Guidelines for assessing planning policy and consent requirements for landslide prone land

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ABSTRACT

These guidelines primarily aim to assist planners (and other interested parties) in determining whether planning documents and resource consent applications at regional and district levels incorporate appropriate information on landslide and slope instability hazards. They provide information on the criteria used to assess landslide hazards at the consent stage, and examples of issues, objectives, policies, rules, and assessment criteria. Basic landslide concepts are outlined to assist planners in understanding landslide processes, triggers, hazard and risk assessment.

Due to the nature of landsliding across New Zealand, the guidelines do not provide prescriptive planning requirements. Rather, they will provide the planner with guidance on what should be considered, and a glimpse of how council's are incorporating landslides into their planning practices.

These guidelines will also be of interest to emergency management planners, engineering geologists, engineers, and others who deal with landslide issues.

It is envisaged that these guidelines will be regularly reviewed and updated as knowledge, technical standards and practices evolve, and as legislative changes occur.

KEYWORDS

Landslide, planning, guidelines, policy, consents, geotechnical, mapping, risk-based approach

1. INTRODUCTION

1.1 Landslide hazard in New Zealand

Much of New Zealand is hilly or mountainous country composed of rocks that range from very weak to strong. Many of the strong and otherwise competent rocks have numerous planes of weakness. Consequently, unstable slopes are an existing or potential hazard in many parts of the country. Slope instability is exacerbated by rain, particularly localised high intensity storms, and strong earthquake shaking. The following examples illustrate some of the landslides that have affected parts of New Zealand.

On 18 May 2005, the Bay of Plenty settlement of Matata was struck by a debris flow landslide. Torrential rain during a severe thunderstorm resulted in more than 90mm of rain in one hour, on two small catchments that drain through Matata. The rain triggered many shallow landslides on steep slopes which, on entering local stream channels, coalesced into debris flows. Two large debris flows, along with associated flooding, destroyed 27 homes, and damaged a further 87 properties. State Highway 2 and the railway were closed for many days. Despite millions of dollars in property damage, there were no deaths or serious injuries – a result of good luck rather than sound planning.

The 8 August 1979 the East Abbotsford landslide on a Dunedin hillside resulted in the destruction of 69 houses. The rapid block slide followed months of slow landslide deformation in the area, and the movement was probably caused by excavation of material from the toe of the slide and/or leaking water mains. This landslide is an example of the type of damage that results when a large landslide occurs in an urban area.

Landslides during the 1929 Murchison earthquake destroyed four farm houses and killed 11 people; another death occurred when a rockfall engulfed a house below a high bluff during the 1968 Inangahua earthquake. These examples illustrate the risk of landslides where homes built on flat ground are too close to steep slopes. The speed of some landslides during earthquakes means that people have little or no time to escape.

The above examples illustrate the destructive potential of landslides and why they are hazards. Not every landslide results in catastrophe, but even small landslides have the potential to cause damage and loss of life. These guidelines aim to show how the loss of life and damage from landsliding can be reduced through good land use planning.

1.2 The need for landslide hazard planning

Before the losses from landslides can be reduced, the hazard must first be recognised and the risk assessed appropriately. The information and methods described in this document aim to provide a better understanding of how landslide hazard and risk can be assessed. A landslide hazard assessment, which is commonly in the form of a map, provides people with a practical and cost-effective way to recognise areas where landslides exist or could occur.

Although only a small number of urban developments experience slope instability and landslide problems, the number affected could increase when developments occur on, or close to, steeper and less stable areas, especially at urban margins. It is important that areas with significant landslide risk are recognised at the planning stage and that they be either left undeveloped or, where practicable, developed so that the landslide risk is reduced to an acceptable level. Landslide hazard needs to be addressed in regional and district plans and an assessment of slope instability and landslide hazards required as part of the resource consent process for new development and the building consents process. Landslide hazard also needs to be identified in areas that are already developed.

1.3 Purpose and scope of guidelines

These guidelines are provided primarily to assist local authority planners, but will also be of interest to developers, engineering geologists and geotechnical engineers who specialise in landslide hazard and risk assessment. Early consultation with geotechnical specialists is recommended so that slope conditions can be assessed early in the development process. A planner is not expected to make technical judgements about the landslide hazard or risk, but should understand the process by which a landslide specialist provides advice. By seeking appropriate advice, the planner will be informed of measures to minimise or avoid the effects of landslides.

From this document, the planner will gain a basic knowledge of the concepts and issues to be considered when incorporating landslide hazard information and assessments into the planning process. The guidelines also provide a list of questions to ask the geotechnical specialist to ensure that all necessary information is obtained. For the geotechnical specialist, these guidelines provide a review of landslide hazard issues and methods for landslide risk assessment in Appendix 3.

These guidelines are not designed to override the planner's decision-making processes. Rather, they provide examples of how landslides and slope instability issues can be incorporated into planning documents, to assist in formulating policy and justifying resource consent decisions. Where possible, the guidelines include examples of current planning practice to assist planners in the formulation of appropriate planning responses to landslides and slope-instability issues. These examples do not necessarily represent best practice.

An extremely wide range of rock and soil types, terrain and types of landslides are found in New Zealand, so it is not possible to establish guidelines which will satisfy all circumstances. These guidelines are intended for use where structures may be subject to damage from landslides. They do not include areas where there are no buildings or infrastructure.

Section 2 of the guidelines "Understanding Landslides", includes definitions, classifications, processes and causes of landslides, triggers, and the impact of land development on landslides. Section 3 discusses the importance of mapping landslides, what scales landslides should be mapped at, and landslide hazard maps. How to plan for, identify and assess the landslide risk is described in Section 4, and is based around four principal planning approaches and a risk-based approach. Section 5 outlines the legislative context for managing landslide risk, and Section 6 provides examples of planning tools to treat these risks. A risk-based approach to resource consents is outlined in Section 7.

A glossary of terms is provided, and six appendices provide additional guidance and information on planning for landslides. For the non-planner, further information on planning processes can be found at www.qualityplanning.org.nz .

It is envisaged that these guidelines will be regularly reviewed and updated as knowledge, technical standards and practices evolve, and as legislative changes occur. If you have any feedback on this guideline, please email w.saunders@gns.cri.nz.

1.4 Formulation of the guidelines

These guidelines were produced as an output for the Foundation of Research, Science and Technology, under the GNS Science Hazards & Society Programme. Wendy Saunders and Phil Glassey of GNS Science compiled these guidelines[1].

The compilers would like to greatly acknowledge the valuable input that was received from a review group consisting of representatives from the following organisations:

- Bruce Sheppard — Earthquake Commission
- Mike Johnston — Nelson
- Tim Davies — Canterbury University
- Mike Page — GNS Science (Avalon), formerly of Landcare
- Richard Hills — Ministry for the Environment
- Keith Evans — Ministry for Civil Defence & Emergency Management
- Karen Warren — Warren Planning Consultancy
- Warwick Prebble — New Zealand Geotechnical Society
- Grant Dellow — GNS Science (Avalon)
- Lesley Hopkins — Beca Carter Hollings & Ferner Ltd
- James Beban — Hutt City Council

Contributions from the following people were also gratefully received: Kelvin Berryman, Jane Forsyth, Graham Hancox, Janine Kerr, Andrew King, Chris Massey, Mauri McSaveney, Nick Perrin, Stuart Read, and Warwick Smith.

1 Wendy Saunders is a full member of the New Zealand Planning Institute, and previous to joining GNS Science (Avalon), she was employed as a resource management planner for a leading New Zealand consultant. Phil Glassey is based at GNS Science (Dunedin), is an engineering geologist and is a member of the New Zealand Geotechnical Society.

2. UNDERSTANDING LANDSLIDES

2.1 What is a landslide?

There are many definitions of a landslide. In commonly accepted international usage the term **landslide** refers to "the movement of a mass of rock, debris or earth down a slope" (Cruden, 1991). Terms such as **landslip, slippage,** and **falling debris** are also used for landslide-type features in New Zealand Statutes, such as the Building Act (2004), the Resource Management Act (1991), and the Earthquake Commission Act (1993). Some of these are defined in the legislation, and such definitions would normally take precedent in relation to these statutes (see Appendix 1 for an overview of legislative definitions).

2.2 Landslide classification

Landslides can be classified in a number of ways. Perhaps the best known and widely used classification in New Zealand is that of Varnes (1978, see also Cruden and Varnes 1996), which emphasises the type of movement and the type of material involved. Landslide movements are classified into five types: fall, topple, slide, spread and flow (Table 2.1, Figures 2.1, 2.2-2.6). The material involved in the movement is rock, debris or earth. Hence the combination of the type of movement and material involved gives a basic description of the landslide, e.g. rock fall, debris flow. Further description of a landslide incorporates terms on the state and style of activity, the rate of movement and expands material descriptions, including water content. There may be several modes and ages of movement present within the same landslide - these are referred to as complex landslides.

Table 2.1 A widely used landslide classification by Varnes (1978).

TYPE OF MOVEMENT		TYPE OF MATERIAL		
		BEDROCK	ENGINEERING SOILS	
			COARSE	FINE
FALLS		Rock fall	Debris fall	Earth fall
SLIDES	ROTATIONAL	Rock topple	Debris topple	Earth topple
		Rock slump	Debris slump	Earth slump
	TRANSLATIONAL	Rock block-slide Rock slide	Debris block-slide Debris slide	Earth block-slide Earth slide
LATERAL SPREADS		Rock spread	Debris spread	Earth spread
FLOWS		Rock flow	Debris flow	Earth flow
COMPLEX		Combination of two or more principal types of movement e.g. rock and debris avalanches (fall, slide and flow)		

Not all landslide specialists follow this classification, so it is important that the classification used is stated.

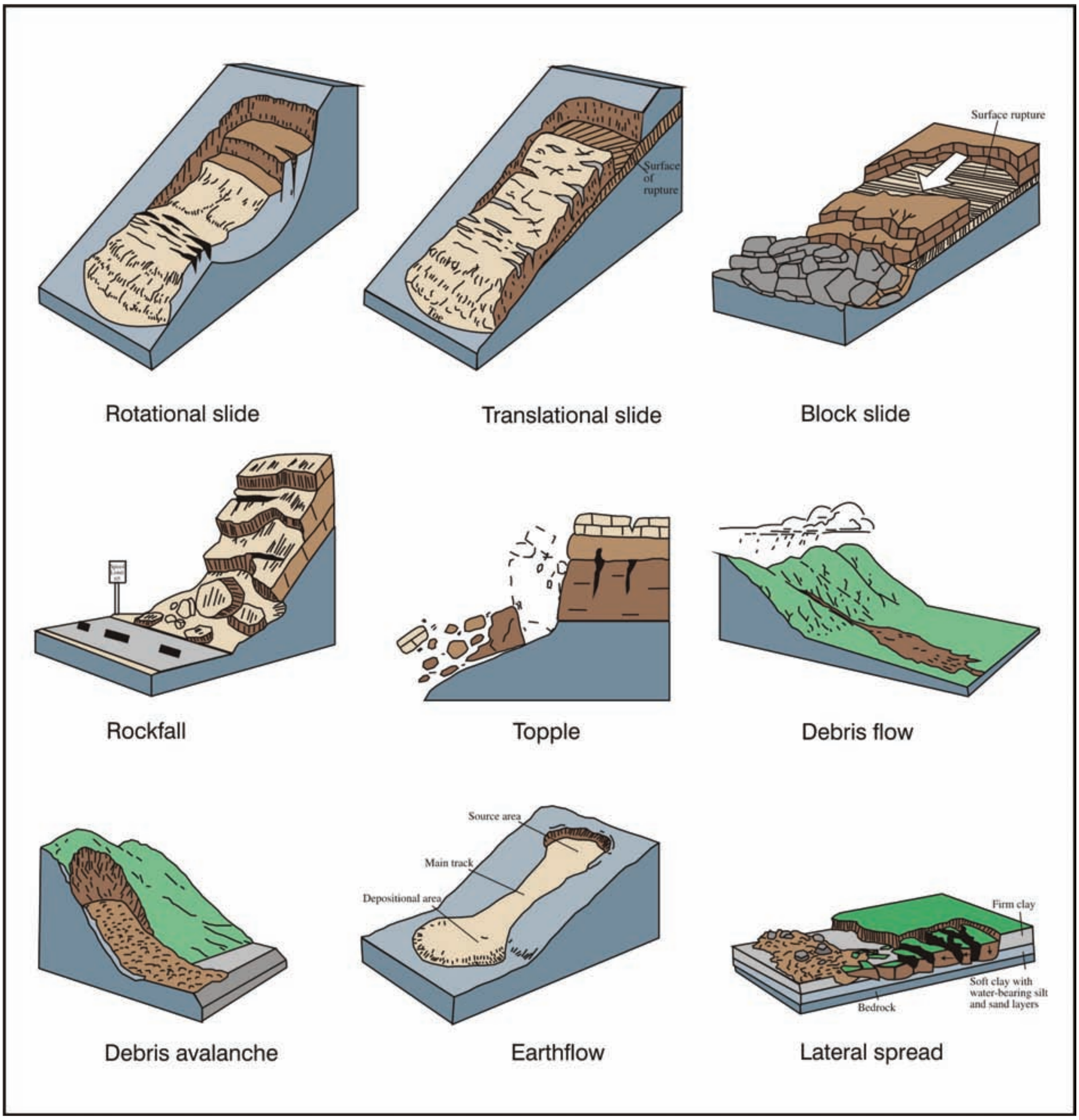


Figure 2.1 Types of landslides. Explanations of these types of landslides are provided in the glossary. (Modified from Highland, 2004).

Figures 2.2 – 2.6 provide examples of the various types of landslides as seen in New Zealand.

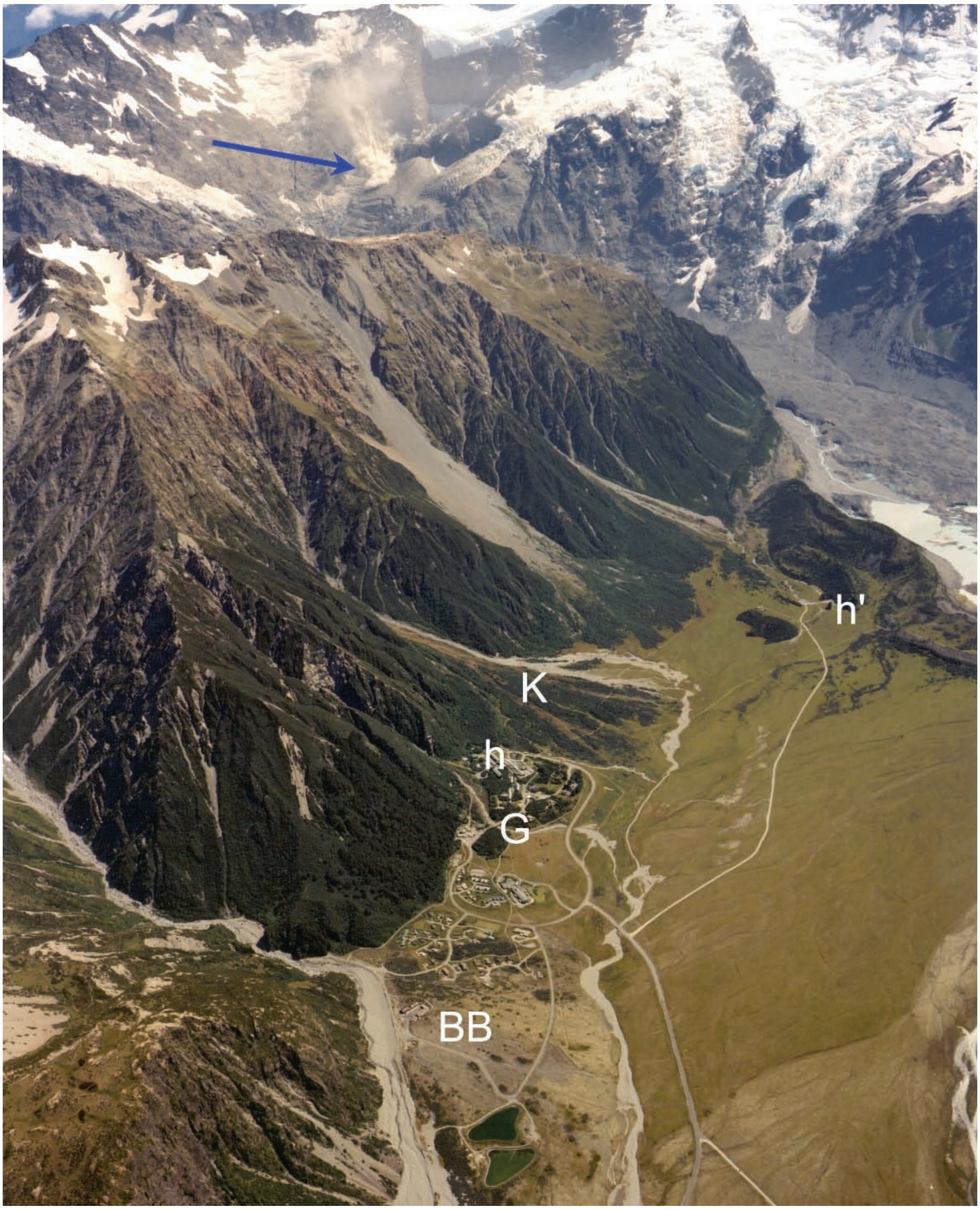


Figure 2.2 Aerial view of Aoraki/Mount Cook village on Black Birch and Glencoe fans. Black Birch fan (BB) forms the foreground, with Glencoe fan (G) in centre, and undeveloped Kitchener fan (K) beyond. Debris flows are of concern only on Glencoe fan. Black Birch fan has substantial mitigation work for flood and debris flood hazards. Kitchener fan has too high a hazard from snow avalanches and rockfalls to be considered for development. Rockfall of February 1996 produces the dust in the background (arrow) as it falls from Mount Thompson to Mueller Glacier. Site of the present Hermitage Hotel complex with debris-flow mitigation works is marked (h). Its former site beside Mueller Glacier abandoned in 1913 because of flooding from a glacier outburst but now free from any of the above hazards is marked (h') (see McSaveney and Davies 2005). Photo: D. L. Homer, GNS Science.

Figure 2.3 Earth slide in regolith and rapid debris flow in the run-out zone, north east of Wanganui at Mangamahu, during the July 2006 rainstorm. Photo: G.T. Hancox, GNS Science, July 2006.

Figure 2.4 Deep-seated rotational slide in mudstone (left) and slow-moving earthflow in the toe area (right), which occurred at Hunterville during the July 2006 rainstorms, causing the temporary evacuation of four houses. Photo: G.T. Hancox, July 2007.

Figure 2.5 Translational landslide, Taihape. Arrow shows the direction of slide, with line showing the headscarp area. Photo: G.T. Hancox, GNS Science.

Figure 2.6 Rain-triggered debris flow, Matata, Bay of Plenty, May 2005. Photo: Whakatane Beacon.

Typical observable features of landslides are illustrated below in Figure 2.7 (Varnes, 1978; IAEG, 1990 – see the glossary for a definition of the terms). On the ground, signs of slope instability include cracking, hummocky terrain, undrained crescent-shaped depressions and ponds, scarps and benches, crooked fences, trees or lamp posts leaning uphill or downhill, uneven road surfaces, swamps or wet ground in elevated positions, plants like rushes growing on a slope, and water seeping from the ground. Many of these signs are also visible on aerial photographs and, if large enough, are included on 1:50,000 scale topographic and geologic maps.

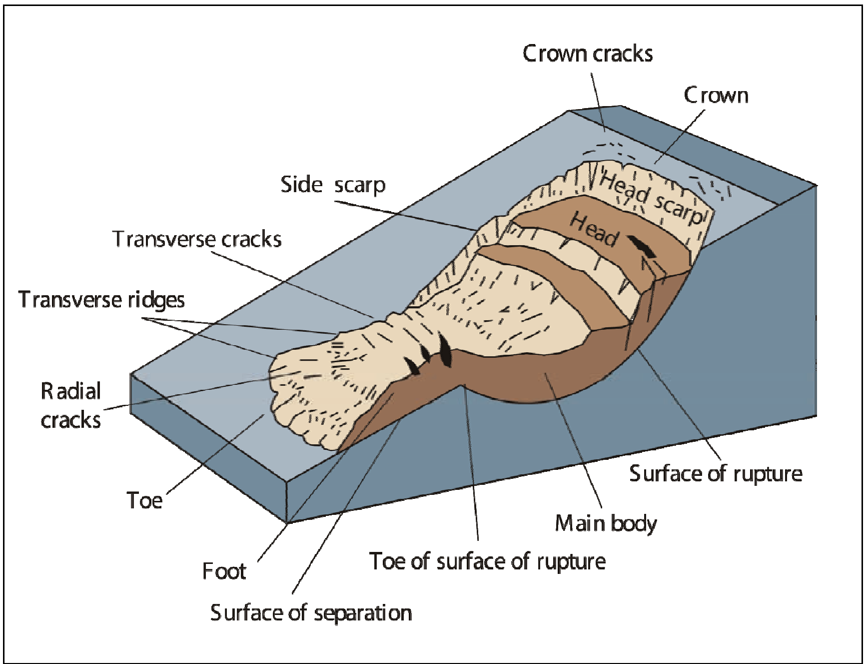


Figure 2.7 Simplified block diagram of a typical, but idealised, landslide showing commonly used technical names given to various parts of a landslide (from Highland, 2004, based on Varnes, 1978). Definitions are provided in the glossary of terms.

2.3 Rate of movement

Cruden and Varnes (1996) proposed seven velocity classes to describe the movement rates of landslides (see Figure 2.8). The velocity of a landslide is important in hazard assessment. An **extremely rapid** landslide (and accompanying air blast) could cause loss of life and property damage as there may be insufficient time for people to evacuate to safety. However large, **slow** moving landslides, although less of a threat to life, can affect many properties and cause significant damage to assets.

The slow moving landslide in Taihape (Figure 2.5) has a velocity of less than 1.6m/year, and has a velocity class of 2. The Hunterville landslide (Figure 2.4) had a velocity class of 5. The Abbotsford landslide of 1979 began with a velocity class 2 (about 15 mm/yr) during May-July of that year, but in August 1979 failed extremely rapidly with a velocity class of 7.

Velocity Class	Description	Velocity (mm/sec)	Typical Velocity	Probable Destructive Significance
7	Extremely Rapid			Catastrophe of major violence; buildings destroyed by impact of displaced material; many deaths; escape unlikely
		5×10^{3}	5 m/sec	
6	Very Rapid			Some lives lost; magnitude too great to permit all persons to escape
		5×10^{1}	3 m/min	
5	Rapid			Escape evacuation possible; structures; possessions, and equipment destroyed
		5×10^{-4}	1.8 m/hr	
4	Moderate			Some temporary and insensitive structures can be temporarily maintained
		5×10^{-3}	13 m/mth	
3	Slow			Remedial construction can be undertaken during movement; insensitive structures can be maintained with frequent maintenance work if total movement is not large during a particular acceleration phase
		5×10^{-5}	1.6 m/yr	
2	Very Slow			Some permanent structures undamaged by movement
		5×10^{-7}	15 mm/yr	
	Extremely Slow			Imperceptible without instruments; construction possible with precautions

Figure 2.8 Landslide rate of movement (velocity) classification taken from Cruden and Varnes (1996).

2.4 Landslide processes and causes

Why do landslides occur? Using the principles of physics, a slope is experiencing two sets of stresses, one set holding the slope together (shear strength) and the other acting to move material downslope (shear stress). When shear strength becomes less than shear stress, the slope fails and a landslide occurs.

2.4.1 Landslide causes and triggers

As hillslopes are stable most of the time, one way to understand slope instability is to think of how the interaction of different factors controls stability. Some inherent conditions of a slope (predisposing factors), such as steepness, rock type and structure, can make a slope susceptible to failure. For example, the predisposing factors of the Abbotsford landslide, were soft, low permeability mudstones containing very weak clay layers dipping down slope.

Slopes can be gradually weakened prior to failure by a range of processes (preparatory factors) such as deforestation, weathering, erosion and undercutting. Detrimental human activity includes the formation of unsupported cuts, slope loading (surcharge) by filling, and uncontrolled water discharges. The construction of earth dams, excavation and mining, irrigation, building construction, services (such as storm water, sewers, etc.), or pilings, can all be preparatory factors in landslide development.

Landslides can have several causes but generally have only one trigger. The most common landslide trigger is prolonged or intense rainfall. Large earthquakes can also trigger landslides, some very large, over a widespread area. Volcanic eruptions and geothermal activity can also trigger landslides, as can rapid drawdown or filling of reservoirs and canals. Erosion resulting in the undercutting of slopes by river or coastal processes and slope modification can also be a common trigger of landslides.

2.4.2 Landslides and land development

As mentioned above, modifications to slopes by development are a common preparatory cause (and sometimes a trigger) of landslides. In most cases, however, there is a time lag (sometimes years) between an alteration to the slope and a triggering event which initiates landslides. Excavation at the base of slopes, particularly at the toes of old landslides (that may not be recognised as such), is the most common cause of instability. Rainfall or leaking water pipes at the site are the most common triggering events (Taylor et al, 1977), as they lead to increased density and water pressures in the slope material, especially where drainage is poor.

Old landslide material (debris) is often weak and unsatisfactory to build on. Despite the material having been displaced into a more stable position overall, its “softness” can lead to slow local ground settlement and recurring localised slumping for a very long time after the main movement has ceased (Taylor et al, 1977). This needs to be considered in development planning, and mitigation measures such as drainage or buttressing of the slopes may be required.

2.4.3 Removal of vegetation

The removal of vegetation, often the first step in land development, can reduce the stability of sloping ground. Land originally stable under heavy bush cover commonly goes through a phase of landsliding when that cover is removed. Under the protection of scrub cover, many slopes are only marginally stable, and immediately deteriorate on its removal (Taylor et al, 1977; Crozier 1986; Crozier et al, 1992). Evidence of landslides may be obscured by secondary growth.

On slopes with adequate soil cover, shrubs and trees are usually advantageous, as they add root strength, reduce concentrated overland water flow, and can alter the rate of water infiltration into the ground. Evapo-transpiration can also remove water from the soil.

Vegetation can also contribute to slope instability. Trees become a liability when they get very large – their weight and the action of wind can contribute to slope instability (Taylor et al, 1977; Crozier 1986; Crozier et al, 1992). On jointed rock, shrubs and trees can promote instability, as the roots can open joints in the rock letting water in, and may even prise blocks off slopes. Any vegetation planting for slope stabilisation should be managed through a vegetation maintenance plan, to ensure planting is fulfilling its purpose.

During the February 2004 rain storms in the lower North Island of New Zealand, scrub and forest cover on steep hill country reduced the incidence of shallow soil slides to 10-20% of that on similar grass-covered slopes (Hancox & Wright, 2005). Milling of exotic forest substantially increased the number of landslides present.

2.4.4 Slope modification by engineering works

It has long been widely recognised that modification of the landscape by cut and fill earthworks can have a profound affect on slope stability. Apart from retaining more of the aesthetic qualities of natural slopes, a policy of minimising earthworks is likely to minimise the likelihood of landsliding and the costs of remedial work (Taylor et al, 1977; Crozier 1986; Crozier et al, 1992).

Adding material to the toe of a slope (buttressing), and/or removing material from the head of a slope, will usually increase slope stability by reducing shear stresses and thereby diminishing the likelihood of landslides. The addition of material near the head of a slope may lead to instability of the slope as a whole, as well as of the fill itself. This action, or surcharging, has an effect similar to removing material from the toe of the slope – in both cases, the shear stresses within the slope are increased (Taylor et al, 1977; Crozier 1986; Crozier et al, 1992). Engineering assessment is always required to determine safe slope modifications.

Excavating house basements, building platforms, and access roads creates potentially unstable slopes which may need to be supported to prevent landslides (Taylor et al, 1977). Stability is often compromised by cut and/or fill for roads and access-ways which sidle across the slope (see Figure 2.9). Good engineering practice and design, such as draining fills and building retaining structures for cuts, reduces landslide potential. Retaining walls require appropriate engineering design based upon realistic evaluation of the amount and weight of the soil to be retained, the capacity of the ground to support the foundations of the wall, and seismic loading from earthquake shaking. In many cases, retaining walls are not a practical means of supporting slopes (Taylor et al, 1977; Crozier 1986; Crozier et al, 1992).

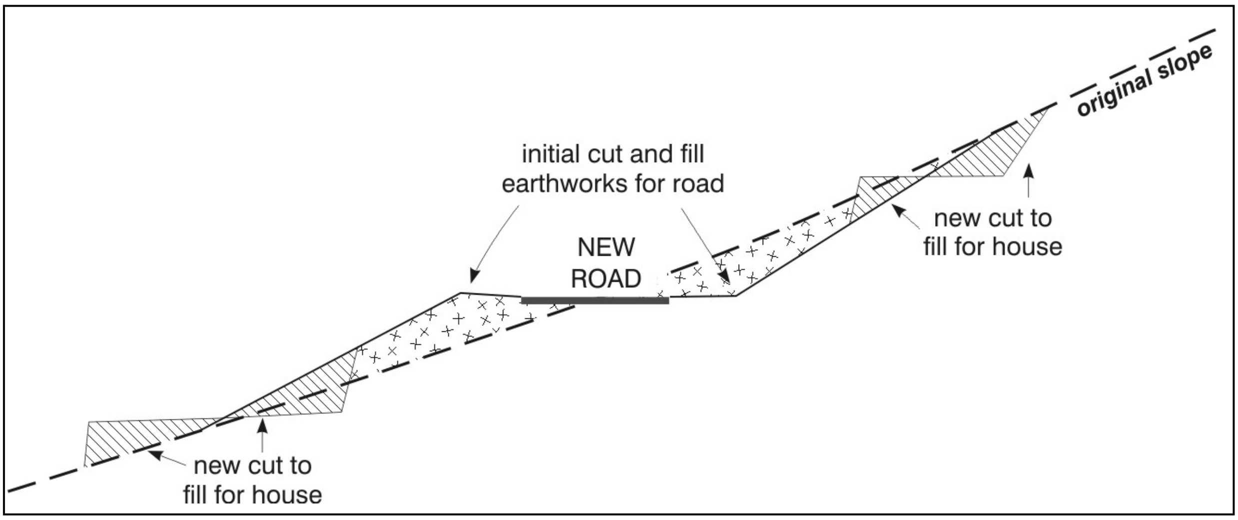


Figure 2.9 House site on left formed by cutting into older, poorly designed fill. House site on right formed by cutting into a slope which had already been steepened. Both situations can be dangerous. (Source: Taylor et al, 1977).

2.4.5 Services

There are many examples where broken service lines have fed water into the ground at the point of landslide failure (e.g. Abbotsford 1979, Kelson 2006). Therefore, it is good practice to consider the placement, design, and monitoring of services (such as sewers, septic tanks, water supply or storm water lines) where they cross areas with evidence of past movement or likelihood of future movements. Placement of water pipes in fill needs very careful design and construction to prevent future leakages and movements.

2.4.6 Run-out zones

Potential landslide or flow run-out zones (e.g. Figures 2.2, 2.3, 2.4 and 2.6) need to be assessed during land development. Areas on debris fans are at particular risk from debris flows and floods. Past fatal landslides in New Zealand (e.g. Murchison 1929 earthquake) have shown that even areas of flat land in valley floors some distance (~500 – 1000 m) from the base of potentially unstable slopes can be overrun by landslide debris. It is therefore prudent to recognise and avoid these hazardous areas prior to an event occurring. Where a run-out hazard has been identified, then either development should be excluded from the potential run-out zone, or other appropriate mitigation measures should be taken (see Section 4.6 – Thames hospital example).

Information Box 1

THE LANDSLIDE SPECIALIST – WHO DOES WHAT?

A landslide specialist may be any of those with appropriate experience in mapping landslides and understanding landslide processes.

A **geologist** is a scientist who studies the dynamics and physical history of the earth, the rocks of which it is composed, and the physical, chemical, and biological changes the earth has undergone or is undergoing. A geologist typically concentrates on regional level geology.

An **engineering geologist** is a geologist skilled in applying geologic knowledge and principles to investigating and evaluating naturally occurring rock and soil for use in civil engineering works and evaluation of geological hazards (including slope instability and landslides) that may affect these works. The scale of work is more specific than that of a geologist.

A **geotechnical engineer** is a civil engineer skilled in applying soil and rock mechanics principles to investigating, evaluating, and designing civil works, including geological hazards that affect these works. A geotechnical engineer is involved in site-specific designs for these structures or works.

There are also ‘earth scientists’ with training and experience in landslides who are neither geologists nor engineers, such as geomorphologists, who are also regarded as specialists in this field.

3. LANDSLIDE AND HAZARD MAPS

To assess landslide hazard an understanding of the conditions and processes controlling existing landslides is required. A map of landslides serves as the basic data resource for landslide hazard assessment. Existing landslides and their relationship with other key factors such as slope steepness, rock and soil types, and groundwater conditions form the basis for assessing landslide susceptibility and ultimately assessing landslide hazard.

3.1 Landslide Maps

An all-inclusive approach to mapping recommended, starting with the regional geologic and geomorphic setting, then focusing in to the detailed scale (see Section 3.3). This information may best be presented as a series of maps rather than a single map. A comprehensive view of the terrain is needed to identify all potential problems associated with slope conditions, including existing and potential instability. It is often important to look beyond the boundary of a site to see what geological features could affect the site in the future. There may be vital evidence of past landslide processes outside the site under consideration, that may provide information and understanding about hazards in the area.

Information Box 2

TYPES OF LANDSLIDE MAPS (from Chacón et al, 2006)

Landslide inventory map
The knowledge of the landslides in a particular area is expressed by a landslide inventory map, which shows the locations and outlines of landslides. A landslide inventory is a data set that may represent single or multiple events. Small-scale maps show only landslide locations, whereas large-scale maps may distinguish landslide sources from deposits, classify different kinds of landslide and show other pertinent data.

Landslide susceptibility map
A landslide susceptibility map ranks the slope stability of an area in categories that range from stable to unstable. Susceptibility maps show where landslides may occur. Many susceptibility maps use a colour scheme that relates stronger colours (red, orange and yellow) to unstable and marginally unstable areas and cool colours (blue and green) to more stable areas.

Landslide hazard map
A landslide hazard map includes zonations showing annual probability (likelihood) of landslide occurring throughout an area. An ideal landslide hazard map has zonations showing not only the chances that a landslide may form at a particular place, but also the chances that a landslide from farther upslope may strike that place.

Landslide risk map
A landslide risk map shows the expected annual cost of landslide damage throughout the affected area and combines the probability information from a landslide hazard map with an analysis of all possible consequences (property damage, casualties and loss of service). It may be founded on concepts of element at risk, vulnerability, specific and total risk.

A landslide inventory map identifies definite and probable landslides, and is the most basic requirement for a landslide hazard assessment. Examples of landslide inventory maps are given as Figure 3.1 and 3.5. Such maps, through appropriate symbolisation, can provide information about the type of landslide, activity, debris and the like, as shown in Figure 3.2.

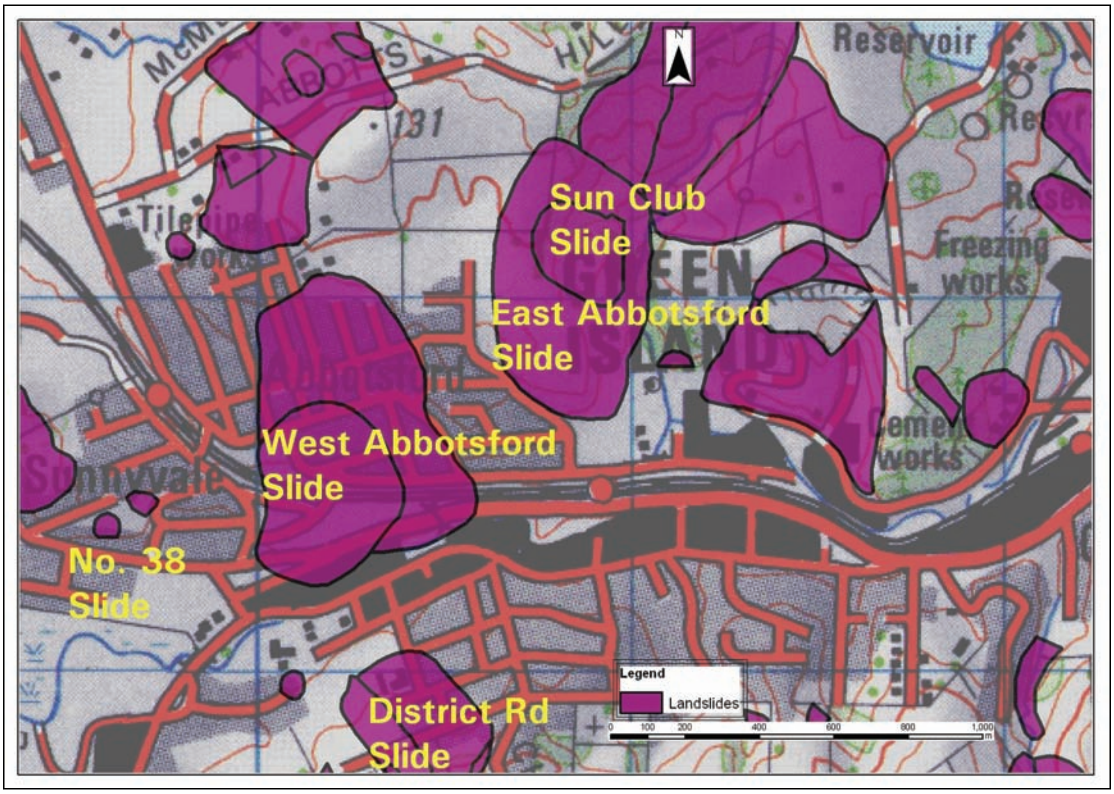


Figure 3.1 Basic landslide inventory map, Green Island Dunedin. More detail regarding type cause and activity is available in the database for many of these landslides.

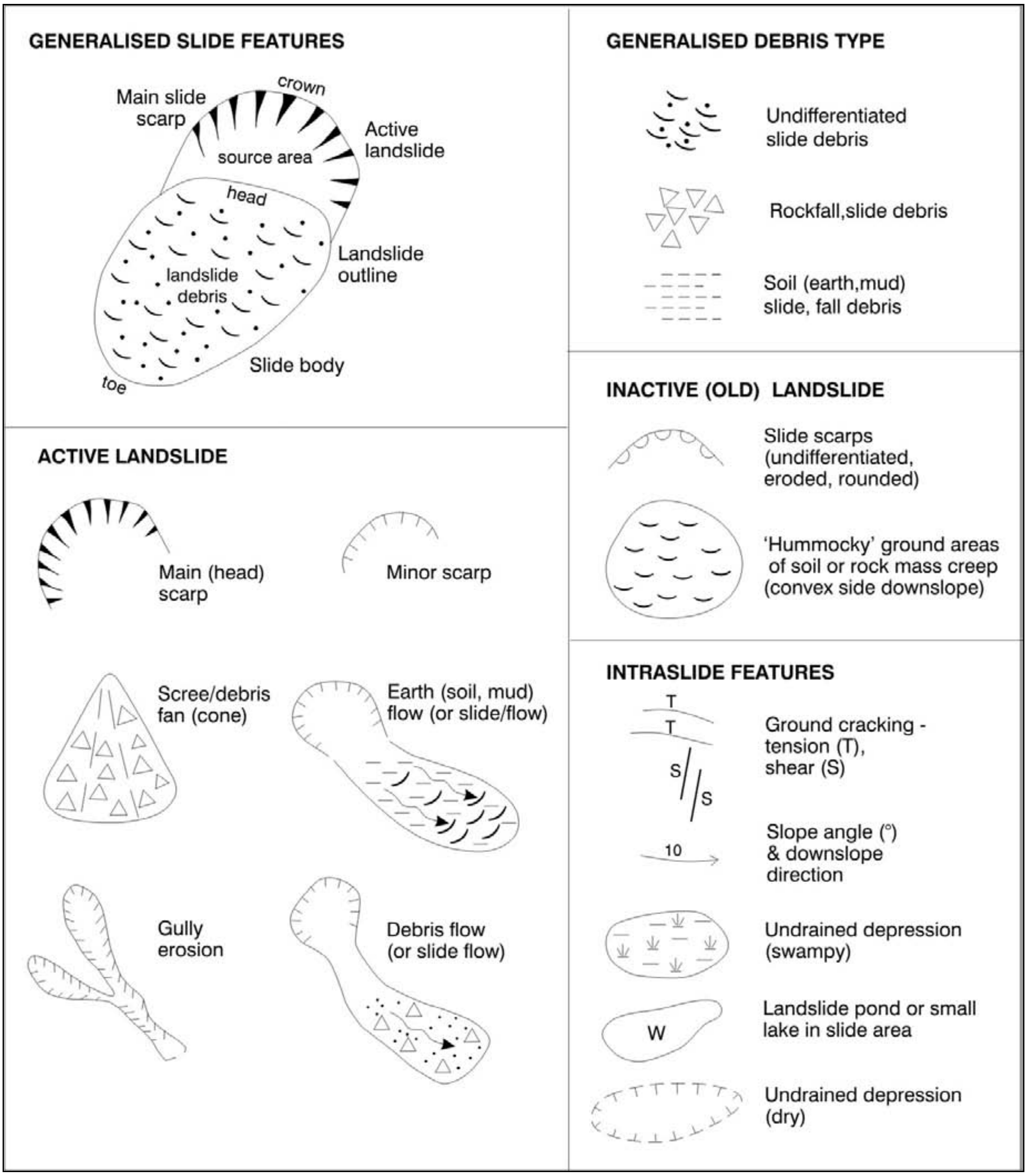


Figure 3.2 Symbols commonly used for mapping landslides up to a scale of 1:50,000 which provide information on type, activity and features.

3.2 Aerial photography

Aerial photography provides a useful resource for identifying and mapping of landslides. Orthophoto maps at larger scales are very useful as bases for both geomorphic and landslide hazard maps. In addition, comparing aerial photographs of an area taken at different times can give an indication of the frequency and extent of landslide events. It is important to use photographs from different periods spanning as much time as possible, as land development can often conceal the presence of landslide features. A series of vertical (or oblique) aerial photos can be used to illustrate the features of concern, and differences that have occurred over a period of time, which can be up to 60-70 years in New Zealand.

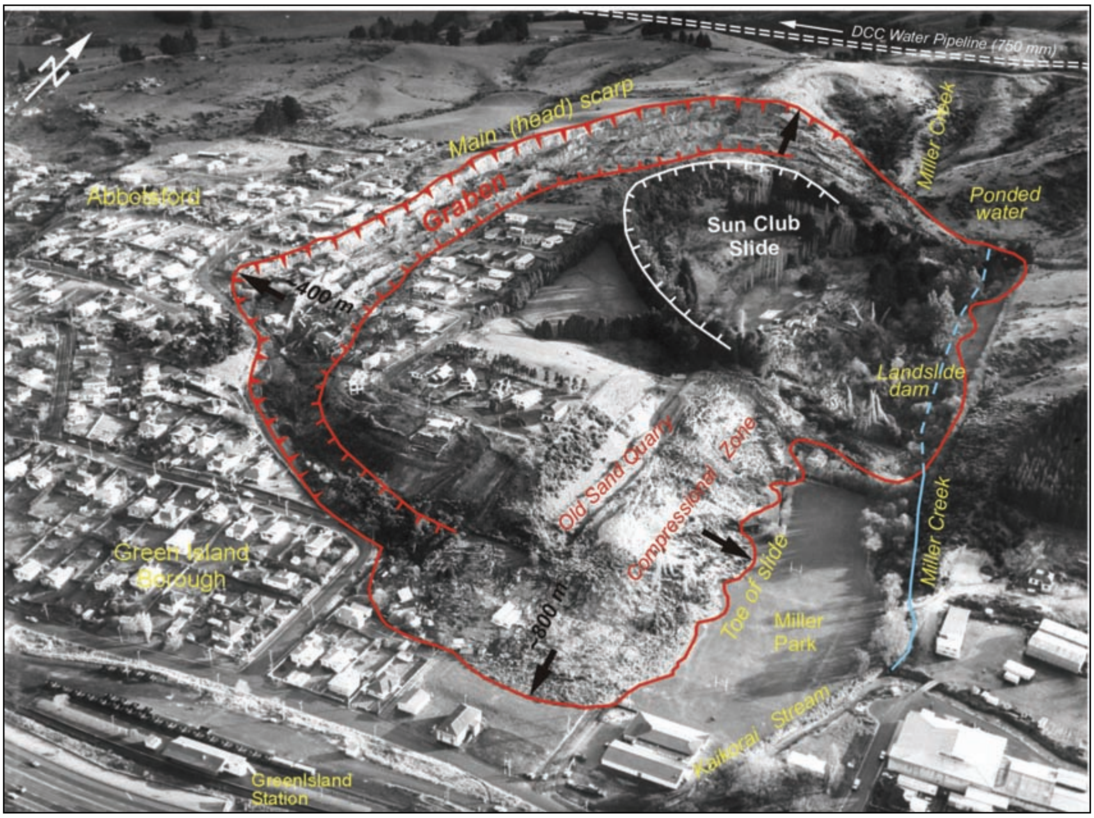
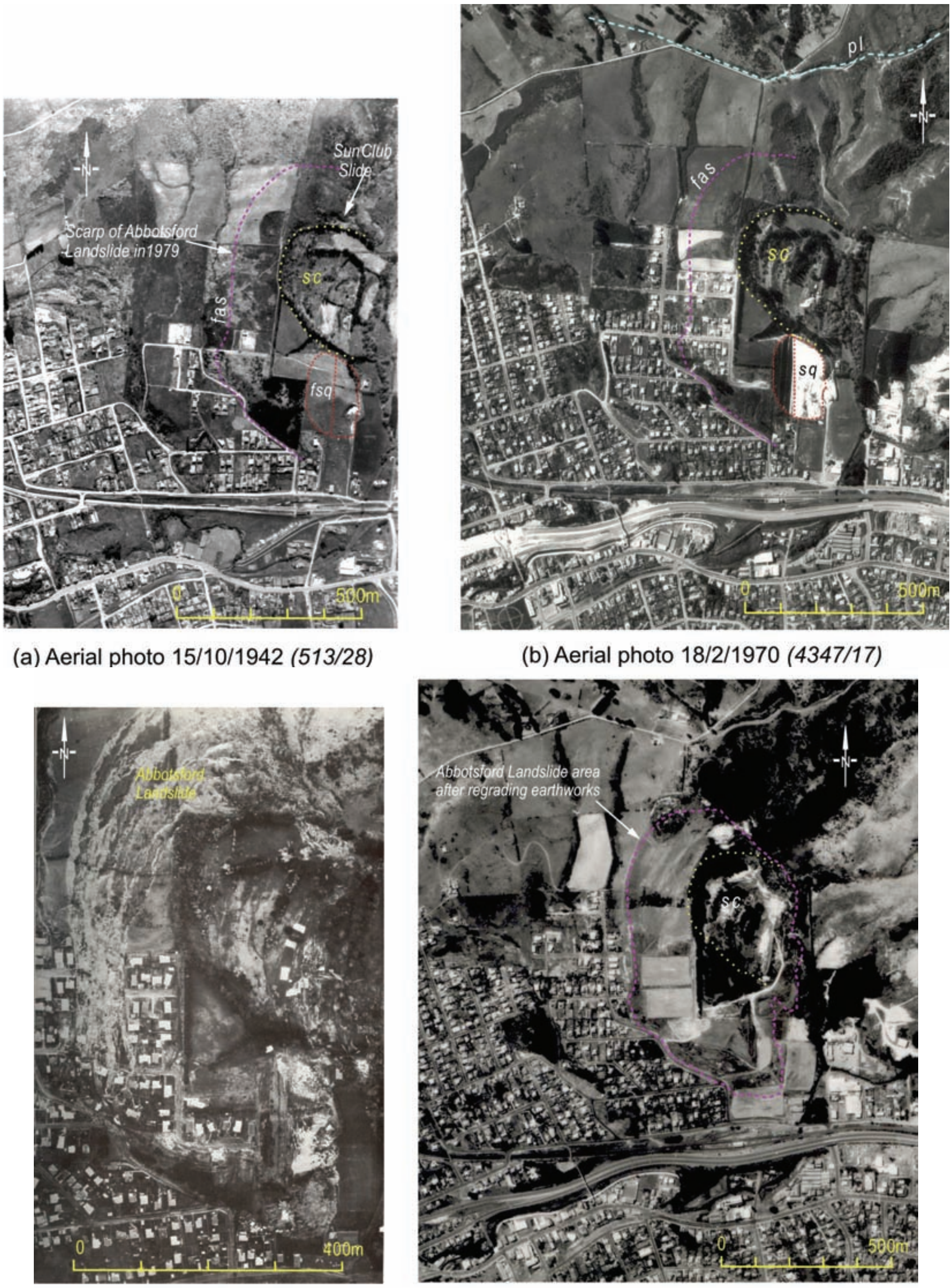


Figure 3.3 Oblique aerial photo of the Abbotsford Landslide taken on 9 August 1979, the morning after the final movement occurred. The landslide mass moved c. 50 m down a 7° bedding plane clay layer in about 50 minutes, forming a graben 70-150 m wide at the head. Features seen here that contributed to the landslide include the old sand quarry at the bottom of slope (which was closed in 1969), and a leaking water main c. 200 m north (up slope) of the landslide. The old Sun Club Slide on the west side of Miller Creek (dammed by the landslide) shows the inherent instability of the area. (Photo by courtesy of Aeropix, Dunedin)

The series of oblique and vertical air photographs (Figures 3.3 and 3.4) show the Abbotsford Landslide area in Dunedin. In 1979, a seven-hectare section of Abbotsford experienced a landslide in which 69 homes were destroyed or made uninhabitable (Hancox *in press*). Figure 3.3 shows the extent of the landslide, the morning after the main movement. The photographs in Figure 3.4 were taken in 1942, 1970, 1979 and 1985. Looking at the historical records it is clear that landslides have occurred in the area and have been exacerbated by human activity, such as the undercutting of the toe of an old slide by quarrying and a leaking water main above where the landslide developed. The 1985 Abbotsford photograph was taken after the 69 houses damaged in the 1979 landslide had been removed and the area had been re-graded and landscaped. The extent of the landslide is now difficult to see.



(a) Aerial photo 15/10/1942 *(513/28)*

(b) Aerial photo 18/2/1970 *(4347/17)*

(c) Aerial photo taken 9 August 1979 *(Paterson Aerial Surveys Ltd. Dunedin)*

(d) Aerial photo 16/2/1985 *(SN8479-F/11)*

Figure 3.4 Series of vertical air photos showing the Abbotsford Landslide area prior to the landslide in 1942 (a) and 1970 (b), on 9 August 1979 (c), and in 1985 (d), after the 69 damaged houses had been removed and the area had been re-graded and landscaped. The 1942 photo was taken before housing was fully established in the area, and shows the scarp of old (prehistoric) Sun Club slide, and future positions of the sand quarry (fsq), which developed in the 1960's, and head scarp of the Abbotsford Landslide (fas). Photo (b) shows the extent of the quarry in 1970 after it was closed in 1969, and the approximate location of the leaking DCC water mains (pl) above where the landslide developed. Photo (c) shows the Abbotsford Landslide the day after it occurred. The main features of the landslide are shown in Figure 3.3.

3.3 Scale

Landslides and associated information should be mapped at a scale appropriate for the end-use, in this case enabling planners to make decisions about land use on or close to landslide-prone ground. At present, few local authorities have mapped landslides to an appropriate planning-level scale of approximately 1:10,000, instead relying on existing smaller-scale maps showing areas of unstable land (1:250,000 to 1:50,000 scale – see Figures 3.5 – 3.7). While such maps are appropriate for regional studies, they are indicative only and do not provide adequate detail for many planning purposes which require detail to at least property-boundary level. Table 3.1 in Section 3.4 provides a further example of mapping scales in relation to hazard analysis techniques.

Information Box 3

SCALE FOR MAPPING LANDSLIDES

- National (1:1,000,000)
- Regional (1:100,000 to 1:500,000) – QMAP Geological Map series
- Medium (1:25,000 to 1:50,000) – typically municipal or small metropolitan areas
- Large (1:5,000 to 1:15,000) – typically site or property level

Compatibility of scale is important when the landslide map is to be combined with other maps to yield a land-use capability map. A landslide hazard map should be at a scale similar to the data maps used to produce it. For example, reliability may be questionable when a landslide hazard map produced at a scale of 1:50,000 has been based on a 1:250,000 slope map. The increased use of GIS readily allows for a combination of various land information. However, planners should be aware that this easily allows inappropriate use of data at various scales.

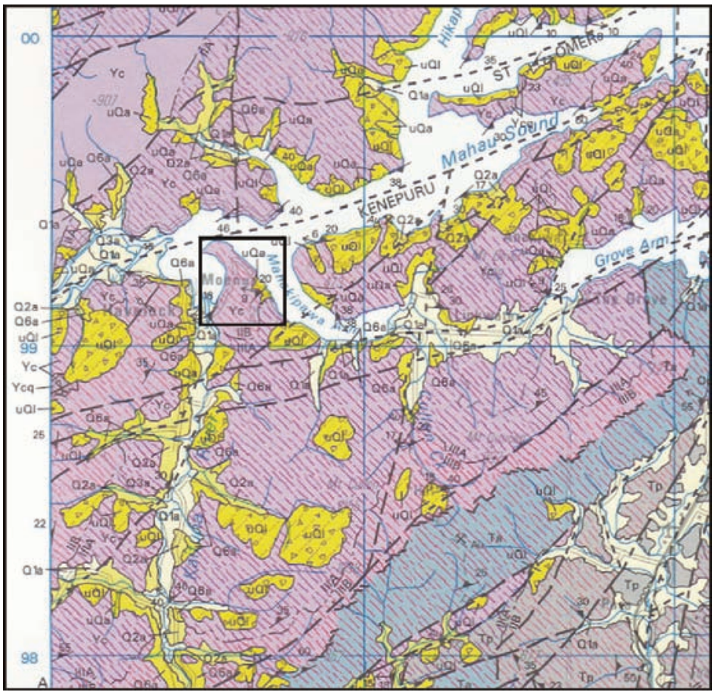


Figure 3.5 Landslide Inventory map. A snapshot of the QMAP 1:250,000 (Begg & Johnston, 2000) regional level geological map showing main features of Mahau Sound (Marlborough Sounds). The speckled yellow areas show the location of large landslides. This is a most basic landslide inventory map. Moenui is located in the inset.

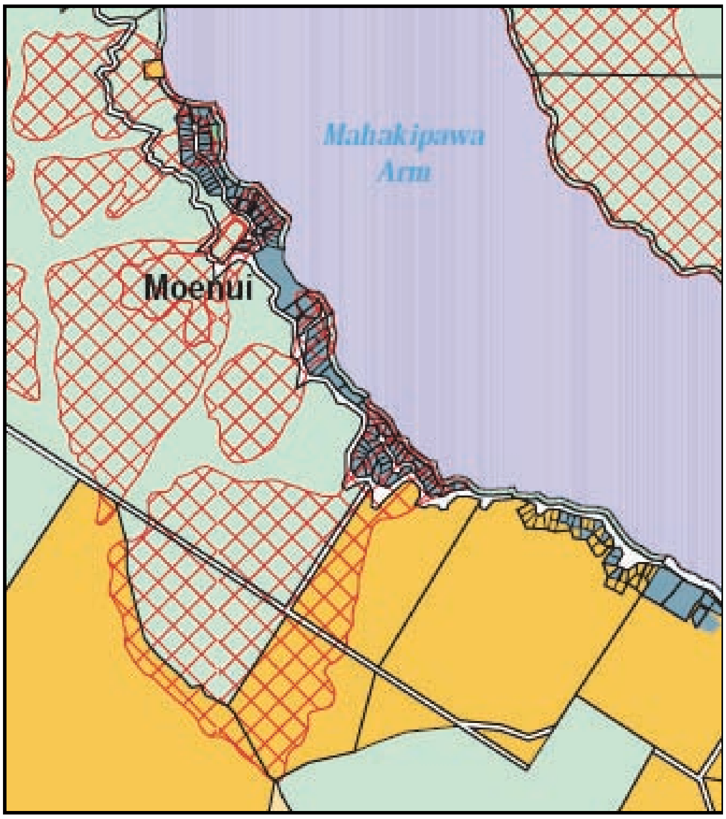


Figure 3.6 A snapshot of the 1:30,000 Marlborough District Council Wairau/Awatere Resource Management Plan Area, Mahau Sound (Marlborough District Council, 2003). This simplistic landslide hazard zonation map highlights existing landslides (thick red line – an inventory map) and potentially unstable areas (red hatching).

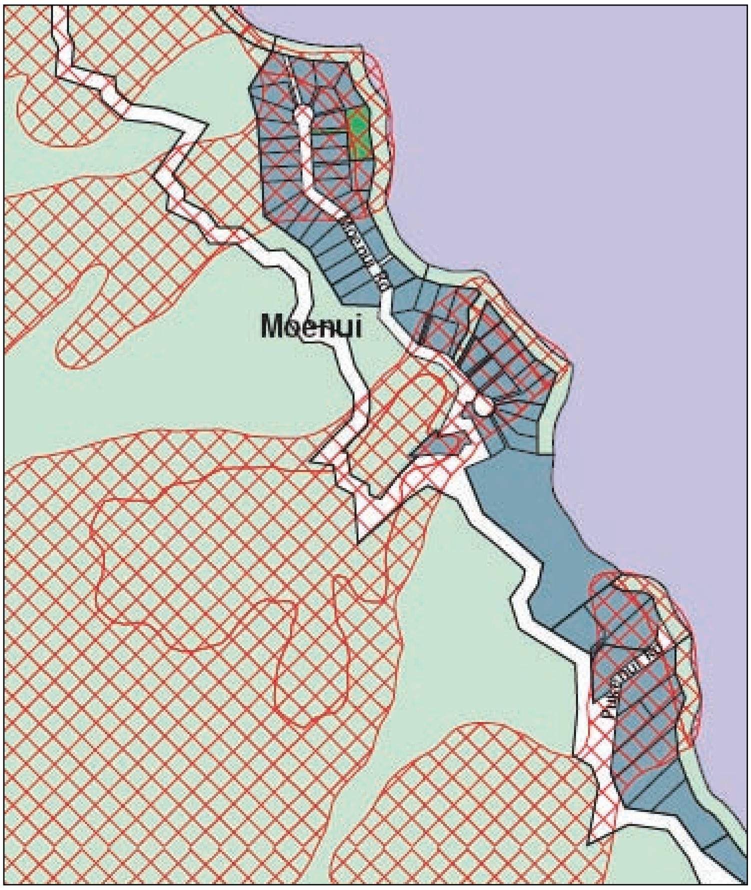


Figure 3.7 A snapshot of the 1:10,000 Marlborough District Council Wairau/Awatere Resource Management Plan Area, Mahau Sound, showing cadastral boundaries at Moenui (Marlborough District Council, 2003) and landslides (thick red lines) or potentially unstable areas (red hatching).

Information Box 4

BASIC INFORMATION FOR LANDSLIDE HAZARD ASSESSMENT

The basic information required for landslide hazard assessment includes:

- Location of existing landslides
  Geomorphic features including slope instability (ground cracks, scarps, hummocky ground, landslide ponds etc)
- Soil and bedrock types and structure (bedding, joints, faults)
- Vegetation
- Slope steepness (slope angle)
- Groundwater levels and hydrological conditions (hydrology)

3.4 Landslide hazard analysis techniques and maps

Existing landslides and their relationship with other key factors such as slope steepness, rock and soil types, and groundwater conditions gives an understanding of the conditions and processes controlling landsliding and forms the basis for assessing landslide susceptibility and ultimately hazard. Table 3.1 provides a summary of hazard analysis techniques and mapping scales.

Table 3.1 Hazard analysis techniques in relation to mapping scales (after Soeters and Van Westen, 1996)

Type of Analysis	Technique	Characteristics	Scale of Use Recommended		
			Regional	Medium	Large
			1:100,000	1:25,000	1:10,000
Inventory	Landslide distribution analysis	Analyse distribution and classification of landslides	Yes	Yes	Yes
	Landslide activity analysis	Analyse temporal changes in landslide pattern	No	Yes	Yes
	Landslide density analysis	Calculate landslide density in terrain units or as isopleth map	Yes	No	No
Heuristic	Geomorphologic analysis	Use in-field expert opinion in zonation	Yes	Yes	Yes
	Qualitative map combination	Use expert-based weight values of parameter maps	Yes	Yes	No
Statistical	Bi-variate statistical analysis	Calculate importance of contributing factor combination	No	Yes	No
	Multivariate statistical analysis	Calculate prediction formula from data matrix	No	Yes	No
	Probabilistic (Magnitude/ Frequency)	Calculate prediction from inventory and time period using power law	Yes	Yes	No
Deterministic	Safety factor analysis	Apply hydrological and slope stability models	No	No	Yes

Heuristic or qualitative methods use expert interpretation of geological and historical information on landslides to estimate the susceptibility of areas to landslide events. The Marlborough District Council maps shown as Figures 3.6 and 3.7 are a combination of a landslide inventory and a geomorphologic analysis to come up with “hazard“ zones. A combination of qualitative and quantitative information forms the basis of relative hazard that can be classified into landslide susceptibility classes (e.g. high, medium, low). An example of a regional earthquake-induced slope hazard susceptibility map is given in Figure 3.8. The methodology behind this susceptibility map is provided in Appendix 2.

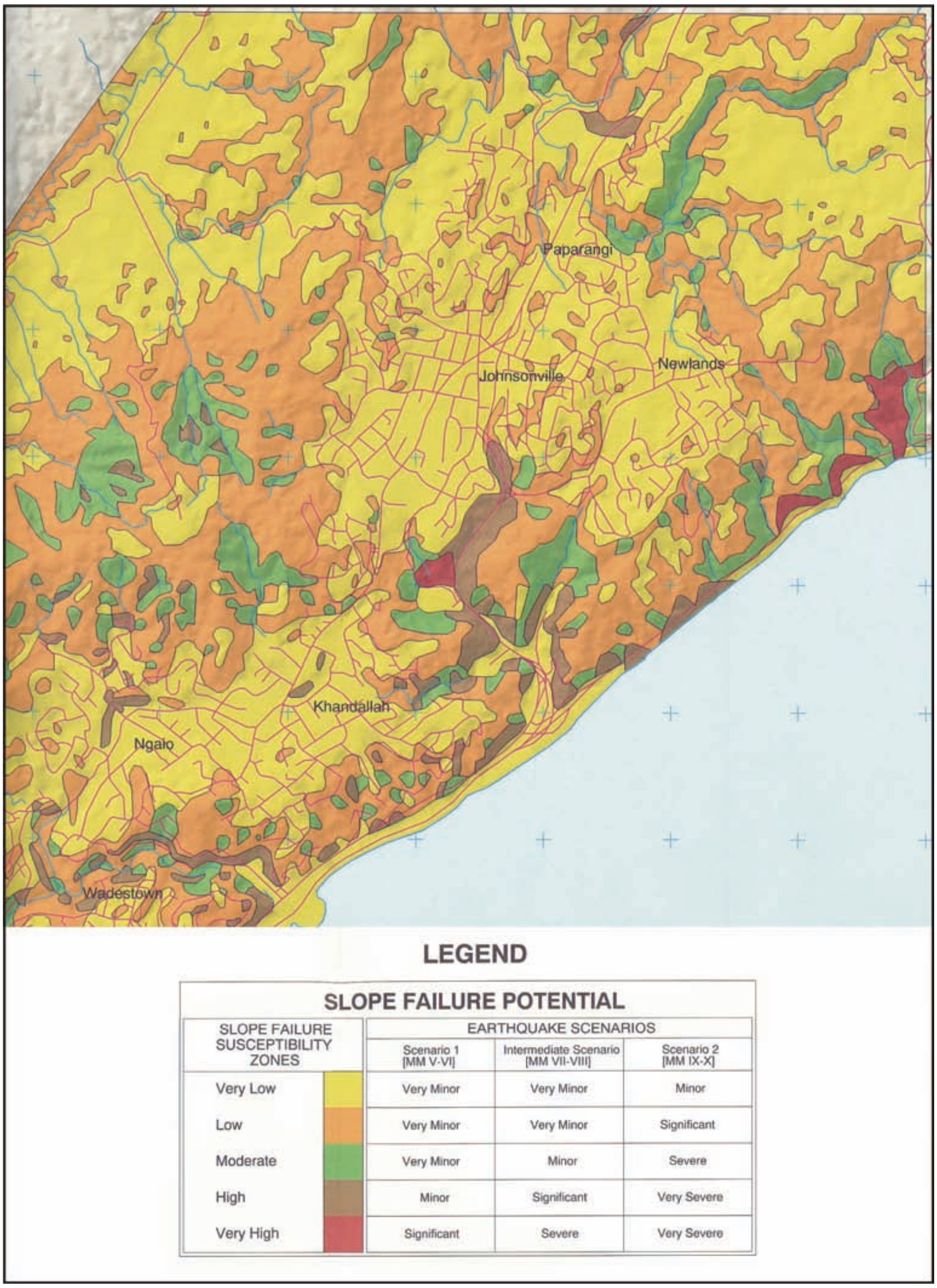


Figure 3.8 Earthquake Induced Slope Failure Susceptibility, Wellington (Kingsbury, 1995)

Statistical hazard analysis methods use landslides, geological, topographic and vegetation information to calculate the susceptibility to landsliding or the probability of landslide events. By strict definition, determining landslide hazard requires determining the magnitude and frequency of landslide events. Determining the spatial and temporal extent of landslide hazard involves identifying areas which are, or could be, affected by a landslide and assessing the probability of similar landsliding occurring within a specified time period. Specifying a timeframe for the future occurrence of a landslide is difficult and often not possible. Landslide hazard maps, depicting the annual probability of a landslide occurring within an area are not common in New Zealand.

The frequency of landslide occurrence can be estimated from analysis of the landslide record and in particular the form of existing landslide features and there relationship to other landform features of known age. This is discussed further in section 3.5 below

Given that determining the magnitude and frequency of landsliding is difficult, landslide hazard is often represented by landslide susceptibility, where only the predisposing and preparatory landslide factors are considered (see Section 2.4). Similar to concepts used for flood-prone areas, landslide susceptibility identifies general areas likely to be affected by landslides, but does not identify a timeframe within which a landslide might occur.

Deterministic methods use limit equilibrium (factor of safety analysis) applied to specific hydrological and slope models and are better utilised for site specific analysis.

Information Box 5

SOURCES OF LANDSLIDE INFORMATION

- QMAP Geological Maps (1:250,000)
- New Zealand Landslide Database (held by GNS Science)
- Land Use Capability maps from the New Zealand Land Resource Inventory
- Local inventories and hazard registers
- Aerial photographs and satellite imagery (interpretation required)
- Field maps (interpretation required)
- Other geological maps (various scales)

3.5 Frequency of landslide occurrence

A key purpose of landslide hazard assessment is to determine the likelihood of future landslides at a specific site. This requires an assessment of landslide magnitude (size) and frequency. Landslide size can be measured, but few people are skilled at “seeing” aspects of time or probability. Landslides can be dated either by direct observation or historical records, or by a number of absolute dating methods, such as radio-carbon dating. The techniques available for determining the age of landslides can be expensive and are often unproductive or inconclusive. However, accurate age assessment is not required for planning or design. What is required is information on the likely occurrence in relation to the proposed land uses and the structures that might be built. Land use and the type of buildings define what likelihood is acceptable or not acceptable.

Landslide ages determined from the historical record, personal observations and aerial photographs are usually reliable for landslides that have occurred over the last 50 years. The most recent events are usually obvious by the very fresh appearance of landslides. Landslide features become more rounded and subdued due to erosion and soil development, and re-growth of vegetation over time. This commonly provides clear differences in appearance of landforms of different ages (tens to thousands of years). This information, together with information on landslide size, type, and likelihood of various trigger mechanisms, such as rain storms and earthquakes, is usually sufficient for quantitative risk-based planning. Risk is usually developed in terms of probability (see Section 4 and Information Box 6).

Relative ages of landslides can also be determined by comparing their relationship with geological features for which some age control can be determined, such as river terraces, ash layers, buried soils and buried organic remains. The frequency of movement of existing landslides can be detected by instrumental monitoring.

Information Box 6

Which is a better measure – AEP or probability?

It is recommended that hazard risk be considered in terms of probability because of confusion over the use of the terms "average recurrence interval" (ARI) and "return period". These have been criticised as leading to confusion in the minds of some decision makers and members of public. Although the terms are simple superficially, they are sometimes misinterpreted as implying that the associated magnitude is only exceeded at regular intervals, and that they are referring to the elapsed time to the next exceedance. Both AEP and probability are frequently used for a number of hazard estimations.

It is therefore preferable to express the rarity of an event (rainfall, for example) in terms of Annual Exceedance Probability (AEP). Using rainfall as an example, a total of 159mm falling in 3 hours at a specific location has a 0.010 (i.e. 1%) probability of being equalled or exceeded in any one year. This can be easier to understand than the equivalent statement of a rainfall total of 159mm in 3 hours has an average recurrence interval of 100 years. With appropriate information, landslides can be put into this context (for example, see the Thames hospital case study in section 4.6).

The 1% AEP event put into perspective

This is an event which has a 1% chance of occurring or being exceeded every year. As the time period is increased, the chance of an event of this magnitude occurring or being exceeded increases as indicated in the table below. There is also a possibility that more than one of these extreme events could occur in the same year.

Chance of occurring or being exceeded	In a single year	In a 10 year period	In a 50 year period	In a 100 year period
Once	1%	9.6%	39.5%	63.6%
Twice		0.4%	7.6%	18.5%
Three times		0.01%	1.2%	6.1%

For more information regarding probabilities for landslides, refer to the Australian Geomechanics Society (2007d) *Commentary on Practice Note Guidelines for Landslide Risk Management 2007.*

4. IDENTIFYING, ASSESSING AND PLANNING FOR LANDSLIDE RISK

4.1 Principles for planning approaches

These guidelines are based on four overarching principles:

1. Gather accurate landslide hazard information.
2. Plan to avoid landslide hazards before development and subdivision.
3. Take a risk-based approach in areas already developed or subdivided.
4. Communicate risk of landslides in built-up areas.

4.1.1 Principle 1: Gather accurate landslide hazard information

Identifying landslide-prone areas and plotting them on planning maps is essential for communicating the risk they may present and mitigating such hazards. Collection of relevant hazard information often requires specialised technical knowledge and surveys. Maps showing the location of landslide hazards in the vicinity of a property must be developed at an appropriate scale for planning purposes. Because the existence of a landslide may have an effect on a decision to purchase or build on a property, all information on hazards should be as accurate as knowledge, technical standards and resources permit.

4.1.2 Principle 2: Plan to avoid landslide hazards before development and subdivision

Landslide hazards can be avoided by preventing building and development on known landslide hazard areas. Where landslide hazards cannot be avoided, mitigation can reduce risk through appropriate engineering works. For example, the developer of a new subdivision may be required to avoid building on or near a landslide. Avoidance is the safest and most satisfactory long-term solution for current and future landowners and for the local authority. It can also be achieved for little or no extra cost (although it is recognised that loss of development opportunities are a cost to the developer). Alternatively, mitigation measures may be implemented so that the risk is reduced to an acceptable level.

4.1.3 Principle 3: Take a risk-based approach in areas already developed or subdivided

If land has been subdivided and sites have been purchased, there is an expectation that building on these sites will be allowed. Planning for land use in landslide-prone areas helps to avoid or mitigate the increased risks from landslide hazards caused by land-use intensification (such as urban infill) and inappropriate building.

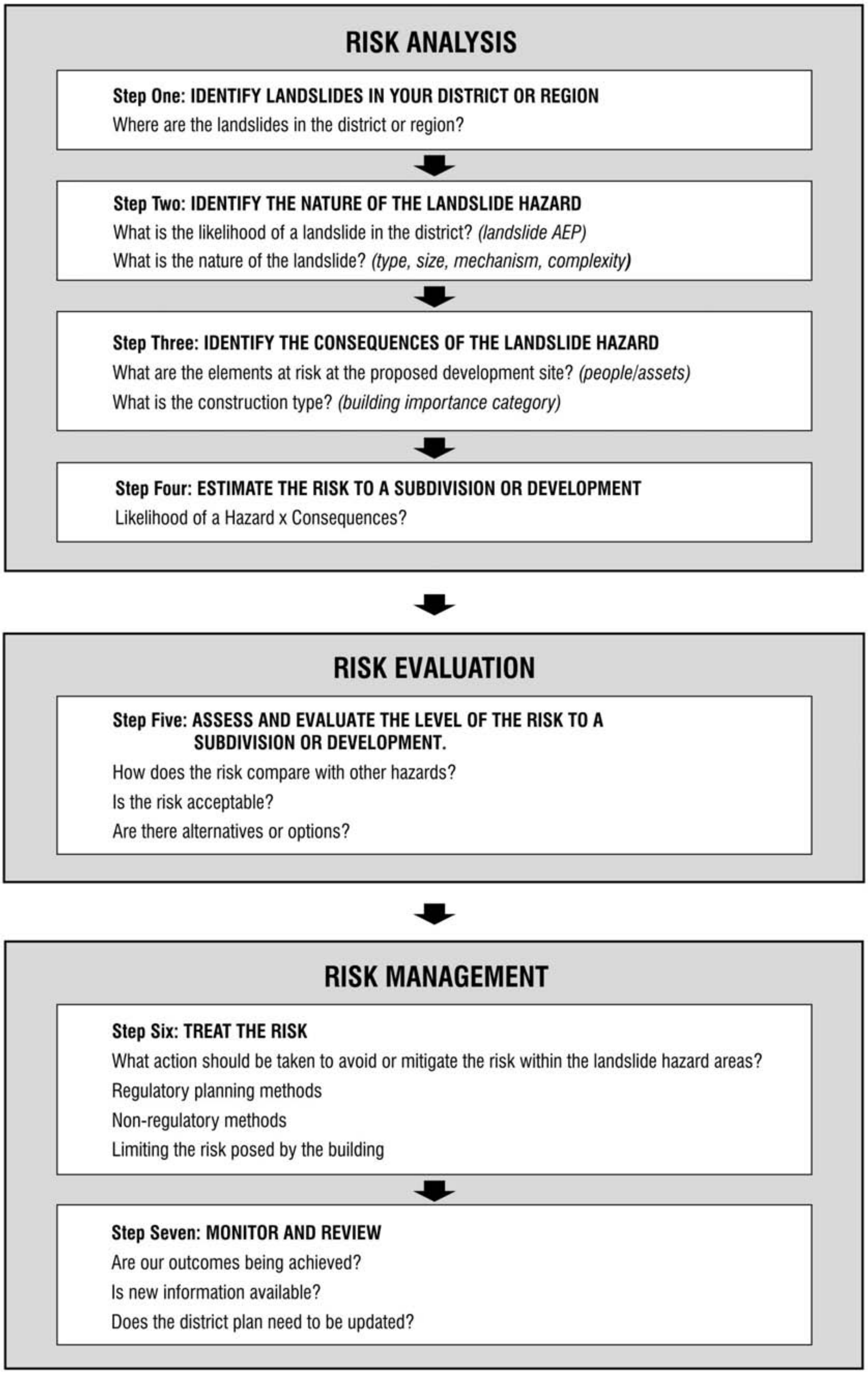


Figure 4.1 Risk-based planning approach (modified after AS/NZS Risk Management Standard 4360:2004).

4.1.4 Principle 4: Communicate risk of landslides in built-up areas

One of the most difficult problems concerning landslide hazards is dealing with existing urban areas where buildings are constructed on or close to a landslide. Although the risks posed by building in such locations are obvious now, they were not clear when urban subdivision started in New Zealand in the 19th century.

The ideal approach in this situation is to avoid further development in high-risk landslide-prone areas, limit existing-use rights to rebuild, and limit the use of buildings. The most realistic approach, however, is to accept the status quo whilst ensuring that:

- any further development and use of buildings (building type) is consistent with the level of risk posed
- district plan maps clearly show landslide hazard zones.

An example where this type of planning has been applied is in Macandrew Bay, Dunedin, where over 40 dwellings have been built over the Howard Street landslide, part of which is periodically reactivated due to rainfall (Glassey et al., 2003). Development started in the 1930-1940's before the landslide was recognised, and development constraints were enforced by the Dunedin City Council following movement in 1968. Through further investigation and consultation the affected residents have contributed to special remediation works and the constraints have been eased.

Non-regulatory approaches, such as hazard education programmes and incentives to retire at-risk land, would also ensure that landowners and building occupiers are made aware of the probability of landslides and the hazards they present. Hazard education initiatives must reflect the complex socio-economic nature of communities, therefore programmes need to target a range of at-risk groups, and may require a mix of approaches.

4.2 The landslide risk management process

These guidelines propose a risk-based approach to land use planning, based on the Australian/New Zealand Risk Management Standard AS/NZS 4360:2004. This approach considers landslide recurrence interval and complexity, and a Building Importance Category (see Section 4.3.2 for a description) of the building proposed for a site. This approach does not guarantee that a building will not suffer damage from a landslide, but it does establish that the risk of damage is sufficiently low to be generally accepted. For example, zones may be developed whereby certain building types are not permitted unless a hazard risk assessment has determined that the risk is acceptable.

Natural processes as well as human activities affect the stability of slopes and formation of landslides. Both the natural processes and the effects of development must be understood when assessing the landslide risk. It is critical for a planner to appreciate these issues early in the planning process to enable them to decide whether the risk posed by the natural hazard is acceptable or unacceptable. Mitigation strategies can often be designed to reduce risk from landslides; but in some cases this might not be possible. The risk-based planning approach, adapted from the Risk Management Standard and summarised in Figure 4.1, involves risk analysis, risk assessment and risk management, and is discussed in the following sections.

Past planning decisions have not always taken this approach. The risk-based approach recognises that a different planning approach is needed for an area that has not been developed (i.e. a greenfield site) and for an area that has been developed or subdivided, or where there exists an expectation to build. Each local authority will need to determine the definition of a greenfield site for their own city/district. It may be an area where there is currently no expectation to build (e.g. no zoning for intensive development), or it may be an undeveloped area of certain defined size (e.g. < 20 acres).

4.3 Risk analysis

Risk analysis involves acquiring information on landslide hazards, as well as considering the consequences if people and property are affected by landslides. Firstly, a thorough assessment of the types, characteristics and frequency of landslides in the area of interest is carried out as part of the hazard identification. Secondly, a consequence analysis establishes the elements at risk (people/property/assets).

4.3.1 Elements at risk

Different levels of hazard can be acceptable to various elements at risk depending on the consequences of a landslide occurring at a particular site. For example, the overtopping of a dam by a wave caused by a landslide may have significantly greater consequences than a minor landslide affecting a single dwelling. However, in any one year, a small landslide is far more likely to occur than a large landslide into a lake.

To classify building elements at risk, a Building Importance Category (BIC) could be used. Examples are the Australia/New Zealand Standard for Structural Design Actions, Part 0 General Principles (AS/NZS 1170.0:2002) or the scheme developed for the "Planning for Development of Land on or close to Active Faults" (Kerr et al*.,* 2003) as given in Table 4.1, The BIC indicates the relative importance of a building within, or proposed to be built within, an identified landslide hazard area. Different risk levels for building damage (collapse, burial, etc) would need to be determined according to the building type, use and occupancy, and the size and type of landslide that could affect the site.

This classification does not cover roads, bridges and other developments that do not necessarily involve buildings, but such elements could be included, based on importance of the road or land being developed. The BIC does not directly classify people within the elements at risk, but does recognise that certain types of buildings have different numbers of people or vulnerability (e.g. many children in schools, and many infirm people in hospitals and care facilities).

4.3.2 Measures of consequence

The consequences of a landslide are commonly described in terms of the cost of damage, and the numbers of deaths or injuries (casualties). The Australian Geomechanics Society (AGS) landslide risk method (Appendix 3) defines measures of consequence to property, depending on the damage to a building using terms such as insignificant, minor, medium, major and catastrophic. The AS/NZS Loadings Standards 1170:2002 defines building damage in terms of serviceability (serviceability limit state) and life safety (ultimate limit state).

Irrespective of the measure of consequence used, the design life of the building, infrastructure or development must be taken into account when assessing the risk. AS/NZS 1170.0:2002 considers the expected lifetimes of various classes of importance of buildings. Most common buildings of BIC 2 and 3 (see Table 4.1) have an expected lifetime of 50 years. The probability of landslides causing irreparable damage to a building, or threat to life, should be within acceptable limits. Riddolls and Grocott (1999) provide guidance on risk to life from landslide based on international research, but acceptability of risk is subjective and varies from person to person, and from organisation to organisation.

Table 4.1 Building Importance Categories: a modified version of New Zealand Loading Standard classifications (AS/NZS 1170.0.2002)

Building Importance Category (BIC)	Description	Examples
1	Low consequence for loss of human life, or small or moderate economic, social, or environmental consequences.	Structures with a total floor area of less than $30m^2$ Farm buildings, isolated structures, towers in rural situations Fences, masts, walls, in-ground swimming pools
2a	Medium consequence for loss of human life, or considerable economic, social, or environmental consequences	Timber framed single-storey dwellings
2b	(As above)	Timber framed houses of plan area more than $300m^2$ Houses outside the scope of NZS3604 "Timber Framed Buildings" Multi-occupancy residential, commercial (including shops), industrial, office and retailing buildings designed to accommodate less than 5,000 people and also those less than $10{,}000m^2$ gross area. Public assembly buildings, theatres and cinemas of less than $1000m^2$ Car parking buildings
3	High consequence for loss of human life, or very great economic, social, or environmental consequences (affecting crowds)	Emergency medical and other emergency facilities not designated as post disaster facilities Buildings where more than 300 people can congregate in one area Buildings and facilities with primary school, secondary school or day care facilities with capacity greater than 250 Buildings and facilities with capacity greater than 500 for colleges or adult education facilities Health care facilities with a capacity of 50 or more residents but not having surgery or emergency treatment facilities Airport terminals, principal railway stations, with a capacity of more than 250 people Any occupancy with an occupancy load greater than 5,000 Power generating facilities, water treatment and waste water treatment facilities and other public utilities not included in Building Importance Category (BIC) 4 Buildings and facilities not included in BIC 4 containing hazardous materials capable of causing hazardous conditions that do not extend beyond the property boundaries

Building Importance Category (BIC)	Description	Examples
4	High consequence for loss of human life, or very great economic, social, or environmental consequences (post disaster functions)	Buildings and facilities designated as essential facilities Buildings and facilities with special post-disaster function Medical emergency or surgical facilities Emergency service facilities such as fire, police stations and emergency vehicle garages Utilities required as backup for buildings and facilities of importance level 4 Designated emergency shelters Designated emergency centres and ancillary facilities Buildings and facilities containing hazardous materials capable of causing hazardous conditions that extend beyond the property boundaries
5	Circumstances where reliability must be set on a case by case basis	Large dams, extreme hazard facilities

4.3.3 Risk estimation

Risk is the combination of the likelihood and potential consequences of (or vulnerability to) a hazard. Vulnerability is normally measured in terms of damage to assets and/or injuries and deaths (the elements at risk). A landslide hazard may be assessed as “extreme”, but if there are no vulnerable elements then there is no risk. Landslide risk analysis is an iterative process, whereby initially a broad appreciation of the hazard, events, and then likelihood (probability) of occurrence, and the resulting consequences is developed. This will assist in determining which aspects need more in depth investigation.

In determining the probability of landslide hazard events occurring, the frequency of past events, and probability of possible triggering events should be considered. The probability of triggering events, such as rainfall and earthquake shaking, are assessed separately. The likely soil moisture conditions also need to be considered. The AGS landslide risk method (Appendix 3) proposes probabilities of events in terms of return periods. These are not necessarily related to rainfall return periods in New Zealand and so should be used with caution.

Annual Exceedance Probabilities (AEPs) are suggested for design landslide hazard events for various building classes, as per AS/NZS 1170.0:2002, to assess the risk. This defines design events in terms of the Ultimate Limit State (the design event where the structure will fail), and the Serviceability Limit State, where the structure can continue to be used following the event. For a design working life of 50 years the following AEP would apply for Building Importance Categories 1 to 4 as per Table 4.2.

Table 4.2 Annual probability of exceedance for Building Importance Categories for a 50 year design life based on AS/NZS 1170.0:2002.

Building Importance class	Annual probability of exceedance for ultimate limit state	Annual probability of exceedance for serviceability limit state
1	1/100	-
2	1/500	1/25
3	1/1000	1/25
4	1/2500	1/500
5	Determined on a case-by-case basis	

Note: AEP = 1/average return period (years)

The assumptions and uncertainties associated with the probability should be clearly stated. Probabilities are usually based on long-term averages of known landslide events and potentially triggering events, but can also consider changes in preparatory factors as described in Section 2.4. For any landslide hazard assessment the following should be defined to qualify the limitations of the assessment:

- the extent of the site and its features
- geological and historical evidence of landsliding at the site or general area
- geographic limits of the processes that may affect the site
- the extent and nature of the investigations
- the type of analysis carried out
- the basis for the hazard assessment
- the numerical uncertainty in the probability assessment (if this can be determined with any confidence).

4.4 Risk assessment

Risk assessment involves evaluating risks, making judgements on the acceptability of the risks and evaluating remedial options and mitigation measures. Such assessments depend on the likelihood (probability) and consequences of the landslide hazard events being considered, and societal acceptance of certain risk levels. This is where policy and decision makers overlap with the geological and geotechnical professionals in making decisions about acceptable risk and appropriate development options.

In assessing the landslide hazard and risk, a local authority should also take account of:

- community values and expectations (what the community wants and what it does not want)
- which areas of the district are, or are likely to be, under pressure for development
- what infrastructure already exists near a landslide hazard (buildings, network utilities etc) and the value of that infrastructure
- what level of risk the community is prepared to accept or not accept (in practice, it is easier to define what the community will not accept using community reactions to past events as a guide)
- consideration of the feasibility (effectiveness versus cost) of possible engineering solutions or other risk reducing mitigation works.

Landslide risk assessment requires an understanding of the likely magnitude or consequences of different types of landslide events, and the risks of injury or loss of life and damage to property and investment. It also requires consideration of the cost of clean-up, or repair or replacement of damaged property or services after the event. Riddolls and Grocott (1999), describe a methodology for quantitative risk assessment for determining slope stability risk in the building industry aimed at New Zealand geotechnical practitioners. However, there is also a need to consider the geotechnical risks in the current framework of New Zealand legislation and accepted codes of engineering practice. For example, it is ineffective to design a building to withstand earthquake ground shaking of 1/500 AEP if the land on which it is to be built is not capable of withstanding this level of ground shaking hazard, or is in the likely path of a large, possibly rainfall-induced landslide of similar or higher AEP.

4.5 Risk management

Where a level of landslide risk has been identified, there are a number of options available to manage that risk, including:

- Ignore the risk - generally not considered as an option.
- Mitigate the risk – engineering works to reduce the risk or likelihood of failure occurring, and the consequence of an event.
- Accept the risk – if the risk is accepted, emergency plans should be made to manage the consequences of an event and/or any residual risk.
- Avoid the risk – avoid putting life and property at risk by not placing them in the risk situation.
- Transfer the risk – insure against any risk, however the intrinsic value of life and treasures can not be compensated by insuring against the risk. This is not generally an option where a landslide could result in loss of life.

Natural hazard risk management is predominantly the domain of the policy- and decision-makers, and in New Zealand terms relates to the responsibilities that regional and territorial authorities have in controlling and consenting development in landslide-prone areas. The instruments and tools available to enforce and monitor development, to ensure that the risk remains acceptable, are discussed in the next sections of the guidelines.

Information Box 7

PLANNING FOR NEW DEVELOPMENTS

It is important to bear in mind that new development activities may increase the landslide hazard, and the absence of evidence of past landslides may not provide certainty that landslides will not occur and pose problems in the future. All modifications to the terrain that result from the planned development need to be considered in relation to slope instability issues.

QUESTIONS PLANNERS AND DEVELOPERS NEED TO ASK:

- Have landslide hazards been identified at the site?
- Has the landslide hazard and risk been assessed and mitigated, and with what certainty?
- Has residual risk been assessed?
- Is there any unacceptable risk, and if so, does the proposed design adequately avoid or mitigate the landslide hazard?

KEY DECISIONS:

- Can the landslide risk be accepted?
- Are the proposed mitigation measures appropriate and sustainable over the longer term, and what maintenance and monitoring measures need to be in place?

4.6 A risk assessment example — Thames Hospital

Following the 2005 debris flow disaster at Matata (Figure 2.6), similarities in setting and climate suggested that a proposed new hospital building in Thames, Coromandel, might be at risk from a future debris flow. While Thames has not experienced debris flows in its 140-year history, a site assessment indicated that Thames Hospital is on the apex of a fan-shaped deposit formed predominantly by repeated large debris flows issuing from Karaka Stream (Figure 4.2). Engineering works mitigate debris-laden floodwater up to 1/50 AEP, but not debris flows. Soil developed on the last debris flow deposit indicates that debris flows reach the fan very infrequently.

Figure 4.2 Example of a landslide hazard assessment including risk. The annotated aerial photograph depicts the 1/1,000 AEP debris flow hazard zone at Karaka Stream, Thames, Coromandel, in relation to existing BIC 3 buildings in the Thames Hospital complex (H).

The soil, climate, nature of the upper catchment, and the size and age of the fan suggest that large debris flows might reach the hospital site less frequently than once every 500 years on average, but probably more frequently than once every 1,000 years. The slope of the land at the hospital, and the substantial buildings, make it unlikely that even very large debris flows could reach beyond the hospital. The proposed development is a BIC3 (Table 4.1), and so should be designed to survive the 1/1,000 AEP debris flow without endangering lives (even if it briefly loses serviceability). This information allowed the area likely to be affected directly by the 1/1,000 AEP debris flow to be delineated (Figure 4.2).

The debris flow hazard area at Karaka Stream, Thames, encompasses a number of residential properties (BIC 2 buildings). They are not within the 1/500 AEP debris flow hazard zone. A debris flow could be triggered by exceptionally heavy rain, most likely associated with a thunderstorm. Thunderstorms can be tracked and monitored as they evolve, so adequate warning can be given. Future property owners are notified through Land Information Memorandum (LIM) notations, but the assessed risk is not so great as to currently affect development up to and including BIC 2. For BIC 2 owners, no other mitigation currently can be justified, but BIC 3 owners must consider other mitigation options. There is a downstream flooding hazard associated with the debris flow, but the Thames flood hazard is well recognised, well mitigated up to 1/50 AEP, and already notified through LIMs for affected properties. A future large debris flow at Thames is likely to change local perceptions, and may change these assessments.

5. THE PLANNING CONTEXT FOR MANAGING LANDSLIDE RISK

This section outlines the context of the landslide risk management process with regard to planning. Responsibilities under the Resource Management Act 1991 (RMA) are discussed, along with examples of policies for landslides and the relationship between the RMA, the Building Act 2004, and other legislative linkages. Figure 5.1 shows the relationships between various pieces of legislation and statutory documents that can influence decisions on natural hazards.

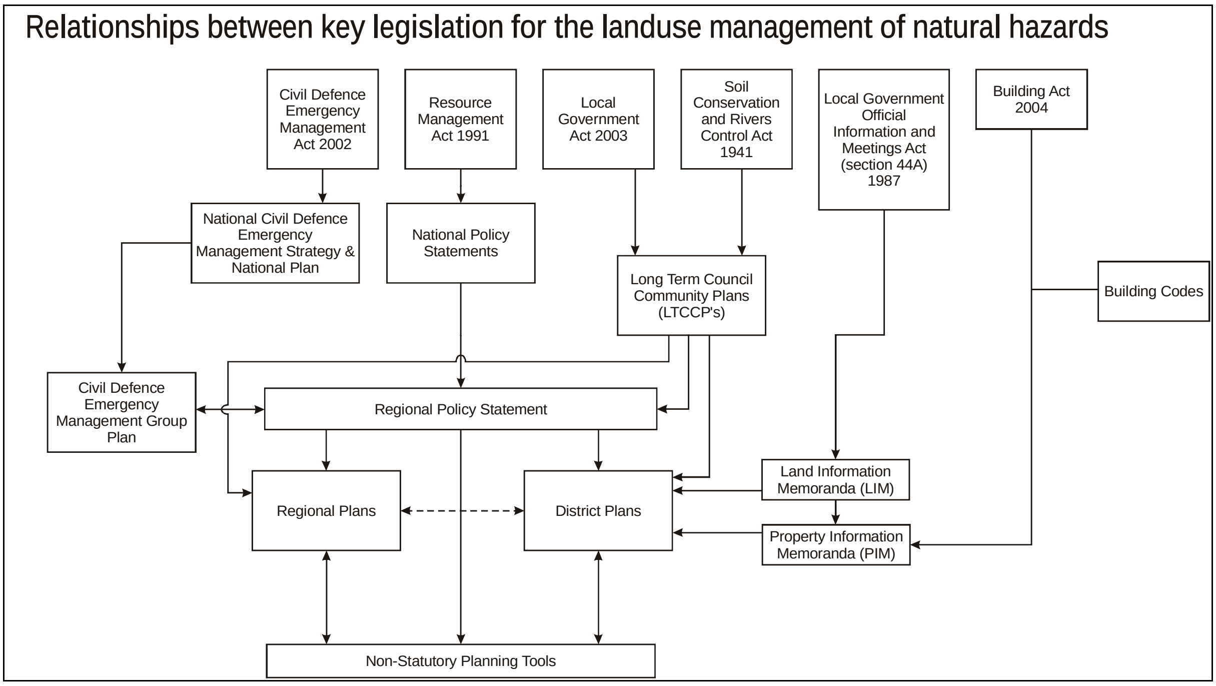


Figure 5.1 Relationships between legislation for managing natural hazards (Saunders et al., 2007).

The key legislative requirements for landslides in the context of this document are the RMA, Building Act, and Civil Defence and Emergency Management Act 2002 (CDEM Act). The RMA and the Building Act provide the legal framework for hazard management policy, planning and decision-making while the CDEM Act deals with emergency management policy, planning and decision-making.

5.1 Responsibilities under the RMA

Under the RMA, both regional councils and territorial authorities have responsibilities associated with natural hazards. Sections 30 and 31 of the RMA determine that natural hazards are managed at a regional council level, with the actual or potential effects at a territorial authority level. Table 5.1 outlines the responsibilities for natural hazards imposed on regional councils and territorial authorities under the RMA.

Table 5.1 Responsibilities of regional councils and territorial authorities for natural hazards management as identified in regional policy statements (modified from Hinton and Hutchings, 1994)

Regional councils (hazard identification)	**Territorial authorities (hazard management)**
• Assess hazards of *regional level significance*	• Assess hazard risks of *district level significance*
• Apply planning control provisions in regional plans	• Control development and activities in hazard-prone areas through district plans and resource consent process
• Implement, maintain and monitor warning systems	• Prepare hazard management plans (e.g. flood management plans, contingency plans)
• Conduct research into hazard risks	• Control stormwater discharges (through involvement in land use planning and the control of building development)
• Provide education and information	• Provide information on site specific and localised natural hazards
• Undertake works and services at a regional level (e.g. stopbank repair)	• Undertake works and services at the district level (e.g. hazard mitigation works)
• Maintain a 'regional natural hazards register'	• Maintain a 'district natural hazards register'
• Administer and update Civil Defence Emergency Management group plans	

The RMA does not prescribe how requirements for managing development in hazard-prone areas are to be met. Rather, the intention is to allow for the development and adoption of a mix of innovative measures together with, or instead of, traditional measures, as long as they support the RMA's single purpose – the sustainable management of natural and physical resources. Therefore, territorial authorities may manage natural hazards by utilising the following tools (after Ericksen et al, 2000):

- Subdivision, through s106 of the RMA
- Building consents, through ss71-74 of the Building Act 2004 (see Section 5.2)
- District plans (through identifying hazards, as required by s35 of the RMA, educating people as to the risks, provision of financial incentives, land use controls, and engineering works) (see Section 6.3)
- Implementing and maintaining hazard registers
- Resource consent applications (see Sections 6.4 and 7)
- Other non-regulatory tools (see Section 6.5).

Section 106 of the RMA provides an important directive to territorial authorities when assessing subdivision resource consent applications. Under s106, a subdivision consent can be refused, or granted subject to conditions, if land (or any structure on the land) is likely to be subject to material damage by erosion, falling debris, subsidence, slippage or inundation from any source, or if any subsequent use likely to be made of the land is likely to accelerate, worsen, or result in material damage to the land, other land, or structure by the same. Section 106 is therefore specifically focussed on the assessment and mitigation of effects of natural hazards on a proposed subdivision.

Section 106 of the RMA requires the territorial authority to undertake an assessment of how natural hazards might affect a proposed development, and of how the proposed development might affect the likelihood or magnitude of any natural hazards. Sections 106, 108 and 220 allow conditions to be placed on resource consent applications. Placing conditions on granted consents allows territorial authorities to exercise control over the effects of development on natural hazards. This is particularly so in the case of s106. Conditions set under s106 can be placed on a granted subdivision consent regardless of the activity status of the application and relate directly to mitigating the effects of subdivision on natural hazards. Conditions set under s108 and s220 are limited to some extent by the activity status of the application. For controlled and restricted discretionary activities, if the district plan reserves council control to natural hazard matters or subdivision matters, conditions under s108 and s220 can relate to avoiding and/or mitigating the effects of natural hazards. For discretionary and non-complying activities, conditions can be set under s108 and s220 regardless of the content of the plan.

Any policy development under the RMA should be checked for linkages with other legislative policies (see Section 6.3), as many plans developed under other legislation can affect the implementation of planning policy.

For further information on planning processes under the RMA refer to www.qaulityplanning.org.nz or www.mfe.govt.nz.

5.2 Landslides and the Building Act

Provisions available through both the RMA and the Building Act can assist in assessing and avoiding or mitigating the effects of landslides. The key differences in the two pieces of legislation are that under the RMA the use and subdivision of land should be such that natural hazards are either avoided or mitigated, whereas the Building Act gives territorial and unitary authorities responsibility for granting building consent on land subject to specific natural hazards, with certain exceptions. The RMA manages land use, such as the location of a building and its effects, and the Building Act focuses on the construction, safety and integrity of buildings, including footings and foundations.

Landslides are not specifically referred to in the Building Act, but are covered under the definition of natural hazards, which includes “falling debris”. Under the RMA, landslides are covered under the term “landslip”. Appendix 1 provides further discussion on the definitions of landslides under the Building Act, RMA, and the Earthquake Commission Act (1993).

Under the Building Act, territorial and unitary authorities can restrict the construction of buildings on land subject to hazards. Under s71 of the Building Act, a building consent authority must refuse to grant a building consent for either the construction or major alteration of a building if the land is *subject to* or *likely to be subject to* one or more natural hazards, or the building work is *likely to accelerate, worsen, or result* in a natural hazard affecting that land or other property. Section 72 allows for the granting of building consents if the work does *not accelerate, worsen or result* in a natural hazard, and it is reasonable to grant the consent in respect of the natural hazard.

The Building Act provides for identification and information where land is subject to natural hazards. On receiving notification of such a hazard under s73, an entry on the Certificate of Title is made, noting that a building consent has been granted under s72, and including any particulars that identify the natural hazard concerned. This enables future owners of the land to be made aware of the hazard and possible risk that is present at the site, and is often referred to as 'tagging' a title.

Building regulations are established under the Building Act. Appendix A B1/VM4 of the Building Code (a schedule to the Regulations) is for information purposes, and provides guidance on preliminary site assessments. Under sA1.2.1, a preliminary site assessment may include the investigation of general land form, geology, and any conditions likely to facilitate landslip, soil creep, shrinkage and expansion, or subsidence. The appendix provides guidance on detailed investigation and recording information; however, it does not provide information or guidance on how these investigations should be undertaken.

5.3 The Civil Defence Emergency Management Act (CDEM Act)

The CDEM Act is primarily focused on the planning and preparation for emergencies. The purpose of the Act is to improve and promote the sustainable management of hazards (as defined in the CDEM Act) in a way that contributes to the social, economic, cultural and environmental well-being and safety of the public, and also the protection of property; and to encourage and enable communities to achieve acceptable levels of risk (as that term is defined in the CDEM Act), including, without limitation:

(i) identifying, assessing, and managing risks; and
(ii) consulting and communication about risks, and
(iii) identifying and implementing cost-effective risk reduction; and
(iv) monitoring and reviewing the process.

A CDEM group is a consortium of local authorities based around the regional council boundaries. The CDEM Group membership includes district and/or city councils and regional councils or unitary authorities. The functions of a CDEM group in relation to relevant hazards and risks, are to:

(i) identify, assess, and manage those hazards and risks;
(ii) consult and communicate about risks; and
(iii) identify and implement cost-effective risk reduction (i.e. mitigation measures and land use planning initiatives).

These functions are outlined in each CDEM group plan, and provide a source of hazard information for planners.

The CDEM Act notes that other legislative requirements under the Building Act, Local Government Act 2002 and RMA will also be relevant to emergency management. An example is that land-use reduction policies within a CDEM group plan should be linked to a regional policy statement, down to the regional and district plan (refer Figure 5.1).

5.4 Other legislative linkages

As well as the RMA, Building Act and CDEM Act, there are other statutes that have linkages with landslide hazard management:

- Soil Conservation and Rivers Control Act 1941 – includes provisions for the prevention of damage by erosion and makes provisions for the protection of property from damage by floods.
- Local Government Official Information and Meetings Act 1987 – provides information held by local authorities for natural hazards via Land Information Memoranda (LIMs)
- Earthquake Commission Act 1993 – allows the Earthquake Commission (EQC) to make limited claim payments towards damage from landslips.
- Local Government Act 2002 – prioritises and allocates funds towards hazard management under the Long Term Council Community Plan (LTCCP) process.

6. PLANNING TOOLS FOR MITIGATING (TREATING) THE RISKS

This section discusses the role of regional policy statements, regional plans, district plans, and other methods for mitigating landslide risks at a planning level. This hierarchy is shown in Figure 5.1. It is important that objectives and policies in planning documents are well constructed, in order to provide a good framework to support planning rules. Examples are provided in boxes below as a guide for planners when assessing their own policies and plans for detail on the landslide risk.

Information Box 8

AVOID, REMEDY AND MITIGATE

Within the RMA, the definition of sustainable management includes avoiding, remedying, or mitigating any adverse effects of activities on the environment. The terms 'avoid, remedy and mitigate' are not defined within Section 2 of the RMA and there is limited case law to provide guidance on how these concepts can be applied to natural hazards. In practice, greater emphasis is given to avoiding and mitigating the risks associated with hazards than remedying the effects. This is reinforced in sections 30 and 31 (functions of regional councils and territorial authorities) where regional councils and territorial authorities are only required to avoid and mitigate natural hazards when controlling the use of the land and the effects of an activity. The common meaning of 'remedy' is "a means of counteracting or eliminating something undesirable"[2] . In the case of a landslide hazard, the hazard cannot necessarily be eliminated and therefore remedying it becomes impractical. Rather, mitigation measures can lessen the risk to people and property and should therefore be given greater emphasis. For this reason most policy documents will only discuss avoiding and mitigating natural hazards.

6.1 Regional policy statements

Regional policy statements (RPS) allow regional councils to address regionally significant natural hazards. The RPS:

- provides an overview of the resource management **issues** facing the region
- sets region-wide **objectives** and **policies**, and
- identifies the **methods** to be used across the region to address the objectives and implement the policies.

The RPS sets the direction for both the regional council and territorial authorities to follow. Both regional and district plans must give effect to the RPS. The RPS is therefore very important, and can be quite directive. RPS provisions tend to be reasonably generic in regard to natural hazards as they generally consider all natural hazards within the same objective or policy. However, a regional council can be more specific, if it wishes, and can set a clear policy direction for territorial authorities to follow. The RPS can identify land instability as an issue across the region, and then state objectives and policies that explain how the issue will be addressed.

An example of current practice is provided by the Tasman District Council (a unitary authority) Regional Policy Statement, which provides detail on land instability issues, shown in Information Box 9.

[2] Definition of 'remedy' obtained from the Oxford Dictionary at www.askoxford.com, accessed on 31 January 2007.

Information Box 9

Example of land instability provisions from the Tasman Regional Policy Statement (emphasis added):

Objective 11.1
Reduced risks arising from flooding, erosion, inundation and **instability** and earthquake hazards.
Policy 11.2
The Council will seek to reduce risks:
(i) to the use and development of land subject to erosion, inundation or **instability**; and
(ii) to the use and development of any other land that may be affected as a result of such erosion or **instability**;
Methods of Implementation
(i) The Council will:
   (a) investigate and collect information on coastal and **land instability** processes and hazards; and
   (b) assess the significance of coastal erosion and **land instability** risks and the options available to reduce these risks.
(ii) The Council will develop policies and rules in the District Plan and make decisions on resource consent applications to regulate the use and development of … land subject to **slope instability**, or ground subsidence, where such regulation is necessary to avoid, remedy or mitigate the effects of these hazards.
(iii) The Council will consider providing assistance for existing developments to relocate or to protect themselves in situations where it is satisfied the community risks are significant.

6.2 Regional plans

The RMA allows regional councils to prepare regional plans to address any issue relating to their functions under the Act. Regional plans may be produced as and when the need arises. Most regional councils have chosen to prepare a suite of documents under the RMA, relating to their various functions. Regional plans describe the regionally significant management issues facing a particular area or resource within the region, and then set out objectives, policies and methods (including rules) to address these issues. They also outline the environmental results that are anticipated from their implementation. Regional councils must ensure that their plans are not inconsistent with national or regional policy statements and other regional plans (www.mfe.govt.nz).

Regional plans may be developed for land use to avoid natural hazards, although to date no region has proposed a specific natural hazards regional plan. Rather, avoidance of natural hazards, and in particular land instability is included in other plans such as sediment and erosion plans, and regional land management plans. Information Box 10 provides an example of land instability issues included in a regional plan. The West Coast Regional Council example demonstrates what can be achieved where limited information currently exists in relation to landslide hazards. The lack of detailed information should not prevent a local authority from providing some guidance regarding landslide hazards.

Information Box 10

Example from the West Coast Regional Council Proposed Regional Land Plan (emphasis added)

The West Coast Regional Council has utilised the New Zealand Land Resource Inventory (NZLRI) 'Dominant Erosion Form' data for the West Coast region to assess land stability. Utilising the NZLRI erosion severity index, the regional plan establishes areas of Erosion Prone Land in order to differentiate between activities that are permitted and those requiring resource consent. This approach is based on a general acceptance that the risks of adverse effects arising from land disturbance are increased in Erosion Prone Areas and that different activities may produce different levels of erosion potential. The establishment of Erosion Prone Areas, applied through the use of land slope angles, and the definition of the Greymouth Earthworks Control Area, provides a set of environmentally justified thresholds from which Plan users and practitioners alike can draw certainty.

The Greymouth Earthworks Control Area incorporates special controls which cover land on the inland fringes of Cobden, Greymouth and Karoro. Disturbance of land in these areas is a discretionary activity due to a predisposition to slope failure and the hazards associated with any failure in the urban environment.

4.2 Issue

4.2.1 Land disturbance can have adverse effects on:
(a) Soil conservation and **land stability**

4.3 Objective

4.3.1 to reduce adverse effects from land disturbance.

4.4 Policies

4.4.1 to manage the disturbance of land in order to avoid remedy or mitigate any adverse effects on:
(a) The **stability of land (e.g. slumping, subsidence, or erosion)**, river banks, and riverbeds.

The areas indicated by the black border and shading on the planning maps are those in the rules of Chapter Eight of the Proposed Land Plan that refer to the Greymouth Earthworks Control Area. General areas were identified as hazard areas in the research "Landslide Investigation and Hazard Zonation in the Greymouth Urban Area" (Metcalf, 1993). This was due to their slope angle, stability of the soil profile, and past history of **slope failure**. In order to have legal certainty those general areas have been aligned to the legal title boundaries of the properties in which they occur.

6.3 District plans

The RMA requires territorial authorities to prepare district plans for the area that they are responsible for. Each plan describes the district's significant resource management issues, and sets out objectives, policies, and methods (including rules) to address these issues. The information that must be submitted with resource consent applications is specified, and the plans also outline the environmental results that are anticipated from their implementation. District plans must not be inconsistent with national or regional policy statements or regional plans (www.mfe.govt.nz).

District plans typically include objectives, policies, methods, and rules relating to the effects of land use, the effects of activities on the surface of rivers and lakes, noise, and subdivision. Natural hazards should be included in relation to land use and subdivision.

The District Plan should contain the specific policies to address landslide risk and any controls concerning land use and land instability. Before developing and adopting objectives, policies, and methods for the district plan, territorial authorities need to:

- understand and gather information about landslide hazards
- assess the appropriate level of risk that is acceptable for landslides, and
- identify and assess landslide issues.

Plan provisions need to be appropriate to the community's circumstances. No one policy response to landslide hazards will fit the needs of all communities within New Zealand because of the highly variable geology, topography, rainfall, and therefore types and locations of landslides and different community acceptance of risk. The issues and objectives between districts affected by land instability may be similar, but the methods (or mix of methods) used to address the risk can be different. Information Box 11 provides an example of an objective, policies, and methods for managing landslide risk.

Information Box 11

Example of Tauranga District Plan's objectives, policies and methods for managing land instability

6.1.2 Objective: Hazard Management – Land Instability

To reduce the risk to life, property and the environment resulting from use and development of land subject to, or likely to be subject to, **instability**.

6.1.2.1 Policy: Avoidance of Areas of Land Instability

Subdivision, use and development should be avoided within areas of known or potential **land instability** where those activities or any subsequent use that is likely to be made of the land are likely to accelerate, worsen or cause damage to land (or in respect of the subsequent use of that land any other land or structure), structures or the environment through **slippage** or **erosion**.

6.1.2.3 Policy: Discharges to Ground

Stormwater discharges directly to ground from development should occur only where ground conditions are identified as being suitable to receive and absorb such discharges without creating any adverse effect on the **land stability** of the site or cumulatively on land in the vicinity of the discharge point(s).

6.1.7.1 District Plan Methods

(1) Require site investigations of land subject to or likely to be subject to **instability** before subdivision or building consent will be considered.

6.1.7.2 Other Methods

(1) Consider **land stability** during planning, design and construction of Council services.

(2) Identify those areas known or likely to be affected by **landslips** in a natural hazard information base, including relic slips and the 2:1 slope envelope line, and apply this information when considering subdivision or development of such land.

(3) Apply Building Act 1991 [sic] provisions for structures and siteworks where appropriate.

(4) Recognise the (Proposed) Regional Land Management Plan controls large-scale earthworks, vegetation clearance and development on steep land. Consider hazard issues as well as sedimentation effects.

The flowchart shown in Figure 6.1 can help determine if the landslide risk has been adequately addressed in a district plan, or whether the district plan needs amending.

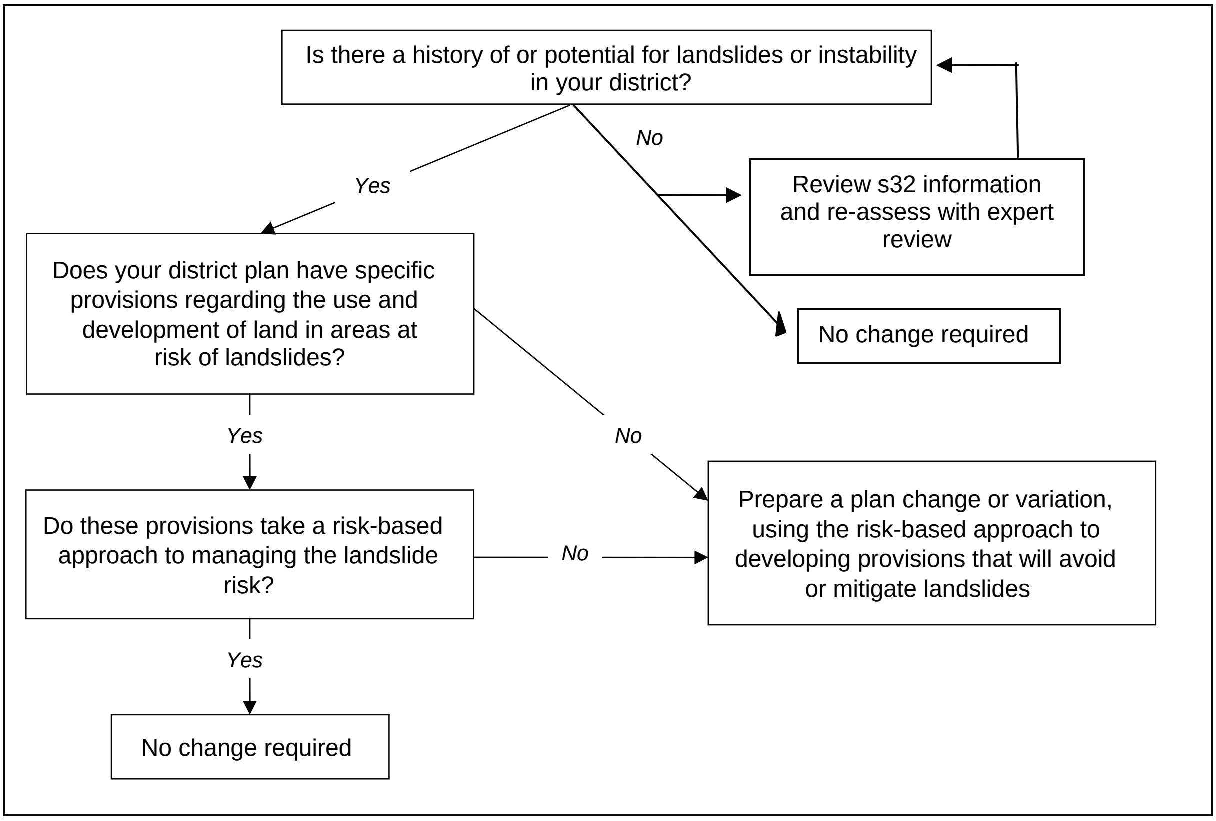


Figure 6.1 Clarifying whether a district plan needs amending

6.4 Regulatory methods (rules)

Rules can be included in regional and district plans to control various aspects of development in hazard-prone areas, including design, construction, location, configuration and density.

Rules need to relate to the avoidance or reduction of risk from landslide hazard. The approach used in existing developed or subdivided areas generally differ from the approach used in a greenfield area. In greenfield areas it is much easier to require a subdivision to be planned around likely areas of instability or to mitigate landslide risk to an acceptable level. An example of this is the Manukau City Council Hill Road Structure Plan (see Appendix 4), which shows an area of future development which is subject to comprehensive stability investigation. This area is shown in the structure plan, and is supported by development rules and assessment criteria for residential subdivision consent applications:

> *'Geotechnical investigations have identified areas which have known potential or suspected instability problems. These areas have been identified on the Planning Maps and on Figure 16.7 as requiring further detailed investigations prior to any development proposals being approved'* (Chapter 16.15.5.3).

A district plan may also include provisions to ensure that the risk is not increased by intensified land use (such as urban infill), or by new building on sites not already occupied (see Information Box 10, which provides an example of how rules in a plan can restrict development in order to reduce, but not eliminate, the level of risk in an area which has known slope instability). It can also require geotechnical investigations where appropriate, as highlighted in the Manukau City Council quote above.

Information Box 12

Example of development restrictions in an area of slope risk – Nelson City Council

The Tahunanui Slope Risk Area, commonly known as the Tahunanui Slump, is defined on the Nelson Resource Management Plan planning maps (see Appendix 5). It consists of a core area where the hazard is known, surrounded by a fringe area where the edge of the active slump is not accurately defined. It is also an area where, even if the site is shown to be outside the active slump, activities could have an influence on the slump.

The Nelson Resource Management Plan categorises earthworks as a discretionary activity and heavy structures, such as fill or pools, which may detrimentally surcharge the landslide, are a restricted discretionary activity. Subdivision, other than for such things as boundary adjustments, is not allowed and applications to build on existing lots is a non-complying activity. Resource consent for building on most parts of the slump can be granted although no more than one residential unit is allowed on each lot. Except for minor alterations or additions, building consents are granted under Section 72 of the Building Act 2004 and the title of the lot is endorsed accordingly.

All applications for resource or building consent must be accompanied by a geotechnical assessment from a chartered professional engineer practising in geotechnical engineering or an experienced engineering geologist and recognised as such by the Nelson City Council. The assessment must list any mitigation measures that should be implemented as part of the consent, such as designing the house so that it can be relevelled and/or the use of light weight cladding, installation of additional drainage with readily accessible inspection points or removal of material equal to the weight of the structure to be built.

6.5 Non-regulatory methods

Non-regulatory methods are useful to encourage people to avoid putting themselves at risk. One of the more important things a local authority can do is communicate the potential risk to the community.

Some of the non-regulatory methods available to local authorities include:

- acquiring or purchasing at-risk land for passive recreational purposes
- exchanging at-risk land with land more suitable for the purpose
- allowing greater development rights on other land if at-risk land is retired or covenanted
- using structure plans to actively identify and avoid areas with stability concerns
- at-risk land forms part of the reserves contribution as a condition of subdivision consent
- using financial incentives (for example, rates relief for at-risk land if it is not developed)
- promoting and helping fund the use of covenants (privately or through the QEII National Trust) for voluntary protection from development of open space on private land
- education to raise awareness of the risk, and to encourage people to locate buildings away from the hazard.

6.6 Maps

Landslide-prone areas still need to be clearly identified on district plan maps if non-regulatory methods are used. This ensures that hazard is communicated to the public, and landowners and building occupiers are aware of the hazard. An example of this is provided in Section 3, where the Marlborough District Council has provided a map (see Figures 3.6 and 3.7) within their district plan showing areas with potential instability problems. The purpose of the map is to make landowners aware of potentially greater difficulties when developing land and additional consent requirements in these areas.

Information Box 13 (Modified from Auckland Local Authority Hazard Liaison Group, 2003)

SUMMARY OF REGULATORY AND NON-REGULATORY OPTIONS FOR TREATING LAND INSTABILITY RISKS

Planning Tool	Land use option available — avoid / mitigate*	Legislative requirement or non-statutory
Concept/structure planning	Avoid	Non-statutory planning process that may be 'required' by the RPS and often given 'statutory' effect through district plans.
Zoning/mapping	**Avoid** and mitigate	Resource Management Act Regional and district plans Building Act Hazards register
Development & subdivision controls	**Avoid** and mitigate	Resource Management Act Building Act Regional and district plans and the Building Act process
Catchment management planning	Avoid	Non-statutory Regional and district councils
Riparian management	Mitigate	Resource Management Act Regional and district plans
Hazards register	Information to avoid or mitigate	Building Act
Stormwater management	**Avoid** and mitigate	Resource Management Act Regional and district plans Non-statutory
Building controls	Avoid	Building Act
PIMs & LIMs	Information to avoid or mitigate	Building Act — PIMs Local Government Official Information & Meetings Act — LIMs
Engineering solutions	Avoid and mitigate	Resource Management Act Building Act
Creation of reserves	Avoid	Reserves Act Resource Management Act
Covenants (to prevent development)	Avoid	Resource Management Act Building Act
Education and information	**Avoid** and mitigate	Non-statutory
Strategic regional & district planning	**Avoid** and mitigate	Non-statutory Regional and district councils

***Bold indicates most desirable**

6.7 Monitoring plans

Plans need to specify measurable outcomes to ensure that landslide hazard issues are addressed, and objectives and policies achieved.

Outcomes can be measured by looking at:

- number of buildings being built on or adjacent to landslide-prone land
- type of buildings being constructed and their intended use (see Table 4.1 Building Importance Categories)
- land subject to landslide activity being set aside/purchased
- the level of awareness of the community and their acceptance of risk-based plan provisions.

If monitoring shows that the provisions are not reducing landslide risk, local authorities need to revise their provisions. If new information becomes available, local authorities need to review the level of acceptable risk and revise their provisions.

Advances in scientific information and technology affect the quality and accuracy of existing landslide hazard data held by local authorities, and create new data that needs to be considered in planning policy. Local authorities need to identify and assimilate new hazard information on an ongoing basis to ensure plan provisions are up to date, and to ensure decisions are based on the best information available.

Regional and district plan reviews provide an opportunity to consider and incorporate new information and data relating to land instability. A programme of consultation should accompany any changes to hazard information gained by the local authority.

To measure the effectiveness of policies and methods contained in plans, Section 35(2A) of the RMA requires that the results of plan monitoring be available to the public every five years. Keeping communities informed about the hazards they face, and changes to existing landslide knowledge, is important because it not only lets them know what is going on in terms of plan development, but raises awareness of hazards in the community.

7. TAKING A RISK-BASED APPROACH TO RESOURCE CONSENTS

7.1 Determining consent categories

Planners should take opportunities to plan to avoid landslide hazards before development and subdivisions go ahead. However, in areas already developed or subdivided, a risk-based approach should be taken. Determining resource consent categories for buildings within a landslide zone involves evaluating the risk of landslide, alongside the level of risk the community is prepared to accept.

The RMA provides for the classification of land use activities as permitted, controlled, restricted discretionary, discretionary, and non-complying. The status of a resource consent determines those matters the local authority can consider when deciding on an application and the conditions that may be imposed. Different types of buildings can be placed into different resource consent activity categories, based upon the level of landslide risk, as shown in Figure 7.1.

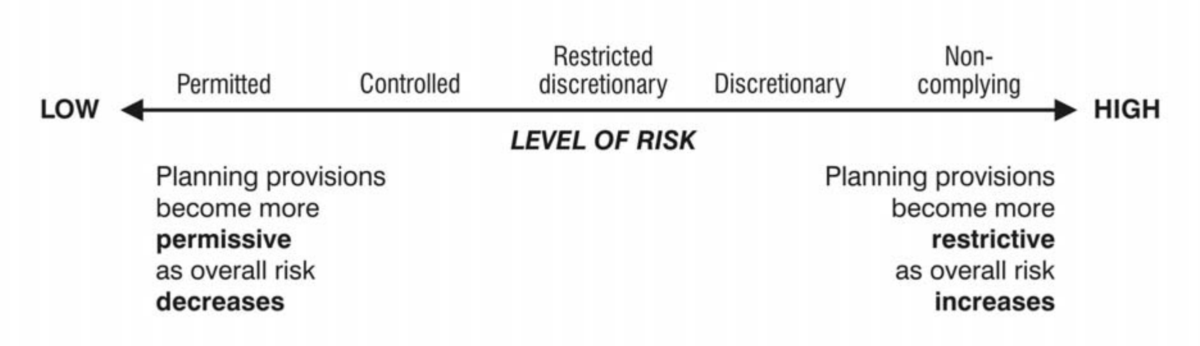


Figure 7.1 Scale of risk and relationship to planning provisions (adapted from Kerr et al., 2003)

As the landslide risk increases the consent category should become more restrictive, and the range of matters the local authority needs to consider will increase. The local authority can set requirements for the bulk, location and foundations of any structure, but has wide powers to impose consent conditions that will avoid or mitigate the adverse effects of any landslide-prone areas considered to be hazardous.

If the landslide risk is low, the provisions contained in plans may be more permissive and make use of the permitted or controlled activity consent categories. If the risk is high, then provisions in plans become more restrictive, and greater use is made of discretionary and non-complying activity consent categories.

A rule may require that a resource consent be obtained for a new building. On landslide-prone land, this may require a geotechnical report, which will likely contain development recommendations, be included with the application as part of the assessment criteria.

Before granting a resource consent the local authority needs to be satisfied that:

- the risk to the community represented by the local authority is acceptable
- appropriate mitigation measures have been taken, or
- consent is not contrary to the district plan.

Each local authority will want to apply the resource consent activity status categories that suit its own circumstances. The key is to ensure a local authority has the ability to address the landslide hazard risk properly when assessing a resource consent application. The matters over which a local authority can reserve control or restrict its discretion could include, but are not limited to:

- the proposed use of the building
- site layout, including building setback and separation distance
- building height and design
- construction type
- financial contributions (for example, reserves contributions).

An example of the way that different consent status could be applied to activities in areas where landslide hazard exists is shown in Appendix 6.

The Gisborne Combined Regional Land and District Plan includes provisions requiring resource consents for certain activities within the Makoriri Township area. Information Box 14 provides examples of restricted discretionary and prohibited activities for Makorori.

Information Box 14

Example from the Gisborne Combined Regional Land and District Plan

The Gisborne District has identified an area of potential instability within the Makorori Township. The Plan recognises that within the Makorori Township Land Instability Hazard Overlay building construction, earthworks of any kind, vegetation removal, stormwater and effluent disposal systems all have the potential to cause or increase slope instability and landslip, and that properties are liable to damage from landslip from the higher slopes behind.

The Regional Land and District Plan contains specific policies and rules to manage the risks associated with land instability in the area. The rules in the plan provide that land disturbance over a certain area, the installation of septic tanks or soak pits; removal of vegetation over a specified area and height are all restricted discretionary activities. Further more the Plan provides that subdivision, except for adjustment of boundaries which will not create any additional housing sites, or for the creation of esplanade reserves is a prohibited activity (5.26.2.1).

7.2 Resource consent planning considerations

The decision-making process for a resource consent application is primarily guided by the objectives and policies within the regional or district plan. It is therefore important that these objectives and policies are developed to assist in decision-making (see Sections 6.2 and 6.3).

As landslide hazards can constrain or limit land use, it is important to identify landslide risk levels early in the planning for new developments. This indicates to planners where landslide risk may be acceptable or unacceptable for a proposed development. Decisions can then be made as to which measures should be undertaken by the applicant – avoidance, prevention, or mitigation of existing and future landslide hazards. Information Box 15 outlines basic questions a planner should ask of applicants.

Information Box 15

Preliminary questions planners need to ask when a consent application is being considered (i.e. at a pre-application meeting):

- Does the area have a history of landslides or slope instability problems?
- Are there any other hazard concerns in the area?
- Is there adequate landslide hazard assessment information available?
- Has the potential of earthquake-triggered landsliding been addressed?
- Has any landslide assessment passed a peer review process?
- Have any landslide risk issues/events been adequately addressed?
- Have any identified landslide risks been adequately treated to reduce risks to acceptable levels?
- Have all relevant facts and sources of landslide hazard and risk information been taken into account by the applicant?
- How likely is it that landslides will affect major and/or significant portions of the application area?

Where development is proposed for an identified landslide hazard area, a geotechnical report should be required as part of the resource consent application. This requirement should be specified in the plan's assessment criteria. To ensure that an applicant submits a geotechnical report that correctly addresses the potential landslide hazard issues, the planner needs to request the right information. Information Box 16 outlines the matters that should be addressed in a geotechnical report where landslide hazards exist or potentially exist for a site. A more detailed checklist is provided in Appendix 7.

Information Box 16

What should a good slope stability/landslide assessment include?

- Site location and proposed development maps and plans.
- Details of investigations undertaken.
- Regional geological information to place the site within the context of the wider area.
- Site history including reference to previous work, past slope instability, regional/district hazard maps and registers, time series aerial photography.
- An engineering geological map showing topography, landforms and significant geological features, surface drainage and groundwater observations.
- Descriptions of materials, test results etc.
- Slope stability issues including type of failure, size, timing, hazard assessment including run out, seismic effects, risk assessment.
- Zones delineating landslide risk.
- Engineering issues, site works, drainage, remedial design, ongoing maintenance, expected lifespan of engineering works.
- Limitations of the assessment.

Councils may request an independent peer review of any geological/geotechnical assessments of landslide risk.

7.3 Assessment criteria

An applicant lodging a resource consent application to build on or near at-risk land is required by Section 88 of the RMA to provide an adequate Assessment of Environment Effects (AEE) with any application. Schedule 4 of the RMA outlines what the AEE should include, and includes particular regard to 'any risk to the neighbourhood, the wider community, or the environment through natural hazards'. The District Plan needs to spell out what is required of resource consent applicants. An AEE should:

- identify natural hazards (in this case, landslides)
- provide a risk analysis
- consider alternatives
- show mitigation measures, and
- determine residual risk with appropriate mitigation if required.

Where there are specific rules in a district plan limiting development in a landslide hazard area, the district plan needs to include assessment criteria that make it clear what factors will be considered when assessing resource consents for subdivision and land use. Such criteria may include:

- risk to life, property and the environment posed by a natural hazard
- likely frequency and size of landslide movement
- type, scale and distribution of any potential effects from the natural hazard
- degree to which the building, structural or design work to be undertaken can avoid or mitigate the effects of a landslide or slope instability
- accuracy and reliability of any engineering and geotechnical information.

A specific example of assessment criteria from Nelson City Council with respect to the active Tahunanui landslide is provided in Information Box 17.

Information Box 17

Nelson City Council Resource Management Plan assessment criteria for the Tahunanui Slump Core and Fringe Overlay

a) Geotechnical assessments should indicate the level of activity to which the area is subject (e.g. superficial, tertiary etc – see table, p4 "Nelson City Council, Geotechnical Assessment – Tahunanui Slump, Nelson, December 1995"). They should also address the assessment matters in the rules below which are relevant to the consent application in question.

b) The location of the site in relation to the slump.

c) The risk to life, property and the environment posed by any hazard.

d) In the fringe area, whether a geotechnical assessment can demonstrate that the property is not part of the active (core) slump, or is only partly within it. Consequently whether the proposed activity would be unaffected by the hazard, and would not in turn affect the hazard itself.

e) Irrespective of whether the activity is within the active slump, the extent to which it would worsen the risk posed by the natural hazard. The extent to which the effects of the hazard, or the effects of the activity on the hazard, can be remedied or mitigated.

f) Where a geotechnical assessment concludes that erection of a permanent structure is not appropriate, whether a re-locatable building may be a practical alternate on sites subject to high or potentially high rates of slope movement.

g) The nature of the proposed activities on the site, or on other sites potentially affected by the natural hazard.

h) In respect of earthworks, the assessment criteria set out in Rule REr.61 (earthworks).

i) The geology of the site including any relationship or effect on areas of actual or potential instability off the site. Any susceptibility to slope failure from oversteepening of the slope and/or water saturation.

j) Irrespective of whether the activity is directly affected by instability, the extent to which it would worsen the risk of instability on other sites e.g. by discharge of stormwater, or changes in water flows.

k) The nature of the proposed activities on the site, or on other sites potentially affected by the natural hazard.

l) The nature of any fill and its effects on the stability of the site, the extent to which the effects of the hazard, or the effects of the activity on the hazard, can be remedied or mitigated.

m) The need to specify any conditions, e.g. that all work is carried out under the supervision of a suitably qualified engineer or geologist, that excavations are retained as soon as possible and drained, with stormwater piped into an approved stormwater system, and avoid periods of rainfall or when the ground is highly saturated.

In making a decision on applications for areas with potential landslide risks, a planner needs to ensure that the assessment criteria set out in the plan have been addressed. Where significant effects from or to landslide hazards are identified as a result of proposed land development or structures, then appropriate mitigation needs to be identified or the application should be declined.

When there is uncertainty about the risks associated with development then specialist geotechnical advice or a peer report should be sought prior to a decision regarding the development.

Knowledge changes over time as the information about landslide hazards improves. It is important for local authorities to identify how this information is passed on to staff and the public. This is a particular issue where there is a high turnover of staff assessing proposed developments. One way to improve staff knowledge of issues is through the development and implementation of a hazard management guideline for planning staff, the use of hazard registers, GIS and databases, external data sets, and training.

GLOSSARY OF TERMS

AEP: Annual exceedance probability – the estimated probability that an event of specified magnitude will be exceeded in any one year (see Information Box 6 for discussion) (AGS 2007a).

Block slide: A translational slide in which the moving mass consists of a single unit or a few closely related units that move downslope as a single unit (Wold and Jochim, 1989).

Consequence: Outcome or impact of an event. There can be more than one consequence from one event, and consequences can range from positive to negative. Consequences can be expressed qualitatively or quantitatively (AS/NZS 4360:2004).

Controlled activity: a resource consent is required for the activity, however the consent authority must grant the resource consent, unless it has insufficient information to determine whether or not the activity is a controlled activity. The consent authority must specify in the plan or proposed plan matters over which it has reserved control; and the consent authority's power to impose conditions on the resource consent is restricted to the matters that have been specified in the plan. The activity must comply with the standards, terms, or conditions, if any, specified in the plan or proposed plan.

Creep: The imperceptibly slow, steady downward movement of slope-forming soil or rock indicated by curved tree trunks, bent fences or retaining walls, tilted poles or fences, and small soil ripples or terracettes (Wold and Jochim, 1989).

Crown: The material that is still in place, practically undisplaced and adjacent to the highest parts of the main scarp (Varnes, 1978).

Debris: A coarse engineering soil, with 20-80 percent of the particles larger than 2 mm.

Debris avalanche: A very rapid to extremely rapid landslide on a steep slope which is unconfined to a channel. Debris avalanches often initiate debris flows.

Debris flow: A form of rapid mass movement in which soils, rocks, and organic matter combine with entrained air and water to form a slurry that flows down a slope in a confined channel. Debris flows are associated with steep confined gullies (Wold and Jochim, 1989).

Discretionary activity: a resource consent is required for the activity. The consent authority may grant the resource consent with or without conditions or decline the resource consent; and the activity must comply with the standards, terms, or conditions, if any, specified in the plan or proposed plan.

Displaced material: The material that has moved away from its original position on the slope. It may be in a deformed or undeformed state (Varnes, 1978).

Earth flow: Landsliding where commonly a bowl or depression at a head where unstable material collects and flows out. The central area is narrow and usually becomes wider as it reaches the valley floor. Flows generally occur in fine-grained materials or clay-bearing rocks on moderate slopes and with saturated conditions. Dry flows of granular material are also possible. Earth flows have a characteristic ‘hour glass’ shape (Wold and Jochim, 1989).

Erosion: Localised removal of rock or soil as a result of the action of water, ice, wind, coastal processes or mass movement (Glade, Anderson & Crozier, 2005).

Falling debris: See Appendix 1 for definition.

Falls: A mass that detaches from a steep slope or cliff and descends by free-fall, bounding, or rolling.

Flank: The side of the landslide (Varnes, 1978).

Flows: A mass that moves down slope with a fluid motion. A significant amount of water may or may not be part of the mass.

Foot: The portion of the displaced material that lies down slope from the toe of the surface of rupture (Varnes, 1978).

Frequency: The number of times an event occurs over a particular period or in a given sample.

Hazard: A potentially damaging event occurring within a given area within a given time.

Head: The upper parts of the slide material along the contact between the displaced material and the main scarp (Varnes, 1978).

Landslide: Part of a slope that collapses and moves downwards under the influence of gravity.

Landslip: See Appendix 1 for definition.

Lateral spreads: The result of the nearly horizontal movement of geologic materials, distinctive because they usually occur on very gentle slopes. The movement is caused by liquefaction triggered by rapid ground motion, such as that experienced during an earthquake (Wold and Jochim, 1989).

Left and right: Compass directions are preferable in describing a slide, but if right and left are used they refer to the slide as viewed from the crown (Varnes, 1978).

Likelihood: Used as a general description of probability or frequency. Can be expressed either qualitatively or quantitatively (AS/NZS 4360:2004).

Main scarp: A steep surface on the undisturbed ground around the periphery of the slide, caused by the movement of slide material away from undisturbed ground. The projection of the scarp surface under the displaced material becomes the surface of rupture (Varnes, 1978).

Minor scarp: A steep surface on the displaced material produced by differential movements within the sliding mass (Varnes, 1978).

Main body: That part of the displaced material that overlies the surface of rupture between the main scarp and toe of the surface of rupture (Varnes, 1978).

Non-complying activity: a resource consent is required for the activity. The consent authority may grant the resource consent with or without conditions or decline the resource consent.

Permitted activity: a resource consent is not required for the activity if it complies with the standards, terms, or conditions, if any, specified in the plan or proposed plan.

Probability: The likelihood of a specific outcome.

Restricted discretionary activity: a resource consent is required for the activity. The consent authority must specify in the plan or proposed plan matters to which it has restricted its discretion. The consent authority's powers to decline a resource consent and to impose conditions are restricted to matters that have been specified in the plan; and the activity must comply with the standards, terms, or conditions, if any, specified in the plan or proposed plan.

Risk: The chance of something happening that will be an impact. A risk is often specified in terms of an event or circumstance and the consequences that may flow from it (AS/NZS 4360:2004).

Risk-based: Uses risk analysis and management methodologies.

Rockfall: One or more pieces of rock falling from a steep rocky slope whether one at a time or all at once.

Rotational landslide: A landslide in which the surface of the rupture is curved concavely upward (spoon shaped) and the slide movement is more or less rotational about an axis parallel to the contour of the slope (Wold and Jochim, 1989).

Run-out: Down-slope extent of the displaced material.

Slide: A mass displaced on one or more recognisable surfaces, which may be curved or planar.

Scarp: A steep surface on the undisturbed ground around the periphery of the slide caused by the movement of slide material away from undisturbed ground or within the displaced material produced by differential movements within the sliding mass.

Side scarp: A steep surface on the undisturbed ground that defines the lateral margins (flank) of the slide, caused by the movement of slide material away from undisturbed ground. Sometimes referred to as "lateral scarp".

Slippage: See Appendix 1 for definition.

Slope instability: The potential or actual movement of material on a slope.

Slump: See rotation landslide above – a slump is an example of this.

Subsidence: See Appendix 1 for definition.

Surcharge: Overload, fill or saturate to excess.

Surface of separation: The surface separating displaced material from stable material but not known to have been a surface of which failure occurred (Varnes, 1978).

Susceptibility: Being prone to.

Tip: The point on the toe most distant from the top of the slide (Varnes, 1978).

Toe: The margin of displaced material most distant from the main scarp (Varnes, 1978).

Toe of surface rupture: The intersection (sometimes buried) between the lower part of the surface of rupture and the original ground surface (Varnes, 1978).

Top: The highest point of contact between the displaced material and the main scarp (Varnes, 1978).

Topple: A block of rock that tilts or rotates forward, eventually to fall, bounce, or roll down the slope as a rockfall (Spiker & Gori, 2003). Often also used for the whole event, including the rockfall deposit.

Transitional slide: A landslide in which the mass of soil and rock moves out or down and outward with little rotational movement or backward tilting (Spiker & Gori, 2003).

Ultimate limit state: the design event where a structure will fail.

Vulnerability: Exposure to damage.

Zone of accumulation: The area within which the displaced material lies above the original ground surface (Varnes, 1978).

Zone of depletion: The area within which the displaced material lies below the original ground surface (Varnes, 1978).

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APPENDIX 1 — LANDSLIDE TERMS IN NEW ZEALAND STATUTES

Landslides have affected people since prehistoric times, and as a consequence there are many entrenched names for various types of landslides that are in general and restricted usage. They are not used consistently, and some terms often have different meanings between different branches of earth science. Landslide terminology is constantly evolving; its evolution is usually based on convenience and utility, and so is not to be decried. The considerate landslide specialist will avoid or define technical terms when conveying information to the general public.

To put landslides into a New Zealand legal context, neither the Building Act (2004), the Resource Management Act (1991), nor the Earthquake Commission Act (1993) use the term ***landslide.*** The Building Act (2004) covers the technical meaning of landslide in two closely related "natural hazards" ***slippage*** and ***falling debris.*** The Resource Management Act and the Earthquake Commission Act use the term ***landslip*** for what is understood to be a landslide.

Landslip, though listed as one of the Resource Management Act's natural hazards, is not defined in it. The Earthquake Commission Act (1993) defines ***natural landslip*** as "the movement (whether by way of falling, sliding or flowing, or by a combination thereof) of ground-forming materials composed of natural rock, soil, artificial fill, or a combination of such materials, which before movement, formed an integral part of the ground; but does not include the movement of the ground due to below-ground subsidence, soil expansion, soil shrinkage, soil compaction, or erosion." A ***landslip*** is therefore legally distinct from what is termed ***subsidence*** in the Building Act and the Resource Management Act, but for the purpose of hazard recognition, mitigation or avoidance, subsidence can and should be included in a landslide hazard assessment.

Falling debris is a listed natural hazard in the Building Act (2004), and is defined as any, or any combination of soil, rocks or vegetation moving under the influence of gravity, moving from offsite to cause harm at a site. Falling debris is not a technical term, but is readily understood by technical experts to include those forms of landslide that comes from upslope to cause damage.

Slippage is another term used in the Building Act (2004). It has the same meaning as ***landslip*** under the Earthquake Commission Act, but in the context of the land on the site moving offsite (and thereby becoming ***falling debris*** for another site).

Subsidence is also listed as a natural hazard in the Building Act (2004), and can occur through groundwater abstraction in some areas, collapse of land over abandoned coal and gold mines, collapse into limestone caverns, collapse over buried melting ice, and differential compaction when soils liquefy during earthquakes. Subsidence is not covered by the Earthquake Commission.

It does not matter whether one classifies a landslide as a landslip, slippage, or falling debris, providing that the measures taken to avoid damage are appropriate for the particular type of landslide. Further, there are other natural hazards, such as earthquakes and strong winds, that are not listed natural hazards under Section 76 of the Building Act (2004), but must be considered in the design and construction of buildings (and are listed under the RMA).

A debris flow appears not to be covered by New Zealand statutes. A ***debris flow*** is internationally recognised as a type of landslide, but it occurs as a matter of definition in a river and stream channel, often in association with flood water. Some past debris flows in New Zealand have been called ***flash floods*** and inadvertently been treated as a type of flood, when in reality they are much more dangerous, and should be treated differently. The Building Act's ***falling debris,*** and the RMA and Earthquake Commission Act's ***landslip,*** should be viewed as including debris flows because a debris flow is a mass of debris moving under the influence of gravity. Recognition of debris flow hazard is more difficult than recognition of the hazard from many other landslide types.

Landslides can be structurally damaging to buildings. Therefore, landslides should be considered in the same context as other structurally damaging hazards such as earthquakes and strong wind. Under the building codes associated with the Building Act (2004) it is appropriate to adopt standards of construction of dwellings so that they have a 90% chance of lasting their expected lifetime, usually taken as 50 years. It follows that the appropriate level of protection from landslips is that of the landslip of 10% probability in 50 years (which is usually rounded to an event of AEP of 1/500), whereas for protection from a non-structurally damaging hazards (such as flood inundation) a lower level of protection may be appropriate (such as the 1/50 or 1/100 AEP).

APPENDIX 2 — SUMMARY OF EARTHQUAKE INDUCED SLOPE SUSCEPTIBILITY MAPPING FOR THE WELLINGTON REGION

In the late 1980s, Wellington Regional Council embarked on a project to assess the risks posed by earthquakes and identify and implement mitigation measures to ensure that the level of risk is acceptable. A component of this work was the preparation of earthquake-induced slope failure (landslide) hazard maps. A series of five map sheets and accompanying explanatory booklets were prepared for the main urban areas in the western part of the Wellington Region and published by the Wellington Regional Council (Kingsbury, 1995). The maps show the geographic variation in slope failure susceptibility for different parts of the region and slope failure potential for three earthquake scenarios. Below is a summary of the process followed in the preparation of the earthquake induced slope failure hazard maps.

The assessment methodology was developed following a review of historical records of earthquake-induced slope failure and a literature review of similar assessments. The methodology was tailored to suit the particular characteristics of the region. The main steps of the methodology were:

- compiling factor maps from available information and site reconnaissance
- integrating of factors by assigning numeric values and weightings to factors, and summing the products of the factor value and weighting for each factor to derive a susceptibility rating
- mapping slope failure susceptibility using the factor maps and susceptibility rating derived for common slope characteristics
- defining earthquake scenarios for seismicity
- appraising potential for slope failure from susceptibility, earthquake scenarios and data from historical earthquake scenarios and data from historical earthquakes
- reviewing slope failure mechanisms, and
- assessing likely ground damage from slope instability.

Slope angle and height, slope modification, existing landslides and geology information were integrated to assess slope failure susceptibility. Five slope failure susceptibility zones were identified, from very low susceptibility to very high susceptibility.

The slope failure susceptibility zones were checked against historical earthquake induced landslide characteristics and subjectively against known areas of earthquake induced slope failure hazard. The factor values and weightings were refined to give susceptibility ratings and therefore susceptibility to slope failure consistent with historical records and consideration of the known slopes. They were then used as the basis for mapping. The resulting maps were produced at a scale of 1:25,000. A portion of one of these maps is shown in Figure 3.8 (Section 3.4).

Three earthquake scenarios were used to represent slope failure opportunities. This was assessed using historical data on earthquake induced landslides in the region. Earthquake induced slope failure potential in the region has been determined by the integration of slope failure susceptibility zones with different levels of opportunity given by earthquake scenarios (Figure 3.8, Section 3.4).

For more information see: Kingsbury, P. (Compiler). 1995. *Earthquake Induced Slope Failure Hazard Wellington – Notes to Accompany*. Publication WRC/pp-T-95/06. Wellington Regional Council.

APPENDIX 3 — QUALITATIVE LANDSLIDE RISK ASSESSMENT EXAMPLE: AUSTRALIAN GEOTECHNICAL SOCIETY METHOD

1 INTRODUCTION

A risk assessment methodology has been developed by the Australian Geomechanics Society (AGS 2000). This methodology is similar to the risk Management Standard developed (for all hazards) for use in New Zealand and Australia (AS/NZS 4360:2004 Risk Management)[5] but is designed specifically for landslide hazards. A flowchart summarising the main components of the landslide risk assessment and management process is presented in Figure A3-1 and summarised as follows:

(a) *Define brief for study* particularly: (i) the *scope of work;* (ii) the *purpose and context* in which it will be used (i.e. regional assessment to meet RMA obligations; RMA application for planned commercial or housing subdivision development, or a new road or engineering structure); and (iii) *the appropriate annual exceedence probability* for the proposed development.

(b) *Landslide hazard assessment:* Identify landslide hazard events that could occur in proposed development area based on: (i) *Mapping of existing landslides and geomorphic features including information relating to their age;* (ii) *mapping of landslide susceptible slopes, runout and collapse zones;* potential debris *flow and debris flood paths* etc.; and (iii) *identification of triggering events* for landslide hazards (heavy or prolonged rainfall; strong earthquakes; excavations for roads, materials, buildings, structures; slope loading by fills; runoff and storm water disposal; leakage from pipes and water mains etc.).

(c) *Risk Analysis* for landslide events, using *Risk Analysis Matrix (3), and Risk Level Implication (4)* shown in Figure A3-2. In this methodology *Landslide Risk* is defined as the combination of the *likelihood* and *consequences* of a landslide hazard affecting a site. *Likelihood* is an indication of the *probability or frequency of a hazard event occurring.* The indicative frequency or AEP of these hazard events can be estimated from historical and prehistoric evidence of geological hazards and processes at a specific site. *Consequence* is the likely impact of the hazard event on the site, expressed in terms of the possible building damage and loss of life if the event occurs. The *Level of Landslide Risk* for each hazard event is estimated by cross matching *Likelihood (Classes A-F)* against *Consequences (Classes 1-5).* The consequences of a particular landslide event will depend on the building or structural damage, and possibly loss of life, that could occur. Generally based on landslide type, size, and speed of movement.

(d) *Evaluate response to estimated risk* – based on expected or possible damage and effects. Examples of *Risk Level Implications* and responses are given in Figure A3-2 (4).

(e) *Response to Risk Assessment:* (i) *Accept Risks:* for some landslide events the *Level of Risk* may be acceptable for development to proceed without conditions being imposed during the resource consent process. (ii) *Risk unacceptable:* the risk posed by some landslide events may be unacceptable, unless mitigation or protective works are carried out to reduce the level of risk. This may involve slope stabilisation works,

protective fences or earthworks, slope drainage and runoff controls, or slope maintenance and monitoring. If mitigation measures are not possible to reduce the level of risk at a particular site from a major landslide hazard (because of cost or planning restrictions), building exclusion zones may be imposed, or some sites may have to be abandoned.

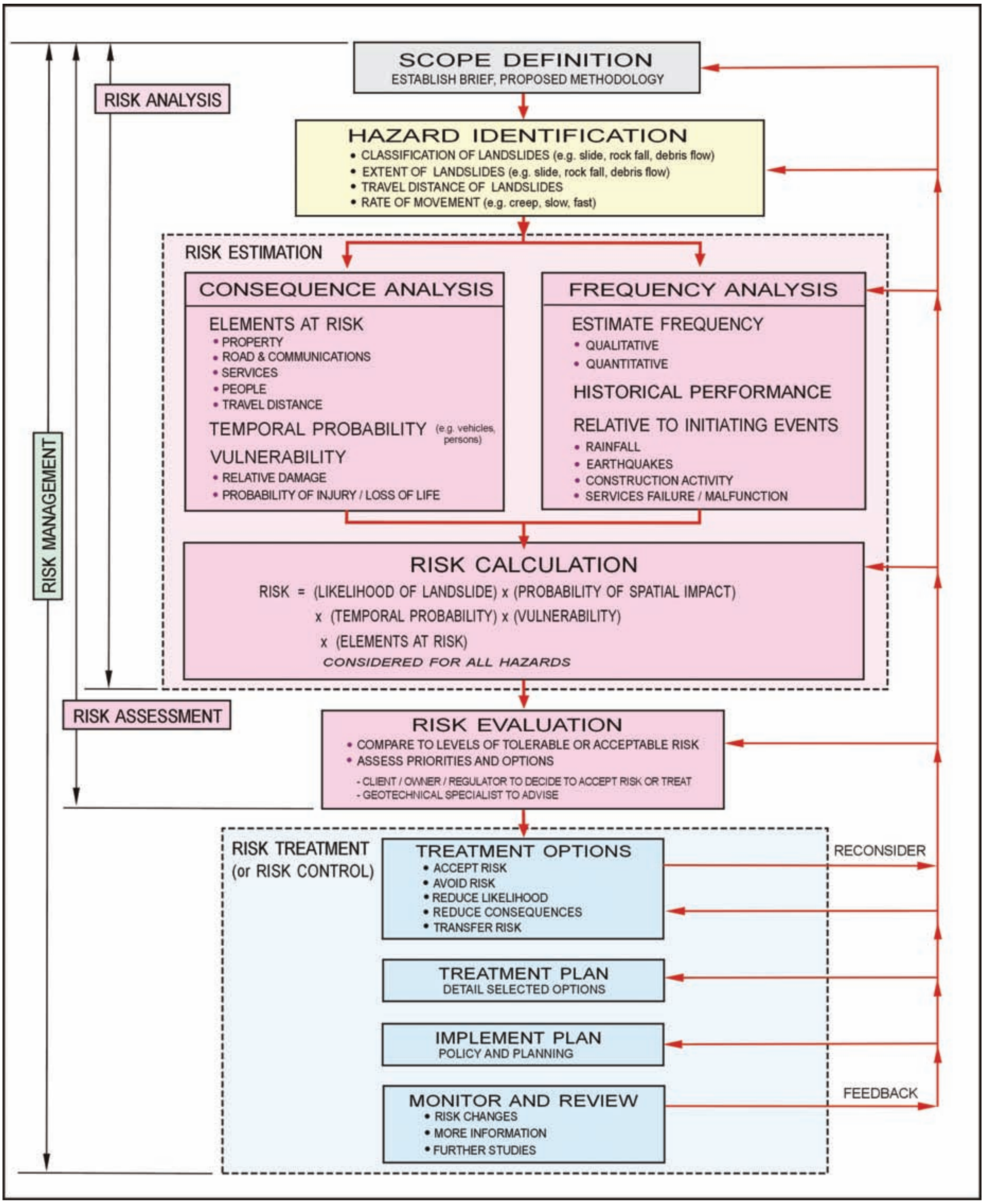


Figure A3-1 Schematic flowchart showing the landslide risk assessment and management process developed by the Australian Geomechanics Society *(after AGS, 2001).*

1 – Measures of Likelihood

Level	Descriptor	Description	Indicative Probability (Return Period)
A	ALMOST CERTAIN	The event is expected to occur (during life of buildings).	~1 – 10 years
B	LIKELY	The event will probably occur under adverse conditions.	~10–100 years
C	POSSIBLE	The event could occur under adverse conditions.	~100–1,000 years
D	UNLIKELY	The event might occur under very adverse circumstances.	~1,000–5,000 years
E	RARE	The event is conceivable under exceptional circumstances.	~5,000 – 10,000 years
F	NOT CREDIBLE	The event is too rare to be considered	>10,000 years
Note: "~" means that the indicative value may vary by say ½ of an order of magnitude, or more.			

2 – Measures of Consequences to Property

Level	Descriptor	Description
1	CATASTROPHIC	Structure destroyed or large scale damage requiring major engineering works for stabilisation.
2	MAJOR	Extensive damage to most of structure, or extending beyond site boundaries requiring significant stabilisation works.
3	MEDIUM	Moderate damage to some of structure, or significant part of site requiring large stabilisation works.
4	MINOR	Limited damage to part of structure, or part of site requiring some reinstatement / stabilisation works.
5	INSIGNIFICANT	Little damage.
Note: "The Description" may be edited to suit a particular case.		

3 – Risk Analysis Matrix — Level of Risk to Property

LIKELIHOOD	CONSEQUENCES TO PROPERTY				
	1: CATASTROPHIC	2: MAJOR	3: MEDIUM	4: MINOR	5: INSIGNIFICANT
A – ALMOST CERTAIN	VH	VH	H	M	L
B – LIKELY	VH	H	H	M	L
C – POSSIBLE	H	H	M	L–M	VL–L
D – UNLIKELY	M–H	M	L–M	VL–L	VL
E – RARE	M–L	L–M	VL–L	VL	VL
F – TOO RARE TO BE CONSIDERED	VL	VL	VL	VL	VL

4 – Risk Level Implications

Risk Level		Example Implications
VH	VERY HIGH RISK	Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to acceptable levels; may be too expensive and not practical.
H	HIGH RISK	Detailed investigation, planning and implementation of treatment options required to reduce risk to acceptable levels.
M	MODERATE RISK	Tolerable provided treatment plan is implemented to maintain or reduce risks. May be accepted. May require investigation and planning of treatment options.
L	LOW RISK	Usually accepted. Treatment requirements and responsibility to be defined to maintain or reduce risk.
VL	VERY LOW RISK	Acceptable. Manage by normal slope maintenance procedures.
Note: "The Description" may be edited to suit a particular case.		

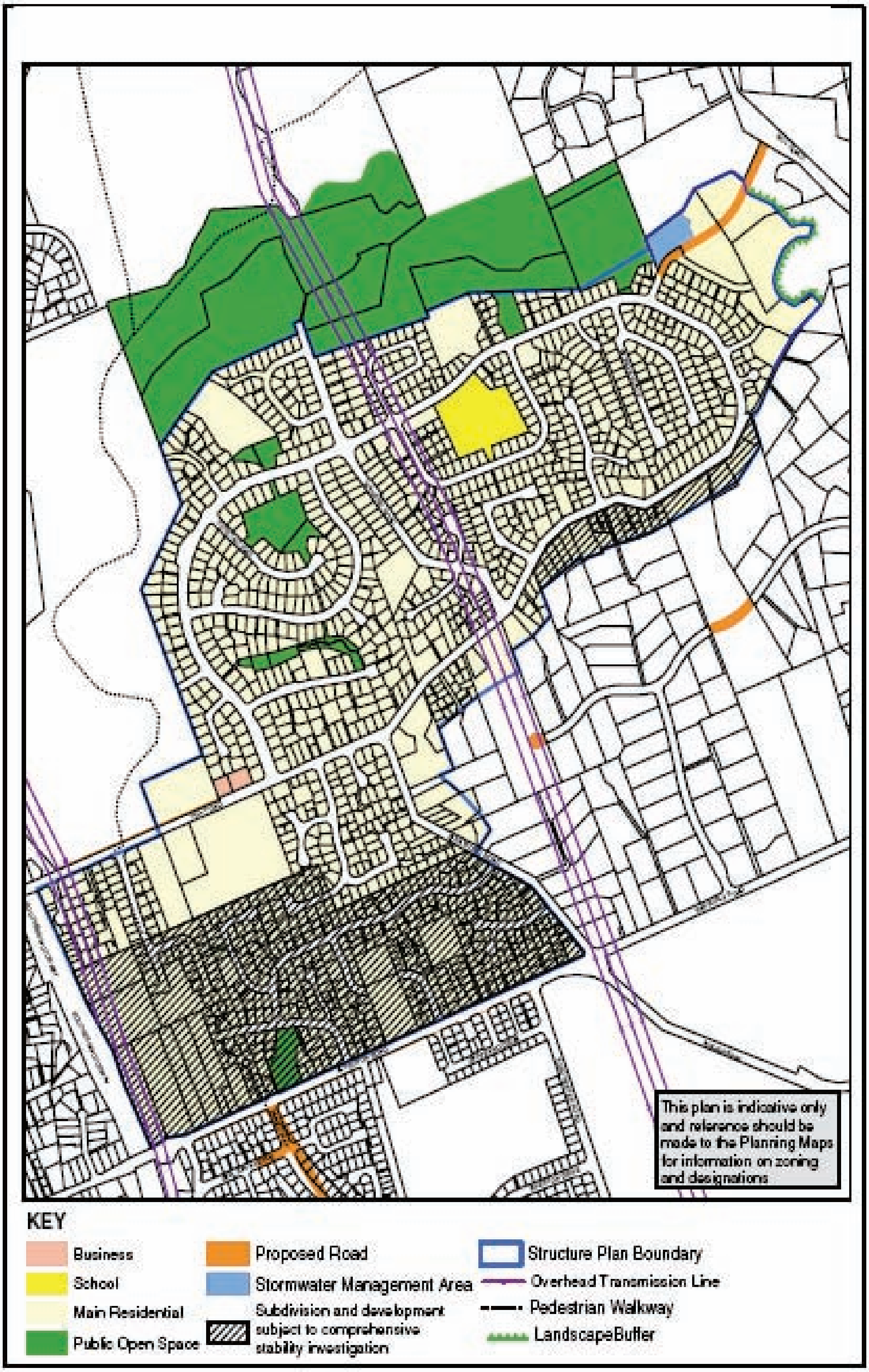
Figure A3-2 Summary of the main steps for qualitative landslide risk assessment and process: (1) Likelihood terms and criteria; (2) Measures of consequence; (3) Risk analysis matrix; (4) Implications of different risk levels (AGS, 2000)

In accordance with guidelines provided with the AGS methodology and the AS/NZS 4360:2004 Standard, descriptions of *likelihood* (indicative return periods), *consequences* and *risk implications* (possible effects and mitigation measures) can be modified to suit a particular case. This would be based on professional judgement and experience of suitably qualified landslide specialists.

The acceptability of an assessed level of risk (very high to very low, as defined in Figure A3-2) is subjectively judged (based on available data and experience) on the likelihood and consequences of an event occurring at a particular site, and the practicality and effectiveness of any mitigation or protective measures that could be provided to reduce the risk to an acceptable level. If the analysis shows the risk from a hazard to be unacceptable, the risk would have to be avoided, either by abandoning the site, or by construction of protective engineering works that reduce the risk to an acceptable level to make it safe for dwellings.

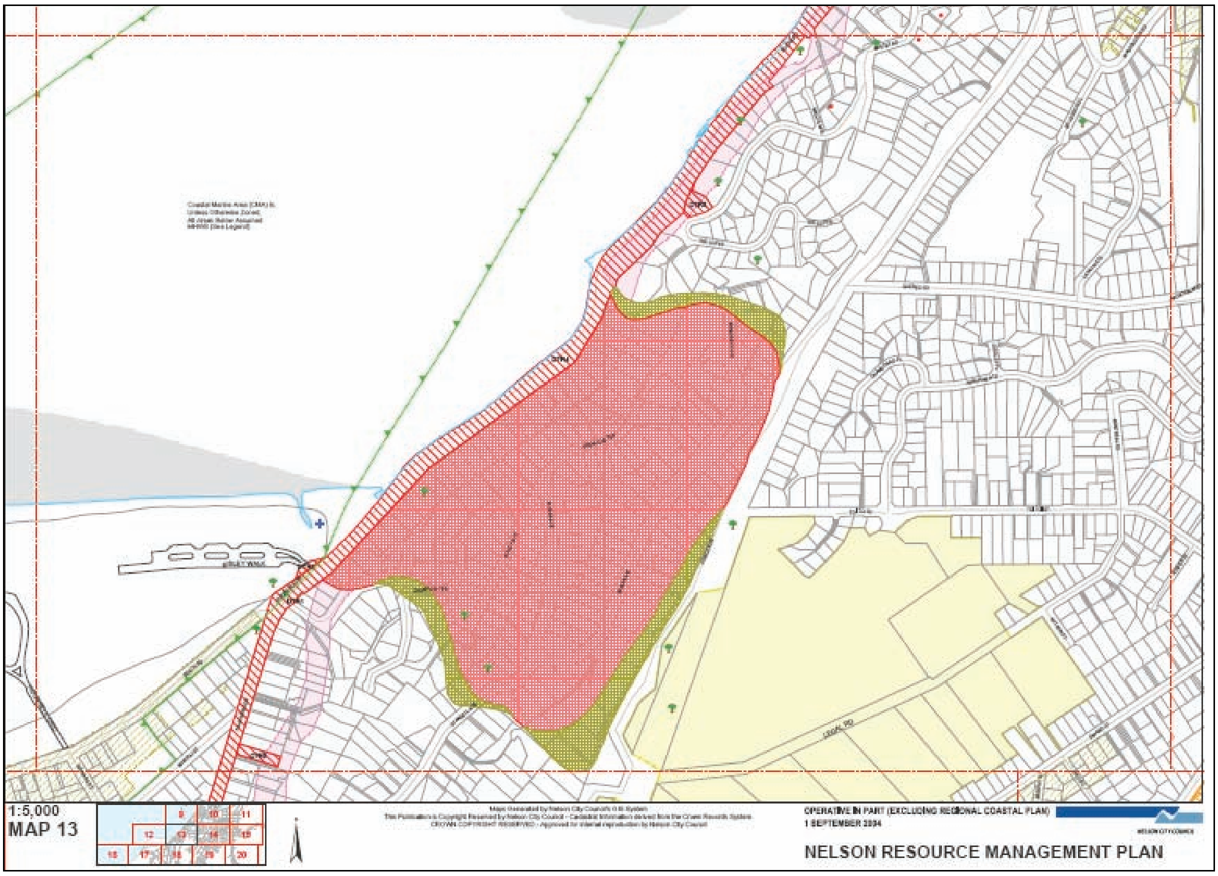
APPENDIX 4 — MANUKAU CITY COUNCIL RESOURCE MANAGEMENT PLAN

Hill Road Structure Plan (Figure 16.7). The hatched area allows subdivision and development, subject to comprehensive stability investigation.



APPENDIX 5 — NELSON CITY COUNCIL RESOURCE MANAGEMENT PLAN

Map 13 of the Nelson Resource Management Plan shows the natural hazard overlays of the Tahunanui Slump Core (red) and Fringe (green). Information Box 15 outlines the assessment criteria for these hazard overlays.



APPENDIX 6 — DETERMINING CONSENT CATEGORIES

Table A6.1 provides an example of one way that different consent status could be applied to activities in areas where landslide hazard exists. The Building Importance Category has been used as the key activity category, and the Annual Exceedance Probability (AEP) as the trigger for a resource consent. This table is presented as a guideline only, and may require refinement for specific locations and activities. The table can only be a guide if sufficient information on the AEP is available.

Table A6.1 Recommended resource-consent activity status for proposed land-use based on the probability of land slippage, falling debris or subsidence1 causing severe building damage or life-safety risk at a specific site, based on proposed uses for buildings of different importance categories as outlined in Table 4.1.

Range of **annual exceedence probability**[2] (AEP)	**<1/24**	**1/25—1/99**	**1/100—1/499**	**1/500—1/999**	**1/1000—1/2499**	**>1/2500**
Qualitative **acceptability of risk**	Never acceptable	Seldom acceptable	Sometimes acceptable	Generally acceptable	Seldom unacceptable	Always acceptable
Building importance category (BIC)	**Recommended activity consent status**[3] based on proposed use and probability of severe damage or life-safety risk from the hazards of landslip, falling debris or subsidence as defined in the RMA					
BIC 1 Low consequences (temporary or uninhabited buildings)	**Non-compliant**	**Discretionary**	**Permitted**	**Permitted**	**Permitted**	**Permitted**
BIC 2 Medium consequences (normal occupancy)	**Non-compliant**	**Non-compliant**	**Discretionary**	**Permitted**	**Permitted**	**Permitted**
BIC 3 High consequences (crowds affected)	**Non-compliant**	**Non-compliant**	**Non-compliant**	**Discretionary**	**Discretionary**	**Permitted**
BIC 4 High consequences (post-disaster functions)	**Non-compliant**	**Non-compliant**	**Non-compliant**	**Non-compliant**	**Discretionary**	**Permitted**
BIC 5[4] Structures of special importance	**Non-compliant**	**Non-compliant**	**Non-compliant**	**Discretionary (special studies)**	**Discretionary (special studies)**	**Discretionary (special studies)**

Notes:

1. Land slippage, falling debris and subsidence are the specified natural hazards in the RMA that are also commonly described by the terms "landslide", "slope instability" and "slope-stability hazard".
2. Annual exceedence probability is 1/(return period in years), See Information box 4 for further explanation of AEP's.
3. Well engineered mitigation works may be used to reduce the probability of damage or life-safety risk to acceptable levels on some otherwise "non-compliant" or "discretionary" sites. This should be taken into consideration when preparing the application for consent, with an assessment of residual risk.
4. BIC 5 buildings are those where the consequences of loss or damage can be expected to have regional or national impact. As such they should be subjected to special consideration and are expected to be subjected to special studies and specific planning restraints. The term 'Special Studies' is used in the New Zealand Loading Standard classifications (AS/NZS 1170.0.2002), and requires justifying any departure from the Standard, or for determining information not covered by the Standard,

The consent categories have been determined using the annual exceedance probability for ultimate limit state as shown in Table 4.2. The stated AEP for ultimate limit state is deemed to be the point at which the local authority should exercise some control over the activity. At this point the activity requires resource consent to allow the local authority to assess the risk and potential effects of the activity on the hazard. For higher AEPs (i.e. more likely) the local authority should exercise greater control. This allows the local authority to decline an application where either the risk or the potential effects of the hazard are significant. This approach recognises that up until the AEP for the ultimate limit state is reached (lower risk), it is appropriate that the activity is permitted.

The BIC categories in Table A6.1 are directly applicable to the construction or alteration of structures, but the table can also be applied to the subdivision and earthworks associated with such developments. Where subdivision or earthworks are required for residential structures, then the BIC 2 consent categories can be applied; where earthworks are proposed for a dam, then the BIC 5 consent categories are relevant; and so forth. Similarly, the categories could be applied during the rezoning of land for particular purposes.

The use of restricted discretionary activity status allows a local authority to restrict the matters that it will consider in the assessment of a resource consent application. The following matters would be particularly relevant in the case of landslides:

- the risk posed by landslide hazard
- the potential effects of the proposed activity on the landslide hazard
- any measures available to avoid or mitigate the effects of the landslide hazard.

Where a discretionary status is applied, local authorities should consider the inclusion of assessment criteria to guide applicants and ensure that relevant issues are addressed during the assessment of resource consent applications. Section 7.3 provides some suggested assessment criteria.

APPENDIX 7 — SUGGESTED CHECKLIST FOR SLOPE STABILITY ASSESSMENTS

Factual Information

1 INTRODUCTION

- ❒ Site Location.
- ❒ Outline of proposed development.
- ❒ Outline of investigations undertaken.

2 TOPOGRAPHY

- ❒ Outline of current landform (slope shape, height gradient, irregularities, erosion, soil creep/terracettes.
- ❒ Outline surface drainage patterns[b].
- ❒ Review aerial photography.
- ❒ Comment on any existing slope modification and instability.
- ❒ Additional site features (e.g. vegetation/trees, structures, roads services existing retaining walls etc)[b].

3 SITE HISTORY

- ❒ Outline current/previous land use.
- ❒ Comment on previous site works[b].
- ❒ Refer to District/Regional hazard maps.
- ❒ Comment on previous instability.
- ❒ Performance of existing structures.

4 GEOLOGY

- ❒ Describe geological setting.
- ❒ Refer to relevant geological maps.
- ❒ Outline geological influences on slope stability (e.g. bedding, weak materials, faults etc).
- ❒ Describe seismic setting.

5 INVESTIGATIONS

Field

- ❒ Inspection and mapping by specialist.
- ❒ Descriptions[1] of soils/rock in outcrop and cuttings[b].
- ❒ Type and location[b] of field investigations
- ❒ Descriptions[1] of soil/rock in drillholes/testpits etc.
- ❒ Other field tests (e.g. CPT, etc).
- ❒ Monitoring of ground movements[b].
- ❒ Groundwater measurements and observations[b] (seepage, subsurface erosion).

Laboratory

- ❒ Outline tests undertaken.
- ❒ Summarise results.
- ❒ Previous testing in local area.

6 SUBSURFACE CONDITIONS

- ❒ Geological interpretation.
- ❒ Summarise subsoils conditions.
- ❒ Describe soil strengths/density, likely behaviour – refer to tests and logs.
- ❒ Highlight weak/sensitive/loose soils or rock defects.
- ❒ Describe groundwater conditions, subsurface drainage expected seasonal fluctuation.

Interpretation/Discussion

7 SLOPE STABILITY

Engineering Geological Assessment

- ❒ Discuss sites features and reasons for landform (local, regional) including timing of formation.
- ❒ Discuss geological setting influences
- ❒ Influence of groundwater/rainfall
- ❒ Likely slope failure mechanism
- ❒ Effects of development on slope
- ❒ Consequence of slope failure
- ❒ Hazard assessed

Geotechnical Engineering analysis

- ❒ Geotechnical slope model correct?
- ❒ Analytical method stated
- ❒ Determination of critical section of slope
- ❒ Assessment of strength parameters
- ❒ Assessment of groundwater profile
- ❒ Back analysis of any existing failures
- ❒ Additional loads due to development
- ❒ Seismic loading analysis
- ❒ Sensitivity analysis
- ❒ Results and comments

8 GEOTECHNICAL EFFECTS OF DEVELOPMENT

- ❒ Risk assessed
- ❒ Need for drainage
- ❒ Need to remove/upgrade fill
- ❒ Need to retain slopes secure rock faces
- ❒ Foundation conditions/requirements
- ❒ Effect of stormwater/effluent disposal
- ❒ Effect of service line rupture (e.g. stormwater, sewer)
- ❒ Effect of river/coastal erosion
- ❒ Seismic effects on development and slope
- ❒ Maintenance requirements for lifetime of the development

9 CONCLUSIONS AND RECOMMENDATIONS

10 DRAWINGS/FIGURES

- ❒ Site plan
- ❒ Outline of proposed development
- ❒ Subsurface testing locations
- ❒ Contours
- ❒ Geology
- ❒ Landform and Engineering geological features
- ❒ Cross sections
- ❒ Geotechnical Model
- ❒ Remedial mitigation measures
- ❒ Stability analysis results

11

- ❒ Bore logs, test pits, logs of exposure
- ❒ Testing results
- ❒ Specifications for earthworks/remedial works
- ❒ Site photos

References

1 Field description of soil and Rock. Guidelines for the field classification and description of soil and rock for engineering purpose, NZ Geotechnical Society Inc (2005).

Notes: [a] Not all this information will be required for all assessments. Information requirements will need to be considered on a case-by-case basis

[b] indicate on site plan

[c] show on engineering geological plan