Province of British Columbia
Ministry of Environment

Present Geological Hazards and Soil Sensitivity to Earthquake Movement

for the Lower Mainland Official Regional Plan Review

by Angela Abrams

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PRESENT GEOLOGICAL HAZARDS AND SOIL SENSITIVITY TO EARTHQUAKE MOVEMENT

Guidelines for the use of 1:50 000 maps prepared as part of the Lower Mainland Official Regional Plan Review

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under the direction of the Resource Analysis Branch and
the Ministry of Transportation, Communications and Highways,
Geotechnical and Materials Branch

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PREFACE

This project, regarding geological hazards, including soil conditions and their affect on the characteristics of earthquake motions, was carried out for the British Columbia Ministry of Municipal Affairs and the Greater Vancouver, Dewdney-Alouette, Central Fraser Valley and Fraser-Cheam Regional Disricts for use in the update of the Official Regional Plan for the Lower Mainland. The project was carried out by Angela Abrams under the direction of the Resource Analysis Branch, British Columbia Ministry of Environment and Geotechnical and Materials Branch, Ministry of Transportation, Communication and Highways.

INTRODUCTION

The series of four maps on "Present Geological Hazards" were compiled from existing information, for use in updating the Lower Mainland Regional Plan.

The maps identify such geological hazards as landslides, snow avalanches, rockfalls, debris flows, fluvial erosion, floodplains, marine erosion, cave-ins resulting from mining operations, small scale slope failures and potential tephra (volcanic) hazards.

Soil types affecting the amplitude of seismic vibration caused by earthquake activity are illustrated on an additional series of four maps. These maps portray the geographical distribution of three broad soil categories, each category influencing the intensity of seismic vibration.

The two map series are at a scale of 1:50,000 and include the study areas of Central Fraser Valley Regional District and large portions of the Greater Vancouver, Dewdney-Alouette and Fraser-Cheam Regional Districts (Refer to Figure 1). The maps do not replace the need for on-site evaluation, but are designed as a guide for land use planning at the regional level.

INFORMATION SOURCES

A wide range of sources at varying levels of detail have been used in compiling the two series of maps. Sources vary from detailed engineering consultant reports to Provincial Government publications, as well as interviews with selected members of government. (See Appendix C for a list of those interviewed and Appendix D for references.)

Geological Hazards Data

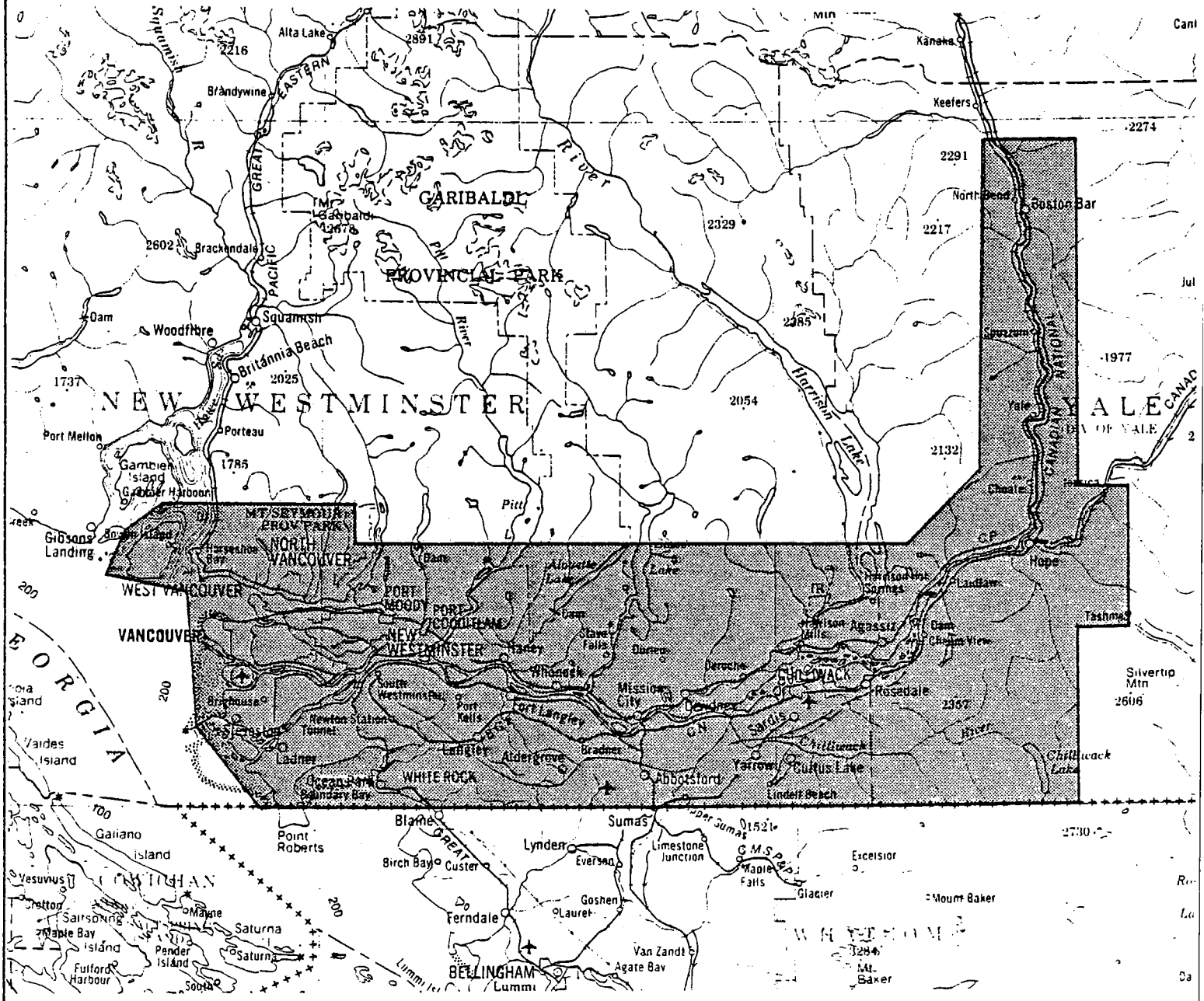
The geological hazards data was taken from a variety of sources. Provincial ministerial file correspondence was reviewed in the Victoria and Burnaby offices of the Geotechnical and Materials Branch, Ministry of Transportation, Communications and Highways. A geological hazards map at a scale of 1:50,000 was provided by the Geotechnical and Materials Branch, Kamloops Regional office. Other mapped information was provided by Water Investigations Branch, Ministry of Environment, Victoria, and by Maintenance Services - Avalanche Section, Ministry of Transportation, Communications and Highways. A variety of reports such as consultants reports, unpublished theses from the Geology Department, U.B.C., unpublished provincial government reports and published articles were reviewed. Selected provincial and municipal personnel were interviewed to discuss areas of geologic concern and to review a preliminary copy of the geological hazards map. Airphoto interpretation was also utilized in confirming boundaries of existing hazardous sites. Field investigations of geologic hazardous areas were not attempted.

Soil Sensitivity to Earthquake Movement Data

The two main sources of the "Soil Sensitivity to Earthquake Movement" maps are the National Building Code of Canada, Subsection 4.1.9 "Effect of Earthquakes"; and Dr. J.E. Armstrong's unpublished set of 1:50,000 surficial geology maps (1978) for the Lower Mainland. (See references 7 and 9.) These sources are further discussed in this report under "Interpretation of Data".

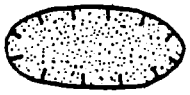
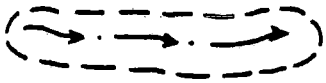
Various members of the Seismology Division, Earth Physics Branch, Department of Energy, Mines and Resources were contacted regarding the most effective method of presenting earthquake hazard data for the Lower Mainland. This method is based

Figure 1 Location of Study Area
Lower Mainland Official Regional Plan Review



Scale 1:1000 000

Table 1: Geological Hazards

Symbol	Type of Geological Hazard
	LANDSLIDE: surfical or bedrock - defined
	LANDSLIDE: surfical or bedrock - assumed
	SNOW AVALANCHE SITE - outline shows area of avalanche activity
	ROCKFALL AND/OR ROLLING ROCK - ticks point down site
	ROCKFALL AND/OR ROLLING ROCK - confined
	DEBRIS FLOW AND/OR EXTREME FLUVIAL EROSION - outline shows extent
	200 - YEAR FLOOD PLAIN BOUNDARY (as defined by Water Investigations Branch, B.C. Ministry of Environment)
	ABNORMALLY OVERSTEEPENED SLOPES - caused by alluvial fan and/or debris fan forcing river in bank
	ABNORMALLY OVERSTEEPENED SLOPES - caused by bedrock - controlled bend in river or river diversion due to landslide
	CAVING - resulting from mining activity
	MARINE EROSION
	SMALL SCALE SLOPE FAILURE
	POTENTIAL TEPHRA HAZARD AREA - from Mt. Baker showing the amount in centimeters

on recognizing that soil conditions can alter seismic amplitudes.

INTERPRETATION OF GEOLOGICAL HAZARDS DATA

The geological hazards maps are a compilation of the geographical occurrence of known past and present geological hazards. These hazards are areas of concern when considering land use planning. Each type of hazard has been given a specific symbol (see Table 1).

INTERPRETATION OF SOIL SENSITIVITY TO EARTHQUAKE MOVEMENT DATA

The wide range of soil types in the Lower Mainland were grouped into three categories specified in the National Building Code of Canada (See Appendix A). These categories based on soil type and depth are shown in Table 2. Category 1 has the least influence in intensifying seismic vibrations. The soil types in Category 2 causes a more apparent variation of maximum recorded amplitudes. Areas consisting of soils found in Category 3 are the most hazardous seismic regions. This category includes low density, saturated silts and clays, man-made landfill, and moderately dense fine sands and silts where the watertable is near the surface. (eg. Richmond Delta and Fraser Floodplain deposits.) Generally, the softer the soil the more severe the amplification of the seismic vibration.

Each category is assigned a value known as the foundation factor (F). These factors reflect experience with these soil conditions in the field, and integrates the effect of soil amplification and soil structure resonance into the estimation of the seismic design forces for buildings, having no unusual structural characteristic

This information is further expanded upon in the seismic provisions of the National Building Code of Canada.

TABLE 2: Soil Sensitivity of Earthquake Movement.

CATEGORY	TYPE AND DEPTH OF SOIL	FOUNDATION FACTOR (F)
1	Rock, dense and very dense coarse-grained soils, very stiff and hard fine-grained soils; compact coarse-grained soils and firm and stiff fine-grained soils from 0 to 50 ft. deep.	1.0
2	Compact coarse-grained soils, firm and stiff fine-grained soils with a depth greater than 50 ft.; very loose and loose coarse-grained soils and very soft and soft fine-grained soils from 0 to 50 ft. deep.	1.3
3	Very loose and loose coarse-grained soils, soils, and very soft and soft fine-grained soils with depths greater than 50 ft.	1.5*

* Where soil deposits are of the order of 300 ft. (91.5 m) or more, amplification factors greater than those given in the Table may arise in the case of tall buildings.

LIMITATIONS OF SOURCES AND INTERPRETATIONS

The "Present Geological Hazards" maps are not a complete inventory of all hazards but of existing data only. For this reason, information in some locations stop abruptly, or in several areas lack information. This does not imply there are no geological hazards beyond a certain point, but indicates further investigation and collection of data is required.

The "Soil Sensitivity to Earthquake Movement" information is limited to that area covered by Dr. J.E. Armstrong's surficial geology maps. The three soil groups are based on many simplifications and should be used as an overview.

SEISMIC ACTIVITY - BACKGROUND INFORMATION

Introduction

The seismic microzoning map for Canada is based on an analysis of past earthquake activity (See Figure 2). The map is based on the maximum peak acceleration experience at a location in each year. After this is computed, the methods of extreme value statistics are used to predict the level of acceleration amplitude for various return periods. The probability of exceedance of 0.01 in one year, also called "100-year" acceleration, represents the bases of the minimum design requirement given in the National Building Code of Canada. The minimum standards are supposed to assure an acceptable level of public safety by designing buildings to prevent major failure and loss of life. The National Building Code is not a legal document but may be adopted in its entirety or certain sections of it by a provincial or municipal government. Thus, the implementation of the present seismic design requirements and any future microzoning regulations are the responsibilities of local government.

Macrozoning

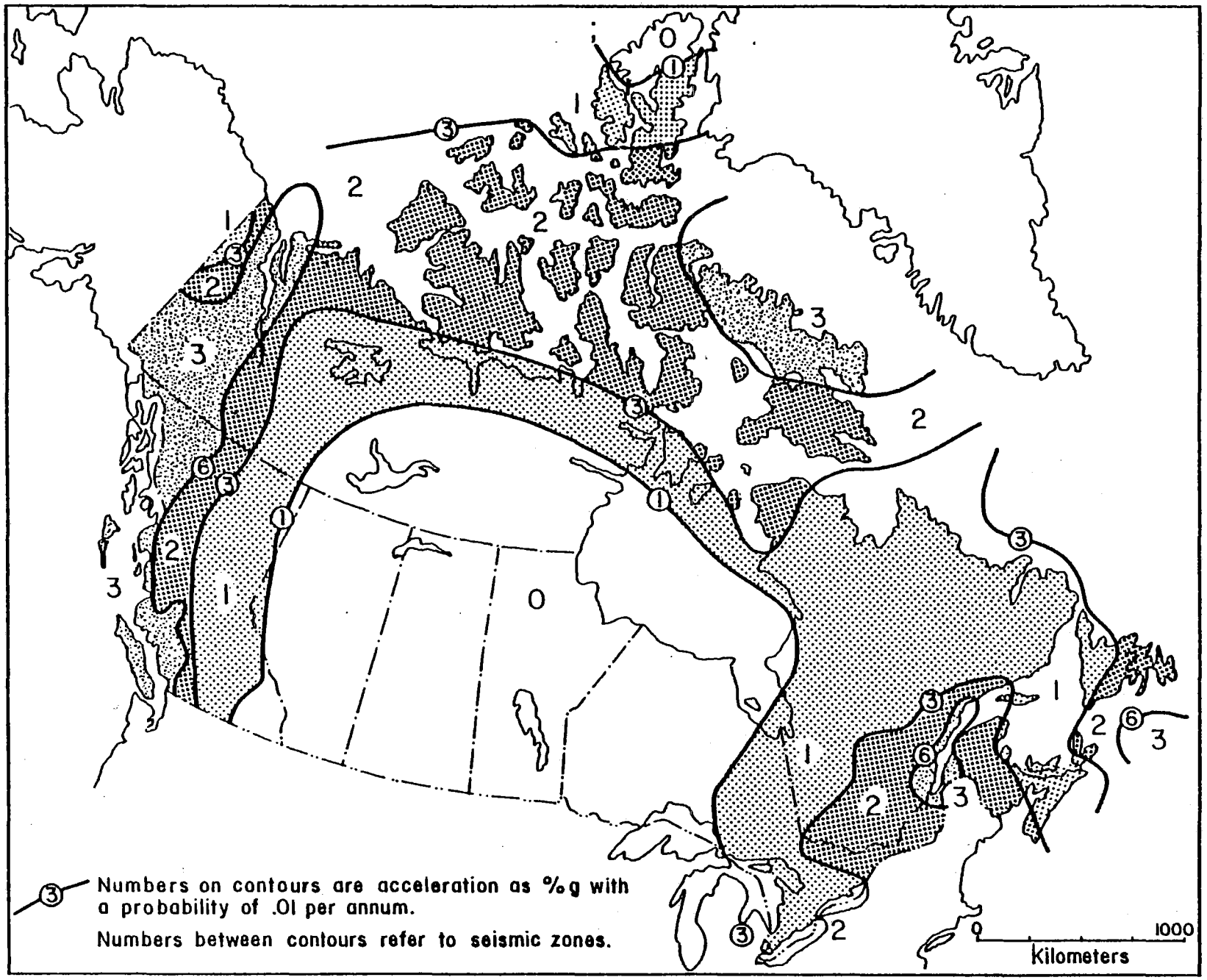
The seismic risk map divides Canada into four zones. The seismic risk is the greatest in zone three. Areas where maximum accelerations have occurred are along the West Coast including the Lower Mainland, the St. Lawrence River Valley and certain parts of the Arctic. The map estimates the areal distribution of seismic hazards and is not concerned with the detailed prediction of specific earthquakes.

Estimated intensities and peak accelerations for a number of sites in the Lower Mainland can be obtained from the Seismology Division, Earth Physics Branch, Department of Energy, Mines and Resources, Victoria, B.C.

Microzoning

At present, the only attempt at microzoning, or recognizing that site conditions may alter seismic amplitudes, is to recommend a 50% increase (factor of 1.5) in the seismic load factor on poor soils such as highly compressible sediments.

Figure 2 1970 Seismic Zoning



APPENDIX A: LOWER MAINLAND GEOLOGY - TAKEN FROM ARMSTRONG'S SURFICIAL GEOLOGY MAPS. (SEE REFERENCE NO. 7)

CATEGORY 1

Quaternary

Postglacial:

Salish Sediments:

1. Slope deposits, colluvial sediments deposited by mass wasting processes: slopewash clayey silt and silty clay up to 2 m thick overlying Sumas Drift; landslide and fan gravel and rubble up to 10 m thick overlying Sumas Drift and Fort Langley Sediments.

Pleistocene:

Sumas Drift:

1. Outwash, ice-contact and deltaic deposits: outwash sand and gravel up to 30 m thick; ice-contact gravel and sand containing till lenses and, clasts of glaciomarine stoney, clayey silt more than 5 m thick; glaciofluvial gravel and sand up to 40 m thick. The Sumas Drift between the Fraser and Chilliwack River valleys in much of the area are mantled by 0.3 m to 1 m of eolian silt and silt loam.

Fort Langley Formation:

1. Glacial and deltaic sediments: lodgement and flow till with sandy loam matrix.

Vashon Drift and Capilano Sediments:

1. Glacial drift including: lodgement of minor flow till and interbeds of substratified glaciofluvial sand to gravel, and lense and interbeds of glaciolacustrine laminated stoney silt; up to 25 m thick but in most places less than 8 m thick.

Vashon Drift:

1. Till, glaciofluvial sandy gravel to gravelly sand outwash, glaciolacustrine, and ice-contact deposits.

Pre-Vashon Deposits:

1. Glacial, non-glacial and glaciomarine sediments.

Undivided Pre-Vashon Deposits:

1. Till, glaciofluvial, glaciolacustrine, fluvial marine and organic sediments.

Tertiary:

1. Tertiary bedrock included sandstone, siltstone, shale, conglomerate, and minor volcanic rocks; where bedrock is not at the surface it is overlain by glacial deposits and colluvium.

Pre-Tertiary:

1. Mesozoic bedrock including granitic and associated rock types; where bedrock is not at the surface it is overlain by glacial deposits and colluvium.

CATEGORY 2

Quaternary

Postglacial:

Salish Sediments:

1. Lowland organic-rich sandy loam to clay loam 15 to 45 cm thick overlying Fraser River Sediments.

2. Marine shore sediments: sand to gravel up to 8 m thick.

3. Stream deposits: mountain stream marine deltaic medium to coarse gravel and minor sand up to 15 m or more thick; mountain stream channel fill sand to gravel up to 8 m thick; lowland stream channel fill sand and gravel, minor silt and clayey silt up to 5 m thick.

Postglacial and Pleistocene:

1. Marine shore and fluvial sand up to 8 m thick.

Pleistocene:

Sumas Drift:

1. Ice-contact gravel and sand containing till lenses and clasts of glaciomarine stoney clayey silt, 2 to 5 m thick overlying glacial and deltaic sediments.

2. Glaciolacustrine deposits: silt, clayey silt, silty clay and sand, minor gravel, 5 to 35 m thick.

Fort Langley Formation:

1. Glaciomarine deposits: glaciomarine stoney clayey silt to silty sand 8 to 90 m thick commonly thinly bedded and containing marine shells.

Capilano Sediments:

1. Raised marine, deltaic and fluvial deposits: raised deltaic and channel fill medium sand to cobble gravel up to 15 m thick deposited by proglacial streams and commonly underlain by silty to silty clay loam; marine and glaciomarine stoney to stoneless silt loam to clay loam with minor sand and silt normally less than 3 m thick but up to 30 m thick, containing marine shells; mainly marine silt loam to clay loam with minor sand, silt and stoney glaciomarine material up to 60+ m thick.

CATEGORY 3

Quaternary

Postglacial:

Salish Sediments:

1. Landfill including sand, gravel, till, crushed stone and refuse.

2. Bog, swamp and shallow lake deposits: lowland peat, organic silt loam and silty clay loam.

3. Stream deposits, includes channel fill, floodplain and overbank sediments.

4. Lacustrine deposits: silt to clay, sand to sandy loam.

5. Marine shore sediments: (beach deposits) sand to loamy sand overlying Fraser River Sediments.

6. Slope deposits, colluvial sediments deposited by mass wasting processes: slopewash sand up to 4 m thick; fan and landslide gravel and sand and rubble up to 10 m thick overlying Fraser River Sediments.

Fraser River Sediments:

1. Deltaic and distributary channel fill sediments overlying and cutting estuarine sediments.

2. Channel fill and floodplain overlain in much of the area by overbank sediments.

APPENDIX B: GLOSSARY

Alluvial fan	- a fan shaped deposit formed by a stream of debris flow either where it issues from a narrow mountain valley onto a plain or broad valley, or where a tributary stream joins a mainstream.
Avalanche	- a large mass of snow, ice, soil or rock or mixtures of these materials, falling or sliding very rapidly under the force of gravity. Avalanches can be classified by their content, ie. snow and ice avalanches, soil or rock avalanches.
Beach Erosion	- the destruction and removal of beach materials by wave action, tidal currents, littoral currents or wind.
Bedrock	- a general term for the solid rock that underlies soil or unconsolidated material.
Cave-in	- the partial or complete collapse of earth material into a large underground opening, such as an excavation or a mine.
Colluvial Sediments	- materials which are products of mass wastage and have reached their present position by direct, gravity-induced movement.
Debris Flow	- a rapidly moving flowage of water, mud, rock and vegetation usually contained within a gully or creek.
Drift	- a general term applied to all rock material (sand, clay, gravel, boulders) transported by a glacier and deposited directly by or from the ice, or by running water emanating from a glacier.
Earthflow	- a slow moving heterogeneous mixture of soils.
Earthquake	- a sudden motion or trembling in the earth caused by the abrupt release of slowly accumulated strain.
Erosion	- the wearing away of rocks and unconsoldiated materials by natural processes such as running water, waves, and wind.
Fault	- a zone of rock fracture along which there has been displacement between two rock masses.
Fill	- a man-made deposit. Fills range from inorganic, well-compacted, dense materials to heterogeneous accumulations of rubbish and debris.
Floodplain	- flat land adjacent to a river channel and subject to periodic flooding; consists primarily of unconsolidated sediments deposited by the stream during flooding.

Fluvial Sediments - materials which are transported and deposited by streams and rivers. They consist of gravel, sand and silt and are commonly moderately to well-sorted and stratified. These sediments occur as channel and floodplain deposits, terrace deposits, alluvial fans and deltas.

Fluvioglacial Sediments - materials deposited by meltwater either in contact with glacier ice or beyond the ice margin as outwash. Ice-contact deposits (kames, kame terraces and eskers) consist of gravels and sands that may be sorted and stratified. Proglacial outwash deposits are sorted and poorly bedded with textures ranging from sand to boulders. Outwash gravels are porous and permeable.

Fracture - a natural break in rock which is continuous and regular over distance.

Glaciolacustrine Sediments - materials deposited in proglacial lakes by meltwater streams during or shortly after deglaciation. Silt and fine sand are most common but coarser sand and gravel can be expected close to the points of inflow.

Glaciomarine Sediments - materials which formed at the time of higher sea level during glaciation and deglaciation by the accumulation of particles released from floating, melting ice. They consist of stoney, silty clay which is non-sorted and may show faint, irregular stratification. These sediments may superficially resemble till, but in places contain Pleistocene marine shells.

Geological Hazard - a naturally or man-made geologic condition or phenomenom that presents a risk or is a potential danger to life and property. Examples of geologic hazards: landsliding, flooding, earthquakes, ground subsidence and beach erosion.

Lacustrine Sediments - sediments that have settled from suspension in bodies of standing fresh water or that have accumulated at their margins through wave action. They commonly consist of stratified fine sand, silt, and clay deposited on the lake bed and of coarser-textured beach and littoral sediments.

Marine Sediments - sediments that have settled from suspension in salt or brackish water bodies or have accumulated at their margins through shoreline processes such as wave action and longshore drift. These deposits consist of clay, silt, sand or gravel, well to moderately well sorted and stratified, and in some places containing shells.

Mass Wasting - a general term for a variety of processes by which large masses of earth material are moved by gravity either slowly or quickly from one place to another.

Mudflow - type of landslide consisting of wet viscous, mostly fine drained soil flowing rapidly downslope, usually in a drainage course.

Organic Soils - materials resulting from vegetative growth, decay and accumulation in and around closed basins or on gentle slopes, where the rate of accumulation exceeds that of decay.

Outwash - (glacial geology) sediments and features produced by deposition from meltwater streams emerging from the margins of an ice mass.

- (sedimentology) soil material washed down a hillside by rainwater and deposited upon more gently sloping land.

Postglacial - pertaining to the time interval since the total disappearance of continental glaciers in the middle latitudes.

Rockfall - the relatively free falling of a newly detached segment of bedrock.

Runoff - the portion of the total precipitation on an area that flows away through stream channels. Surface runoff does not enter the soil. Groundwater and near surface runoff enter the soil and flow through the geological materials before reaching a water body.

Sediment - solid fragmental material, or a mass of such material, either organic or inorganic, that originates from weathering of rocks and is transported by, suspended in, or deposited by air, water or ice.

Silt - a rock fragment or detrital particle smaller than a very fine sand grain and larger than coarse clay, having a diameter in the range of 1/256 to 1/16 mm.

Slope Stability - the quality of permanence of resistance of a natural or artificial slope to failure by landslides.

Talus - (scree) sharp angular rock fragments produced by physical weathering of an exposed bedrock slope.

Tephra - a general term for all clastic rock material formed by volcanic explosion or serial expulsion from a volcanic vent.

Till - unsorted and unstratified drift, generally unconsolidated deposited directly by and underneath a glacier, and subsequent reworking by water from the glacier, and consisting of a heterogeneous mixture of clay, sand, gravel, and boulders varying widely in size and shape.

Undercutting - the removal of material at the base of a steep slope or cliff or other exposed rock by the erosive action of falling or running water.

Volcanism - the process by which magma and its associated gases rise into the crust and are extruded onto the Earth's surface and into the atmosphere.

APPENDIX C: LIST OF THOSE INTERVIEWED

Provincial Agency Staff

- Mr. G.E. Miller, P. Eng., Regional Geotechnical and Materials Engineer, Geotechnical and Materials Branch, Ministry of Transportation, Communication and Highways, Kamloops.

- Mr. D. Nyland, P. Eng., Geotechnical Engineer, Geotechnical and Materials Branch, Ministry of Transportation, Communications and Highways, Kamloops.

- Mr. B.W.R. Eastman, P. Eng., Senior Rockwork Engineer, Operations Division, Geotechnical and Materials Branch, Ministry of Transportation, Communications and Highways, Burnaby.

- Mr. M. Oliver, Technician, Geotechnical and Materials Branch, Ministry of Transportation, Communications and Highways, Burnaby.

- Mr. D.R. Lister, P. Eng., Geotechnical Engineer, Geotechnical and Materials Branch, Ministry of Transportation, Communications and Highways, Victoria.

- Mr. R.G. Buchanan, Research Officer, Geotechnical and Materials Branch, Ministry of Transportation, Communications and Highways, Victoria.

- Mr. L. deBoer, P. Eng., Supervising Geotechnical Engineer, Geotechnical and Materials Branch, Ministry of Transportation, Communications and Highways, Victoria.

- Mr. G.L. Freer, Senior Avalanche Co-ordinator, Maintenance Services - Avalanche Section, Ministry of Transportation, Communications and Highways, Victoria.

- Ms. S. Smith, Planning Officer, Water Investigations Branch, Ministry of Environment, Victoria.

Municipal Engineering Staff and Officers

- Mr. Y.H.L. Tong, P. Eng., Port Moody

- Mr. L. Chu, P. Eng., Surrey

- Mr. R. Payer, P. Eng., Delta

- Mr. C. Timms, P. Eng., Delta

- Mr. A. Louie, P. Eng., Richmond

- Mr. R.G. Gascoyne, P. Eng., White Rock

- Mr. Bridgman, P. Eng., North Vancouver City

- Mr. F. Field, P. Eng., West Vancouver

- Mr. M. Thomas, P. Eng., North Vancouver District

- Mr. V. Wiebe, P. Eng., Burnaby

- Mr. L. Melnechenko, P. Eng., Port Coquitlam City
- Mr. W. Foreseth, Cartographic Section, District of Coquitlam
- Mr. J.D. Kenyon, P. Eng., Langley District
- Mr. Tindale, Public Works Director, Abbotsford
- Mr. W. MacIsaac, Public Works Supervisor, Maple Ridge
- Mr. B. Wilson, Public Works Foreman, District of Kent
- Mr. E. Holter, P. Eng., Chilliwack District

Federal Government Agencies

- Messrs. G.C. Rogers, W.G. Milne and D. Weichert, Seismology Division, Earth Physics Branch, Ministry of Energy, Mines and Resources, Victoria, B.C.

Private Sector

- Mr. D.C. Martin, Engineering Geologist, D.R. Piteau and Associates Limited, Geotechnical Consultants, West Vancouver, B.C.

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