GEOLOGICAL HAZARD ZONATION AND LAND USE PLANNING ASSESSMENT IN THE SOUTH EASTERN MARLBOROUGH SOUNDS, NEW ZEALAND.

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1. INTRODUCTION

The Marlborough Sounds, located at the top of the South Island, New Zealand (Figure 1.), is well known for its scenic beauty. However, the area is less well known for the high degree of weathering and instability associated with the steep slopes. There is a high demand for land in the south eastern Marlborough Sounds due to urban expansion from Picton and Waikawa. Increasingly, the land being selected for house sites is on steeper and potentially more unstable land.

Quaternary climatic influences saw the beginning of the deep weathering profile typical of the Marlborough Sounds today. Periglacial and interglacial periods assisted in the preferential weathering of shear zones and the development of significant amounts of regolith and colluvial material overlying the schistose and greywacke bedrock.

2. GEOLOGICAL PROCESSES

Mass Movement

Weathering has produced a veneer of unconsolidated surficial material which frequently fails due to the steepness of the slopes and the influence of high antecedent water conditions. Failure types are twofold (Figure 2.). Using the Varnes Classification Scheme, the complex failures in the Marlborough Sounds are either translational/flow failures, or rotational/translational/flow failures. Within thick, >1m, deposits of colluvium and regolith on the lower slopes, the failure types tend to have a rotational headscarp region, the middle of the slide fails in translational motion, while the toe region becomes a flow. On the higher, steeper slopes where the surficial material is <1m failures are predominantly translational with the typical flow features at the base of the slide. Generally, both types of failure occur along the bedrock/surficial material interface which acts as a zone of increased water movement and reduced shear strength.

Several factors are influential in producing the surficial failures readily seen in the Marlborough Sounds. Rainfall is the principal factor which induces failures as high antecedent water conditions are common during the generally wet winters in the Sounds. Failures are most likely to occur when high antecedent conditions combine with the frequent high intensity or long duration rainstorms which occur throughout the year. Additionally, urban development on slopes prone to sliding will often aggravate previous failures or induce new slides. Removal of support at the base of slopes will also promote the development of slope failures. Therefore, roading, cut batters for house sites, and stream bank erosion in gullys all provide potentially unfavourable conditions. Consequently failures are commonly associated with urban expansion and roading. As such, slides often develop below main roads in response to frequent heavy traffic. Large logging trucks are particularly damaging to roads in the area due to their weight and frequent use of the roads. Finally, vegetation removal will generally reduce stability for slopes in excess of 35°, which is approximately the angle of repose for surficial materials. Rain may fall directly onto the ground inducing rilling and additionally no soil moisture is taken up by trees and other vegetation.

Tunnel Gully Erosion

In addition to slope failure, the Marlborough Sounds are subject to other geological processes which have hazard potential. Tunnel gully erosion is a widespread feature which is rarely identified. Many tunnels are not obvious and often only become apparent after building has taken place. Tunnels occur generally at the bedrock/colluvium interface, or in relation to tree roots and large rock fragments in thick colluvial material. The collapse of tunnels leads to instability and can also undermine house foundations if they are not properly identified.

Flooding

Flooding is also a prominent geological hazard in the south eastern Marlborough Sounds. The Graham River in Whatamango Bay and Waikawa Stream which flows through Waikawa township are both capable of flood events which threaten property. Stream flow responses to high intensity rainfall are sudden with very little lag time identified between rainfall and flood events in the lower reaches.

Seismicity

Seismic hazards are important due to the near vicinity of the active Wairau Fault and the occurrence of numerous fault traces within the Marlborough Sounds. However, activity of faults such as the Waikawa Bay Fault has not been determined and therefore, seismic hazards are difficult to quantify.

3. HAZARD ZONATION

Background

Prior to the work of P.J. Horrey in 1989, the data concerning the geology and soils of the Marlborough Sounds was at large scales (1:50,000) and wholly unsuitable for geotechnical or hazard evaluations. With the introduction of the Resource Management Act and the Building Act in 1991, the requirement for a detailed database of geological or natural hazards became a priority. Local authorities in the Marlborough Sounds saw the need for small scale (1:5000) geological maps identifying the active geological processes and their hazard potential with regard to urban development.

Methodology

Geological hazard zonation in the Marlborough Sounds has developed a specific methodology and ultimately leads to decisions regarding land use planning issues. Previous hazard zonation schemes have used the various physical attributes of the land to produce a terrain evaluation. The scale of the final map, therefore, will define the detail of the evaluation. For the purposes of hazard zonation in the Marlborough Sounds, scales of 1:5000 or less require detailed field and limited laboratory analysis of geological processes and materials. Following the GASP system used in Hong Kong, the current hazard zones were determined after analysis of the current natural state of the land. Hazard maps are similar to the GASP physical constraint maps. However, they attempt to quantify the different types of constraints to development rather than just identify them. The maps provide an intermediate level between engineering geological information (Terrain Classification maps) and land use planning maps (GLUM - Geotechnical Land Use Maps). The principal factor in the production of hazard zonation maps is the identification and mapping of geological processes which are deemed potentially hazardous. Hazard assessment is predominantly made on the basis of the time frame between events; the periodicity. Using remote sensing techniques such as air photographic interpretation, detailed field mapping and limited field and laboratory testing, the age and activity of hazardous processes can be estimated .

Zonation Parametres

The degree of hazard is subdivided into high, moderate, low and negligible hazards and maps utilise the 'stoplight' method of presentation; red represents high hazard areas while blue identifies negligible hazards. High hazard zones are those areas which have undergone modification by slope movement, flooding, debris deposition or erosion within the last 36 years; the extent of the aerial photography database for the area. Moderate hazard zones, coloured orange, are areas active earlier than 36 years ago. Any unmodified slopes in excess of 35° were also included as being of moderate hazard. Low hazard was allocated to slopes between 15°-35° which had not previously failed, and areas prone to flooding should protection measures fail. Low hazard areas are coloured green. Any areas which are not seen to be affected by hazardous geological processes are allocated negligible hazard.

Additional to the hazard zonations depicted on the maps, additional geological and geomorphic information is included. Features such as headscarps, terraces, runout zones, tunnel gullys and erosion provide evidence of the type of process which presents the greatest hazard. The principal hazard type is allocated an uppercase letter representative of the active process involved. Processes which present lesser degrees of hazard ar represented by lowercase letter. Figure 3 shows the application of hazard zones to the slopes east of Waikawa township

4. LAND USE PLANNING

Methodology

Following the analysis of hazardous geological processes, land use constraint maps were produced. Again using the principal of the GASP program, these maps are essentially the equivalent of the Geotechnical Land Use maps (GLUM). The development constraint evaluation is derived from the hazard zonation maps, however the assessments are not equivalent. The constraint assessments represent the suitability of land for the purposes of residential development. Therefore, the maps represent the expected foundation conditions, and the necessity for additional, site specific geotechnical investigations. Figure 4. shows the land use planning map derived from the hazard map presented in Figure 3.

Development constraints are subdivided into four classes. Class IV areas have extreme limitations to development due to poor foundation conditions and require extensive geotechnical investigations and remedial measures prior to development. Commonly, such areas equate to zones of high hazard. Class III indicates moderate limitations and the requirement of site specific investigations before residential development is permitted. Class II land is generally suitable for development. Additional geotechnical assessment may be required. Finally, Class I development constraints are applied to the land best suited for urban development and that which is of low or negligible hazard.

While hazard zonation maps represent the natural state of the land at the present time, no attempt is made to interpret land conditions should additional urban development occur. The land use planning maps indicate the expected geotechnical problems and foundation conditions of future landscapes. For example areas of mass movement which are not considered to be active and are of moderate hazard, may be assigned an extreme classification due to the requirement of significant geotechnical investigations prior to development.

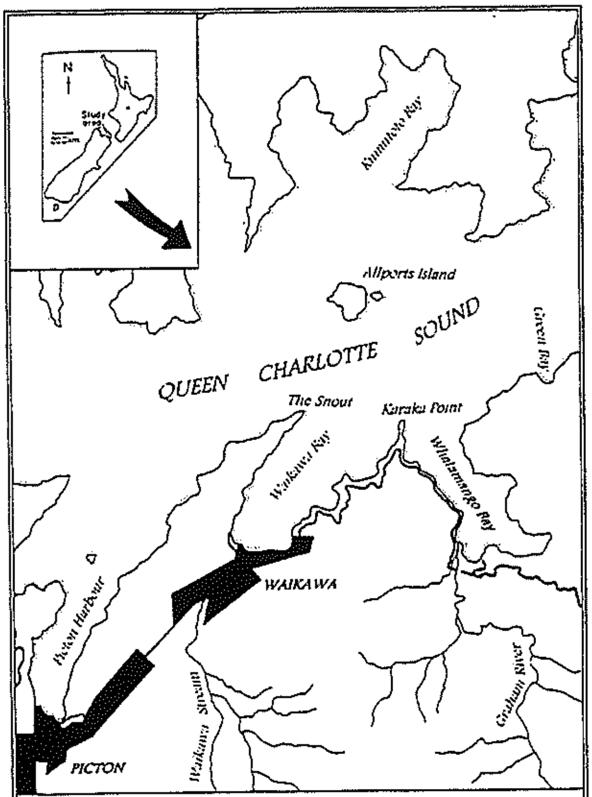


FIGURE 1. Location diagram of the Marlborough Sounds.

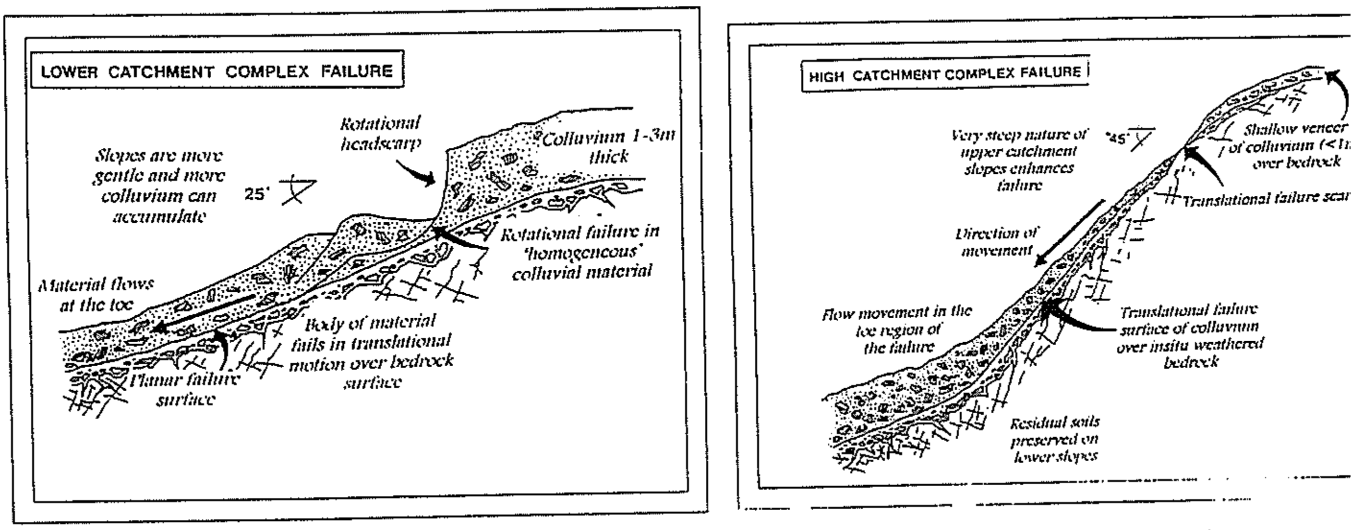
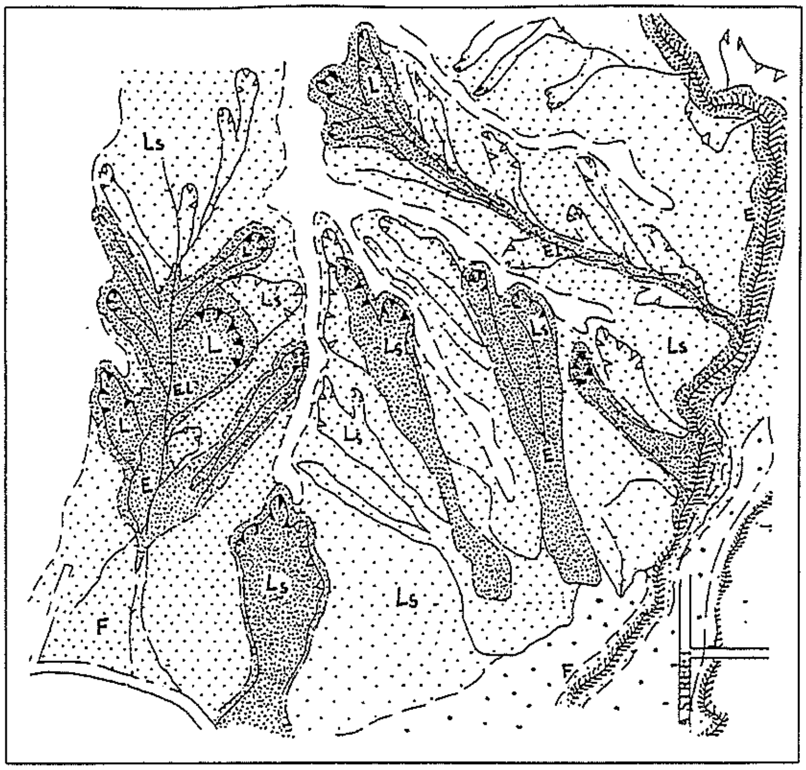


FIGURE 2. *Schematic diagrams of complex flow types in the Marlborough Sounds*



GEOLOGICAL HAZARD ZONATIONS

HAZARD	SLOPE MOVEMENT L	FLOODING F	STREAM BANK EROSION E	TUNNEL GULLY T	SEISMIC S
HIGH	Active within the last 36 years	Inundation or siltation within the last 36 years	Active erosion within the last 36 years	Observed collapse or rilling within the last 36 years	20m either side of active fault traces due to rupture.
MODERATE	Active more than 36 years ago. Slopes over 35°	Inundation and siltation within a 100 year return period.	Active erosion more than 36 years ago.	Old inactive tunnels formed more than 36 years ago.	Areas of unconsolidated material on 35°+ slopes. Jointed rock faces. Liquefaction in reclaimed areas.
LOW	Unmodified slopes between 15° and 35°	Inundation and siltation only if flood control measures fail.		Areas of unconsolidated material less than 1m thick.	Slopes less than 15° and low angle rock faces.
NEGLIGIBLE	Unmodified slops less than 15°	No Hazard	No Hazard	No Hazard	No Hazard

FIGURE 3. Hazard zonation classification and example map showing varying degrees of natural hazard.

DEVELOPMENT CONSTRAINTS FOR URBAN LAND USE

	SLOPE MOVEMENT L	FLOODING F	STREAM BANK EROSION E	TUNNEL GULLY T	SEISMIC S
CLASS IV	Extreme geotechnical limitations. Development generally unsuitable.	Extreme geotechnical limitations. Development generally unsuitable.	Extreme geotechnical limitations. Development generally unsuitable.	Extreme geotechnical limitations. Development generally unsuitable.	Not enough information to assign a constraint classification
CLASS III	Significant geotechnical limitations. Extensive site investigations essential.	Significant geotechnical limitations. Extensive site investigations essential.	Significant geotechnical limitations. Extensive site investigations essential.	Significant geotechnical limitations. Extensive site investigations essential.	Not enough information to assign a constraint classification
CLASS II	Generally favourable for development. Some site investigations required	Generally favourable for development. Some site investigations required	Generally favourable for development. Some site investigations required	Generally favourable for development. Some site investigations required	Not enough information to assign a constraint classification
CLASS I	No limitations to development Residential development recommended.	No limitations to development Residential development recommended.	No limitations to development Residential development recommended.	No limitations to development Residential development recommended.	Not enough information to assign a constraint classification

FIGURE 4. Classification for development constraint zonation.