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Islands Trust
#200 - 1627 Fort Street
Victoria, B.C.
V8R 1H8

Attn: Mr. R. Kojima, Island Planner

Dear Sir:

Re: Geological Hazard Mapping Project
Galiano Island, B.C.

We have undertaken an assessment of available geological hazard (geohazard) mapping methodologies and have provided associated guidance for development of a mapping program for Galiano Island. Our objective was to identify land that may be potentially hazardous to proposed development because of a combination of steep slopes and geologic conditions, and provide recommendations for consideration to restrict development that may increase or exacerbate such hazardous areas.

Background

We have undertaken similar work for two other Gulf Islands, with North Pender Island being the pilot project and Salt Spring Island following a similar methodology. In the course of our development, we reviewed alternative GIS based approaches for developing geohazard mapping, including the probabilistic infinite slope analysis (PISA) mapping program. These methods all rely on the same elevation information that has been obtained using recent aerial photography to generate 2 m contour interval topographic mapping, from which a Digital Elevation Model (DEM) was created using 5 m pixilation. However, mathematical models are entirely dependent on the input variables. In such models, slope gradient, geology type and rock fracture characteristics, soil type, occurrence of surface and ground water, and presence of vegetation are all considered as input variables, along with seismic acceleration when considered. Of this information, only slope gradient is readily available from the existing data capture systems at a resolution that would be appropriate and suitable for development of mapping to be used in prediction and assessment of geohazards at the scale of most residential properties.

It is also important to note that a model that uses an increased number of variables would inherently require more aerial photo interpretation and associated field work/ground truthing to confirm that the model is reasonably representative of the actual ground conditions. With multiple parameters affecting the selected simulation model in different ways, it becomes more complex to determine which parameters have the greatest influence on the results. In addition, inclusion of seismic effects further compounds the problem of identifying the predicted driving mechanism of failure.

Accordingly, we have recommended adopting a form of slope classification on the basis of the known occurrence of terrain failure on increasingly steep slopes as inclination itself is believed to be the most reliable parameter for developing mapping that identifies hazardous or potentially hazardous areas. In this regard, our work included a review of the available elevation data and inherent limitations of such for use in geohazard mapping, an assessment of draft mapping output, refinement of a slope gradient classification system, and recommendations relating to filtering for an end result. We have also undertaken a comparison of the predicted classification with the site conditions at several locations to verify that the mapping reasonably reflects the field conditions.

Geologic Regime

The geologic regime of Galiano Island is relatively simple in comparison to some of the other Gulf Islands. The sedimentary bedrock is comprised of the Gabriola Formation of the Nanaimo Group, typically consisting of strata of conglomerate, massively bedded sandstone, interbedded shale, and limestone, varying spatially in thickness, all deposited during the late Cretaceous period (70 to 65 Million years ago). The rock is commonly moderately to relatively highly fractured due to post-Tertiary (1.6 Million years ago) faulting, tilting and uplift that has affected the region. Isostatic rebound following glacial unloading as well as stress relief is believed to have resulted in further development of bedrock fractures – particularly fractures sub-parallel to the slope faces. The surficial soils mapping along with our experience and observations of ground exposure indicates that the soils on Galiano Island are typically very thin silty and/or sandy marine deposits, basal glacial till, undifferentiated colluvium, and/or weathered bedrock.

Geohazards

It is essential for development of any geohazard mapping program to recognize modes of natural hazard associated with steep slopes that might impact development. The most common natural geohazards on Galiano Island consist of rock slope instability and associated rolling rockfall. Landslides, landslip or creep (solifluction) and surficial soil erosion are less common but do occur locally on the Island. Additional hazards such as shoreline erosion, tsunami, windthrow, and flooding may be present but are not purely geologic in nature or consist of either significantly low risk or perceived impact that they have not been addressed herein. We have not attempted to identify areas where past anthropogenic modifications such as excavation and/or fill placement may have resulted in an associated hazard, although such are significant in some areas.
Geohazard associated with rock slope failures is typically the result of rock falls or topples that are usually sudden and occur on steep slopes. These failures may be initiated by imperceptible ongoing natural processes (weathering by the action of freeze/thaw, heat/cool, expansion/contraction, root

heave, and/or animal activity), or they may be triggered by seismic activity. In a rock fall, rocks may fall, bounce, or roll down the slope. A topple occurs when part of a steep slope breaks loose and rotates forward. In either case, an associated hazard exists to development at or near (back of) the crest of slope, as well as to development within the rockfall shadow or rollout zone below. Our experience indicates that the primary natural geohazard on Galiano Island is in the form of rockfall hazard – either within the rockfall shadow or near the crest of steep slopes that might be affected during/subsequent to a large scale rock fall.

A landslip or landslide occurs when the gravitational force that is pulling the slope downward exceeds the shear strength of the materials that comprise the slope. These failures commonly occur in areas where the soil is saturated with water from heavy rains or snowmelt. Changes in groundwater, disturbance or change of a slope by man-made construction activities are typically contributory factors. The soils on Galiano Island may be prone to surface erosion and shallow landslip, however, the Island does not have many areas that are prone to large scale/deep seated landslip or landslide instability because of the limited soil thickness and proximity to bedrock.

Creep (solifluction) is the often imperceptibly slow, steady, downward movement of slope-forming overburden soil or weak rock. Creep can occur seasonally, where movement is within the depth of soil affected by seasonal changes in soil moisture, or can be continuous or progressive. Creep is indicated by curved tree trunks, bent fences or retaining walls, tilted poles or fences, and small soil ripples or ridges. Our experience indicates that this type of slope movement is less common and more localized on Galiano Island than other types of slope movement.

Soil erosion is the downslope transport of soil particles most commonly by water, particularly with unprotected silty or sandy soils. It is often a slow process that can continue relatively unnoticed, or it may be more rapid and perceptible. The impact of raindrops is a significant mechanism contributing to soil erosion, along with channelization of surface runoff. Naturally, the steeper and longer a given slope the more susceptible it is to soil erosion, particularly if existing vegetation is disturbed and/or removed, or if surface runoff patterns are modified. Surficial soil erosion is a significant consideration on Galiano Island where removal of vegetation and/or extensive disturbance on steep slopes has occurred.

Coastal shoreline erosion is not typically considered a significant hazard on Galiano Island and although it could be considered a geohazard in terms of land planning, we have not addressed such in the course of the current assignment. It is also a common regulatory requirement that approval be sought for various development/land enhancement activities proximal to the shoreline.

Galiano Island is located in a region that may be affected by a Cascadia subduction seismic event that could induce instability on many of the moderate to steeply inclined slopes. There have been recent changes to the B.C. Building Code (as of February 1, 2010) and adoption of the Legislated Landslide Hazard Assessment for single family residential development. These changes require consideration of a slope instability resulting from a seismic event with a 2% probability of exceedance in 50 years (1 in 2,475 year event), whereas previously, the Office of Housing and Construction of the Building Policy Branch of the Government of B.C. had adopted a 10% probability in 50 years of a landslide affecting a structure as its threshold level of landslide safety. This results in a performance criteria for slope hazards where the threat to "life safety" for single family residential properties is less than a 2% chance in 50 years, with such now stipulated by the B.C. Building Code and assessed in advance of issuance of building permits.

Assessment of risk tolerance (ie: the amount of risk any given land use activity can be exposed to) should not be within the practice of geotechnical professionals. It is important to recognize that there is some degree of risk in almost every aspect of day to day life. Risk tolerance is a complex issue that takes into account factors such as personal and societal hazard acceptance values, engineering practices, and assessment standards. Many countries subject to substantial geohazards have implemented risk tolerance criteria for consideration of proposed development. In British Columbia, assigned risk tolerance and hazard return periods vary depending on the local government and the type of geohazard. For example, one regional district considers flooding at a 200 year return period, landslip and seismic induced rockfall at a 2,475 year return period, while non seismic rockfall was considered at a 475 year return period.

We believe that the geohazards discussed should be considered with a 10% probability of exceedance in 50 years (1 in 475 year return period), as the proposed Geological Hazard mapping project is not intended for residential construction. Any land development related to or potentially affecting future or existing residences should be assessed on a site specific basis considering the required 2% probability of exceedance standard.

Hazard Designation

Considering the above, the principal geohazards on Galiano Island consist of rockfall hazard, with localized areas prone to landslip and/or landslide, creep, and surficial soil erosion. As discussed, the slope gradient is considered the most significant characteristic that affects the hazard mapping for most forms of slope instability that are anticipated on Galiano Island. We have reviewed available literature, which supported by our own experience, indicates that slopes less than 3 H:1 V (Horizontal : Vertical), or 18.5 degrees (33%), over greater than a 6 m distance are not typically prone to risk of initiation of slope movement, including landslip, landslide, or rockfall, and although surficial erosion may occur, it would not normally be considered a hazard. It should be noted, although it is less frequent, that rock block slides and slumps may occur at a critical minimal slope of 15 degrees under particular conditions, such as where bedrock has well-defined fracture or bedding plans dipping out of slope, or the rock is extensively fractured.

Slopes steeper than this, up to 1 H : 1 V or 45 degrees (100%), over greater than a 6 m distance may potentially be prone to geohazard, depending on the site conditions. Slopes steeper than 45 degrees would generally be considered highly probable for one or a combination of the noted geohazards, particularly during low to moderate seismic activity.

We have defined three classifications based on slope gradient for geohazard mapping to be used as a planning tool on Galiano Island: Low Hazard Areas, Moderate Hazard Areas, and High Hazard Areas. Those areas not included in one of the three classifications are not considered at risk of failure under normal circumstances.

The Low Hazard Areas are those areas that are low to moderately steep, inclined from 15 degrees to 22.5 degrees, such that they may be subject to limited geohazard. It is possible that a slope in this classification may experience periodic localized raveling or total failure under extremely adverse conditions which have a relatively low probability of occurrence (ie. high magnitude earth quake). This is not to say that all properties identified with slope gradients within the limits of the Low Hazard Area are in fact at risk or subject to such hazard, but rather, that they are potentially subject to such hazard. It is expected that there will be locations on the Island that have been identified as Low Hazard Areas where the geologic site conditions are favourable such that a geohazard does not exist. It should be recognized that it is possible that some areas may not have been identified in the mapping program due to the data limitations discussed below, although a site assessment may indicate that such should have been identified as being exposed to a geohazard.

The Moderate Hazard Areas are those slopes inclined steeper than 22.5 degrees but less than 45 degrees. Areas included within this classification have a moderate probability of failure under severe conditions. These slopes are best considered as possible hazard areas that may exhibit a geohazard risk.

The High Hazard Areas are those slopes inclined steeper than 1 H:1 V or 45 degrees. Geologic processes on slopes of this magnitude resulting in hazards to development above or below the slope occur relatively regularly and are often somewhat unpredictable. Generally, it is statistically probable that one or more of the noted geohazards will be present within such areas on Galiano Island. A slope within this classification can be considered to be at a high probability of failure at some point in time if such has not already done so, particularly during and/or subsequent to a seismic event.

Data Limitations

It should be noted that there are a number of limitations in utilizing aerial photographs to develop a DEM. The quality of the DEM may vary according to many conditions : terrain roughness, sampling density, grid resolution (or pixel size), interpolation algorithm, vertical resolution and terrain analysis algorithm. The aerial photographs that were used for the mapping of Galiano Island were flown at a scale of 1:16,000. We can approximate the accuracy of the DEM, considering that the quality of the air photos and the scale used may have affected the DEM resolution, as the air photos may not have captured all topographic elements, such as ravines, localized bluffs, or small scale features. We understand that elevation data was derived from the air photos with 0.5 m vertical accuracy on open ground surfaces and 1 m horizontal resolution (using a pixel size of 1 m).

For those areas with extensive forest canopy, the elevation accuracy could vary by as much as half of the tree height.

We have noted that there continues to be an unreliable classification of the hazards along the marine shoreline. For this reason, we had recommended against using this mapping solely for determination of natural hazards in close proximity to the coastal shoreline.

It is also important to note that a filter has been applied to the data such that locations reported as steeper than the defined hazard classes but encompassing an area of less than 36 m^2 have been removed. The primary justification for such is to eliminate the numerous small anomalies that are inherent to mapping based on aerial photography. This threshold area was based on the approximate limitation of the DEM in considering prediction of geohazards that occur within a horizontal distance of less than 6 m.

This inherent uncertainty with respect to elevation exists regardless of the adopted methodology and must be accepted and considered by the end users of the geohazard mapping. The mapping is not suited for building permitting purposes in those area where a potential or probable geologic hazard exists, and does not preclude the effectiveness of a site inspection by the building official prior to issuance of a building permit to satisfy the concern that localized hazards may exist that were not detected given the scale of the aerial photography and subsequent mapping assessment. Therefore it should be considered by the regulatory agencies as a guide in recognizing where potentially hazardous geological conditions exist, and used as a planning tool.

Planning Recommendations

Section 923 of the Local Government Act provides the authority under which a local trust committee can designate development permit areas for the protection of development from hazardous conditions, and establish tree cutting permit areas on land it considers may be subject to flooding, erosion, land slip or avalanche, respectively. Recommendations relating to future site assessments by registered professionals of such geohazards at properties that are applying for a Development Permit are difficult because the variability of the geologic conditions at the site ultimately leads to variability in the complexity of the assessment. In addition, Professional Engineers and Professional Geoscientists are accountable for their work under the Engineers and Geoscientists Act (RSBC 1996, Chapter 116, with amendments).

An assessment of those areas subject to proposed development within the High Hazard Area should be conducted by a qualified professional with relevant expertise in geohazard assessment to evaluate the presence of geohazards including but not limited to soil slope instability, rock slope instability, and surficial erosion susceptibility. It is recommended that all development activities that result in ground disturbance, including construction of driveways, septic fields, tree removal etc., be professionally assessed within the High Hazard Area to protect the public from the geohazard and to prevent against inadvertently exacerbating the geohazard. Depending on the site conditions and the proposed development, it may be that the professional assessment follows the "Guidelines for Legislated Landslide Assessments for Proposed Residential Developments in B.C." as published by the Association of Professional Engineers and Geoscientists of B.C. (APGEBC). The intent would be to address those areas that may pose a risk to residential development, or be exacerbated by the proposed development thereby increasing the risk of negatively impacting an adjacent property. Subsequent to the assessment and forming a conclusion of the report, we expect that it will be necessary to state that, as required by the Local Government Act and subject to any conditions outlined in the report, it is the professional opinion of the qualified professional that the land may be used safely for the use intended, and/or complete and submit a "Landslide Assessment Assurance Statement" as per Appendix D of the noted APEGBC Guidelines. Approval of proposed subdivision layouts is under the mandate of the Provincial Ministry of Transportation and accordingly we have not included it in this discussion.

We suggest that significant land development within the Moderate Hazard Area should be professionally assessed to evaluate the potential impacts that may result. Activities such as localized tree removal, construction of driveways and septic fields, and general preparation for single family residential construction would typically not be expected to significantly alter the exposure to existing geohazards. Construction of habitable structures is governed by the B.C. Building Code and regulated by the Capital Regional District, which typically require a professional assessment of steep slopes before issuance of a building permit, and has also not been addressed in the current scope.

In this regard, we recommend that locations within the Moderate Hazard Area that are subject to land development involving extensive land clearing, construction of retaining structures greater than 1.2 m in height, blasting, excavation and fill placement exceeding 0.5 m vertical thickness (beyond localized areas) should be professionally assessed to ensure such development is not exposed to undue hazard. A review of available scientific literature indicates that there is not a consensus regarding the impact of land clearing on geohazards, and accordingly, we suggest that this is highly dependent upon the site conditions. Considering the extent of the development, and where such is proposed, a brief site assessment by a qualified professional could be provided that confirms that either there is no significant geohazard at the site, or that the proposed development is not anticipated to impact, exacerbate or be at risk from such geohazard. We suggest that an exemption should be available from this geohazard area where a site assessment by a qualified professional supports such with follow up to confirm development is as proposed.

Generally, land development within the Low Hazard Areas is unlikely to have significant implications except in rare and unusual circumstances. We recommend that consideration be given to regulating only those activities undertaken on a larger scale such as extensive logging and clearing, large scale earthworks involving fill placement greater than 1 m (vertical thickness), or excavation creating cutslopes greater than 2 m in height. We do not expect that a development permit process would be necessary for Low Hazard Areas, and instead, regulatory authorities should be made aware of the geohazard mapping. In scenarios whereby owners are contemplating large scale development activities, a geotechnical assessment by a registered professional could be called for at the discretion of the regulatory authority.

Conclusion

The Islands Trust has requested guidance in developing a geologic hazard mapping program to identify areas where development may be at risk. We have recommended that three hazard designations be considered on the basis of slope gradient and anticipated geohazards – Low Hazard, Moderate Hazard, and High Hazard Areas. We have further recommended that, for the safety of the public, development within the Moderate and High Hazard Areas be restricted as necessary, subject to an assessment by a qualified professional.

The mapping has identified Low, Moderate and High Hazard Areas that we believe will encompass the majority of geologically hazardous areas, however, given the nature and level of study, it is expected that some areas will not have been captured. Therefore, it must be recognized that the mapping prepared is not of sufficient accuracy to preclude visual site inspections where such is warranted, and in particular, prior to issuance of building permits.

If you have any questions with respect to the information contained herein, please contact us.

Yours very truly,
C.N. Ryzuk & Associates Ltd.

Shane Moore, P.Geo.
Geoscientist

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