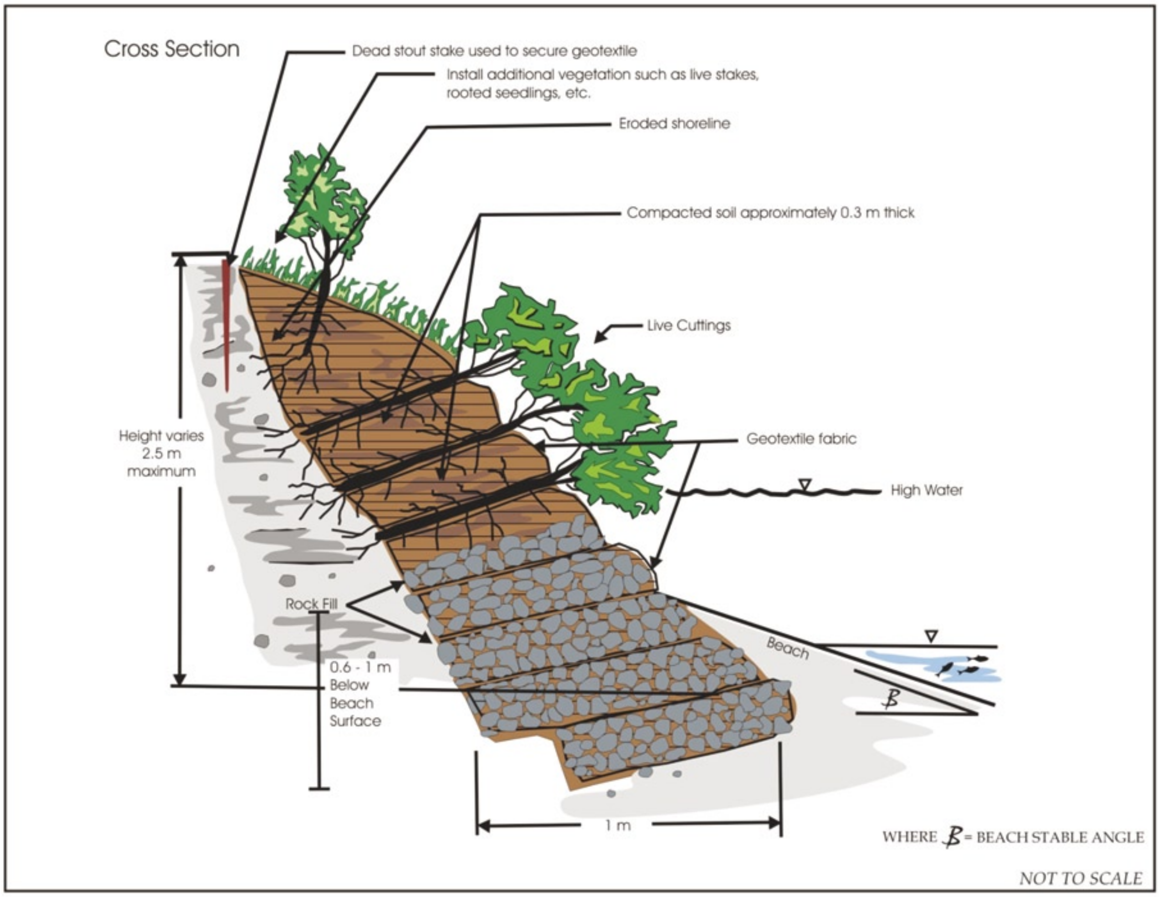

Figure 16. *Conceptual design to mitigate High and Very High lakeshore erosion hazard. Note that geotextile fabric wraps both the soil and gravel layers.*

HAZARD CLASS MEDIUM

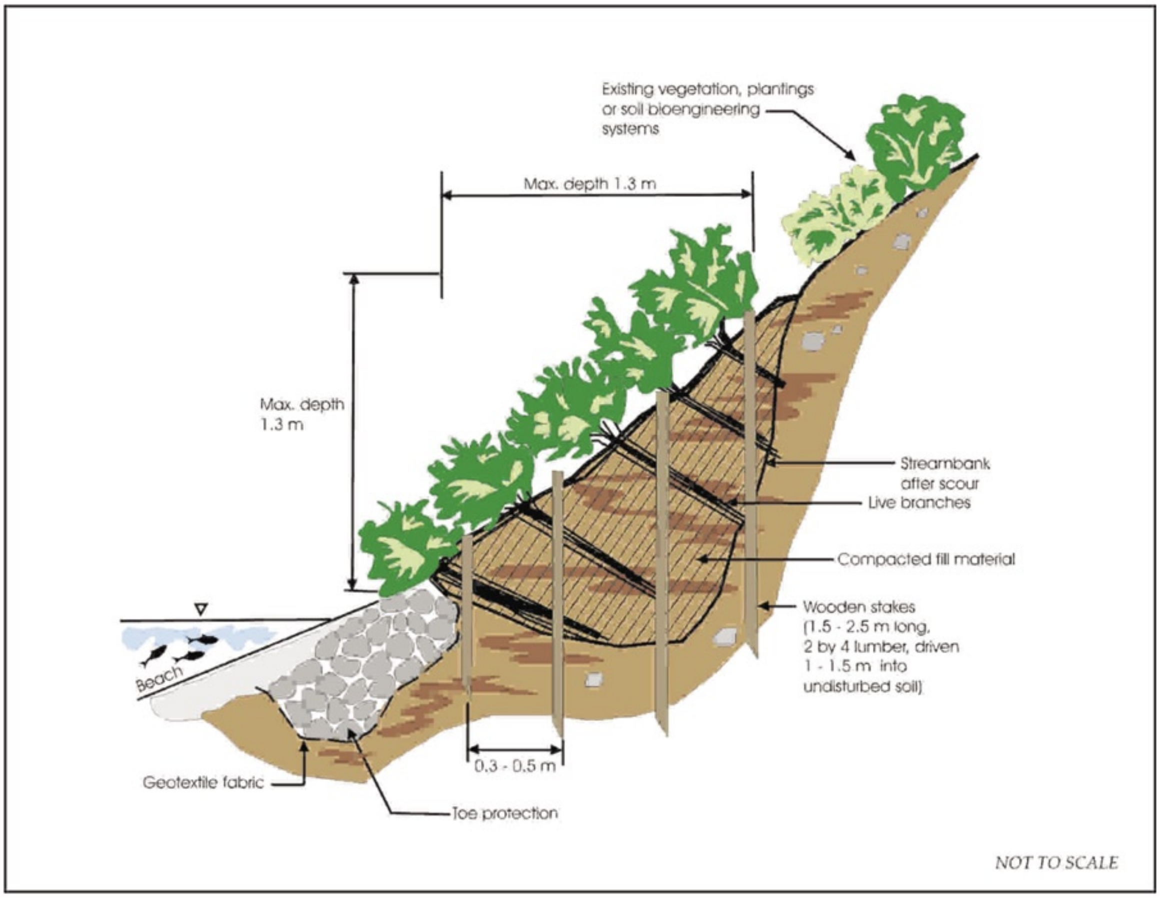

Figure 17. *Conceptual design to mitigate Moderate lakeshore erosion hazard. Note that this design is primarily meant to deal with the upper range of the Moderate erosion class.*

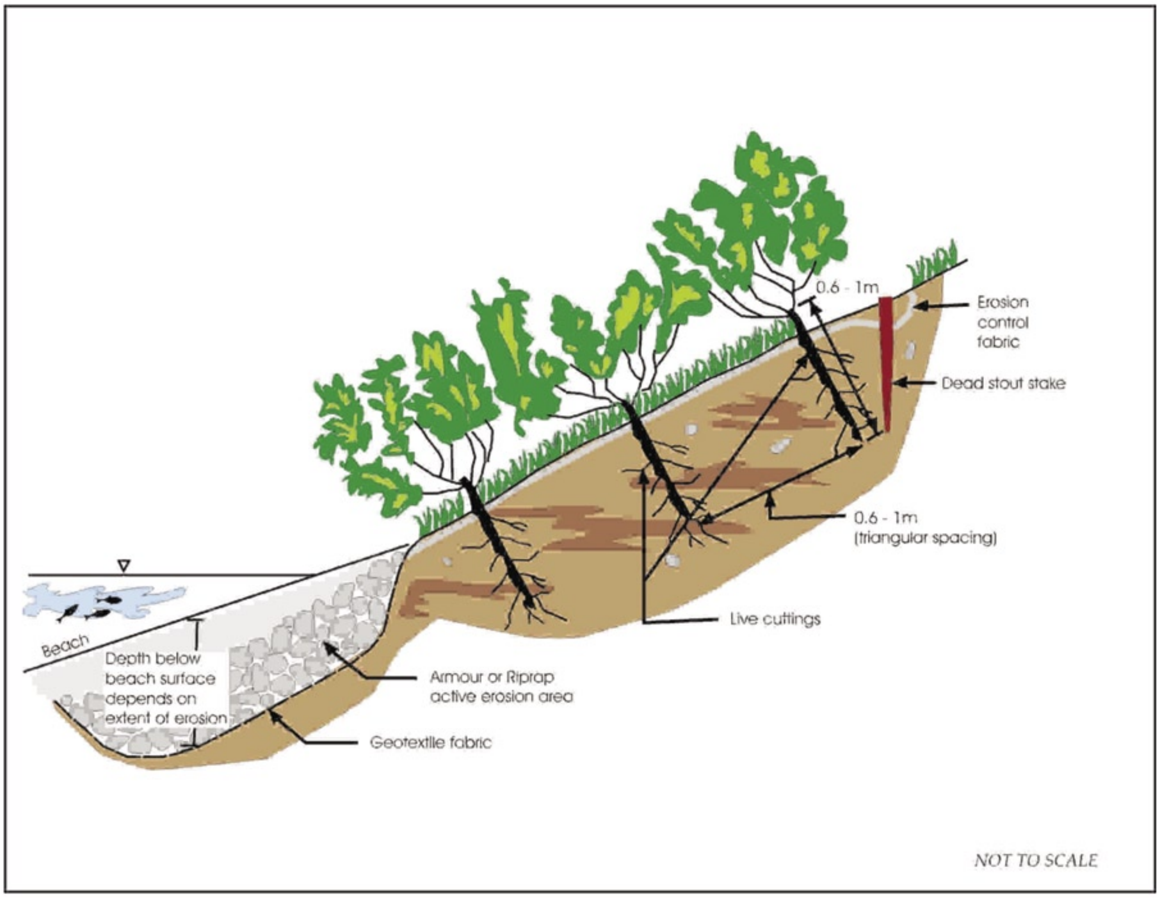

Figure 18. *Conceptual design to mitigate Moderate lakeshore erosion hazard.*

The following designs are intended to provide the beach with some rough components that allow finer sediments to deposit naturally behind them at higher water levels, and to break up wave action on the shoreline. Wave attenuators may also be useful in a variety of locations. The simplest wave attenuator is a floating log on chains anchored to the lake floor. In addition leaving vegetation, even in pockets or strips along the shoreline, will substantially reduce the impact of wave energy. Clearing, de-stoning, and raking the beach almost always results in an increase in erosion potential. Designs for vegetation should incorporate the use of native successional species for the area, based on the Biogeoclimatic Ecosystem Classification system and the standard Terrestrial Ecosystem Mapping methods for British Columbia. http://www.for.gov.bc.ca/hre/becweb/papermap/FieldMapsIndex.htm , http://srmwww.gov.bc.ca/ecology/tem/manuals.html .

The examples below should be manageable without machines during summer months. Similar principles may be used to protect minor erosion around tree roots that are being undercut (a rock groin or terrace in front of the exposed portion of the root ball for example). Typically, the material is not simply placed on the beach surface, but is keyed-in to the ground.

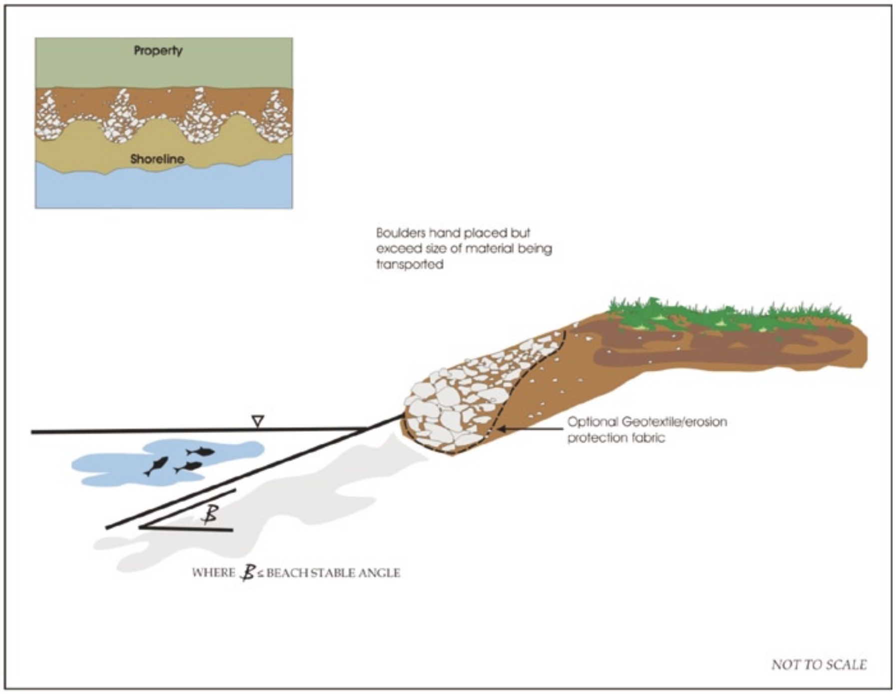

Figure 19. *Conceptual design to mitigate Moderate to Very Low lakeshore erosion hazards.*

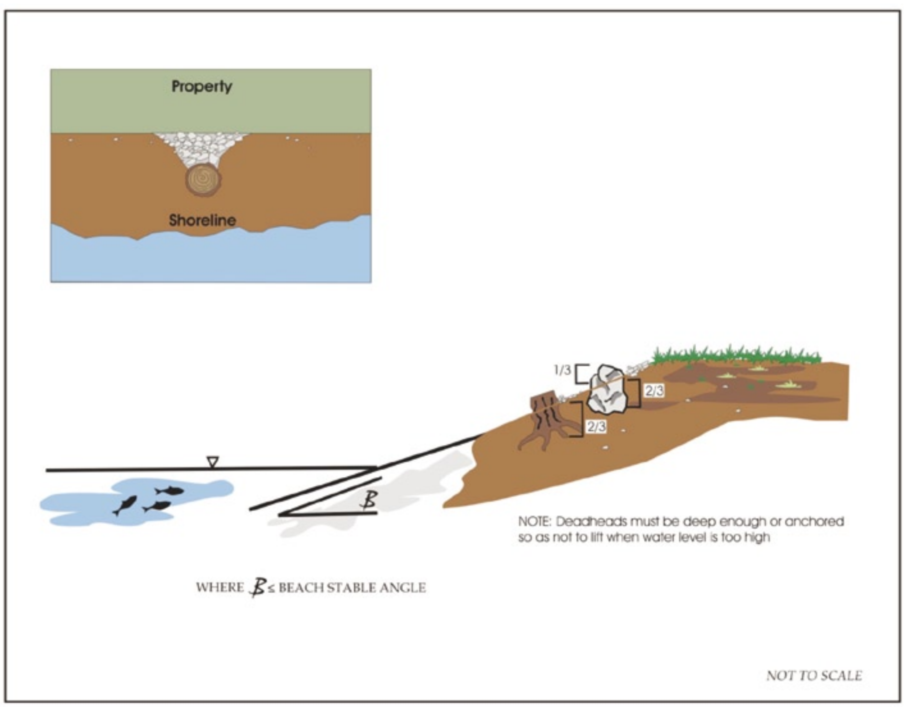

Figure 20. *Conceptual design to mitigate Moderate to Very Low lakeshore erosion hazards.*