SAVARY ISLAND DUNE AND SHORELINE STUDY

Report

To

The Powell River Regional District

D. Smith, P.Eng.
Project Principal

D. Regehr, EIT
Project Engineer

03/12/03
R. Gerath, P.Geo.
Project Geoscientist

Thurber Engineering Ltd.
Vancouver, BC

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SUMMARY

Thurber Engineering Ltd. (TEL) and Strix Environmental Consulting have conducted a geotechnical and environmental assessment of Savary Island, BC. The study was carried out for the Powell River Regional District with the following objectives:

- To establish hazard setback lines for the entire perimeter of the Island to ensure building locations are safe from erosion hazards for 50 and 200 year horizons.

- To confirm the location, extent and sensitivity of the dune area on the Island.

- To refine draft development guidelines for a Savary Island Official Community Plan.

We anticipate that this report will be used by Savary Island property owners and Regional District officials to guide development that limits exposure to geological hazards and risks and which promotes environmental stewardship.

Savary Island is influenced by erosive storm waves driven by prevailing southeasterly winds. The winds have formed now relict longitudinal sand dunes on the central Island. Storm wave attack over the past 11,000 years since deglaciation has reduced the Island from its former extent as far southeast as Mystery Reef. Storm waves and other natural processes continue to reduce the Island's south shore.

Shoreline and bluff erosion rates have been estimated in previous studies by TEL and others and it is evident that, in general, the south shore erodes at a significantly higher rate than the north shore. A more definitive study of bluff crest retreat was made for this study using superimposition and comparison of ground detail from geometrically rectified 1967 and 1999 aerial photos of the Island. Within an accuracy of plus or minus 1 m, measurements at 51 locations around the shoreline indicated a maximum erosion of 13 m along the south shore and 8 m along the north shore over the 32 year period between airphotos. These values correspond to average rates of erosion of 0.41 m/year and 0.25 m/year

on the south and north shores, respectively. These values are similar to those that have been revealed by the previous studies.

Primarily based on the erosion rates obtained from the airphoto study, projected for 50 and 200 years, building setbacks from the current bluff crest have been established from geotechnical considerations of a safe long-term slope. Recommendations for building setbacks from the current natural boundary in shoreline areas where no bluffs exist or the shoreline is bedrock are also provided. These setbacks will guide residential development around the Island shoreline.

Supplemental geotechnical advice to land owners is also provided in the report together with recommended guidelines for professional reporting in hazard and risk assessment work.

Our review of existing draft development guidelines suggests that their non-regulatory nature will not adequately protect public health and safety along high bluff areas or provide assurance over the quality and quantity of shallow aquifers utilized for domestic water supplies.

The Island's relict and active sand dunes provide unique ecological habitats which are described with special reference to plant species and plant communities. Some modifications of existing, environmentally defined, Development Guideline areas are recommended, as are several new ones.

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1. INTRODUCTION

This report is an assessment of bluff erosion rates and limits and related geotechnical development issues on Savary Island. The location and environmental sensitivity of Island sand dune areas are also evaluated. This report provides recommendations based, in part, on our professional mandate under Bylaw 14(a)(1) of the Engineers and Geoscientists Act of BC[1].

The study has been carried out in accordance with the Request for Proposal (RFP) issued by the Powell River Regional District (the Regional District) on February 21, 2002. Geotechnical elements of this study were evaluated by Thurber Engineering Ltd. (TEL). Environmental issues were evaluated by Strix Environmental Consulting (Strix). Strix's report is included in Appendix A in its entirety. Highlights are presented in Section 8.

Our work involved office studies of aerial photos, maps and reports provided by the Regional District and information contained in the TEL library. Background reports, maps and aerial photos used in the study are listed in *References*. Previous reports by Tupper (1996) and Bornhold et al (1996) were especially useful for the geotechnical assessment. We do not include all the factual or interpretive information contained in these reports, nor do we refer to their many original sources of information. TEL and Strix conducted field work in early May and mid-June 2002.

McElhanney Consulting Services Ltd. completed an analysis of 1967 and 1999 airphotos to establish bluff crest retreat over the 32 year period between the airphotos.

1 "Professional Engineers and Geoscientists shall hold paramount the safety, health and welfare of the public, the protection of the environment, and promote health and safety in the workplace."

We understand this report will be used by Regional District staff and Savary Island landowners for guidance in planning and permitting for safe and environmentally appropriate residential development.

Use of this report is subject to the enclosed Statement of General Conditions.

2. GEOLOGY AND GEOLOGIC PROCESSES

2.1 Climate and Weather

Savary Island is surrounded by the Strait of Georgia and is located in a distinctly dry and mild, rain-shadow climate zone identified as the Coast Douglas-Fir Biogeoclimatic Zone by the BC Ministry of Forests (1988). The Island receives between 950 and 1,300 mm of precipitation a year (Tupper, 1996). The comparatively dry climate and prevalent, often well-drained but erodible soils on the Island condition its distinctive ecologic settings and surface processes such as wind erosion and deposition. Prevailing storm waves, driven by southeast winds, have important erosion and sediment transport effects along the Island's south shore.

2.2 Geology

2.2.1 Bedrock

The only known bedrock on Savary Island is granitic rock around Mace Point at the east end of the Island, as shown on Dwg. 14-197-0-1. The bedrock resists ocean wave erosion.

2.2.2 Pleistocene-Age Deposits

Most of the Island is formed by a Pleistocene (Ice Age) deposit known as Quadra Sand (Clague, 1977). It is a thick sequence of nearly horizontal layered, fine to coarse sand with lesser clay, silt and gravel. This material was deposited by meltwater streams in front of glaciers which advanced southward through the Strait of Georgia over 20,000 years ago. The sandy deposits were eventually overridden by advancing ice which deposited cobble and boulder-rich glacial till and other glacial sediments (collectively identified as 'drift') on top of the Quadra Sand (Photo 1).

The Quadra Sand contains discontinuous beds of silt and clay. Some sand units have a significant silt content. Groundwater breaks out in springs and seeps along these relatively impermeable beds on the Island's steep bluffs. Buried, relatively impermeable silt and clay rich beds also control several island aquifers which are tapped for domestic water supplies (Tupper, 1996).

2.2.3 Holocene-Age Deposits

The period since the great deglaciation about 11,000 years ago is known as the Holocene (Recent) Period. Holocene deposits and features include sand dunes, active along the ocean shore and comparatively inactive across the central Island, beaches (including forested beach deposits at Indian Point) and the extensive sandy shoals that surround the Island.

Much of the Island's surface materials (including variably thick sheets of wind-blown sand) are relatively permeable and there are no identifiable creek systems. Groundwater discharges on bluffs, coupled with ocean wave erosion, promote a variety of slope activities including gullying and landslides.

The Island has been considerably affected over the Holocene Period by southeast storm winds which reduced the Quadra Sand and its drift cover to boulder-mantled sand shoals which extend southeastward to Mystery Reef and southward to Stradiotti Reef (Bornhold et al, 1996). Relict, longitudinal sand dune orientations on the central Island reflect a long history of prevailing southeast winds.

2.3 Shoreline Erosion

All of the Island is surrounded by Holocene sand beaches. Accreted (i.e. built-up) beach deposits attain considerable width at Indian Point. In our judgment, the 200 to 300 m wide tract of low ground between Mace Point and the government wharf and the shoreline beneath bluffs as far west as First Point are Holocene beach deposits.

Beach sand may continue to accrete in these and other Island areas but deposition is punctuated by episodic, localized and sometimes intense erosion.

2.4 Bluff Erosion

Much of the Island is ringed by 20 to 50 m high, steep shoreline bluffs. The highest bluffs are located along the south shore where the slope is exposed to storm wave attack. Wave erosion at the base of slopes triggers slumps and slides up higher (Photo 2). Groundwater discharges also promote slide activity (Photos 3 and 4). Sandy debris from the slopes and wind-blown sand from offshore accumulate at the foot of the south bluffs. The accumulated material may temporarily protect the bluffs from wave erosion but eventually it is mobilized by storm wave attack and is cycled into an offshore sediment drift system which moves from east to west along the south shore.

Bluff erosion on the south shore is relatively high compared to that on the largely forested north bluffs. Further discussion of bluff erosion is presented in Section 4.

2.5 Offshore Sediment Transport

Sediment in the Island's offshore transport system originates in the south shore beaches, bluffs and shoals. It is transported westward by storm waves and tidal currents. Bornhold et al (1996) state:

> *"Net sediment transport on the south side of Savary Island is east to west in winter, with an estimated total possible sediment*

transport of 330,000 cubic metres per year. From observations made during field work and from prevailing summer wind directions, west to east longshore sediment transport at a much reduced rate is predicted through the summer months. Sediment sinks in the local sediment transport system are the deep area northwest of Indian Point and the broad sand shoal in Manson Passage".

"*Sediment from the south shore of Savary Island is driven westward into Manson Passage . Some ...is accreted to Indian Point. The spit at Indian Point appears to grow episodically; i.e. it extends offshore for several years and catastrophically disappears during violent storms, into the deep basin to the north of Savary Island. Sidescan sonar and high-resolution seismic reflection surveys revealed the presence of numerous prominent downslope-oriented channels along the north coast of the island. These are conduits through which sediment, originally moved by longshore drift along the south coast, is periodically carried into the deep basin north of the island. This process of slow growth and rapid erosion at Indian Point is anticipated to continue for a very long time without any net overall accretion in the area except perhaps at the west side of the point in the very shallow Manson Passage."*

2.6 Wind-Blown Deposits

Sand dunes on the Island are unique physical features which host ecologically significant plant communities. Much sand has accumulated in dunes in various states of activity. Strix (Appendix A) describes dune formation processes. Tupper (1996, Map 1b) maps active dune areas along the Island shores.

The prominent longitudinal dunes on the central Island appear to be relatively inactive (relict) features. They must have been formed by prevailing southeast winds. We suspect they formed when the island extended southeastward to Mystery Reef. The sand probably originated from west-facing beaches that are now eroded away. Tupper (1996) notes that the relict dunes are likely to have formed during periods of wildfire.

The RFP for the study requires the relict dunes to be mapped, with particular reference to their western extent. The extent of the dunes is shown on the Appendix 1 map of the Strix report (Appendix A).

We have observed remarkable amounts of sand entrained by strong southeast wind at the crest of a 50 m high bluff above South Beach. Prominent, forested, transverse dunes are situated along the bluff rim. In some locations, sand is well exposed in excavations made to improve ocean views from the bluff crest.

Sand sheets extend north of the bluffs beneath forest soil. Wind blown sand is loose and highly erodible. We observed what appear to be naturally eroded holes and tunnels (soil pipes and caves) in dune sand along the South Beach bluff crest.

2.7 Groundwater Systems

The Island's groundwater systems are evaluated by Tupper (1996). His work uses available data to assess the availability of groundwater for domestic supplies, rates of groundwater consumption and the quality of selected well and spring water samples. Although Tupper's work is preliminary, it is systematic and valuable.

The Island's hydrogeology is complex and not yet fully understood. Groundwater systems on the Island are a valuable and locally vulnerable resource. Some are geotechnically significant (e.g., Indian Spring). Evidence of current development activity on the Island indicates that the number of wells counted by Tupper in 1996 (and cited by us below) must have increased.

Tupper identifies a single Main Aquifer on the Island. It appears to comprise the lower portion of the Quadra Sand and it extends beneath the entire island. He subdivides it into 6 groundwater domains as shown on his Map 1b. The domains are further subdivided along the Island's topographic divide that trends east to west. This aquifer provides excellent well capacities with theoretical values of greater than the 7.6 and 9.5 l cited by Tupper (p.20). The latter value is estimated from a well drilled to below sea level; perhaps below the Main Aquifer.

Tupper also identifies, on his Map 1b, 3 perched or shallow aquifers, including the Keefer Bay Aquifer, the 3-component West Aquifers and the Indian Point Aquifer. Tupper's mapping of the shallow aquifers is reproduced on Dwg. 14-197-0-1. These aquifers feed 4 springs: Indian Spring, Neilsen Spring, Julian Road South Spring and Sutherland Road North Spring. All but the Sutherland Road North Spring are used for domestic water. The Julian Road and Neilsen Springs have very low flows (Tupper, 1996, p. 18) and Indian Spring is the only public and reliable source of drinking water.

The Keefer Bay aquifer is defined by a cluster of shallow wells and well points. It occurs at a depth of 3 to 4.5 m below ground. Rates of consumption suggest it has a relatively high yield.

The West Perched Aquifers are based on the Island's relatively impermeable drift. Tupper estimates the extent of its 3 separate portions from the distribution of shallow dug wells and area springs. The east portion is related to Indian Springs but there are only 2 shallow wells in its 9 ha area. Groundwater clearly flows north from this area to Indian Springs (Tupper, 1996, p. 21). The central portion of the West Perched Aquifer has an area of about 30 ha and is located on the highest part of the Island. Its average depth is only 1.5 m and its waters rise to the ground surface after periods of rain. This portion of the aquifer supplies about 15 known shallow wells, some of which dry up seasonally.

The west portion of the system occupies about 36 ha in a broad, flat bowl that slopes southward to the sea. It supplies 12 wells from an average depth of 4.3 m. This portion has been affected by area development and it appears that it is recharged by surface water flows (Tupper, 1996, p. 21-22).

The Indian Point shallow aquifer is about 20 ha in extent and has at least 72 wells, almost all of which are shallow, extending to depths of 2 to 4.6 m (Tupper, 1996, p. 22). In spite of high demand, the wells have sustained yields. Tupper suggests there is considerable groundwater flow from the uplands to the east which supports his contention that the Main Aquifer is under hydrostatic pressure from the Burnett Road area westward.

In our judgment, hydrogeological investigations, including pre-development water level monitoring and water quality testing, are warranted if increased development is anticipated in shallow aquifer areas.

3. EROSION PROCESSES

Shoreline and bluff erosion is a widely recognized geological hazard. The BC Ministry of Environment and Parks (1987) presented a discussion paper on coastal environment construction. A paper on erosion at Indian Point on Savary Island was published by the BC Ministry of Environment, Lands and Parks (1993). Most shoreline erosion literature indicates that a building setback from eroding bluffs is the only cost-effective means of limiting risk to residential buildings.

Shoreline erosion, as defined by storm wave removal of sand, occurs at several locations on Savary Island. These include accreted beaches near Indian Point and the north side of Malaspina Promenade, just west of Mace Point, dune sand along South Beach and debris below steep bluff faces along the south shore.

From a development perspective, shoreline accretion or long term balance between erosion and accretion is ideal. Unfortunately, as pointed out by Bornhold et al (1996) for Indian Point, long periods of shoreline accretion and equilibrium are punctuated by significant erosion events.

Bluff erosion is a continuous, but episodic activity which involves regression of the bluff crest resulting from shoreline erosion at the toe or landslide activity, uncontrolled surface drainage, seepage erosion, falling trees and incautious human activity on the slope. Larger areas of bluff erosion are shown on Dwg. 14-197-0-1.

The rate of bluff erosion is reduced by established brush and tree cover on the slope and accumulations of gully and landslide debris and stranded logs and till-derived boulders which protect the steep slopes from direct storm wave attack. A heavy cover of broom was planted in 1912-1914 to limit erosion on the high bluff above South Beach (Strix, Section 2.2.1). Wildfires on the bluffs are likely to increase the rate of slope erosion.

4. BLUFF EROSION RATES

4.1 Sources of Information

In this Section, we present all of the data concerning the rate of erosion of the bluffs that has been collected by various investigations to allow the hazard limits discussed in Section 5 to be established. The sources of data are described below.

Previous estimates of bluff crest retreat were made by Klohn-Crippen Consultants Ltd. (Klohn-Crippen) in 1993 for a landowner, Bornhold et al (1996) and Golder Associates Ltd. (GAL) in 1999. GAL's report was provided for our information by the Regional District. We evaluated bluff erosion for a site at the east end of Malaspina Promenade and the same site as Klohn-Crippen (1993) on the south shore, about 1 km from Mace Point, for the landowner in 2001.

To provide further data regarding bluff erosion for this study, McElhanney Consulting Services Ltd. (McElhanney) was retained to evaluate bluff retreat using airphotos of the Island taken in 1967 and 1999.

4.2 Analysis Procedures

To establish a long term bluff erosion rate, Klohn-Crippen (1993) inferred that the existence of shallow water which extends for about 1.5 km offshore of the current shoreline at the study site (on the south shore about 1 km west of Mace Point) marks the position of an ancient sea cliff which has been subject to wave attack and erosion over the last 8000 years.

Information in Bornhold et al (1996) concerning bluff erosion rates is based on a comparative study of 1965 and 1982 aerial photos. They note (p. 7):

> "*the lack of reliably recognized datums over much of the island meant that the measurements, in general, had to be made on the total width from the north coast to the south coast along transects approximately normal to the axis of the island.*"

In effect, Bornholm et al measured the rate of narrowing of the Island by erosion or widening by accretion. Two of the authors, Drs. Bornhold and Conway, confirmed (*pers. com.*, August 2002) that numbers shown in the Geological Survey of Canada report are estimates of Island narrowing based on aerial photo measurements between north and south high tide lines, not bluff crests.

GAL (1999) estimated the rate of bluff erosion in the Second Point and Beacon Point areas using aerial photo interpretation. They reference the estimated rates of erosion to the natural boundary and survey cross sections.

TEL's evaluation of bluff erosion for sites along Malaspina Promenade and southwest of Mace Point utilized legal survey plans from 1910 and recent survey by the landowner.

McElhanney's work involved superimposition and comparison of ground detail from the 2 series of airphotos using photogrammetric techniques. The comparisons required the aerial photo images to be geometrically rectified using existing map control data. Measurements were made or attempted at 51 locations selected by TEL. No measurements were possible in areas obscured by trees, particularly along the north coast. Furthermore, McElhanney judges the distance measurements to be accurate to plus or minus 1 m.

4.3 Analysis Results

The bluff erosion rates (defined by the average over the period of record) obtained from the various studies described in Section 4.1 are presented on Dwg. 14-197-0-2 for each location studied. Except for Klohn-Crippen (1993), all of the studies reported herein consider a period of record of, at most, the last 90 years. In contrast, Klohn-Crippen's calculated rate of erosion is based on an 8000 year period. Considering the episodic nature of bluff retreat, Klohn-Crippen's rate, if based on a correct assumption, provides the most reliable estimation of all reported values. Additional comments relevant to each analysis are presented below.

Estimated rates of erosion estimated by Bornhold et al (1996) have an uncertain error. Except for bluff crest retreat measured at 3 locations over about 1 year, the numbers are estimates of total erosion (or accretion) between the north and south shores over 17 years. The authors do not differentiate rates of erosion on the north and south coasts and note:

> "*It can be assumed that, in general, erosion is considerably greater along the south coast than along the north whereas accretion can occur on either.*"

Bornhold et al (1996) show shoreline erosion rates are especially high on the west sides of Garnet, Whalebone and Beacon Points where refracting waves have strong effects.

At TEL's study area on Malaspina Promenade, the road right of way has been almost fully breached by waves developed by strong northwest winds and/or by refracted waves around Mace Point developed by southeast winds. Wave erosion may also be influenced by tidal effects.

The 1980 aerial photos show what appear to be waves billowing northwest from the narrow passage between Mace Point and Hurtado Point on Malaspina Peninsula.

4.4 Estimated Rates of Erosion Around Island

4.4.1 Mace Point to Garnet Point

This portion of the Island's shoreline is the most exposed to storm waves driven by prevailing southeasterly winds and it is reasonable to expect the rate of bluff crest retreat to be comparatively high. However, McElhanney's analysis of 7 locations along this section of shoreline indicates no apparent change in the bluff crest from 1967 to 1999. For a location about 1 km from Mace Point, shown on Dwg. 14-197-0-2, based on consideration of legal lot lines established during the 1910 subdivision in relation to the current top of bank, we concluded that the bluff crest retreated 12.5 m between 1910 and 2001 for an average erosion rate of 0.14 m/year. We consider our evaluation to be correct implying that the erosion took place between 1910 and 1967, confirming the episodic nature of bluff retreat around the Island's shoreline. In comparison, Klohn-Crippen (1993) estimated a long term erosion rate of 0.2 m/year.

4.4.2 Garnet Point to Whalebone Point

Bornhold et al (1996) measured a bluff crest erosion rate of 0.38 m/year on the west side of Garnet Point of over a 1year period in 1994-1995 ascribed to refracted wave effects. This very high rate of erosion is confirmed by McElhanney's estimated erosion rate of 0.34 m/year for the same location. However, McElhanney recorded no significant erosion over 32 years between the west side of Garnet Point and Whalebone Point.

4.4.3 Whalebone Point to Beacon Point

Between Whalebone Point and Beacon Point, McElhanney's analysis indicates no significant erosion. In comparison, Bornholm et al measured an erosion rate of 0.08 m/year on the west side of Whalebone Point and Golder (1999) estimated a rate of 0.07 m/year at 3 locations within 0.6 km of Beacon Point. It is evident that the erosion rate in this section of the shoreline is low.

4.4.4 Beacon Point to Indian Point

Around the west side of Beacon Point, there is some inconsistency in erosion rates determined by Bornholm et al, Golder and McElhanney. We tend to accept McElhanney's analysis which suggests the erosion rate is between 0.1 and 0.2 m/year within 0.5 km of Beacon Point.

Further west, for nearly 2 km, McElhanney indicates an erosion rate of between 0.13 and 0.40 m/year. This section of shoreline is the most extensive in exhibiting consistent and relatively high erosion rates.

Most of the remaining west facing shoreline up to Indian Point is shown by McElhanney to have negligible erosion, with the exception of the bay 0.5 km south of Indian Point where a 12 m bluff retreat was recorded, giving an average rate of 0.38 m/year.

4.4.5 North Shore

Of 18 locations studied by McElhanney along the north shore of the Island, only three showed measurable bluff retreat. The maximum retreat, equivalent to 0.25 m/year occurred on the east side of Second Point. These results are supported by Golder's 1999 analysis of the shoreline from 0.5 km west of Second Point to 0.3 km east of the Point.

At the east end of Malaspina Promenade, good agreement is shown between the average erosion rate of 0.19 m/year calculated by Thurber for the period 1910 to 1989 and the average rate of 0.14 m/year calculated by McElhanney for 32 years between 1967 and 1999.

5. PRELIMINARY BLUFF CREST HAZARD SETBACKS

5.1 Klohn-Crippen's Recommendations

Klohn-Crippen (1993) recommended that permanent buildings on the top of the bluff be set back 30 m behind the intersection of a line drawn at 35° from the toe of the slope with the ground on top of the bluff. The 30 m distance was based on a 200 year erosion allowance of 0.15 m/year, somewhat less than the long term 0.2 m/year calculated by geologic reasoning. At the location studied by Klohn-Crippen, the setback from the crest of the bluff determined in accordance with this criteria was about 40 m.

5.2 Golder Associates' Recommendations

Golder Associates (1999) made the following recommendations for building setbacks from the crest of the bluff in the west portion of DL1375 , east and west of Second Point on the north shore and Beacon Point on the South Shore for a 50 year horizon:

- From the natural boundary at the toe of the bluff extend a horizontal distance equal to the estimated erosion over the 50 year assessment period.
- Extend the line at 40° to intersect the ground surface at the top of the bluff.
- Add a horizontal setback of 10 m for slopes up to 20 m high and 15 m for slopes more than 20 m high.

5.3 BC Ministry of Water, Land and Air Protection (formerly Environment, Lands and Parks) Subdivision Requirements

The Ministry's August 3, 2000 memorandum concerning a proposed subdivision on Savary Island refers to the *Floodplain Development Control Program Procedure Manual* of the *Interim Coastal Procedures* published in November 1988. This Manual states that no building shall be closer than 15 m, to or less than 1.5 m above, the natural boundary along a coastal shoreline [2]. The setback from the natural boundary can be reduced to 7.5 m where the shoreline is bedrock. In bluff areas on the Island, the natural boundary will generally be defined by the high water mark along the toe of the bluff. The Manual further states that where the building site

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[2] The BC Land Act (Section 1) defines the naturel boundary as "the visible high water mark of any lake, river, stream or other body of water where the presence and action of the water are so common and usual, and so long continued in all ordinary years, as to mark on the soil of the bed of the body of water a character distinct from that of its banks, in respect to vegetation as well as in respect to the nature of the soil itself."

is at the top of a steep coastal bluff the subject to erosion, the setback, as measured from the toe of the bluff shall be a horizontal distance equal to 3 times the height of the bluff. This requirement is illustrated on Figure 1a. The Ministry's memorandum points out that this criterion makes no allowance for future erosion at the toe of the bluff caused by wave action. The memorandum concluded that the Manual's requirements were not sufficiently conservative and recommended that the building setback line should be based on revised criteria similar to those recommended by Golder Associates (1999), except for an increased assessment period of 100 years for the bluff erosion allowance. These criteria are illustrated on Figure 1b and defined as follows:

- From the natural boundary at the toe of the bluff, extend a horizontal distance equal to the estimated erosion over 100 years, subject to a minimum allowance of 15 m (equivalent to an erosion rate of 0.15 m/year).

- Extend the line by the typical natural slope angle (40°) to intersect the ground surface at the top of the bluff.

- Add a further horizontal setback of 10 m for slopes up to 20 m high and 15 m for slopes more than 20 m high to define the geotechnical hazard setback.

- Check that the total horizontal setback is more than 50 m from the natural boundary.

As indicated in the Ministry's memorandum, application of these guidelines results in a 100 year building setback varying from about 50 m to about 120 m from the bluff crest for the site studied by Golder Associates

5.4 Recommended Setback Criteria

We recommend that bluff crest setback be determined in accordance with the revised criteria provided by the MWLAP and presented in Section 5.3, except that, in accordance with the terms of reference established by the Regional District, the erosion period is to be 50 years and 200 years and a 40° line should be used to define the stable slope angle. However, we consider that the Ministry's 15 m minimum erosion allowance for a 100 year period for shoreline areas where the observed rate is low or zero, but could increase over the long term, should also apply to the 200 year period. This is equivalent to an average erosion rate of 0.075 m/year, similar to the minimum rate reported by Golder Associates (1999) but conservative in comparison to the zero rate reported by McElhanney (2002) for many locations around the Island's shoreline for the 32 year period. For the 50 year horizon, we recommend a minimum erosion allowance of 5 m, equivalent to an average erosion rate of 0.1 m/year. These criteria are illustrated on Figure 2. Setbacks determined in accordance with these criteria, subject to a minimum horizontal setback of 50 m from the natural boundary, are shown on Dwg. 14-197-0-3 and discussed in Section 5.5. A minimum setback of 7.5 m should apply where the natural boundary is formed by bedrock bluffs for 50 and 200 year horizons.

It should be recognized that the setbacks recommended herein are for guidance only and can be revised, more likely reduced than increased, by a site specific geotechnical study carried out by a suitably experienced geotechnical engineer. It should also be recognized that this study and its recommendations make no allowance for the rise in sea level which is projected to occur due to global warming. One estimate, by the US Environmental Protection Agency, is that the most likely rise in sea level is 0.15 m by year 2050 and 0.34 m by year 2100. Such an increase in sea level may cause the rate of bluff crest regression to increase significantly from the rates identified to date. Shoreline erosion will also increase.

Building setbacks elsewhere on the Island where no bluff exists, such as Indian Point, require a setback of not less than 15 m from the natural boundary in accordance with MWLAP's guidelines. However, even though we are not aware of any instances of building damage due to proximity to the natural boundary along the shoreline to account for the episodic, localized and sometimes intense erosion referred to in Section 3, we recommend a minimum setback of 20 m from the current natural boundary for 50 and 200 year horizons.

5.5 Bluff Setbacks

Building setbacks from the current bluff crest for 50 and 200 year horizons determined by application of the recommendations in Section 5.4 are shown on Dwg. 14-197-0-3. It should be recognized that the setbacks are preliminary and for guidance only. They assume that the current slope angle of the bluff is 40° and that the contours on the base plan accurately represent the bluff height. They should be defined in the field by survey of the bluff height and crest and consideration of the erosion which might have taken place since this report was prepared.

Additional comments are presented below.

- Setbacks established in the Golder Associates (1999) study of DL1375 on the north and south shorelines for the 50 year horizon have not been changed in these locations. The 200 year setback allows for 150 years of additional erosion.

- A 7.5 m setback from the natural boundary is shown for the bedrock-controlled shoreline around Mace Point. This will protect buildings from flooding due to wave run-up.

6. SUPPLEMENTARY GEOTECHNICAL RECOMMENDATIONS

6.1 Introduction

Although our report focuses on geotechnical hazard issues related to bluff erosion on the Island, we consider that other geotechnical issues require discussion. These issues include general advice to landowners to limit the need for geotechnical services and adversities which may arise if the concepts cannot be implemented.

6.2 Least Costly Hazard and Risk Prevention Concepts

The following hazard and risk prevention concepts are the easiest and least costly to apply by landowners who plan development activity:

- Do not locate residential buildings on or near the crest or base of steep slopes.

- Do not direct surface water or a significant quantity of groundwater onto any portion of a steep slope.

- Do not dump fill (including soil, rock, lawn clippings, brush cuttings or trash) on or below the crest of a steep slope.

- Do not excavate soil on any portion of a steep slope.

6.3 Septic Fields

In general, almost any septic system will pollute groundwater directly beneath it but as effluent travels through soil, purification takes place and effluent may be rapidly returned to drinking water quality. If aerobic conditions are maintained in well drained soils, harmful bacteria and viruses can be absorbed over remarkably short flow distances above the groundwater level.

The density of septic fields and their relationship to shallow aquifers present significant potential problems on Savary Island. Notably, the residential lot densities shown on the two Garden and Taylor Survey Maps of 1910 are impossible to achieve given modern septic field siting standards. If septic field densities are to increase in shallow aquifer areas, hydrogeological investigations are warranted. Tupper's 1996 findings and his delineation of aquifer areas are critically important in considering septic field design and placement. The BC Health Officer in Powell River provides guidelines and instructions for septic field design including their proximity to steep slopes.

6.4 Road Ditch and Culvert Systems

The Island's ditch and culvert systems allow passage of storm water but, to the best of our knowledge, all most such facilities allow excess water to infiltrate into the ground. Tupper (1996, p. 21-22) describes a situation in which newly constructed road ditches appear to have diverted surface water which supplied a shallow well in the west portion of the West Perched Aquifer.

Hydrogeological investigations may be warranted if ditch and culvert systems are planned in other shallow aquifer areas. We recommend that storm water directed to bluffs or other steep slopes should be conveyed downslope in well secured and periodically inspected pipe systems. Outlets for such systems at the base of steep slopes or along shoreline slopes are likely to require considerable erosion protection.

The outer edge of the road directly above Indian Spring is being eroded by surface runoff that originates on Vancouver Boulevard and Cunningham Road. Road repair will require interception and redirection of road drainage.

6.5 Roof and Footing Drain Systems

Roof and footing drain outlets or other concentrated water flows should not be directed to bluff slopes or crests. We do not recommend that such drainage be conveyed downslope in pipes because individual homeowners cannot take responsibility for periodic inspection and repair of pipe systems.

If residential buildings are located well away from bluff crests and if roof water is not collected for gardening or other needs, we recommend that roof and footing drains be directed to surface outlets with appropriate erosion protection or into engineer-designed rock pits.

6.6 Uncontrolled Soil Excavation and Fill Placement

Incautious soil excavation on or at the foot of steep slopes and uncontrolled fill dumping on or below slope crests may each generate significant over-steepening effects. Some steep slope excavation and filling can proceed with geotechnical design and supervision.

6.7 Bluff Tree and Brush Clearing

Trees may be cleared from a development site for many reasons. Geotechnical specialists are often asked to comment on hazard consequences after trees are removed from steep slopes or slope crests. Tree roots draw water from the soil and also tend to anchor soil masses on or near steep slopes. On the other hand, large trees add considerable mass to potentially unstable ground. Wind may generate adverse dynamic effects in large trees on unstable ground. Trees will not remove excess volumes of water; rates of soil water removal decline during dormant periods. Tree removal on steep slopes may cause considerable ground disturbance.

Ecological issues are pertinent to considerations of tree removal, as discussed by Strix. Geotechnical issues defy ready analyses and professional judgment must prevail. We recommend that no large trees be removed from the bluffs or bluff crests. Heavy brush should be promoted and maintained for the same reason. Danger trees require advice from a professional arborist.

6.8 Guidelines for Professional Reporting

Our experience in geotechnical hazard and risk assessment work indicates that Regional Districts and municipalities are best served by BC geotechnical professionals (including professional engineers and geoscientists) if guidelines for professional reporting are made available to permit applicants.

Guidelines should differentiate professionally recognized roles for engineers and geoscientists. Hazard and risk assessment investigations should only be conducted by professionals with required training or experience. Designated or nominated professionals should confirm that they have requisite credentials.

Reports should be supported with factual data (including exploratory test pits or drill holes as necessary), slope monitoring results, engineering analyses, professional judgments, determination of hazard and risk, technical recommendations and certification required by the BC Local Government Act. All such reports must be signed and sealed in accordance with requirements of the Engineers and Geoscientists Act of BC. Sketch maps and diagrams, if not survey maps, are almost always required. In general, we recommend that reports should be substantive enough to be constructively reviewed (if requested by the Regional District) by an independent professional without a requirement to engage in fieldwork.

7. PROPOSED REVISIONS TO HAZARD LAND DEVELOPMENT GUIDELINES

7.1 General

The current Savary Island OCP is a draft document. It defines 5 development guideline (DG) areas. The guidelines are non regulatory and are intended to protect the Island's natural environment and residential development from hazardous conditions such as bluff erosion activity. These guidelines are included in Appendix A. There is no provision for issuance or refusal of building permits by the Regional District. Septic field approvals are regulated by the BC Health Act and shoreline development is regulated by the BC Land Act.

Presumably, Island landowners are expected to voluntarily follow the guidelines. However, unenforceable geotechnical recommendations involving consideration of hazard and risk provide no assurance over public health and safety.

7.2 DG-1 Shoreline Areas

DG-1 areas form an almost continuous band along and above the Island shoreline. Mapped DG-1 areas include accreted beach areas (i.e. the margins of Indian Point and the south shore of Keefer Bay) and almost all Island bluffs and zones along bluff crests.

For geotechnical clarification, we suggest that DG-1 areas be revised to only include low-relief shorelines where residential development is subject to minimum setback requirements from the natural boundary. We suggest a new classification (DG-1B) for bluff slopes and along bluff crests where our recommended slope hazard limits apply. The following discussion assumes that DG-1 areas only include portions of subdivided land along Indian Point and the south shore of Keefer Bay between Mace Point and Phyllis Road near First Point.

Item a

As we observe in Footnote 6 and considering Provincial guidelines for 200 year flood proofing and 475 year landslide occurrence with 10% probability, 50 years is a short period of time to consider building vulnerability to erosion hazards. The point may be moot because the minimum building setback is defined by the BC Land Act. Geotechnical specialists may recommend greater but not lesser setbacks.

Item d

This item suggests limiting garden watering and other surface water discharges within 30 m of the top of the shoreline, presumably meaning the natural boundary. We have no objection to the general intent of this item but, given probable rates of soil evapotranspiration, the permeable nature of accreted beach deposits and the presence of shallow aquifers beneath Indian Point and south Keefer Bay, garden watering is highly unlikely to generate significant or observable shoreline erosion effects.

Item h

This item seeks to avoid shoreline erosion by limiting foot access to public trails. This is a worthy goal, but potential erosion effects in low-relief beach front areas may best be limited by construction of removable or permanent wooden walkways.

Item i

This notes that works to protect against natural shoreline erosion shoreline are not recommended. Somewhat inconsistently, it then notes that such works should not alter or disturb shoreline habitat. We agree that *ad hoc* or piecemeal shoreline protection measures may do more harm than good. However, BC Ministry of Water Land and Air Protection approval officials must approve or reject such measures.

As best we can tell, beach groins built between Garnet and Whalebone Points may have some positive effect in retaining beech sand. The groins and a cover of broom may help to limit erosion along the adjacent bluffs (Dwg. 14-197-0-1). We do not detect adverse shoreline changes to the west, the direction in which offshore sediment migrates. We suggest that professionally designed shoreline protection measures warrant consideration on Malaspina Promenade near Mace Point.

7.3 DG-1B Bluff Residential Areas

We recommend that a new designation (DG-1B) be established to include bluff slopes and the recommended 15 to 30 m to 40 m preliminary bluff hazard limits presented in Section 5. The following discussion conforms to the items given in the current DG-1 guidelines. The discussion applies to all subdivided land along the Island's north and south bluffs except areas where previous, more detailed geotechnical evaluations have defined building setbacks (see Section 5.4).

Item a

As we observe in Footnote 6 and considering Provincial guidelines for 200 year flood proofing and 475 year landslide occurrence, 50 years is a short period of time to consider the eventuality of erosion hazards. However, Island land owners and their elected representatives may choose a 50 year or longer period. In our judgment, recommended preliminary bluff hazard limits be can be interpreted to approximate erosion limits some 200 years hence.

Item d

This item suggests limiting garden watering and other surface water discharges within 30 m of the bluff crests. In our judgment it is prudent not to place a garden within 15 m or so of a bluff crest but with this advice, limited hose watering or sprinkling is unlikely to have significant or observable bluff erosion effects. We suggest that below-ground irrigations systems be equipped with shut off valves that will be triggered by sudden losses in system pressure. In our judgment, Section 6.5 recommendations for roof and footing drains are most important in bluff crest areas.

Item e

This item is intended to preserve vegetation to preserve habitat and prevent erosion. In our judgment, a recommended 5 m wide leave strip from the top of bluff slope is too narrow. Instead, the leave strip should be defined by the possible presence of a transverse sand dune as along the crest above south beach. In some places this dune is very wide and it is covered with trees and brush. We recommend that because of geotechnical concerns over soil erosion and slope instability, no vegetation should be removed from any flank or crest of a transverse dune along a bluff crest. This means that no transverse dune should be excavated away to build a home or improve an ocean view. (Also see Section 6.6).

Item h

This item suggests seeks to avoid bluff erosion by limiting foot access to public trails. Potential erosion effects in on steep bluff slopes may best be limited by construction of removable or permanent wooden walkways in selected locations.

Item i

This item is intended to prevent slope protection measures from causing environmental or property damage. The narrow width of most bluff crest lots means slope repairs on individual lots will rarely avoid affecting adjacent land. Furthermore, major slope repairs on individual residential lots are unlikely to be practicable or economically feasible.

Considering this, new houses located near bluff crests without the benefit of professional geotechnical advice should be constructed in a manner that allows them to be moved, as readily as possible, to a new location further away from the crest.

7.4 DG-2 Ecologically Sensitive Areas

Six ecologically sensitive areas are defined on the Island, all partially active shoreline dune areas. We do not endorse residential development of these areas and although blowing sand can be a considerable nuisance and freshly deposited sand may require continuous clean up, they are not geotechnically hazardous in the normal context of geotechnical hazard and risk assessment.

Five areas are adjacent to steep bluffs along the south shore; one area is located on the accreted beach just east of Indian Point. Aerial photos from 1999 indicate none have residential development. The western 3 areas are located beyond the limits of subdivided land in the Sunset Trail shoreline corridor and near Indian Point. We assume no residential development is allowed at these locations.

The eastern 3 areas are located along the south margin of the Inland Dunes (DG-3 Area), a significant portion of which is now jointly owned by a private citizen and the Islands Trust. Geotechnical engineering guidance for residential development was provided by GAL (1999) in the DG-2 area on the east side of Beacon Point. One of the two ecologically sensitive areas east of here is partially located in a bluff area where we recommend a 30 m wide bluff hazard area along the crest (Dwg, 14-197-0-3). If development is allowed in the area above Duck Bay, our judgment is that building setbacks from the natural boundary should be defined by the BC Land Act .

7.5 DG-3 Inland Dune Area

This area includes the relict dunes on the central Island. Part of the dune area west of Leighton Road is densely subdivided. Except in the area previously investigated by GAL in 1999 (Dwg. 14-197-0-3) our 15 and 30 m preliminary bluff slope hazard limits apply along the north and south shores. We do not necessarily endorse residential development on Inland dunes but, like comparable features in DG-2 areas, they are not distinctly hazardous.

7.6 DG-4 Indian Springs Watershed

The Indian Springs Watershed is in a densely subdivided portion of the Island. The watershed area is mapped by Tupper (1996) and is also shown on Dwg. 14-197-0-1. Indian Springs is a licenced water supply for several residents and a public water supply for many others. The area and its guidelines are defined to protect the springs from excess drawdown of its aquifer and from septic pollution. Considering the importance of other shallow aquifers described in Section 2.7, it is not clear why they are designated with similar development guideline areas.

We attempted to map the Indian Springs aquifer limits by looking for changes in vegetation. We were not successful. Tupper’s 1996 work remains the best attempt to date.

Severe erosion is occurring on an apparently unregistered road right of way above the springs. Some erosion appears to be caused by groundwater discharge on the north bluff. We visited the site one day after heavy rain in early June 2002. Riprap placed we are told, by

Ministry of Transportation personnel in an apparent attempt to limit erosion activity (and which we observed in place in early May) was eroded away during the heavy rain. Area residents pointed out that surface water originating on a newly constructed section of Vancouver Boulevard. and on Cunningham Road flowed to the erosion site and caused erosion of the riprap which is now deposited on the beach below. We confirmed these observations. On July 22, we observed that some surface water may have also originated in the forest just south of the erosion site and that groundwater also appears to affect the erosion site. Also on July 12, we were informed that area residents, not the Ministry of Transportation, had constructed the new section of Vancouver Blvd. The Indian Springs Road erosion site requires investigation, design and construction to reopen the road. In the meantime, groundwater and surface water erosion activity will continue.

Our comments on the draft development guidelines for the Indian Springs watershed are as follows:

Item a

Section 5.3 recommends that a 30 m wide preliminary bluff hazard limit be defined along the bluff crest above Indian Springs. Evidence of seepage related slope instability and severe surface water erosion justify this recommendation.

It is not unreasonable to limit disturbance of vegetation within 10 m of the springs although adjacent vegetation is already disturbed by natural processes. Vegetation along the top of the bluff was removed to build the local roadway. It is not unreasonable to limit use of chemicals (presumably fertilizers, cleaning solvents and similar products) within 30 m of the springs but chemical spills could adversely affect the water from greater distances.

In our judgment, prohibition of septic systems within 100 m of the springs and on more than 40% of residential lots within the aquifer does not ensure that the Indian Springs will remain uncontaminated. The only way to investigate the possibility of spring water contamination, ground water utilization and septic field densities is to conduct a detailed hydrogeological evaluation of the aquifer system. This admonition covers most elements of Items b through g of the draft guidelines.

Surface drainage has not been controlled at Indian Springs and the shallow aquifer is susceptible to several development adversities. In our judgment is that it is unlikely that voluntary compliance with well intended but generalized guidelines will adequately protect Indian Springs.

7.7 DG-5 Retention of Vegetation and Development of Large Parcels

This guideline has no bearing on geotechnical hazards. Bluff crest portions of large parcels are affected by our recommended hazard area limits.

8. ENVIRONMENTAL ISSUES

8.1 General

Highlights from Strix's report are presented in this Section. It does not form a complete summary of the report and reference should be made to Appendix B for a complete assessment of the environmental issues.

8.2 Dune Areas

Strix describes various dune settings, dune formation processes, plant successions and the environmental values in the Island’s unique dune areas. Relict dune environments do not pose particularly difficult geotechnical problems but development activity will destroy the features themselves and their sensitive ecology.

8.3 Development Guideline Areas

Strix discusses several Development Guideline Areas including DG-1 (Shoreline Areas), DG-2 (Ecologically Sensitive Areas) and DG-3 (the Inland Dune Area). These areas were defined prior to our work. Strix (p.1) recommends subclassification of several DG-2 areas and suggests (p. 14) that further work may be required to identify defining ecologic features in the Indian Spring area (DG-4). It is also recommended that Mace Point be defined as an Ecologically Sensitive Area (p. 14).

9. SUMMARY OF CONCLUSIONS

Savary Island will continue to be reduced in width from south to north by natural erosion forces. Soil erosion, including landslide activity is a constraint to residential development along south island bluffs. Bluff wildfires are an ominous potential hazard which could greatly increase the rate of local slope erosion. If global warming causes a significant rise in sea level, erosion rates will almost certainly increase from those of the past.

Much of the island was densely subdivided early in 1910 but there are indications that dense residential development may eventually generate adversities including septic contamination of shallow aquifers which are commonly utilized for domestic water supplies. Dense residential development is also likely to affect portions of the Island's unusual sand dunes and their plant communities.

______Non-regulatory (i.e. un-enforceable) geotechnical recommendations involving consideration of hazard and risk provide no assurance over public health and safety. Our geotechnical evaluation of Indian Springs Watershed guidelines suggests that recent *ad hoc* development activity and non-regulatory guidelines with no scientific grounding are unlikely to protect the Indian Springs aquifer system.

REFERENCES

REPORTS

Bornhold, B. D., K. W. Conway and T. Sagayama. 1996. Coastal Sedimentary Processes, Savary Island, BC. A Preliminary Assessment. Geological Survey of Canada Open File.

BC Ministry of Environment and Parks, Water Management Branch, 1987. Coastal environment and coastal construction, a discussion paper *re* elevations and setbacks for flood and erosion prone areas. Prepared by B. J. Holden.

BC Ministry of Environment, Lands and Parks, 1993. An investigation of erosion, Indian Point, Savary Island. Prepared by B. J. Holden.

BC Ministry of Environment, Lands and Parks, 2000. Savary Island Proposed Subdivision of D.L. 1375 - Coastal Setbacks. Memorandum to File 24-00-95-005.

BC Ministry of Forests, 1988. Biogeoclimatic zones of British Columbia. 1:2,000,000 scale map.

Clague, J. J. , 1977. Quadra Sand: A study of the Late Pleistocene geology and geomorphic history of coastal southwest British Columbia. Geological Survey of Canada Paper 77-14.

Dunster, K., 2000. Sand dune ecosystems on Savary Island, BC with particular reference to DL 1375. Report to Savary Island Land Trust.

Eis, S. and D. Craigdallie. 1977. Landscape Analysis of Savary Island. Report to Powell River Regional District.

Golder Associates Ltd., 1999. Geotechnical investigation and report, shoreline erosion and stability setbacks, west portion of DL 1375, Savary Island, BC. Report to Mr. T. Mishaikov.

Klohn-Crippen Consultants Ltd., 1993. Geotechnical assessment, Savary Island property. Report to Mr. G. Hungerford.

Savary Island Official Community Plan - Background Information, 1997.

Tupper, D. W., 1996. A preliminary assessment of the groundwater resources of Savary Island, BC. Report to Powell River Regional District. In association with Pottinger Gaherty Environmental Consultants Ltd.

MAPS

BC Ministry Environment, 1982. 92F.096.2.3, 2.4 and 92F.097 1.3, 3.1. 1:5,000 scale with 2 m contours and physical features shown.

Fisheries and Oceans Canada. 1999, Chart 3513, Strait of Georgia, North Portion. 1:80,000 scale.

Fisheries and Oceans Canada. 1992. Chart 3538. Desolation Sound and Sutil Channel. 1:40.000 scale.

Garden and Taylor Land Surveyors, 1910. Savary Island Park showing subdivision of Parts of DL 1372 and 1373, (East Island) New Westminster District. 1 inch = 200 ft. Dated June 10, 1910.

Garden and Taylor Land Surveyors, 1910. Savary Island Summer Resort showing subdivision of Lots 1376 and 1377. (West Island) New Westminster District. I inch = 200 ft. Dated June 10, 1910.

G. F. Drabble 1891 Survey of Savary Island. Plotted by Anonymous from original survey notes, 1968. 1 inch = 400 ft. Survey data plotted by Underhill and Underhill Surveyors, Vancouver. November 25, 1968.

NTS 92F/15 (Powell River) 1:50,000 scale

AERIAL PHOTOS

Year	Flight Lines	Photo Numbers
1965	BC4319	157-161, 168, 169
		168-169
1982	BC82004	128,132,138
	BC82011	178 .
1994	30BCC941439	001-009
1999	167330 R352	L29 1-7