Department of Premier and Cabinet
STATE FRAMEWORK FOR MITIGATION OF NATURAL HAZARDS

Landslide Planning Report

Version 5 – 19 August 2013

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Tasmanian Government

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EXECUTIVE SUMMARY

A landslide hazard is a source of potential harm resulting from the *downslope movement of a mass of rock, debris, or earth* (AGS 2007b) that may have negative consequences on vulnerable infrastructure or communities.

Landslides include falls, topples, slides, flows, and spreads. In the context of defining landslide susceptibility for Tasmania, it does not include ground subsidence and collapse, or shallow downslope soil creep.

Since 1950, Mineral Resources Tasmania has identified 150 buildings, including 125 residential houses, which have been damaged or destroyed by landslides in Tasmania. It is estimated that State and local governments have paid $10 million in compensation to landowners for houses in landslip A or B areas. The true cost of landslides for communities is unknown.

The *Guide to considering natural hazards in land use planning* (Guide) outlines the Tasmanian Government approach to risk tolerance and identifying appropriate statewide land use planning and building controls to reduce risks from natural hazards to within tolerable limits.

The *hazard treatment approach* outlined in the Guide and this paper uses the best available evidence to define 'hazard bands' throughout the State and to identify development and use controls that best reflect the State's tolerance to risk. A *Landslide Planning Matrix* outlines the level of control that is considered appropriate within each 'hazard band'.

In relation to landslide hazard in Tasmania, the best available evidence has been used to define areas that may be susceptible to landslide. Five Landslide Hazard Bands have been identified and can be used to inform public policy and land use planning decisions, along with strategic and development control levels. Figure 1 depicts the process undertaken.

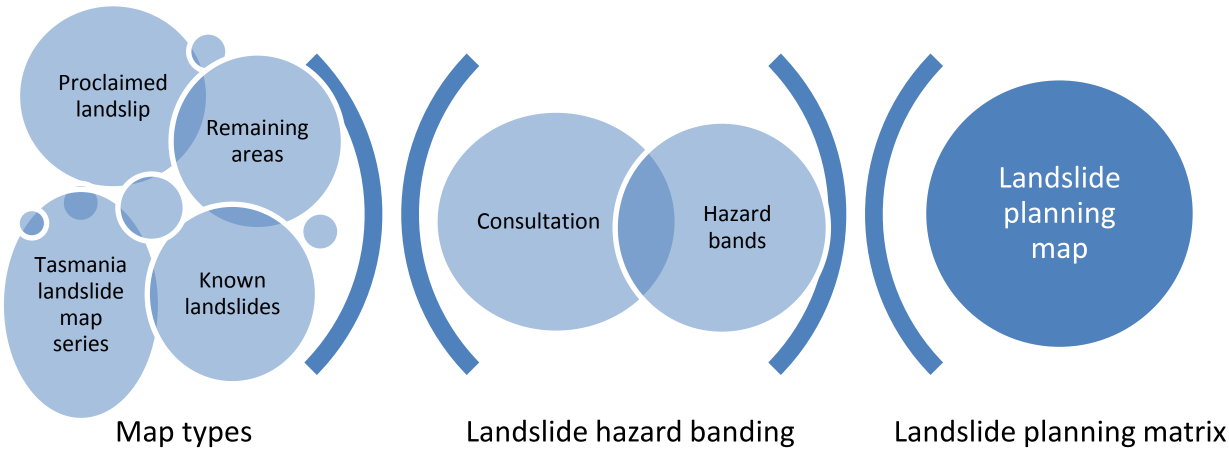


Figure 1: Landslide planning mapping process

The landslide hazard bands (and a summary of control levels) are outlined below. A full matrix is outlined in Chapter 6.

Acceptable Band	A landslide is a rare event in this area based on current understanding of the hazard, but it may occur in some exceptional circumstances. Development and use is not subject to landslide controls. The **acceptable** band includes 66% of the land area of Tasmania, 91% of vacant parcels and 92% of residential buildings.

Low Band	This area has no known landslides, however it has been identified as being susceptible to landslide by Mineral Resources Tasmania (MRT). While non-construction requirements are not necessary for most use and development, controls may be necessary to reduce the risks associated with vulnerable and hazardous uses or post-disaster and catastrophic risk-based use to ensure that risks are tolerable (as recommended by AGS 2007a). The ***low*** band covers 19% of the land area of Tasmania, 6% of vacant parcels and 5% of residential buildings.

Medium Band	The area has known landslide features, or is within a landslide susceptibility zone, or has legislated controls to limit disturbance of adjacent unstable areas. Planning controls are necessary for all use and development to ensure that risks are tolerable (as recommended by AGS 2007a). Any vulnerable or hazardous use will only be allowed in exceptional circumstances. The ***medium*** band covers 15% of the land area of Tasmania, 3% of vacant parcels and 3% of residential buildings.

Medium Active Band	The area has known recently active landslide features. Planning controls are necessary for all use and development to ensure that risks are tolerable (ABCB 2006 Landslide Hazards – Handbook for good hillside construction). Any vulnerable and hazardous uses or post-disaster and catastrophic risk-based uses are prohibited. The ***medium-active*** band covers less than 0.1% of the land area, vacant parcels and residential buildings,

High Band	The site is within a declared Landslip A area. All use and development requires significant investigation and engineered solutions to mitigate the natural hazard and enable the development to achieve and maintain a tolerable level of risk, however, the mitigation measures may never achieve comprehensive levels of security and safety. The ***high*** band covers less than 0.1% of the land area, vacant parcels and residential buildings,

1 INTRODUCTION

1.1 Purpose

To mitigate the impacts of landslide hazard by encouraging responsible land use and development through the land use planning system and building controls.

1.2 Objective

To enable sustainable development on land susceptible to landslide in accordance with the sustainable development objectives of the *Land Use Planning Approvals Act 1993* (LUPAA) and through appropriate management of building standards under the *Building Act 2000*.

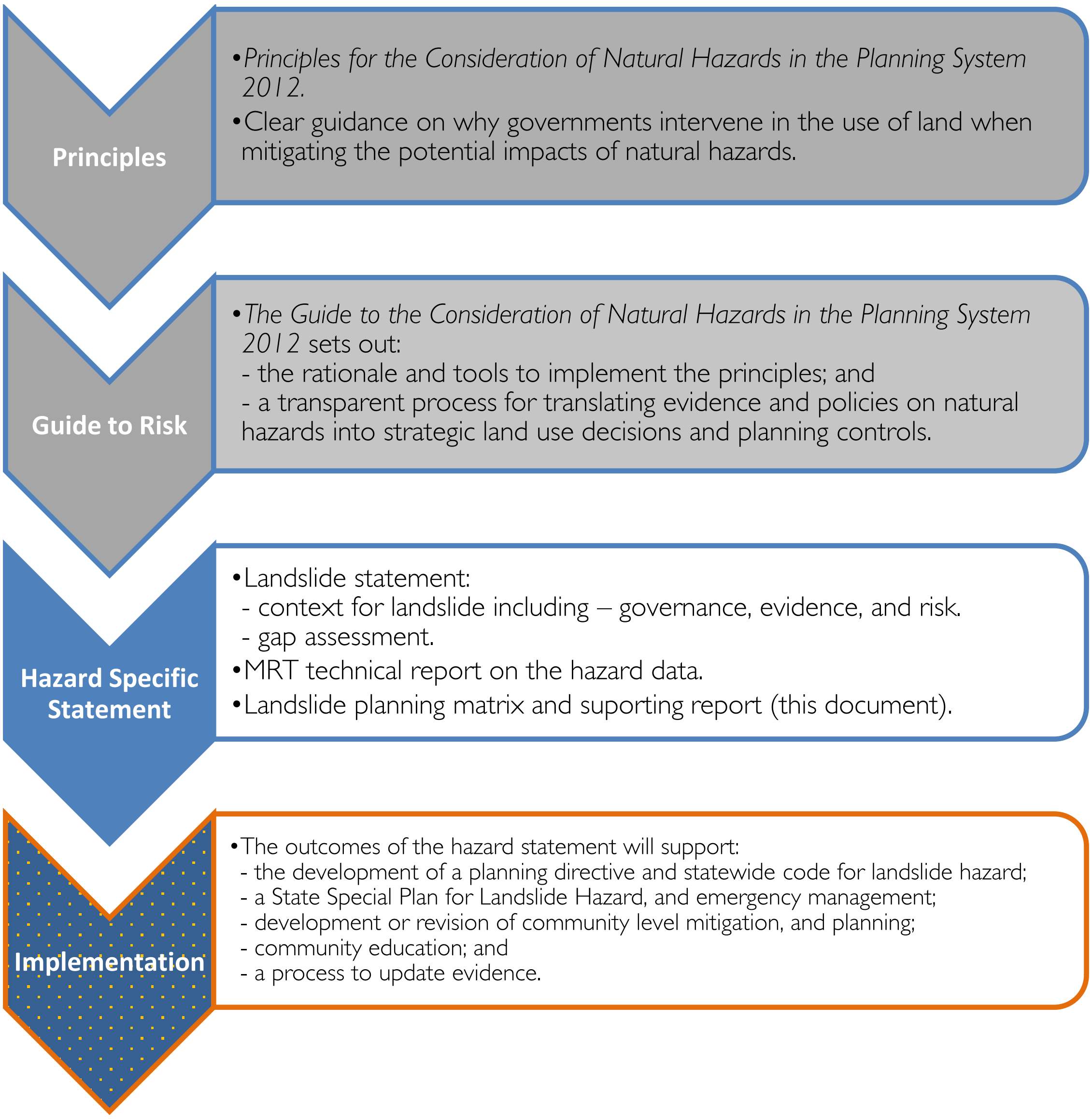
1.3 Background

The objectives of the Resource Management and Planning System (RMPS) contained in the LUPAA state that a role of the State Government is to promote sustainable development through, among other things, securing "…*a safe working living and recreational environment*".

The *Principles for the consideration of natural hazards in the planning system* (Principles) and Guide outline how the State Government translates the RMPS objectives into specific controls on the use and development of land that may be exposed to natural hazards (

Figure 2).

Figure 2: State Framework for the mitigation of the impacts of natural hazards through land use planning



Government (State and local) intervention in the use of land to mitigate the impacts of natural hazards is in accordance with the following principles (*Principles for the Consideration of Natural Hazards in the Planning System* DPAC 2012b):

- Private risks associated with natural hazards are the responsibility of individuals and business.
- Governments should encourage public and private risks to be factored into investment decisions.
- Governments can support individuals and business to understand and manage private risks through the collection of evidence, provision of information, and facilitation of collective action.
- Governments should ensure that private investment minimises unacceptable public risk.

- Governments should avoid investment, regulation, or policy that give rise to unacceptable public or private risks.
- Governments should have regard to, and support individuals and business to consider, how natural hazards may change in the future, including through climate change.

The Guide sets out a transparent process for translating evidence and policy on natural hazards into strategic land use decisions and planning controls. The Guide is consistent with the Principles and:

- assists to establish a reasonable balance between the productive and sustainable use of land and the protection of the community from the costs associated with natural hazards;
- promotes the ownership of private risks by an individual or business;
- ensures that the potential impact of a hazard is identified early in the decision process when considering a development (and potentially in the transfer of land);
- assists government at all levels to inform/educate the community, industry and officials on the nature of hazards;
- clarifies the approach to managing both public and private risks;
- assists the prioritisation for investment in research and mitigation of natural hazards by individuals, businesses and governments;
- facilitates collective action by landowners; and
- enables governments to identify and avoid actions that give rise to unacceptable public and private risks to the community.

This Report outlines how the guide is implemented to define how land is to be managed to reduce the public risks associated with landslide. It also outlines the evidence used and judgements made to develop the *Landslide Planning Matrix* that underpins the development of a Statewide Planning Code for Landslide by the Tasmanian Planning Commission (TPC) and the further consideration of landslide in the building system. The work may also influence future iterations of Regional Planning Strategies.

1.4 Process and Structure

The *Landslide Planning Matrix* uses the hazard treatment approach, which is one of four approaches to managing risks from natural hazards that arise from the development and use of land (see Box 1). The hazard treatment approach uses the best available evidence to support judgements on defining 'hazard bands' throughout the State and to identify development and use controls that best reflect the State's tolerance to risk.

The hazard treatment approach is underpinned by a series of workshops held with hazard experts, land use planners, and industry stakeholders for the purpose of:

- defining the hazard;
- considering available evidence and identifying options for mapping areas that may be exposed to hazards throughout the State;
- defining the boundaries of 'hazard bands'; and
- developing planning outcomes and controls to apply within each band.

A summary of outcomes of the workshops held to discuss landslide hazards and potential controls is provided at Appendix 1.

Box 1: Approaches to mitigating natural hazards (Guide 2012,)

Risk-based

Government defines risk tolerance.

Development considered on the basis of government risk assessments at regional or local levels.

Emergency Management

Is based on Planning, Preparation, Response, and Recovery (PPRR) to assist individuals and communities to recover from an event.

Precautionary

Government presumes that all properties within defined areas are at risk from a hazard.

Assessment of development in defined areas required to include an assessment of the risks at the cost of the developer.

Hazard treatment approach

Draws on elements of the risk approach, precautionary approach, and emergency response

Development controls based on agreed 'banding' of hazard likelihood based on best available knowledge

Process involves consultation, multi-agency participation in developing policy

Graduated imposition of assessment and control requirements.

2 WHAT IS A LANDSLIDE HAZARD?

A landslide hazard is a source of potential harm resulting from the *downslope movement of a mass of rock, debris, or earth* (AGS 2007b) that may have a negative consequence on vulnerable infrastructure or communities. Landslides include falls, topples, slides, flows, and spreads. In the context of defining landslide susceptibility for Tasmania, it does not include ground subsidence and collapse, or shallow downslope soil creep. The types of movement and relevant Tasmanian examples are in the *Tasmanian Landslide Map Series User Guide and Technical Methodology* (Mazengarb & Stevenson 2010).

Landslides are caused by the concurrence of conditioning factors and triggering factors (AGS 2007a).

- Conditioning factors[1] are terrain attributes (slope, geology, soil, geomorphology, vegetation cover, etc) that with time bring the slopes to a marginally stable state.

- Triggering factors may include one or more of the following: intense rainfall, rise of groundwater levels, earthquakes, or various human modifications.

The relationship between triggering events and conditioning factors is complex and difficult to judge without a localised geotechnical assessment. While broad geological types and slope can be mapped at the regional or statewide level, any attempt to make regional assumptions regarding triggering conditions such as local groundwater movements, or the impacts of human modifications, are likely to lead to outcomes with unacceptable levels of inaccuracy and uncertainty.

As outlined in the Guide, the likelihood of complex hazards, such as landslide, can be assumed by defining areas that are considered (for planning purposes) to be susceptible to landslide. This will not provide guidance on the expected frequency of landslide events in any given area, but will provide a basis for caution in terms of the placement, design and construction, and infrastructure to reduce the potential costs of landslide to the Tasmanian Community.

2.1 Landslide Exposure in Tasmania

All parts of Tasmania are exposed to the hazard of landslide. Recently, Mineral Resources Tasmania has been compiling information on the occurrence of landslide around the State and the number of houses damaged or destroyed. In addition, it has developed a landslide inventory that provides a geographical location for all landslides.

Since the 1950s, 150 buildings are known to have been damaged or destroyed by landslide. Included in this figure are 76 houses that have been destroyed, demolished or removed due to extensive damage. Appendix 2: Known Landslide Losses, provides a summary of the events.

[1] Conditioning factors have been called pre-conditions in the Guide.

Tasmania's most significant landslide events include:

- the 1950s Lawrence Vale landslide in South Launceston, which resulted in the loss of 43 residential houses.
- the Taroona Landslide in Kingborough, a large deep-seated landslide that is gradually moving towards the Derwent River, is known to be affecting 10 houses and a high school.
- the Rosetta landslide in Glenorchy is known to have destroyed or demolished 9 houses and significantly damaged a further 13 houses.
- the Beauty Point landslide in west Tamar is known to have destroyed or demolished 15 houses and significantly damaged a further 13 houses.

The actual cost of the losses due to landslide is largely unknown, as much of it is borne by homeowners, or is built into the maintenance budget for infrastructure, including roads, rail, and utilities.

It is noted, however, that State and local governments have paid approximately $10 million in compensation to private landowners for 96 houses that were built in landslide prone areas. The State government paid the compensation through the three acts that relate to specific landslides. These are:

- *Lawrence Vale Landslip Act 1961* (South Launceston).
- *Beauty Point Act 1970* (Beauty Point and Deviot).
- *Rosetta Landslip Act 1992* (Rosetta and Casuarina Crescent, Berridale).

The compensation paid out under the Acts allows for further compensation to be awarded to any of the home owners still living in the areas and meeting a set criteria, as defined in each Act. Typically, the compensation is limited to 75 per cent of the pre-landslide market value of the property.

3 UNDERSTANDING THE EVIDENCE FOR LANDSLIDE PLANNING BANDS

The purpose is to translate the science into a format that can support policy development

Mineral Resources Tasmania (MRT) has been actively mapping landslides and landslide susceptibility since the 1950s. The current program by MRT has resulted in the production of the Tasmanian Landslide Map Series. This Series combines all recently collected data with all previous susceptibility mapping such as the Landslide Risk Maps (1970-80).

Over the past decades, the available evidence on landslides has been used to develop a range of statutory instruments designed to reduce the risks from landslide. Part 10 of the Building Act 2000 authorises the Minister to control development by declaring Landslip A and B Areas. A number of planning schemes also include provisions to limit development in areas considered susceptible to landslides.

Any recommended approach for the treatment of natural hazards in the planning system should, as far as is reasonably practicable, be consistent with the management of landslide risk under the Ministers Resources Development Act 1995 and the Building Act 2000. Any proposed approach should also minimise the extent to which development and use that does not currently require a permit under the land use planning system becomes discretionary and, therefore, requires further assessment by a Planning Authority.

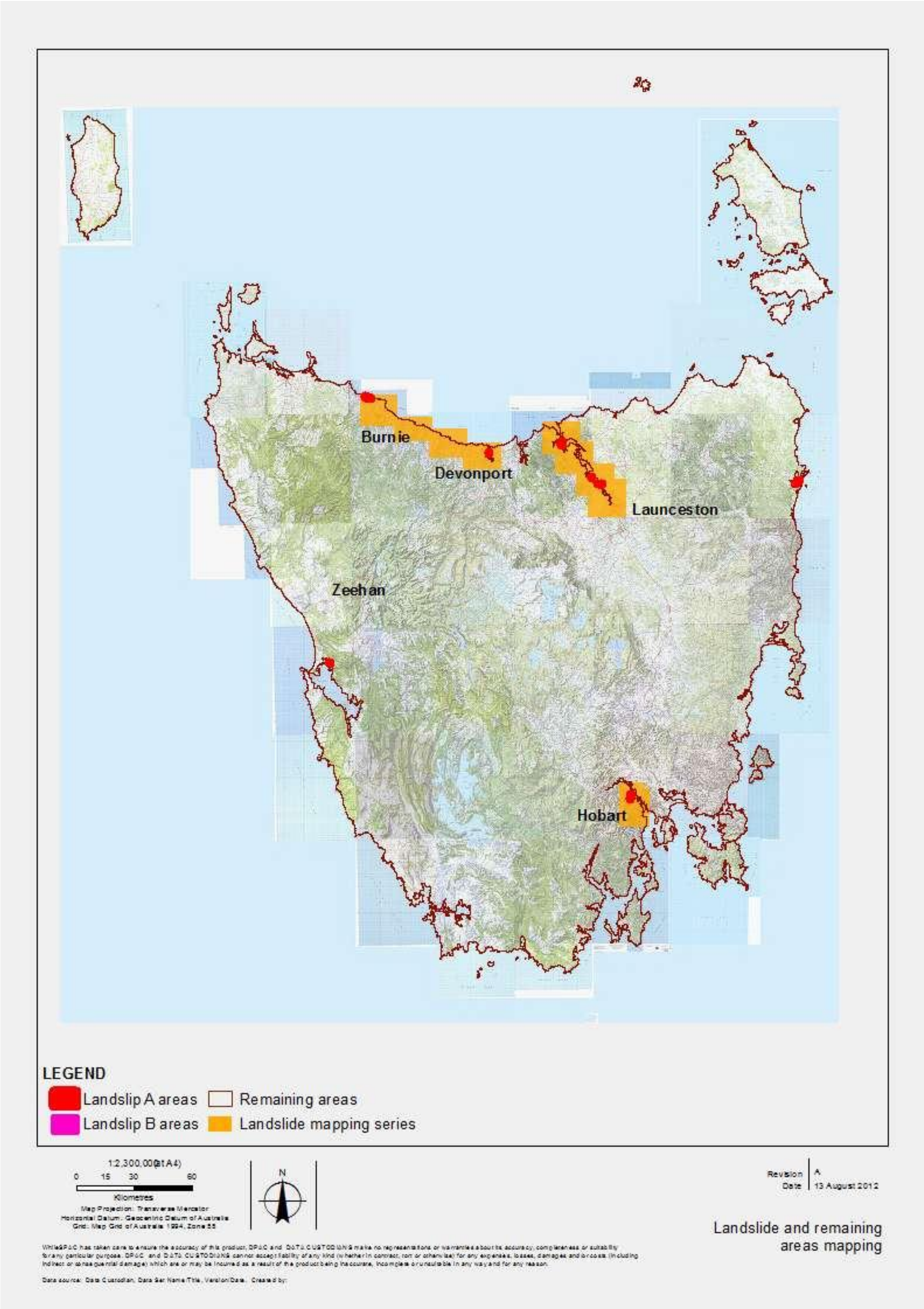
A range of options for defining areas considered susceptible to landslide hazards and alternatives for managing development and use in those areas were presented at regional workshops held during April and May 2012. Workshop attendees included State Government officers from Mineral Resources Tasmania (MRT), Department of Premier and Cabinet (DPAC), State Emergency Service (SES), Tasmanian Planning Commission (TPC), local government planning and emergency management officers, the Local Government Association, and industry bodies. During the workshops, the strengths and weaknesses of each option were considered. The use of slope, landslide susceptibility, and known landslides was the preferred option (see Appendix 1 for the outcomes of the workshops).

The workshop recognised that the landslide susceptibility mapping of the Tasmanian Landslide Map Series represents the best available data in the State.

For areas outside of those mapped for landslide susceptibility, the use of slope thresholds alone was considered the preferred approach due to the significant weakness associated with the geological data. The workshops considered that using the geological data would introduce significant uncertainties and may contribute to 'false confidence' in the boundaries of landslide planning bands. The workshop also noted that geology is a factor that is considered in the Tasmanian Landslide Map series by MRT.

The landslide data outlined below is divided into four groups. The first comprises legislated Landslip Areas; the second components have been identified as part of the MRT Tasmanian Landslide Map series; the third includes the slope components in the remaining areas of the State; and the last group is the known landslides that have been mapped (identified in Figure 3). The detailed assessment of the evidence is provided in Appendix 3.

Figure 3: Landslide and remaining areas mapping



3.1 Proclaimed Landslip Areas

Proclaimed Landslip A and B areas constitute legislated areas in Tasmania for which strict development controls exist. The geographic areas are defined by MRT under the *Mineral Resources Development Act 1995* and controls are imposed under the *Building Act 2000* and its Regulations. Any controls imposed in Landslip A and B areas override controls imposed through the land use planning system.

The first proclaimed landslip area was created in 1971 and the latest was proclaimed in 2003. Most of these areas have been created as a reaction to landslides that occurred between the 1970s and the 1990s, eg the Rosetta Landslip Area (Glenorchy) in 1992. Areas are designated Landslip A where the landslide is apparent, and Landslip B where the threat of movement is thought to exist.

3.2 Tasmanian Landslide Map Series – Susceptibility Zones

The work undertaken by MRT provides a foundation for defining planning bands in those areas that have been mapped. Each component for the landslide susceptibility mapping areas is outlined below.

Areas identified as susceptible to landslide activity

Since the 1960s, MRT has surveyed areas of urban growth throughout the State to identify those areas of land that may be susceptible to landslide (Mazengarb & Stevenson 2010). Figure 3 outlines the extent of the areas assessed by MRT.

The types of landslide susceptibility mapping considered in the development of planning bands include:

- Deep-seated slide susceptibility (landslide movement type – slide) is failure of geological units where the failure plane extends below any unmapped surficial soil or regolith material that may exist at the site. The depth of these landslides usually exceeds 5 metres.

- Shallow slide and flow susceptibility (landslide movement types – slide and flow) is failure of geological units that are relatively small in size, and where the failure plane does not usually extend below surficial soil or regolith material. The depth of these landslides is less than 5 metres. These shallow failures can then develop into earth or debris flows if conditions are wet enough.

- Debris flow susceptibility (Mountain) (landslide movement type – flow) is a type of landslide triggered by the action of torrential rain on loose material on a mountainside or escarpment. The boulders and finer material, mixed with water, flow down the slope as a torrent with coarser material (the proximal part of the debris flow) deposited near the base of the slope, while the finer material (the distal part of the debris flow) travels further as a flash flood across the floodplain. Debris-flows may initiate as debris-slides that transform into flows during movement.

  Alternatively, debris-slides may form dams that, in turn, fail catastrophically to become debris-flows and flash floods. In lowland areas, where the channel is unconfined, debris-flows may depart from the channel and deposit lobes of material on the surrounding landscape.

- Rockfall susceptibility (landslide movement types – fall and topple) is defined as the independent movement of rock or soil fragments through free fall, bouncing, rolling and sliding. They are usually sourced from cliff or steep slopes and are a fast moving type of landslide.

- **Very low to no susceptibility** areas have been judged in mapping programs as not susceptible to the landslide types outlined above.

Table 1 provides an outline of the landslide types that make up the MRT landslide susceptibility mapping and the components that make up each type. The components represent the smallest logical grouping for each type of landslide susceptibility.

Table 1: Components of susceptibility mapping

Mapping Type	Components
Deep-seated slide susceptibility	Deep-seated slide susceptibility (source-runout-regression)
	Launceston Group slide susceptibility (large and small)
	Hobart-Glenorchy deep-seated slide susceptibility (Rosetta scenario)
Shallow slide and flow	Shallow slide + flow susceptibility source high
	Shallow slide + flow susceptibility source moderate
	Shallow slide + flow susceptibility source low
Debris flow susceptibility (Mountain)	Debris flow susceptibility Mountain source + runout >30 Q1
	Debris flow susceptibility Mountain runout 30-26 Q2
	Debris flow susceptibility Mountain runout 26-22 Q3
	Debris flow susceptibility Mountain runout 22-12 Q4
Rockfall susceptibility	Rockfall susceptibility source + runout area 34 degree
	Rockfall susceptibility runout area 30 degree
Very low to no susceptibility	Very low to no susceptibility

3.3 *Defining Susceptibility in the Remaining Areas*

The areas of the State that have not been mapped for landslide susceptibility ('the remaining areas') cover almost 95 per cent[2] of the Tasmanian land mass, including the World Heritage Area, National Parks, forestry, agricultural land, towns, peri-urban and urban areas. The remaining areas contain 42 per cent of the existing residential buildings and 66 per cent of the private vacant land.

Using slope to define susceptibility

The preferred approach to mapping landslide susceptibility in the remaining areas is to use the slope of land (see Appendix 2). This is a relatively simple method of mapping susceptibility to landslide.

Slope-based parameters for landslide susceptibility were defined using the cumulative frequency of mapped landslides (largely from the Tasmanian Landslide Map series) based on slope throughout the State. To derive a cumulative frequency graph, the known landslides were separated into:

- The Launceston group – to illustrate the frequency of landslide on highly susceptible geology.
- Shallow slides and flows on basaltic soils – to illustrate the frequency of landslides on geology more reflective of Tasmanian landscapes.
- Mountain debris flows – to illustrate the frequency of landside on the mountain escarpments.

Figure 4 shows the cumulative frequency of landslides in the Launceston group, shallow slides and flows in basaltic soils, and mountain debris flows. The figure also shows the relative susceptibility boundaries developed by the Australian Geomechanics Society (AGS) (AGS 2007a) and defined as:

- Very low range – slopes on which only one per cent of landslides are found.
- Low range between very low and moderate – slopes on which nine per cent of landslides are found.
- Moderate range – slopes on which forty per cent of known landslides are found.
- High range – slopes on which fifty per cent of known landslides are found.

It is noted that AGS 2007a does not provide a clear explanation of how the ranges were defined.

In order to assess the impact of defining the susceptibility of slope, the cumulative frequency of existing buildings, residential buildings, and vacant land by slope has been overlaid onto Figure 4. This allows judgements to be made regarding the potential impact on current and future development of setting slope-based thresholds for defining susceptibility to landslides.

Further detail on data used in Figure 4 is provided by MRT in Appendix 2.

(0 %) (100 %)

[2] The remaining areas cover around 6 477 000 ha of 6 813 800 ha.

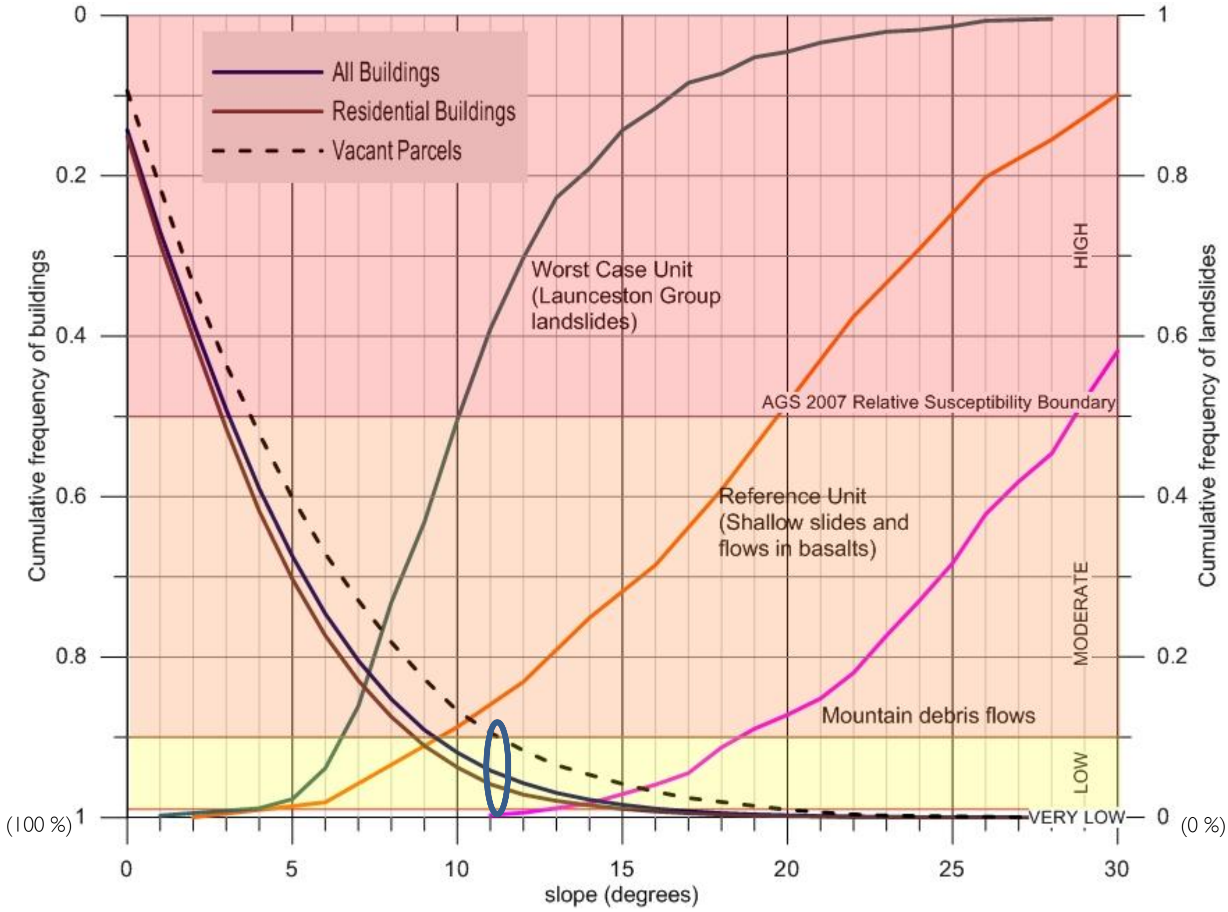


Figure 4: Cumulative frequency for slope for landslide, building, and private vacant parcel

The landslide curves represent the pre-failure slope of each landslide event for three different types of landslide; over 2 700 landslide records were used in constructing the curves. MRT has advised that the "Reference Unit" curve of shallow slides and flows in basaltic soils should be used to guide the slope thresholds as it represents a reasonable, but conservative, geological unit.

The "All Buildings" and "Residential Buildings" are the cumulative frequencies based on the inferred slope at each of the 260 000 buildings in the TASmap 1:25 000 mapping series. The slope has been inferred from the statewide 25 metre Digital Elevation Model. These curves represent the number of buildings within the built environment.

The final curve on the graph is the mean slope[3] of almost 13 000 private vacant parcels of land less than 2 000 square metres in area. The vacant parcels have been identified using the Valuer General's VisTAS dataset and represent parcels of land that may be 'ready for development'.

[3] The mean slope has been calculated based on the average slope within each cadastral parcel. The slope is based on the statewide 25 m DEM.

The susceptibility boundaries developed by the AGS (AGS 2007a) were used as a base for identifying appropriate slope-based parameters for landslide susceptibility in Tasmania. Some minor adjustments were, however, necessary to reflect local circumstances and local tolerances to landslide risk.

Using the cumulative frequency for landslide across the reference unit in Figure 4, the AGS relative susceptibility boundary for 'low' would be defined as any land with a slope greater than approximately 9.5 degrees. This, however, is likely to represent an overly cautious approach to landslide risk based on advice of MRT that:

- The reference unit is a conservative unit, as it is based on basaltic geology that will marginally over-predict the frequency of landslide at a given slope on average throughout the State (see Appendix 2).
- Analysis of LiDAR data is that the 25 m DEM broadly under-predicts the actual slope, meaning that slope used for landslides included in the reference unit may be marginally underestimated.
- The Tasmanian Landslide Map series has already mapped areas of greater concern from landslide based on geology and density of development.

It is recommended that the boundary of 'low' hazard bands for the purposes of defining susceptibility to landslide in the remaining areas of Tasmania is set at 11 degrees (refer to Appendix 2). This will affect around 10 per cent of all existing vacant land less than 2 000 m^2 and around 7 per cent of all buildings.[4]

It is further recommended that the boundary between 'low' and 'medium' hazard bands be defined at the slope of 20 degrees (refer to Appendix 2). This aligns with the AGS susceptibility boundary for 'medium' and covers around 1 per cent of buildings and vacant land under 2 000 m^2 (150 parcels).

It was not necessary to use a slope-based parameter to define the boundary between 'medium' and 'high' hazard bands.

3.4 Known Landslides

Known landslides include deep-seated landslides, shallow slides and flows, rockfall, and mountain debris flow. Since 2003, MRT has compiled an inventory of mapped landslides and their location (Figure 5). This inventory only registers actual landslides that have been recorded by MRT staff, local government, government agencies, or identified by the private sector. The current database identifies over 2 700 landslides.

[4] In 'non-susceptible' areas below 11 degrees in slope, the National Construction Code requires that footings and foundations are constructed in such a way to stop a building from failing and injuring either the occupants or the neighbours. This non-planning-based mitigation measure will contribute to a reduced risk from landslide at lower slopes.

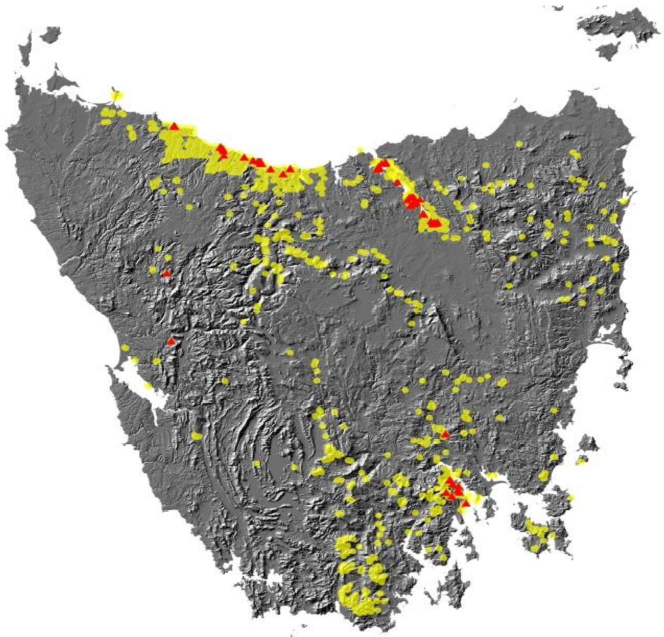


Figure 5: Landslide occurrence in Tasmania (Mazengarb & Stevenson 2010)

For the purposes of defining components for inclusion in the Landslide Planning Bands, known landslides have been categorised as:

Data source	Components
Known landslides	Mapped slides – deep-seated/Launc. Gp, recently active
	Mapped slides – deep-seated/Launc. Gp, activity unknown
	Mapped slides – other slides/flows, recently active
	Mapped slides – other slides/flows, activity unknown

Only known landslides with mapped extent (ie polygon) have been included. The extents of debris flow and rock fall events have been excluded, as their spatial extent does not reflect areas of likely future failure. It is considered by MRT that the existing landslide susceptibility mapping and statewide slope categories will be better suited to identifying areas of likely future failure for these types of landslide.

3.5 *Summary of Data Layers considered for Hazard Planning Bands*

The mapping layers used in the preferred approach, including the areas covered by the proposed components, are outlined in Table 2. Mapping outlined in the table is being revised based on the schedule in Appendix 5.

Table 2: Landslide mapping components and coverage

Mapping Type	Components	Statewide Mapping	MRT Susceptibility Mapping Area				
			Glenorchy	Hobart	Launceston	Tamar[5] Valley	North West
Proclaimed Landslip Areas	**Landslip A areas**		**X**	**X**	**X**	**X**	**X**
	Landslip B areas		**X**	**X**	**X**	**X**	**X**
Remaining areas susceptibility	**Slope <11 degrees**	**X**					
	Slope 11 – 20 degrees	**X**					
	Slope > 20 degrees	**X**					
Tasmania Landslide Map Series	**Rockfall susceptibility source + runout area 34 degrees**		**X**	**X**	**X**	X	**X**
	Rockfall susceptibility runout area 30 degrees		**X**	**X**	**X**	X	**X**
	Shallow slide + flow susceptibility source high						**X**
	Shallow slide + flow susceptibility source moderate						**X**
	Shallow slide + flow susceptibility source low						**X**
	Debris flow susceptibility Mountain source + runout >30 Q1		**X**	**X**		X	
	Debris flow susceptibility Mountain runout 30-26 Q2		**X**	**X**			
	Debris flow susceptibility Mountain runout 26-22 Q3		**X**	**X**			
	Debris flow susceptibility Mountain runout 22 - 5 Q4		**X**	**X**			
	Launceston Group slide susceptibility (large and small)				**X**		
	Hobart-Glenorchy deep-seated slide susceptibility (Rosetta scenario)		**X**	**X**			
	Deep-seated slide susceptibility					X	**X**
	Very low to no susceptibility		**X**	**X**	**X**		**X**
Known landslides - actual	**Mapped slides – deep-seated/Launc. Gp, recently active**	**X (limited)**	**X**	**X**	**X**	**X**	**X**
	Mapped slides – deep-seated/Launc. Gp, activity unknown	**X (limited)**	**X**	**X**	**X**	**X**	**X**
	Mapped slides – other slides/flows, recently active	**X (limited)**	**X**	**X**	**X**	**X**	**X**
	Mapped slides – other slides/flows, activity unknown	**X (limited)**	**X**	**X**	**X**	**X**	**X**

[5] The Tamar Valley mapping program is expected to be completed by mid-2013 as per the schedule in Appendix 5. Early results have been used to inform the overlay. The Grey "X" indicates that this component will be available in the Tamar Valley area.

4 DEFINING LANDSLIDE PLANNING BANDS

To apply policy judgements on the evidence and understand the impact of the bands

Defining the landslide planning bands is a process of understanding the landslide data through ranking the components and consulting with industry, policy makers, and regulators. A 'pairwise assessment' ranks the components from most to least important. Table 2 (previously) identifies the components that have been compiled for generating the landslide planning bands.

4.1 Pairwise Assessment

A pairwise assessment is a tool to support decision-making by assisting non-technical experts to understand the relative importance of the technical landslide components outlined in Section 4 (Hansen and Ombler 2009). The assessment delivers two outcomes:

- It translates the expert knowledge on landslide to policy makers. The expert knowledge includes an understanding of the components that make up landslides in the Tasmanian landscape, confidence in the spatial and attribute accuracy, and the expert opinion on the 'likelihood' that a landslide may occur in this area and its scale/magnitude.
- It provides an order of importance for the merging of the components into a single planning layer, ensuring that a less important component does not overwrite a more important feature.

During the data analysis stage (Section 4), the landslide components are broadly divided into two groups. The first can be ranked based on a natural order[6]; the second are un-dominated components for which there is no natural order of importance. The components with a natural order include Landslip A, Landslip B, 'slopes of greater than 20 degrees', 'slopes of between 11 and 20 degrees' and 'slopes less than 11 degrees'. Un-dominated components make up the remaining elements, including data components such as "Launceston Group slide susceptibility (large and small)" or "Hobart-Glenorchy deep-seated slide susceptibility (Rosetta scenario)".

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[6] Components that can be ranked by 'natural order' are those where there is a clear order of importance. For example, as slope is being used as an indicator of landslide susceptibility, areas with a slope of 11 to 20 degrees have a 'natural order' that is higher than areas with a slope of 0 to 11 degrees.

Mineral Resources Tasmania (MRT) landslide specialists completed the pairwise assessment. These specialists considered the components outlined in section 4 and completed a pairwise matrix that allowed each component to be compared against every other component. For each comparison, a value of 1 000 was given to the component that was 'more important' and one was given to the component that was 'less important'. A value of 100 was given to both components if they were considered equally important.

Table 3 provides an extract of the pairwise assessment, while Appendix 3 details the background behind each component and the results of the pairwise assessment.

Table 3: Extract of the pairwise assessment

Y is 1 000 N is 1 = is 100	Proclaimed "Landslip A areas"	Proclaimed "Landslip B areas"	Statewide slopes (25 m DEM and LiDAR) 0-11deg	Statewide slopes (25 m DEM and LiDAR) 11-20deg	Statewide slopes (25 m DEM and LiDAR) >20deg	Rockfall susceptibility source + runout area 34deg	Rockfall susceptibility runout area 30deg	Shallow slide + flow susceptibility source-high
Proclaimed "Landslip A areas"	NA	1000	1000	1000	1000	1000	1000	1000
Proclaimed "Landslip B areas"	1	NA	1000	1000	1000	1000	1000	1000
Statewide slopes (25 m DEM and LiDAR) 0-11deg	1	1	NA	1	1	1	1	1
Statewide slopes (25 m DEM and LiDAR) 11-20deg	1	1	1000	NA	1	1	100	1

Table 4 and Figure 6 provide the relative ranking of the components by MRT. Of note in the table is the relationship between the components with a natural order and the un-dominated components, indicating the broad spread of values within the components.

Table 4: Comparison of pairwise assessments

Landslide Component	MRT ranking (average pairwise score)
Proclaimed "Landslip A areas"	1 (69.5)
Proclaimed "Landslip B areas"	**2 (1 118)**
Mapped slides - deep-seated/Launc. Gp, recently active	3 (1 667)
Mapped slides - other slides/flows, recently active	4 (3 264.5)
Launceston Group slide susceptibility (large and small)	5 (4 214)
Shallow slide + flow susceptibility source-high	6 (5 910.5)
Debris flow susceptibility Mountain source + runout >30 Q1	7 (7 112)
Mapped slides - deep-seated/Launc. Gp, activity unknown	8 (7 211)
Rockfall susceptibility source + runout area 34 degrees	9 (7 359.5)
Remaining areas susceptibility > 20 degrees	**10 (7 359.5)**
Debris flow susceptibility Mountain runout 30-26 Q2	11 (8 111)

Mapped slides - other slides/flows, activity unknown	12 (9 308)
Shallow slide + flow susceptibility source-moderate	13 (9 357.5)
Debris flow susceptibility Mountain runout 26-22 Q3	14 (10 356.5)
Rockfall susceptibility runout area 30 degrees	15 (11 954)
Debris flow susceptibility Mountain runout 22-12 Q4a	16 (12 453.5)
Hobart-Glenorchy deep-seated slide susceptibility (Rosetta scenario)	17 (13 305)
Remaining areas susceptibility 11-20 degrees	18 (13 704.5)
Shallow slide + flow susceptibility source-low	19 (14 753)
Debris flow susceptibility Mountain runout - dam-burst	20 (18 051.5)
North West deep-seated slide susceptibility (source-runout-regression)	21 (19 050.5)
Remaining areas susceptibility 0-11 degrees	22 (19 100)
Very low to no susceptibility	23 (20 000)

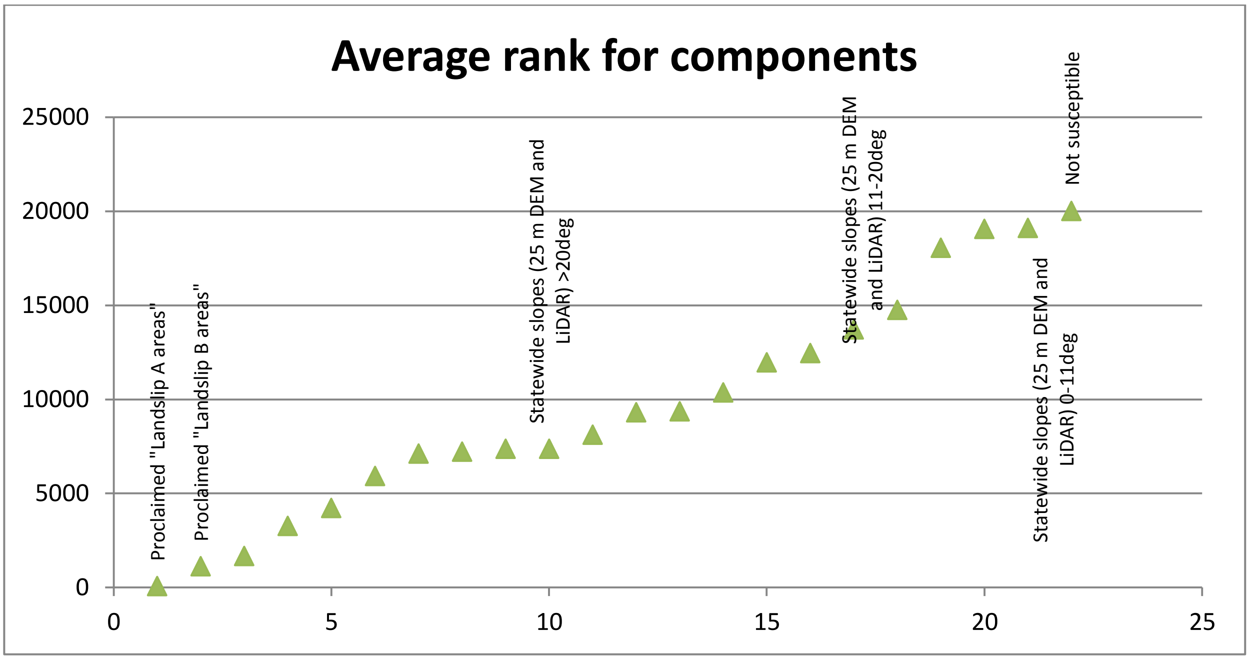


Figure 6: Averaged rank for components

4.2 Defining the Boundaries

The boundaries are defined based on the ranking of the components, consultation with regulators, industry and policy makers (Appendix 2), current regulatory practice, and consultation on the draft matrix and mapping.

Boundary between acceptable and low hazard bands

The workshops agreed that the boundary between 'acceptable' and 'low' should include components that have been valued in the pairwise as being more important than 'remaining areas' with a slope of 11-20 degrees.

This threshold concords with the current landslide hazard tolerance in local government areas that use a slope-based threshold that ranges between 11 degrees[7] and 14 degrees[8]. This threshold also considers that the more severely impacted areas in Hobart, Tamar Valley and the North West Coast have undergone more detailed mapping.

Boundary between low and medium hazard bands

The workshops identified the "remaining areas slopes >20 degrees" component as an appropriate boundary between low and medium hazard bands. However, during the workshops the component "Debris flow susceptibility mountain runout 30-26 Q2" was also included in the medium hazard band, based on the advice of MRT.

Initially the upper boundary of the medium band was placed at the landslip B. During the consultation period, the active landslide components were separated into a medium active band (see below).

Box 2 – Building Act 2000

150. Effect of order in an A Landslip area

(1) A person must not erect, alter or add to a building in an A Landslip area except in accordance with subsection (2).
(2) The Minister, on the recommendation of a general manager, may permit a person to –
  (a) erect, in an A Landslip area –
    (i) a shed; or
    (ii) a building that has a total floor area not exceeding 25 square metres and is not more than one storey high; or
  (b) carry out building work, other than erections, in respect of a building in an A Landslip area; or
  (c) erect a building within the boundaries of a wharf in an A Landslip area.

151 Effect of order in a B Landslip area

(1) A person must not erect, alter or add to a building in a B Landslip area except in accordance with the Building Regulations.
(2) A person must not store in a B Landslip area –
  (a) more than 10 000 litres of water; or
  (b) any explosive, flammable liquid or other dangerous substance.

[7] Dorset (1996) and Kingborough (2000) planning schemes identify 11 deg considered a problem.

[8] Circular Head (1995), Flinders (1994), Meander Valley (1995), Northern Midlands (1995), Glenorchy (1992), and Tasman (1979) planning schemes use 14 degrees as the threshold for landslide to be considered a problem.

Boundary between medium and medium-active hazard bands

The medium-active hazard band includes the recently active landslides; landslides that have occurred (in the past 100 years) or are occurring. While the pairwise assessment ranked these elements below the Landslip B components, concern was raised during the consultation that these components require a higher level of control than is proposed in the medium band.

The creation of a 'medium-active' band allows for some tightening of controls for development and use in these areas, while recognising that the legislative controls for Landslip B Areas are more closely aligned with the medium band, as opposed to the high band.

Boundary for high hazard bands

The high hazard band includes the Landslip A areas, and has been assessed as consistent with the intent of the 'high' planning band (outlined in Box 2). Controls proposed in the 'high' band are consistent with the legislative requirements for development in Landslip A areas.

Composition of the landslide hazard band

Figure 7 and Table 5 illustrate the outcome of the assessment of the relative importance of components in the Landslide Planning Map.

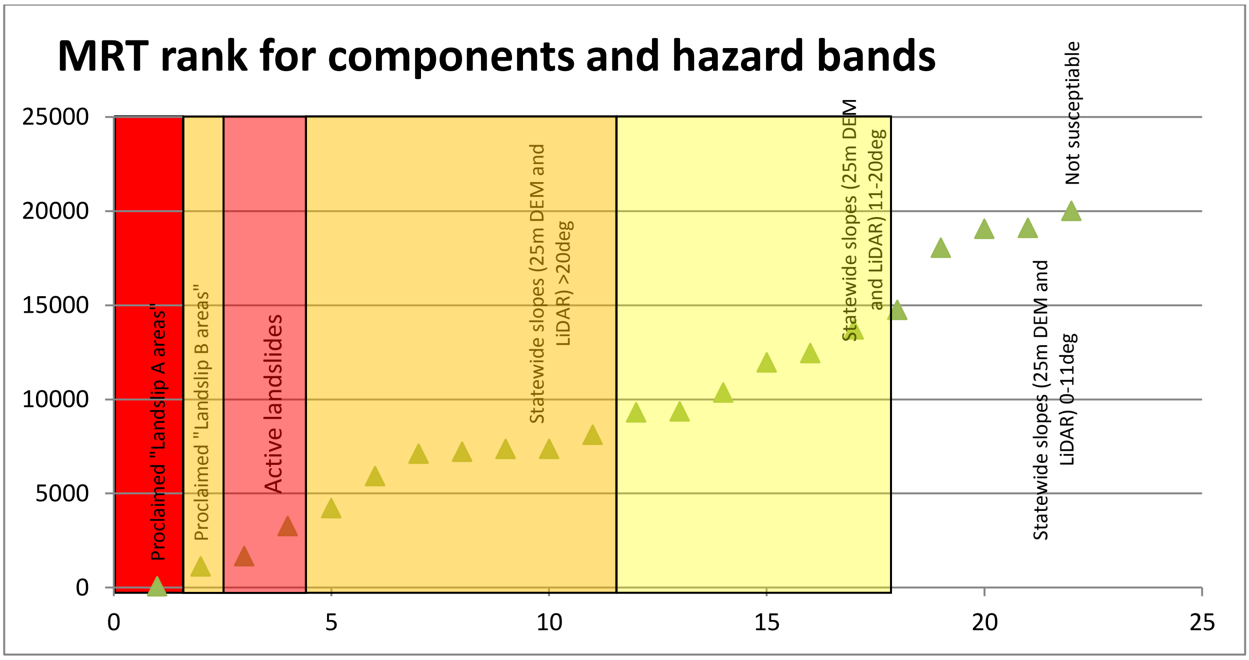


Figure 7: MRT rank for components and hazard bands

Table 5: Hazard banding

Landslide Component	Average	Landslide planning band
Proclaimed "Landslip A areas"	70	High
Mapped slides - deep-seated/Launc. Gp, recently active	1118.5	Medium - Active
Mapped slides - other slides/flows, recently active	1667.5	Medium - Active
Proclaimed "Landslip B areas"	3265	Medium
Launceston Group slide susceptibility (large and small)	4214.5	Medium
Shallow slide + flow susceptibility source-high	5911	Medium
Debris flow susceptibility Mountain source + runout >30 Q1	7112.5	Medium
Mapped slides - deep-seated/Launc. Gp, activity unknown	7261	Medium
Rockfall susceptibility source + runout area 34 degrees	7360	Medium
Remaining areas slopes >20deg	7360	Medium
Debris flow susceptibility Mountain runout 30-26 Q2	8111.5	Medium
Mapped slides - other slides/flows, activity unknown	9308.5	Low
Shallow slide + flow susceptibility source-moderate	9358	Low
Debris flow susceptibility Mountain runout 26-22 Q3	10406.5	Low
Rockfall susceptibility runout area 30 degrees	11954.5	Low
Debris flow susceptibility Mountain runout 22-12 Q4a	12953.5	Low
Hobart-Glenorchy deep-seated slide susceptibility (Rosetta scenario)	13305	Low
Remaining areas slopes 11-20 degrees	13754.5	Low
Shallow slide + flow susceptibility source-low	15253	Acceptable
Debris flow susceptibility Mountain runout - dam-burst	18551.5	Acceptable
Deep-seated slide susceptibility (source-runout-regression)	19550.5	Acceptable
Remaining areas slopes 0-11 degrees	19600	Acceptable
Very low to no susceptibility	20 000	Acceptable

4.3 Analysis of Landslide Planning Boundaries

Understanding the impact of landslide planning boundaries is important when gauging the effect of policy on the Tasmanian community. The indicators detailed in this section provide the total area of private and public land, the number of residential properties, and the number of vacant parcels. The analysis is provided at both the State level and for each local government area, and includes:

- The area (hectares) of land in each band.
- The number of vacant cadastral parcels in each band. For the purpose of this assessment, these parcels are included if more than 10 per cent of their area is affected (considered to be more than a minor impact). Of the affected parcels, the band is allocated based on which band has greater than 50 per cent of the parcel areal. Parcels have been classified based on criteria:
    - If the parcel is private vacant land;
    - If the parcel is less than 2 000 square metres. This indicates that is more likely to be available for immediate development; and
    - if the parcel has more than 10 per cent of its area within a landslide planning hazard band.
- The number of residential dwellings is based on data supplied by LIST data services and is correct at the time publication for each 1:25 000 topographic map series.

<u>Landslide planning bands by area – State</u>

The low-medium-medium (active)-high landslide planning bands contain approximately 34 per cent of the State's land mass. Figure 8 shows the proportion of land and the area (hectares) within each band.

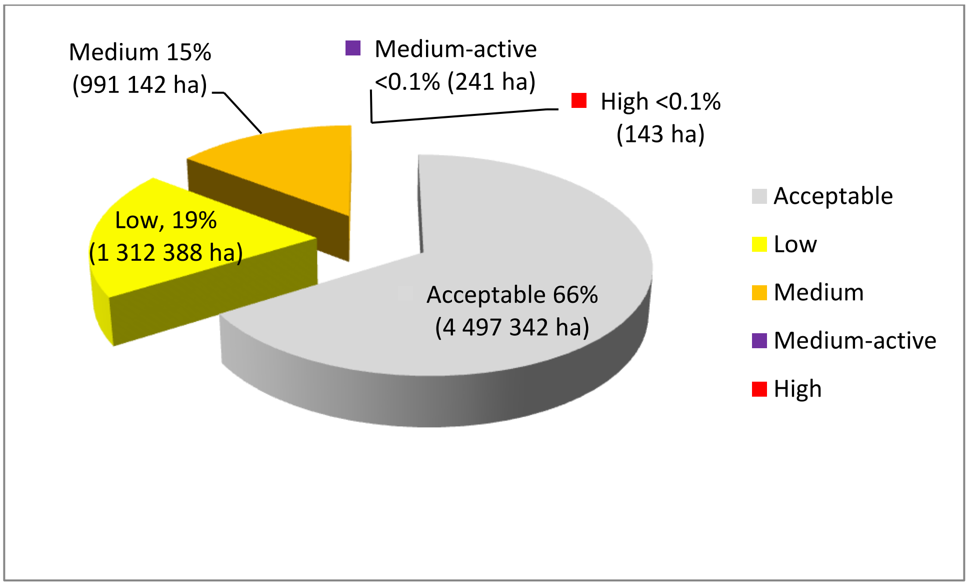


Figure 8: Proportion of land area by landslide hazard band

Table 8 in Appendix 3, provides the area of land in the Acceptable, Low, Medium, Medium-active and High landslide planning bands for each Local Government Area.

Vacant Land – State

Of the 12 000 parcels of land less than 2 000 m^2, 17 per cent are impacted, with 14 per cent of parcels having at least 10 per cent of their area within the Low-Medium-High landslide planning bands. This represents 1 749 parcels of land, of which:

- 552 parcels have more than 50 per cent of land in the acceptable band.
- 780 parcels have more than 50 per cent of land in the low band.
- 346 parcels have more than 50 per cent of land in the medium band.
- 1 parcel has more than 50 per cent of land in the medium-active band.
- 50 parcels have more than 50 per cent of land in the high band.
- 21 parcels are equally impacted by the acceptable - low - medium bands.

A depiction of this is shown in Figure 9.

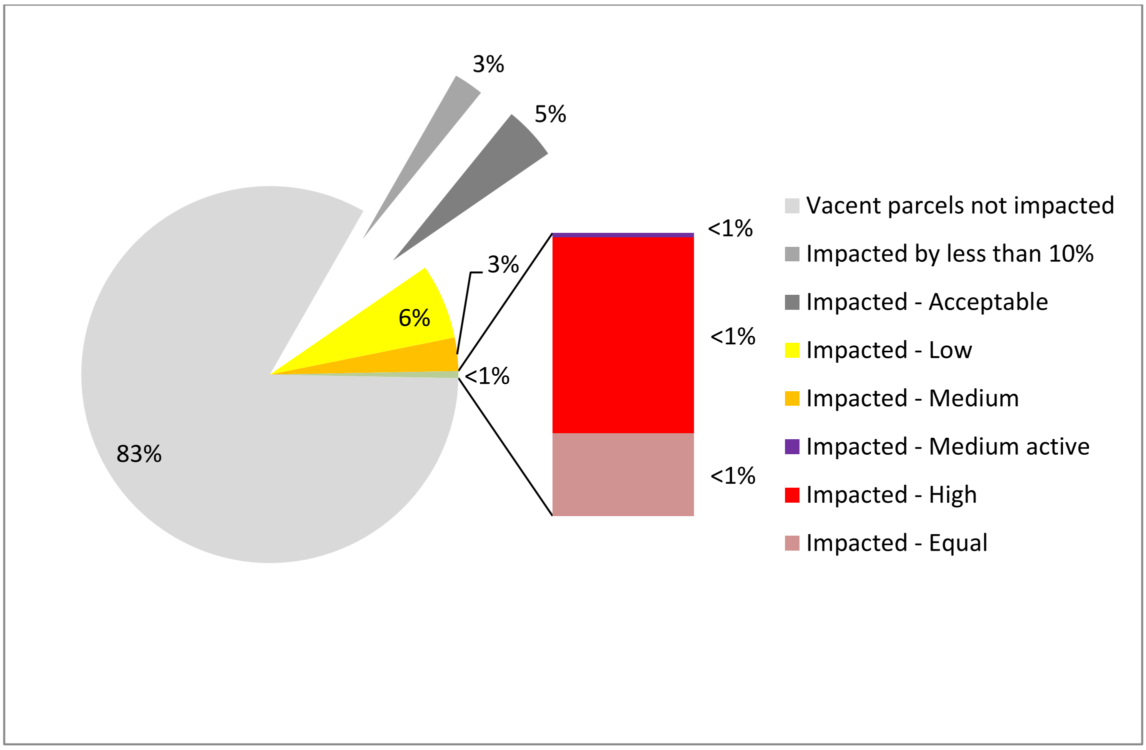


Figure 9: Vacant parcels of land less than 2000 m2

Table 9 in Appendix 3, provides the number of vacant parcels of land in the Acceptable, Low, Medium, and High landslide planning bands for each Local Government Area.

Number of Residential Buildings – State

Approximately 8 per cent of residential buildings are within the Low-Medium-Medium (active)-High landslide planning bands. Figure 10 provides the proportion of residential buildings in each band, while Table 10 in Appendix 3 shows the number of residential buildings in each Local Government Area.

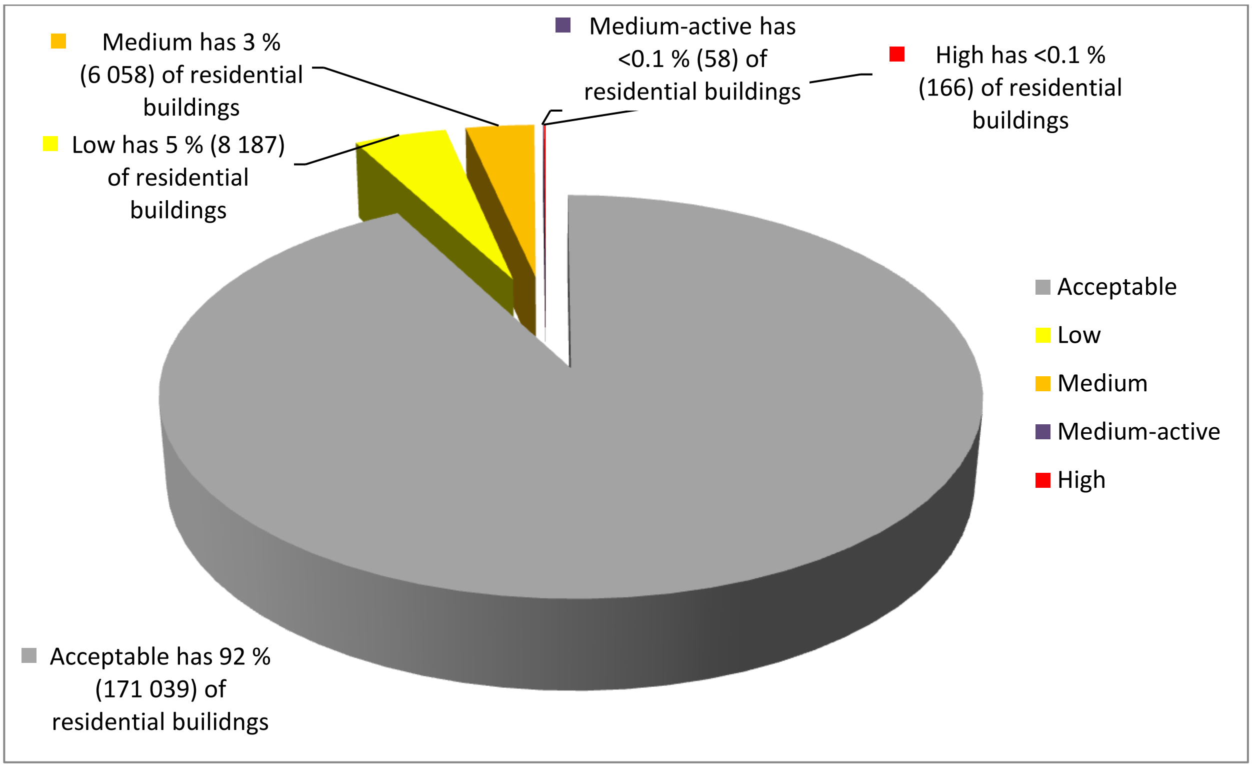


Figure 10: Residential buildings by landslide planning band

5 DEFINING CONTROLS WITHIN THE LANDSLIDE PLANNING BANDS

The Landslide Planning Matrix brings together mapping, assumptions on consequence and vulnerability, and risk tolerance into a form that can be used to inform public policy on land use planning decisions at both the strategic and development control levels.

5.1 Elements of the Planning Matrix

The Guide (Section 3.2) provides an overview of how the Matrix operates, including the hazard banding, control levels, and strategic planning level, along with use and development controls.

- *Planning bands (likelihood)*: regions where it is presumed that landslide hazard will exist at a relatively high, medium, low, or acceptable level.

- *Control level:* generalised statements regarding the presumed consequences associated with landslide planning bands.

- *Strategic planning level*: agreed measures that should be employed through strategic planning to determine if the benefits to the community of requiring consideration of whether development in certain areas is subject, or likely to be subject, to a natural hazard outweigh the costs to the community and individuals.

- *Use and development controls*

  Use Controls: agreed measures that should be imposed on use to reduce risks from landslides. The *Land Use Planning and Approvals Act 1993* (LUPAA) defines use as "…*in relation to land, includes the manner of utilising land but does not include the undertaking of development*". Table 6 provides the use classifications for the Landslide Planning Matrix.

Acceptable: It is presumed that the risk in the area is acceptable, as either the natural hazard does not apply at all to the area, or occurs with such low frequency that it is not considered a matter that needs to be addressed. Normal building controls and emergency management responses are considered adequate to address any residual risk.

Low: The hazard occurs in the area but the frequency is low enough, or the magnitude when it does occur is low enough, that it might be experienced by a significant portion of the community without concern, or where there is reasonable expectation that a natural hazard may be present based on the characteristics of the land and our understanding of the hazard. Precautionary controls that are proportional to the importance of the use and development may be appropriate, including requirements for further site assessment or building standards.

Medium: Our knowledge of the hazard demonstrates that the likelihood is such that when it does occur the impact could be regarded as significant. Mitigation measures should be required to discourage vulnerable and hazardous uses from being located in these areas, or impose discretionary planning control on the form of a use or development through assessment against performance standards.

High: The hazard is frequent or severe, in that it creates conditions not normally considered as manageable or tolerable without exceptional measures to respond to the natural hazard. It is to be presumed that most use and development is unacceptable in this area and any exceptional development needs to be considered on a case-by-case basis against rigorous tests and through demonstrating a need and community benefit for locating in the area.

Table 6: Use types for natural hazards

Use	Definition
Occasional or temporary use	The infrequent use of land; and The temporary use of land for which a permit has been granted.
Residential and other uses	Residential uses as described in Planning Directive No.1: The Format and Structure of Planning Schemes with the exception of those in Vulnerable and Hazardous uses; and Other uses as defined in Planning Directive No.1: The Format and Structure of Planning Schemes not included in other categories in this table.
Vulnerable and hazardous uses (Note: This category is not identical to the categories of Vulnerable use or Hazardous use in P.D. 5 the Bushfire Prone Areas Code.)	Structures that, as a whole, may contain people in crowds or contents of high value to the community or pose risks to people present in the structure. The following use classes are included: • residential use for respite centre, residential aged care facility, retirement village and group home; • educational and occasional care; • visitor accommodation, community meeting and entertainment; • custodial facility; • crematoria and cemeteries; • recycling and waste disposal; and • manufacturing and processing, research and development, and storage, if involving the use of dangerous substances .
Post-disaster or catastrophic risk-based use	Post-disaster and catastrophic risk-based use are a subset of vulnerable and hazardous uses that are either required to assist in the response or recovery from a disaster, or, if impacted, would reduce the State's ability to function during a disaster. The following uses are included: • emergency services and hospital services use classes; and • uses involving large dams, major electrical supply, and facilities with a capacity for more than 5 000 people.

Development controls: agreed measures that should be imposed on development to reduce risks in each hazard band. LUPAA defines development as:

- the construction, exterior alteration or exterior decoration of a building;
- the demolition or removal of a building or works;
- the construction or carrying out of works;
- the subdivision or consolidation of land, including buildings or airspace;
- the placing or relocation of a building or works on land; and
- the construction of, or putting up for display, signs or hoardings.

Table 7 provides the development types for the purpose of the Landslide Planning Matrix.

Table 7: Development types for natural hazards

Development	Definition
Ancillary structures	Fences, carports, garden sheds, domestic water tanks and the like.
Minor extension	An extension or renovation to an existing building where a small extension or renovation is less than 40 m^2.
Infill/new buildings	Development on existing vacant residential titles (including subdivision, multiple dwellings and strata title) that creates one or two new titles.
Habitable buildings and large extensions	Buildings of Class 1-9 of the Building Code of Australia; and An extension to an existing structure over 40 m^2.
Minor utilities	Use of land for utilities for local distribution or reticulation of services and associated infrastructure, such as a footpath, cycle path, stormwater channel, water pipe, storm water retarding basin, telecommunications line or electrical substation and power lines up to but not exceeding 110 kv.
Swimming pools and non-domestic water tanks	All swimming pools and all non-domestic water tanks.
Major subdivision and major works	A development (including subdivision, multiple dwellings and strata title) that creates three or more new titles, or a requirement to extend public roads or infrastructure.

5.2 Landslide Planning Matrix

Based on the items set out in the previous sections, the objectives for each band are outlined below.

Acceptable Band	White or clear on the landslide hazard map.
Hazard Exposure	A landslide is a rare event in this area, based on current understanding of the hazard, but it may occur in some exceptional circumstances.
Control Level	Development and use is not subject to landslide controls.
Strategic Planning	No impacts on land use strategies or change to zoning required.
Guidance on Use Standards	No hazard specific controls. No controls are required to bring the use into an acceptable risk level.
Guidance on Development Standards	No hazard specific controls. No controls are required to bring the development into an acceptable risk level.

Low Band	Yellow on the landslide hazard map.
Hazard Exposure	This area has no known landslides, however, it has been identified as being susceptible to landslide by Mineral Resources Tasmania (MRT).
Control Level	Whilst non-construction requirements are not required for most use and development, controls may be necessary to reduce the risks associated with vulnerable and hazardous uses or post-disaster and catastrophic risk-based use to ensure that risks are tolerable (as recommended by AGS 2007a).
Strategic Planning	Where broader planning considerations support the development of the area, the low band should not inhibit use or development.
Guidance on Use Standards	**Residential and other use, and occasional or temporary use** may be required to meet additional development standards to ensure the form of the development does not contribute to a landslide occurring. **Vulnerable and hazardous uses**, the proposal should demonstrate that the risk associated with the development's exposure is tolerable through the completion of a Landslide Risk Report[9]. **Post-disaster and catastrophic risk-based use** are discretionary in this area, subject to demonstrating the community benefit of being located in this area, and completion of a landslide risk report that demonstrates how the hazard will be managed.
Guidance on Development Standards	**Ancillary structures** do not have landslide specific controls. **Minor extensions** may be constructed in the same manner. **Infill/new buildings, habitable buildings and large extensions, and minor utilities** will be considered a Problem (P) site for landslide under AS2870 unless considered otherwise by an engineer. **Swimming pools and non-domestic water tanks, major subdivision and major works** requiring the extension of public roads or the creation of three or more lots should complete a Landslide Risk Report.

[9] A Landslide Risk Report is an assessment by a competent person that is consistent with the AGS 2007 guidelines. The report should be proportional to the proposal, qualifying the landslide risk, and demonstrating how the form of the development, or change in use, will mitigate the risk to a tolerable level. The Report will set out any ongoing maintenance that the current and future site owners will undertake to maintain the tolerable risk exposure. Landslide Risk Reports may be completed either for an individual development or a hazard area.

Medium Band	Orange on the landslide hazard map.
Hazard Exposure	The area has known landslide features, or is within a landslide susceptibility zone, or has legislated controls to limit disturbance of adjacent unstable areas.
Control Level	Planning controls are necessary for all use and development to ensure that risks are tolerable (as recommended by AGS 2007a). Any vulnerable or hazardous use will only be allowed in exceptional circumstances.
Strategic Planning	Where there is no compelling reason to include land identified in this band for development, it should be zoned for open space, rural, or environmental purposes. Compelling reasons may include that it is an existing residential area and further development will be infill. Alternatively, a landslide risk assessment may be required to demonstrate that a proposed zoning is reasonable and avoids areas of high or very high risk.
Guidance on Use Standards	Development in declared Landslip B areas is controlled under Part 10, Division 1 of the *Building Act 2000* and by Part 2, Division 1 of the *Building Regulations 2004*. Residential and other use and occasional or temporary use in existing residential areas are permitted (no permit required), however, the rezoning of areas for residential use should only be considered subject to a Landslide Risk Report that avoids high or very high risk areas. Vulnerable and hazardous uses are discretionary subject to the completion of a Landslide Risk Report that demonstrates how the risk will be made tolerable. Post-disaster and catastrophic risk-based use are discouraged. However, if there is an overriding community benefit or an exceptional circumstance they may be allowed as an exceptional use, subject to the completion of a Landslide Risk Report that demonstrates how the use will achieve a tolerable risk.
Guidance on Development Standards	Ancillary structures do not have landslide specific controls. Minor extensions will be considered a Problem (P) site for landslide under AS2870 unless considered otherwise by a Geotechnical Engineer or an Engineering Geologist. Infill/new buildings, habitable buildings and large extensions, and minor utilities with floor areas of less than 200 m^2 should[10] be considered a Problem (P) site for landslide under AS2870 unless considered otherwise by a Geotechnical Engineer or an Engineering Geologist. Infill and works with a final floor area over 200 m^2 should complete a Landslide Risk Report that shows how the development will achieve a tolerable risk level. Swimming pools and non-domestic water tanks, major subdivisions and major works are discretionary, subject to the completion of a Landslide Risk Report demonstrating how the subdivision will achieve tolerable risk.

[10] Clause 9, Division 1 of the Building Regulations 2004 uses the 200 m^2 threshold as the maximum acceptable development in landslip B areas without a Landslide Risk Report.

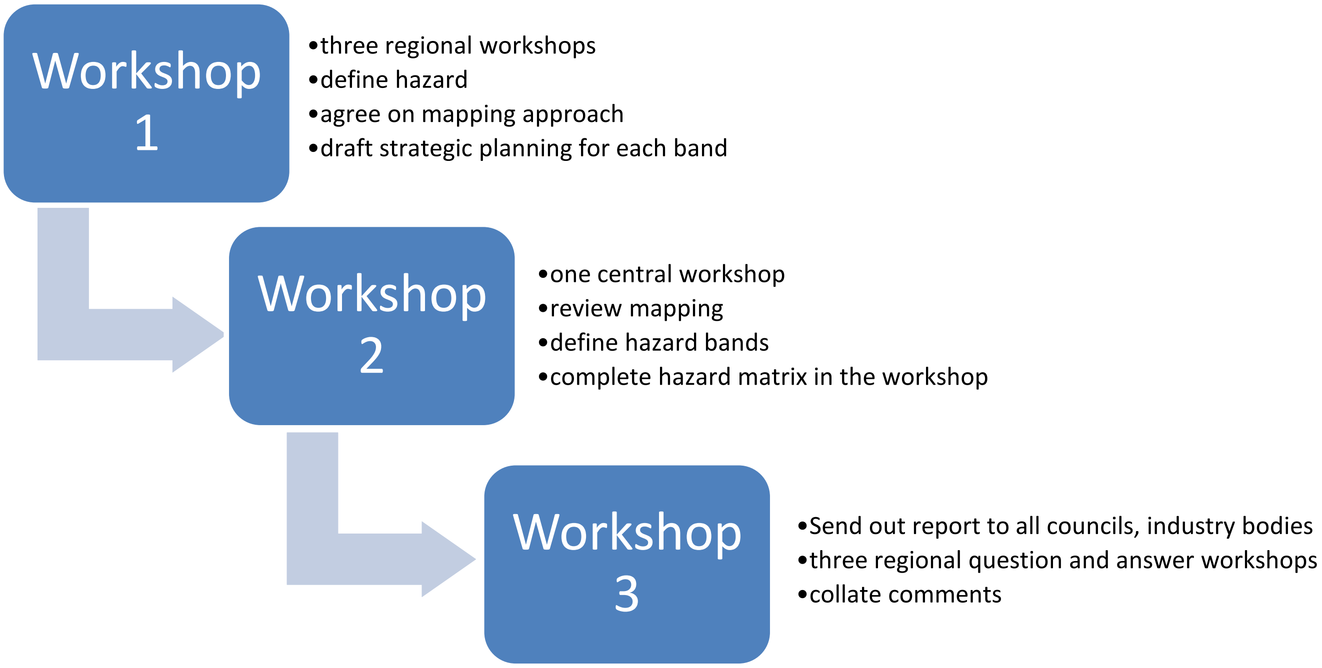
Medium-Active Band	Violet on the landslide hazard map.
Hazard Exposure	The area has known recently active landslide features.
Control Level	Planning controls are necessary for all use and development to ensure that risks are tolerable (ABCB 2006 Landslide Hazards – Handbook for Good Hillside Construction). Any vulnerable and hazardous uses or post-disaster and catastrophic risk-based uses are prohibited.
Strategic Planning	Where there is no compelling reason to include land identified in this band for development, it should be zoned for open space, rural, or environmental purposes. Compelling reasons may include that it is an existing residential area, however, a Landslide Risk Report will be required for all use and development except occasional and temporary use or ancillary structures. A Landslide Risk Report should consider the whole landslide and be completed to the satisfaction of the council.
Guidance on Use Standards	Minor uses are permitted. Residential use in existing residential areas is permitted, however, the rezoning of areas for residential use should only be considered subject to a Landslide Risk Report that demonstrate how the rezoning will achieve a tolerable risk. Vulnerable and hazardous uses, and post-disaster and catastrophic risk-based use are generally prohibited, however, if there is an overriding community benefit or an exceptional circumstance they may be allowed as an exceptional use, subject to the completion of a Landslide Risk Report.
Guidance on Development Standards	Extensions, Infill and Works should be subject to a Landslide Risk Report that guides the form of the development, and demonstrates how the development meets a tolerable level of risk. Subdivisions are subject to the completion of a Landslide Risk Report that demonstrates how the subdivision will achieve a tolerable risk.

High Band	Red on the landslide hazard map.
Hazard Exposure	The site is within a declared Landslip A area.
Control Level	All use and development requires significant investigation and engineered solutions to mitigate the natural hazard and enable the development to achieve and maintain a tolerable level of risk, however, the mitigation measures may never achieve comprehensive levels of security and safety.
Strategic Planning	Strategies should discourage all development except vital community infrastructure that cannot be reasonably located elsewhere. Strategies must indicate appropriate zoning and overlays to provide a clear message to the public and the drafters of local government planning schemes to ensure use and development is generally prohibited except under special circumstances.
Guidance on Use Standards	All use may only be undertaken in accordance with controls under Part 10, Division 1 of the *Building Act 2000* and Part 2, Division 1 of the *Building Regulations 2004.*
Guidance on Development Standards	All development may only be undertaken in accordance with controls under Part 10, Division 1 of the *Building Act 2000* and Part 2, Division 1 of the *Building Regulations 2004.*

6 APPENDICES

6.1 Appendix 1: Workshop Consultation

The landslide planning matrix is developed through a series of workshops held with local government, industry groups, and state agencies. The process involves three sets of workshops, including:



<u>Workshop series one</u>

The purpose of workshop series one is to review and agree on a definition for the hazard, including the scope of application for the definition, and an approach to mapping the hazard and draft consequence statements.

Three workshops were held for landslide in Burnie, Launceston, and Hobart during late April and mid May.

Participants

Jo Oliver	Meander Valley Council
Michael Purves	West Tamar Council
Paul Godier	Northern Midlands Council
Wendy Mitchell	Dorset Council
Geoff Davis	George Town Council
Jacci Viney	Flinders Council
Leigh Stevens	Break O'Day Council
Leon Murray	Launceston City Council
Shane Eberhardt	Launceston City Council
Colin Mazengarb	Mineral Resources Tasmania
Michael Stevenson	Mineral Resources Tasmania

Luke Roberts	DPAC
Mat Healey	DPAC
Patrick Earl	Burnie City Council/ Regional Planner
Matthew Saward	Circular Head Council
George Walker	Circular Head Council
Cr John Oldaker	Circular Head Council
Cr Charles Arnold	King Island Council
Wayne Richards	State Emergency Service
Shane Warren	Devonport Council
Sharon Holland	Latrobe Council

Ian Sansom	Central Coast Council
Tom Reilly	Central Coast Council
Ian Newman	West Coast Council
David Masters	Kingborough Council
Grietje Van Randen	Glenorchy City Council
James Dryburgh	Brighton, Tasman, Central Highlands Councils
Mark Nelson	State Emergency Service
Shane Wells	Huon Valley Council
Damian Mackey	Southern Midlands / Regional Planner

Rowan Moore	Hobart City Council
Dr Liza Fallon	TPC
Doug Rossiter	SES
Dr Katrena Stephenson	LGAT
Simon Roberts	DPAC
John Harkin	DPAC
Dan Ford	Clarence City Council
Stuart Clues	Housing Industry Association
Mary Massina	Property Council of Australia
Michael Kerschbaum	Master Builders' Association

Outcomes:

Definition for landslide

A landslide hazard is a source of potential harm resulting from the *downslope movement of a mass of rock, debris, or earth* (AGS 2007b) that may have a negative consequence on vulnerable infrastructure or communities.

Landslides include falls, topples, slides, flows, and spreads. In the context of defining landslide susceptibility for Tasmania, it does not include ground subsidence and collapse, or shallow downslope soil creep. The types of movement and relevant Tasmanian examples are in the *Tasmanian Landslide Map Series User Guide and Technical Methodology* (Mazengarb & Stevenson 2010).

Landslides are caused by the concurrence of conditioning factors and triggering factors (AGS 2007a).

- Conditioning factors[11] are terrain attributes (slope, geology, soil, geomorphology, vegetation cover, etc) that, with time, bring the slopes to a marginally stable state.
- Landslides require a triggering event. A trigger event may include one or more of the following: intense rainfall, rise of groundwater levels, earthquakes, or various human modifications.

The relationship between triggering events and conditioning factors is complex and difficult to consider above the level of a localised geotechnical assessment. Consequently, judgements at a regional or statewide level are best made using the evidence of condition factors that is currently available. While judgements based on condition factors alone may be suitable for planning purposes, they cannot be used to understand the true localised exposure to a landslide hazard.

Approach to mapping the hazard

Three options for mapping landslide hazards were considered, including the slope, slope/geology, and a hybrid method. The strengths and weaknesses of the three options are outlined below. Option three is the preferred approach.

[11] Conditioning factors have been called pre-conditions in the Guide.

Option	Weakness	Strength
Option 1 – Basic (slope) susceptibility.	Slope only would need a catch-all clauses to developments in non-susceptible areas to be called in for assessment. Too broad in its application. Difficult to set a slope threshold that will capture all known landslip areas and not be too onerous.	Simple and straightforward. The default position. Precautionary, conservative. Transparent.
Option 2 – Intermediate (slope and geology) susceptibility.	Geology mapping is too crude outside of 1:25 000 mapping areas.	Well-established in Hobart. Relatively simple and transparent. Allows the likely failure angle for each type of geology to be applied.
Option 3 – Intermediate (slope and geology) susceptibility, Basic (slope) susceptibility, and known landslides.	Intermediate susceptibility mapping is only located over a small area of the State. Current system is not well set up to allow updates to the mapping. Intermediate susceptibility mapping is only located in the majority of areas in the North West. Boundary of bands will be an issue. It will take up to a year to deliver the final overlay. Perception of inaccurate mapping at the boundaries for basic and intermediate susceptibility mapping.	Based on the advice of MRT. Intermediate susceptibility mapping covers 80 per cent of the populated areas. Uses our current knowledge and AGS standards. Intermediate susceptibility mapping identifies areas with little to no potential exposure to landslide. Increased confidence in the mapping.

Guidance for hazard band consequence statements

The example Landslide Hazard Matrix given in the Guide provides a good starting point for the Hazard Matrix, with the following suggestions:

- MRT will explore the relaxing of the boundary between acceptable and low bands from nine degrees. Noting that this will need to be based on the best available science and engineering practice.
- New infill residential developments present issues that need to be resolved, while understanding that the zoning and surrounding development have already given the 'right to develop' when subdivided or zoned as residential.
- The controls should relate to the use and development type.
- Stronger controls should apply at the subdivision or when considering significant intensification or the rezoning of an area.
- When considering new subdivisions, the ability to protect the developments must be considered alongside other values. If a compromise cannot be reached, the development may not be able to proceed in its current form.

Guidance for hazard band controls

- Low band
  - The hazard should be treated primarily at the subdivision.
    - General development controls could be used, as an example:
      - Lightweight construction;
      - No excavation below one metre;

    - Drainage design; or
    - Storm water is connected to the mains.
  - Should include 'acceptable' solutions that consider the form of the development, not whether the development should occur.

- Medium band
  - Development areas in subdivisions should not be affected by a landslide.
  - A landslide risk assessment could be required for most types of development.
  - Small use and development, including extensions (not including swimming pools), should not be a planning issue but would require some development assessment.

- High Band
  - Ideally, identified high landslide hazard areas should not be zoned for residential or industrial uses.
  - Discourage development.
  - Require a landslide risk assessment.

<u>Workshop two</u>

The second workshop is a more focused consultation that applies the boundaries for the hazard bands, reviews the consequence statements, and considers the controls.

The workshop was held in Campbelltown in June 2012

Participants

Tony McMullan	Glenorchy City Council
Jo Oliver	Meander Valley Council
Michael Purves	West Tamar Council
Leigh Stevens	Break O'Day Council
Patrick Earl	Burnie City Council/ Regional Planner
Mat Clark	Planning Institute of Australia (PIA)
Dr Liza Fallon	TPC
Brian Risby	TPC
Colin Mazengarb	MRT
Michael Stevenson	MRT
Luke Roberts	DPAC
Mat Healey	DPAC

Outcomes

Boundaries for the landslide hazard bands

- It was noted that the current version of the map is a draft map and further refinement of evidence and thresholds is required.
- A preference to calculate slope in degrees for the following reasons:
  - potential for confusion between per cent slope and per cent annualised exceedance probability that is used when measuring likelihood; and
  - degrees is the simpler, preferred construct.

- Threshold acceptable to low has two basic options for nine and twelve degrees, the discussion highlighted the following:
  - Nine degrees is a conservative figure.
  - Agreement to use the AGS 2007 cumulative frequency analysis method to define the thresholds.
  - Agreement for MRT to rerun the landslide cumulative frequency analysis for all known landslides in the state.
  - Undertaking the cumulative frequency analysis for each geological type would be superior, however, it was noted that the geological model for Tasmania in areas which have not been corrected through the intermediate susceptibility mapping would lead to a greater confidence in the data than should be assumed.
  - Agreement to exclude the Launceston group slides identified in the 2005 mapping from the analysis, as the intermediate susceptibility mapping has been completed. This will allow a more representative slope threshold to be assessed.
  - Preference for an evidence-based approach to defining the threshold. MRT will undertake an assessment of the cumulative frequency of known landslides.
- Cumulative analysis for statewide landslides using AGS guidelines to determine slope thresholds for all geology layers, this then helps define the choice of a value (see slide in attached Powerpoint presentation).

Landslide Hazard Matrix – consequence and controls

- A roundtable discussion, with the updates included in the Powerpoint presentation.
- The outcomes of this section are presented in the Landslide matrix – section 6.2 of the report.
- The use and development column will be split into a use column and a development column.

Workshop series three

Workshop series three is undertaken to seek submissions on the draft landslide matrix and mapping, and to provide an opportunity for councils to ask questions prior to any written submissions.

The consultation period was from mid-August until the end of October, with workshops held in early October.

Participants

Local governments, State agencies, natural resource management bodies, regional water authorities, and industry bodies (43 groups) were invited to make submissions on landslide hazard mapping and reporting.

Outcomes

Changes to the mapping and hazard matrix

- Creation of a fifth landslide hazard band called medium-active in response to submissions made by Launceston City Council, Hobart City Council, Kingborough Council, and Glenorchy Councils.
- The purpose of the medium-active hazard band is to allow greater controls to be placed on recently active landslides. The hazard band requires almost all use and development to undergo a risk assessment.

Use and development classes

- In response to submissions from the Tasmanian Planning Commission (TPC), Hobart City Council, Clarence City Council, Glenorchy City Council, and West Tamar Council the use and development classes have been made consistent with the advice provided by the TPC.

6.2 Appendix 2: Known Landslide Losses

Area	Comment
Statewide	Over 150 buildings are known to have been damaged or destroyed since the 1950s; of these, 125 are houses. Of the 125 houses, 78 are known to have been demolished or removed due to extensive damage.
Lawrence Vale	43 houses are known to have been destroyed, demolished, or removed due to extensive damage caused by landslide.
Beauty Point	15 houses and a police station are known to have been destroyed, demolished, or removed due to extensive damage.
	At least 13 houses are known to have been damaged by ground movement, but are still standing.
	Considerable ongoing repairs to Flinders St due to landslide movements.
Deviot	1 house is known to have been destroyed or demolished due to extensive damage.
	2 houses are known to have been damaged by ground movement but are still standing.
Rosetta	9 houses are known to have been destroyed or demolished due to extensive damage caused by landslide.
	13 houses are known to have been damaged by ground movement but are still standing.
	36 houses have been purchased and rented by the Crown until they become uninhabitable.
Berriedale (Casuarina Crescent)	1 house is known to have been demolished due to extensive damage caused by landslide.
Boat Harbour Beach	1 house is known to have been demolished due to extensive damage caused by landslide.
	14 houses/shacks are known to have been damaged by ground movement but are still standing.
Legana (Beach Rd)	2 houses are known to have been demolished due to extensive damage caused by landslide.
	1 house was removed from the site due to damage caused by landslide movement.
Windermere	1 house is known to have been destroyed or demolished due to extensive damage caused by landslide.
	3 houses are known to have been damaged by ground movement but are still standing.
Parnella (St Helens Point Rd)	1 house was removed from the site due to damage caused by landslide movement.
	1 house is known to have been damaged by ground.
Burnie	1 house is known to have been destroyed or demolished due to extensive damage caused by landslide (Parklands).
	2 houses are known to have been damaged by ground movement but are still standing.
Spreyton (Squibbs Rd)	1 house was removed from the site (moved about 80 metres to South-East) due to damage caused by landslide movement.
Taroona	1 house is known to have been demolished due to extensive damage caused by landslide.
	MRT has located 10 houses, and the High School, that are known to have been damaged but are still standing.

6.3 Appendix 3: A Statewide Landslide Susceptibility Zonation in Tasmania

Written By

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Contents

1 PURPOSE

This document provides scientific evidence and analysis of landslide mapping in Tasmania. It is intended to support the development of a statewide policy and its mapped implementation.

2 HISTORY OF LANDSLIDE ZONING IN TASMANIA

Mineral Resources Tasmania (MRT) has a long history of undertaking landslide site investigations and regional scale landslide zoning in the State. Much of the earlier work, between the 1970s and 1990s, is largely summarised by Peter Stevenson (2011) and includes the drivers for undertaking this work.

In 2001, an independent consultant, Dr Fred Baynes, was contracted by MRT to review the previous zoning methodologies employed thus far (Appendix 1 in Mazengarb 2005). He outlined a number of issues, including inconsistent approaches between the various study areas, and that there were no real concepts of risk to evaluate the potential impact of landslides of differing levels of activity. In order to address these issues, Baynes proposed a new methodology to be used in future mapping by MRT. One of the key components of the new approach was the adoption of GIS software that had recently become available for use on mainstream personal computers.

In 2003, MRT embarked on a new phase of landslide zoning in Tasmania, which is hereafter known as the Tasmanian Landslide Map Series, and which utilises the Baynes methodology. The mapping has targeted the major urban areas of the State and areas of likely future development where it is considered that a significant landslide hazard exists.

It is important to note that the methodology developed by Baynes has been modified progressively by MRT staff for a number of reasons that are discussed in full elsewhere. However, in brief, one of the reasons for change was to adapt to local conditions in each study area. The methodology used by MRT has been published in Mazengarb (2005) and Mazengarb and Stevenson (2010), with additional details provided on the published maps.

A more significant driver for modifying the methodology was the publication of a set of guidelines for landslide zonation by the Australian Geomechanics Society in 2007 (AGS 2007 a, b), which is regarded as best practice in Australia. In 2011, MRT undertook a review and self-assessment of its Tasmanian Landslide Map series in order to compare it against the AGS documents (Mazengarb and Stevenson 2011). The authors concluded that their landslide zoning maps broadly fit into the framework of the AGS guidelines and were fit for purpose.

Outside of the targeted areas for the Tasmanian Landslide Map Series, much of the State has not been assessed for landslide susceptibility or hazard in a systematic way and, therefore, little guiding information exists for land use planning and other purposes.

3 METHODOLOGY FOR THE DEVELOPMENT OF A STATEWIDE LANDSLIDE PLANNING MAP

3.1 Guiding Principles

The following guiding principles are adopted:

- The Australian Geomechanics Society guidelines 2007a,b are accepted as best practice in the absence of a landslide standard. Where these guidelines are not sufficiently specific, the approach adopted will be based on professional judgement subject to independent peer review.
- The statewide planning map will be based on a susceptibility approach to landslide zoning, given that landslide hazard (*sensu strictu*) is currently very poorly constrained.
- The statewide planning map will take advantage of the best available information where it exists.
- Improvements will be made to previous mapping, where time allows to reflect the discovery of obvious errors, improvements in technology and methods, and the subsequent information and advances in our understanding of landslide processes that results from the systematic mapping projects.
- The transformation of the landslide susceptibility mapping into a planning map will be based on expert judgement using a pairwise ranking approach in a matrix.
- The process is sufficiently documented and transparent.

4 DATA COMPONENTS

The data components forming the Statewide Landslide Planning Map are derived from MRT data. The components are divided into four principal groups:

- Known Landslides.
- Proclaimed Landslip Areas.
- Tasmanian Landslide Map Series – Modelled Susceptibility Zones.
- Remaining Areas Susceptibility – Statewide Slope Categories.

The components within these groups will be described in sufficient detail below. A further technical report in preparation will provide additional information to support the approaches taken.

4.1 Known Landslides

4.1.1 Overview of the MRT Landslide Database

MRT has compiled and maintained a database of landslides in Tasmania since 2003 – the MRT Geohazards database. This inventory of landslides has been mainly compiled from recent mapping programmes and also research into MRT archives dating back to the 1960s. Known or mapped landslides include several types of features including slides, flows, falls and spreads, as identified in the field or by remote sensing techniques (eg aerial photo interpretation or airborne laser scanning (LiDAR) survey interpretation).

The Geohazards database was designed approximately 10 years ago to conform to international best practice as demonstrated in key references contained in Turner and Schuster (1997). It is consistent with the AGS 2007a guideline in that it refers to a collection of landslide records that capture information on the location, classification, volume, activity and date of occurrence, amongst other attributes. The MRT landslide database represents an intermediate to sophisticated resource as assessed by ourselves (Mazengarb and Stevenson 2011) against the AGS Guidelines 2007. Furthermore, we consider it rates very favourably against other landslide databases in Australia.

About 2 700 landslide records currently exist in the MRT database, but there will be many more in areas that have not yet been mapped. In addition to the mandatory fields described previously, the database stores all reported records of landslide damage to buildings, property and infrastructure since about the 1950s; currently totalling about 260 records. It also records compensation paid to landholders for landslide damage, largely under landslide compensation Acts, with a total of 96 compensation payouts to date.

4.1.2 Spatial and Attribute Accuracy and Reliability of Database

The inventory of landslide records in the MRT database is mainly derived from systematic mapping projects that cover only a small percentage of the area of the State. We expect that in the 'Remaining Areas' of the State there will be many landslide features in the landscape that have not yet been recognised.

The landslide data is divided into two parts reflecting its heritage; the pre-2003 mapping and the later mapping undertaken as part of the Tasmanian Landslide Map series.

- The earlier, pre-2003 mapping has a number of limitations, such as inconsistent mapping methodology and classification. Many of the landslides have only been recorded as points when, in fact, they may be of a significant size. Some landslides have been included into zones when, in fact, some could have been mapped separately, and some of these have been further amalgamated incorrectly during the conversion of cartographic maps into GIS form.

  The data was largely collated on 1:25 000 base maps prior to modern GIS and GPS technology becoming available. The implications of these limitations are that the spatial accuracy of the features is lower than our current mapping practices. Fortunately, much of this mapping, as mentioned below, has been revised in the course of producing the Tasmanian Landslide Map series.

- The methodology for capturing landslide information as part of the post-2003 Tasmanian Landslide Map series is largely reported within Mazengarb & Stevenson (2010) and parts of it are repeated below. Landslide mapping is largely a subset of the geomorphological analysis MRT geologists undertake as part of the Tasmanian Landslide Map series. Within each study area this involves a substantial component of aerial photograph interpretation (API) assisted by field inspections. The geomorphological analysis included re-mapping of all the landslides appearing on earlier maps, and spatially adjusting them to more accurately fit the current map base, while some have been substantially reinterpreted. This component also draws on historical records of recent movement that could not be derived from API alone. The historical research is by no means comprehensive, but has included researching earlier MRT/Department of Mines reports, various other State and local government reports, newspaper reports and some consultants' reports for individuals or organisations. It is recognised that much more information exists in local government records and elsewhere that could not be easily retrieved. All councils in mapping project areas were contacted to obtain any relevant geotechnical information they may have held. However, this proved to be a more difficult task than originally anticipated, as the information is often not stored in a readily accessible manner.

  The spatial accuracy of data capture has generally improved in recent years as new mapping technology has become available to us at MRT. This has meant that the accuracy of most of our mapped features is now well below 5 metres in many instances.

  Landslides are classified according to a confidence measure into two types, to indicate whether the feature recognised is *certain or probable*, or *possible.* These descriptors reflect whether there is strong evidence for the existence of a landslide or not. An example of the latter is where there are features in the landscape morphology or records of damage whose cause is somewhat uncertain and not necessarily related to a landslide process.

  The MRT landslide database contains many fields for capturing information about each landslide and provides a valuable tool to support our analysis and reporting requirements. Most landslides can be confidently classified according to material and movement type (eg earth flow, rock fall, etc). However, it is often not practically possible to reliably determine other important properties specified in the AGS guidelines and professional judgement is often used to determine these parameters:

  - The volume of many of our landslides, which is used by AGS (2007) to discriminate between large and small landslides that are either greater or lesser than 1 000 m^3, cannot be easily calculated without knowing the depth of the failure plane, something that would typically require a drilling rig to determine. Given the number of landslides in our database, this is beyond our resources to consider.
  - The approximate depth of failure is an alternative method to the volume-based method, above, that has been used by MRT since 2003 to subdivide our landslides into

shallow or deep-seated features. It is roughly synonymous with the volume-based method that, for the reasons given above, is often difficult to determine.

- The date of first time failure and the activity state is poorly known across most of the landslide records. Landslide events that have been directly observed and recorded since European settlement are classified as *Recent or Active*. However, for most of the landslides in the landscape their age is uncertain and they have not been directly dated using established geological dating methods, which is beyond our resources. These landslides are classified as *Activity Unknown*. Geomorphic considerations of the landscape can provide some constraints to enable us to attempt a qualitative assessment of likelihood. The determination of these parameters is critical in order to determine likelihood. The lack of reliable likelihood indications has been the principal reason why MRT has not produced true hazard maps to date.
- The velocity of landslide movement is an important parameter as it is used as an indicative proxy for the destructive potential of landslides in the AGS Guidelines (AGS 2007a). Unfortunately, the velocity of movement has only been measured in a few instances in Tasmania, and other recorded velocities are largely an estimate based on professional judgement.

However, with the limited velocity and frequency data that is available for landslides in Tasmania as points of knowledge, it is possible to make some professional judgements and inferences to assess qualitative likelihood against typical landslide velocities for broad groups of landslide types. The foundations for these judgements and inferences are based on the many years of landslide research conducted by Mineral Resources Tasmania and its predecessor, the Department of Mines. The results of this qualitative assessment are shown on a chart in Figure 1. This chart demonstrates the likelihood vs velocity characteristics for the typical range of landslides in each major landslide group. The points on the chart show landslides that have caused damage and for which the velocities (maximum and/or average) are well established and an estimate of the frequency can be made.

The landslide points with associated damage in Figure 1 also show the number of buildings damaged in each case. It is quite apparent from Figure 1 that the great majority of building damage caused by landslides in Tasmania is related to very slow-moving landslides. It is also apparent that most of these damaging landslides are reactivations of existing deep-seated landslides and/or have occurred within the Launceston Group sediments of the Tamar Valley.

An important consideration in using the Known Landslide data as a component of the Statewide Landslide Planning map is that the MRT landslide database is a live database and subject to change. Landslide records are added as new landslide events occur and are reported, and landslide records are also modified, including changes to the mapped extent, as new information comes to light and new mapping programmes are undertaken. This will, over time, result in differences between the Known Landslides component of the Landslide Planning Map being utilised by the planning community and MRT's live database, which is available for the public to access.

4.1.3 Components of the Landslide Database used in the Landslide Planning Map

A series of queries and geoprocessing operations have been performed to extract and categorise the Known Landslide data, from the MRT landslide database, for inclusion in the Statewide Landslide Planning Map. The following pre-conditions have been applied in performing these operations:

- Only the most current mapped extents (polygons) of landslides have been included. All out-dated interpretations that have been 'retired' or 'closed' in the MRT landslide database were excluded.
- Landslide records without polygons have been excluded. Mapping and research is required to define the extent of these landslide features, and defining an arbitrary spatial extent for the point records will not be valid in a large number of cases.
- The polygons of landslide records for debris flow and rock fall events have been excluded. The extents of such polygons often do not reflect very well the areas of likely future failure. The existing susceptibility mapping and statewide slope categories will be better suited to identifying areas of likely future failure. Where debris flow or rock fall polygons are located in association with an underlying 'parent' landslide feature, the polygon has been merged with the 'parent' landslide.

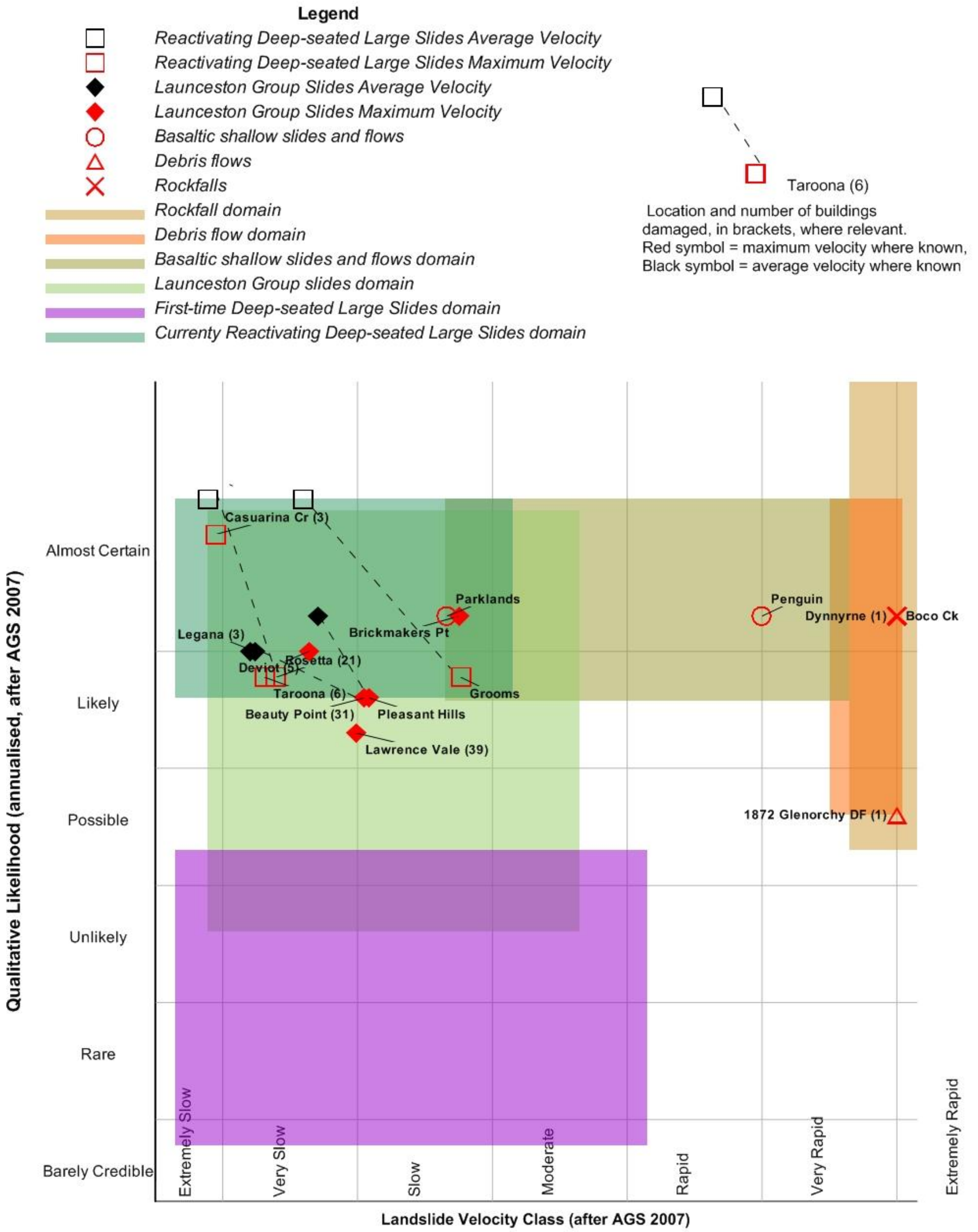

Chart of qualitative likelihood vs velocity for major landslide types in Tasmania, with indication of damage to buildings. The x-axis provides a proxy to the probable destructive significance figure of AGS 2007, but suprisingly most of the damage to buildings in Tasmania are in the second lowest category (Very Slow) contrary to the consequence description. The symbols provide our known control on the expected behaviour of each landslide type. Note that much of the damage recorded in the state is associated with reactivations of existing landslides.

Figure 1. Qualitative likelihood plotted against typical landslide velocities for broad groups of landslide types in Tasmania. This chart demonstrates the likelihood vs velocity characteristics for the typical range of landslides within each major landslide group.

The queries and geoprocessing operations are guided by AGS guidelines and our professional judgement of which mapped landslide features represent a potential hazard to the community. The four principal extracted components to be included are:

1. Mapped slides – deep-seated/Launc. Gp, activity unknown. This group contains large, deep-seated landslides, including possible landslides and landslide zones, whose activity is unknown. It also includes most of the slides in the Tertiary sediments of the Launceston Group, which show a range of failure depths from shallow to deep. Experience and analysis has shown that the range of Launceston Group landslides are expected to represent a similar hazard to the community as the mapped large, deep-seated landslides (refer to Figure 1). Some of the landslides in this group could be reactivating periodically, or even seasonally, at very slow rates – but without evidence to the contrary this is difficult to prove. Landslides within the Launceston Group that have specific evidence for being quite shallow have been placed in the 'Other slides/flows' categories.

2. Mapped slides – deep-seated/Launc. Gp, recently active. These landslides are similar to the above, but there is evidence or documentation showing that they have either failed for the first time or reactivated since European settlement. Many of the reactivating landslides respond to climatic variables, either short-term (seasonal) or long-term (eg inter-decadal cycles). In several cases, movement may have been initiated by disturbance of the slopes. The majority of the records of landslide damage in Tasmania are related to landslides in this category.

3. Mapped slides – other slides/flows, activity unknown. This group contains all of the landslides that have been recorded as shallow in the MRT landslide database, including possible landslides and landslide zones, whose activity is unknown. This includes some slides within the Launceston Group that have specific evidence for being quite shallow. The landslides in this group are generally much smaller than the above groups.

4. Mapped slides – other slides/flows, recently active. These landslides are the same as the above, but there is evidence or documentation of recent activity.

4.2 Proclaimed Landslip Areas

4.2.1 Definition

Proclaimed Landslip Areas constitute legislated areas in Tasmania on which strict controls to development exist. The geographic areas are defined by MRT in accordance with the *Mineral Resources Development Act 1995*, whereas the controls are contained in the *Building Act 2000* and its Regulations, which are administered by Workplace Standards Tasmania. The two pieces of legislation override controls contained in the State's planning scheme legislation – the *Land Use Planning and Approvals Act 1993*.

Landslip Areas comprise two components, A areas and B areas.

- The A area represents places where, essentially, no more building is allowed, recognising that this is the area in which the highest potential/actual risk of landslide is considered to be located.
- Landslip B areas have strict development controls. They serve as buffer zones to Landslip A areas and recognise the importance of activities within the B area with the potential to affect the stability of the adjacent sensitive A areas. Parts of the B area could also be susceptible to landslide movement.

4.2.2 Methodology and Spatial Accuracy

The existing Proclaimed Landslip Areas (proclaimed from 1971 to 2003) represent a very small portion of the State and have been defined using a variety of methodologies, some of which are poorly documented. Most of the areas have been created as a reaction to landslide disasters between 1970 and 1990. For instance, a significant zone was created in 1992 at Rosetta (Glenorchy), where a number of houses were damaged, several of which were demolished. This document need not detail how each area was created as they are enshrined in law and not readily open to challenge. Rather, the spatial accuracy of the features, as represented in the GIS landslide planning map, needs to be clarified to provide a level of certainty to the users of the information on the ground.

The location of each Proclaimed Landslip Area is defined on a registered plan that typically includes surveyors' measurements and cadastral boundaries. The plan must be regarded as the ultimate point of truth, although relating the plan to real world coordinates exposes a number of issues. In some cases, the boundaries were created to coincide with cadastral boundaries, whereas in other places they follow geomorphic features with curved (non-linear) form. The translation from plan to GIS format has been with reference to the statewide digital cadastre layer, the accuracy of which has been improved over a series of iterations spanning a number of years. In these cases, as each iteration has occurred, it has meant that the precise landslip area has had to be adjusted once the cadastre shift was discovered. For boundaries coinciding with geomorphic features, an additional challenge is introduced in clearly transposing the boundary to digital form, especially given the potential for inaccuracies in decades old mapping that may have relatively poor spatial control. Furthermore, the curved form has proved challenging for surveyors to accurately identify in the field and for Councils to check to ensure that developments are not encroaching into the Proclaimed Landslip Areas.

Even with these uncertainties, we suggest that the boundary uncertainty of the Proclaimed Landslip Areas will normally be much less than 2 metres horizontal.

4.2.3 Components of the Landslip Areas

The two types of Proclaimed Landslip Area, Landslip A and Landslip B, need to be treated as separate components in the Statewide Landslide Planning Map. The two types have significantly different implications for planning due to their legislated controls.

1. Proclaimed Landslip A areas. The legislated intent of these proclaimed areas is not to allow any further development, except for some insubstantial buildings or modifications, but only then with Ministerial approval.

2. Proclaimed Landslip B areas. The legislated intent of these proclaimed areas is to only allow development that will not compromise the stability of the underlying slopes or the stability of an adjacent Landslip A area.

4.3 Tasmanian Landslide Map Series – Modelled Susceptibility Zones

4.3.1 Definition

The Tasmanian Landslide Map series provides a collection of input layers that feed directly into the Statewide Landslide Planning Map. These input layers are landslide susceptibility zones presented on maps within the map series.

The susceptibility zones are derived by MRT using sophisticated modelling techniques, and each has been developed to predict areas where particular landslide processes could occur in the landscape. Each major type of landslide process is modelled separately because each has unique characteristics. Each landslide modelling process will identify a source area and, depending on the process, runout and regression areas.

4.3.2 Methodology, Spatial Accuracy and Reliability

The mapping and modelling methodology has evolved with each new mapping programme due to the varying landslide processes in different areas, and the differences in available input data. The methodologies are described in detail in Mazengarb (2005) and Mazengarb and Stevenson (2010), with additional details provided on individual map sheets.

In providing quality assurance to stakeholders, periodic independent peer reviews of the maps in the Tasmanian Landslide Map Series, and the associated documents, have been undertaken by respected practitioners, and, as far as possible, the recommendations have been implemented into our mapping programmes.

Like all maps, those of the Tasmanian Landslide Map Series have limitations. Standard caveats are placed on the maps:

- The hazards identified are based on imperfect knowledge of ground conditions and models that represent our current understanding of the landslide process. As this knowledge improves, our perception of the hazard, and the depiction on the map, may also change.
- These maps can be used as a guide (or flag) to the need for specific assessment in potential hazard areas.
- Planning decisions should not be made solely on the basis of the zones delineated on the map.
- The scale limitations of the data should be considered at all times, as exceeding this limit could lead to inaccurate decisions about the hazard.
- Site-specific assessment of landslide hazard and risk should be undertaken by suitably qualified and experienced practitioners in the fields of engineering, geology, and geotechnical engineering.
- Practitioners undertaking site-specific assessments should read the map text and associated documents to obtain a thorough understanding of the methodology and limitations of the maps.

- Areas where no susceptibility or hazard is shown can still have issues with slope instability.
- Anthropogenic influence on slopes cannot be predicted and the occurrence of slope instability resulting from the influence of human actions is specifically excluded from these maps.
- The identification and performance of cut and filled slopes have not been specifically considered in map production and their scale is such that they often cannot be resolved on the maps. The presence of such slopes should always be considered in site-specific assessments.

Note: the use of the word 'hazard' in these standard caveats does not imply any knowledge of the likelihood of any particular type of landslide movement.

4.3.3 Components of the Modelled Susceptibility

For the purpose of the Statewide Landslide Planning Map the following components of modelled landslide susceptibility are supplied as inputs layers:

1. **Rockfall susceptibility, source and runout area 34°** – modelled susceptibility for source areas of rockfall and runout to a travel angle of 34° (refer to Figure 2). The travel angle is based on field measurements of existing talus slopes.
2. **Rockfall susceptibility, runout area 30°** – modelled susceptibility for extended rockfall runout to a travel angle of 34° to 30° (refer to Figure 2). This increasing runout will occur with decreasing likelihood.
3. **Debris flow susceptibility (Mountain), source and runout >30°** – modelled susceptibility for source areas of mountain debris flow and runout to a travel angle of 30°. This travel angle represents the first quartile of possible runouts. MRT will be producing an updated set of debris flow susceptibility zones for the Hobart and Glenorchy map-sheet areas as part of an upcoming review of the earlier debris flow modelling of the Mt Wellington slopes, and this update will benefit significantly from the 2011 LiDAR survey now available.
4. **Debris flow susceptibility (Mountain), runout 30-26°** – modelled susceptibility for mountain debris flow runout to a travel angle of 30° to 26°. This travel angle represents the second quartile of possible runouts. MRT will be producing an updated set of debris flow susceptibility zones for the Hobart and Glenorchy map-sheet areas as part of an upcoming review of the earlier debris flow modelling of the Mt Wellington slopes, and this update will benefit significantly from the 2011 LiDAR survey now available.
5. **Debris flow susceptibility (Mountain), runout 26-22°** – modelled susceptibility for mountain debris flow runout to a travel angle of 26° to 22°. This travel angle represents the third quartile of possible runouts. MRT will be producing an updated set of debris flow susceptibility zones for the Hobart and Glenorchy map-sheet areas as part of an upcoming review of the earlier debris flow modelling of the Mt Wellington slopes, and this update will benefit significantly from the 2011 LiDAR survey now available.

6. **Debris flow susceptibility (Mountain), runout 22-12°** – modelled susceptibility for mountain debris flow runout to a travel angle of 22° to 12°. This travel angle represents the fourth quartile of possible runouts. The susceptibility zones for this component initially provided by MRT for the draft Statewide Landslide Planning Map were produced in 2004, and were originally conceived to model runouts with travel angles of 22° to 5°. This broad range of runouts was designed to include the relatively uncommon dam-burst scenario (see below), and so in its current form this component will be an over-estimation. MRT will be producing an updated set of debris flow susceptibility zones for the Hobart and Glenorchy map-sheet areas as part of an upcoming review of the earlier debris flow modelling of the Mt Wellington slopes, and this update will benefit significantly from the 2011 LiDAR survey now available. The updated susceptibility zones for this component will be restricted to runouts with travel angles of 22° to 12°.
7. **Debris flow susceptibility (Mountain), runout – dam-burst** – modelled susceptibility for mountain debris flow runout in extreme cases of debris dam formation, followed by a catastrophic dam burst (eg the 1872 Glenorchy debris flow). The modelling for this component will be produced by MRT along with an updated set of debris flow susceptibility zones for the Hobart and Glenorchy map-sheet areas, which will be part of a review of earlier debris flow modelling of the Mt Wellington slopes. It is our professional judgement that the frequency of these types of events impacting on developed areas is reasonably low (perhaps 1 in 100 to 500-year event); so at this stage, pending further study, we consider that it is not required as an input to the draft Statewide Landslide Planning Map.
8. **Shallow slide and flow susceptibility, source high** – modelled high level of susceptibility for shallow slides, as well as earth or debris flows in environments other than mountain slopes (eg North-West coastal escarpment).
9. **Shallow slide and flow susceptibility, source moderate** – modelled moderate level of susceptibility for shallow slides, as well as earth or debris flows in environments other than mountain slopes (eg North-West coastal escarpment).
10. **Shallow slide and flow susceptibility, source low and flow runout** – modelled low level of susceptibility for shallow slides, as well as earth or debris flows in environments other than mountain slopes (eg North-West coastal escarpment).
11. **Launceston Group slide susceptibility (large and small)** – modelled susceptibility to slides and flows in the relatively weak Tertiary sediments of the Launceston Group, which shows a range of failure depths from shallow to deep. Many of the records of landslide damage in Tasmania are related to landslides within the Launceston Group, and many of those have occurred on relatively low slopes. Because of the well-documented history of property damage on a wide range of slopes within the Launceston Group, the modelled susceptibility zones (based on two slope thresholds) have been combined for the purposes of the Statewide Landslide Planning Map. The susceptibility zones for this component initially provided by MRT for the draft Statewide Landslide Planning Map were produced in 2006 and only cover the Launceston map-sheet area. MRT will be producing an updated set of susceptibility zones to cover the Launceston map-sheet and the three new Tamar Valley map-sheets, and this update will benefit significantly from the 2008 LiDAR survey now available.

12. **Hobart-Glenorchy deep-seated slide susceptibility (Rosetta scenario)** – modelled susceptibility to deep-seated slides within the Hobart-Glenorchy region using the published "B model" (2004), which, for the Tertiary sediments of the area, is based on the Rosetta landslide scenario. This component includes both the modelled source and setback areas for deep-seated slides, using the "B model". The modelled susceptible areas could possibly include pre-existing deep-seated landslides that may be prone to reactivation, but due to erosion and/or human modification of the landscape these may not be particularly evident. It is thought that one such disguised landslide existed at Rosetta and was reactivated by the subdivision and development of the area.

13. **Deep-seated slide susceptibility (source-runout-regression)** – the combined modelled source, runout and regression areas for first-time failure of deep-seated landslides, other than those occurring in the Tertiary sediments of the Launceston Group. This does not include the reactivation of pre-existing deep-seated landslides in the landscape, some of which are possibly reactivating periodically. The first-time failure of deep-seated landslides is considered to be a rare event under existing environmental conditions, and the initial formation of the pre-existing deep-seated landslides was probably related to past climatic regimes not operating currently.

14. **Very low to no susceptibility** – those areas covered by the Tasmanian Landslide Map Series that are not included in the various modelled landslide susceptibility zones (eg Figure 2). This does not completely rule out the possibility of any of the landslide types occurring within these areas, but the susceptibility on the natural slopes is considered to be at least very low, as defined by the AGS Guidelines (2007a). However, as stated above in the caveats on map use, the affects of human modifications of the slopes cannot be predicted and the occurrence of slope instability resulting from human actions is specifically excluded from the susceptibility mapping. The presence of such slopes should always be considered in site-specific assessments.

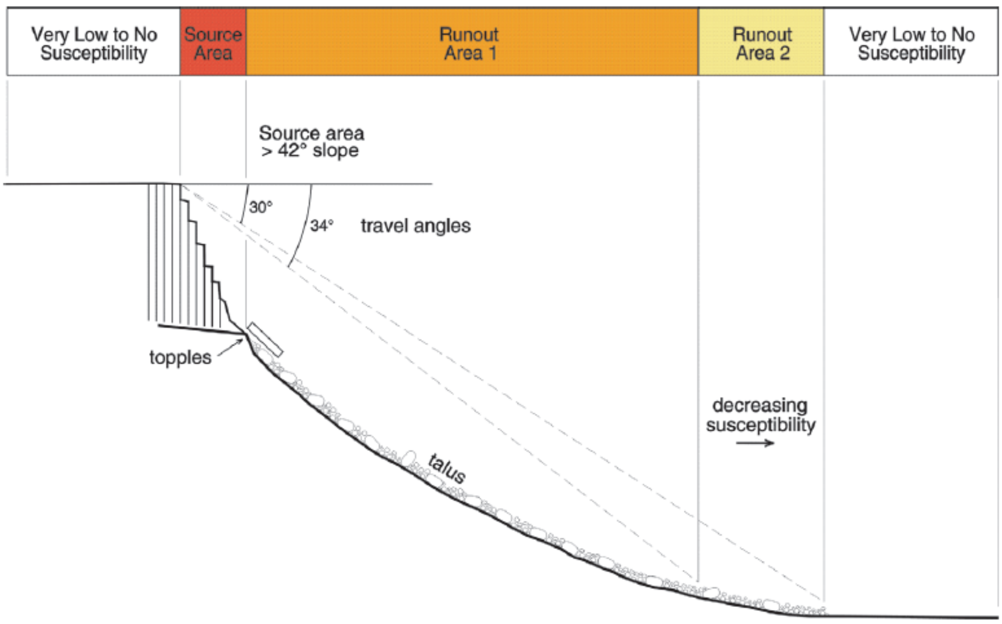

Figure 2. Conceptual diagram of the rockfall modelling process. The setting in this example is based on a dolerite talus slope.

4.4 Remaining Areas Susceptibility – Statewide Slope Categories

4.4.1 Definition

In the remaining areas of the State that do not have the advantage of detailed mapping or susceptibility modelling, a somewhat simplistic and pragmatic approach is required to define the zones that are potentially susceptible to landslides. The 'Remaining Areas' are defined as those parts of the State where no detailed landslide susceptibility modelling has been carried out by MRT, where there are no proclaimed Landslip Areas, and no landslide features have been mapped – with the exclusion of mapped landslide features that only exist as points in the MRT database, or represent debris flows or rock falls.

In the 'Remaining Areas' of the State, a basic indication of landslide susceptibility could be simply defined by slope alone, or by slope and geology.

Slope

Slope as an indicator of basic susceptibility provides a very simple indicator for assessing the potential for landslide activity.

Slope is commonly used in existing planning schemes throughout Tasmania. However, the parameters used range from 15 per cent slope (9 degrees) to 25 per cent slope (14 degrees). This approach is also used by both Queensland (2003) and Western Australia (2006). Table 1 provides an overview of the current use of slope as an indicator for landslide susceptibility within Tasmania and in other States.

Table 1. Slope-based triggers and Council Planning Schemes

Slope	Council
25 per cent (14 degrees)	Circular Head, Flinders, Meander Valley, Northern Midlands, Glenorchy, Tasman
20 per cent (11 degrees)	Dorset, Kingborough
15 per cent (9 degrees)	Launceston (interim) in areas outside of MRT susceptibility mapping Queensland state planning policy 1/03 Western Australian policy on natural hazards

The strength of using slope as an indicator of landslide susceptibility is that it is easy to measure, to communicate, and relatively easy to map. The most significant weakness, however, is that it is a crude indicator and does not accommodate the significant local conditioning factors that will contribute to landslide susceptibility (eg geology, hydrological influences). The use of slope alone may over-predict areas that are not truly susceptible to landslide, and under-predict areas that are susceptible.

Slope and Geology

Geology is a significant conditioning factor for landslide susceptibility. The underlying geology, or upslope geology, is usually a significant factor in determining what surficial material is present and the degree to which the substrate is prone to movement under certain conditions.

While geology is an essential component of detailed susceptibility mapping, its use as a broad indicator of landslide susceptibility across the Tasmanian landscape is significantly undermined by the scale, accuracy and intent of much of the available geological mapping. Current geology maps in Tasmania have been developed primarily for mineral exploration purposes with a focus on sub-surface geology, and, while informative, are not always suitable for sub-regional modelling of landslide susceptibility. The surface geology and soils are of much greater importance to landslide susceptibility.

There are some examples that use slope-geology indicators for landslide susceptibility in Tasmania but the parameters used differ markedly. Table 2 outlines, for comparative purposes, the MRT deep-seated landslide susceptibility parameters, the landslide slope indicators in the Forest Practices Code (FPB 2000), and the current parameters used in the Interim Planning Scheme for Hobart.

Using slope and geology as indicators of landslide susceptibility in Tasmania would require a review and reconciliation of the indicators outlined in Table 2, between each other and with the 165 types of geology identified in the Statewide 1:250 000 geology maps. Reconciliation and expansion of the indicators would require MRT to develop cumulative frequency analysis for the geology types and make assumptions of what is a reasonable slope threshold in that area. For many of the geology types there are simply not enough landslide records or materials analyses in our databases to be able to make a useful assessment.

Preferred approach to defining landslide susceptibility in the 'Remaining Areas'

The preferred approach to identifying potential landslide susceptibility in the remaining areas of the State is to use the slope only method. This method may be crude, but it provides a simple method given the available data for the remaining areas of the State. With this approach, three broad slope categories have been used to define very basic susceptibility zones across the State. The slope categories are based on slope alone without any consideration given to the underlying geology, geomorphology or past instability.

Table 2. Geology Slope Indicators

Geological rock type	Draft landslide code/Hobart draft scheme instability indicator	MRT deep-seated failure parameter (Mazengarb, C, and Stevenson, M D, (2010))	Landslide slope indicators (FPB 2000)
Jurassic dolerite	12°	41° (Hobart/Glenorchy) 50 (Launceston) 12-15° (Launceston – weathered)	
Tertiary sediments (Clay, Sandy Clay, Lignite)	5°	10° (Rosetta) 6.5° (Taroona) 7-12° (Launceston)	11°
Tertiary basalt	12°	38° (Hobart/Glenorchy) 50° (Launceston) 14° (North-West for weathered)	19°
Quaternary sediments and talus landforms • Colluvium • Dolerite Slope Deposits (Talus) • Basalt Slope Deposits (Talus) • Landslide Debris • Fluvioglacial Deposits, Till	7°	Not assessed	15° 19° 15° 11° 15°
Parmeener supergroup: Triassic Sediments • Triassic sandstone • Triassic mudstone (Mudstone, Siltstone, Shale, Coal, Coal Measures, Carbonaceous Mudstone) Permian Sediments • Permian sandstone • Permian mudstone (Mudstone, Siltstone, Micaceous Shale, Carbonaceous Shale and Mudstone, Coal, Coal Measures)	10° 10°	41° 41° 32° 32° (Hobart/Glenorchy) 16° (North-West)	15° 15°
Basaltic colluvium		14° (North-West)	
Triassic Basalt			19°
Cambrian (Volcanics and Greywacke)			19°
Precambrian (Phyllite, Schist)			19°

4.4.2 Methodology and Spatial Accuracy

In order to determine appropriate slope thresholds for the 'Remaining Areas' an analysis of three major landslide associations was carried out. These three associations were chosen because they occur on a range of slopes and geomorphic settings and a large amount of data is currently available from Tasmania. The three landslide associations are: the *mountain debris flows*, *basaltic soils*, and *Launceston Group soils*.

- While there is currently little development on the source areas of the mountain debris flows, as will be seen below, this setting provides an upper limit for setting thresholds.

- The Launceston Group soils provide a worst-case example, or lower limit, to the setting of thresholds. This association has seen significant past landslide issues in and around the Tamar Valley. Fortunately, most of the Launceston Group and other equivalent Tertiary sediment units have been included on the modelled Launceston and Tamar Valley landslide susceptibility maps.

- The basaltic soils refer to those areas of the State composed of weathered in situ basalt and associated sediments and its transported equivalents, the colluvial soil deposits. This association occurs widely in the North-West of the State and significant development has occurred in these areas.

The determination of the slope threshold values for these three associations is substantially based on professional judgement in consideration of:

- Determination and analysis of the general natural slope (pre-failure conditions) for each of the recognised landslides occurring in each geological unit and charting their frequency distribution in accordance with AGS 2007a.
- Analyses of the material properties for each geological unit and particularly those from site investigations related to specific landslides.
- Analysis of the landforms that occur in each of the major geological units and with regard to the geomorphic setting.

Comparison of the data for the three landslide associations indicates that each type has unique characteristics, from which distinct slope thresholds can be nominated.

Table 3. Nominated slope thresholds for each of the three Geological Associations.

Geological Association	Landslide Slope Distribution 99 per cent	Landslide Slope Distribution 90 per cent	Analysed Physical Properties
Launceston Group	>5°	>7°	
Basaltic soils	>5°	>10°	>10°
Mountain Debris Flows	>13°	>19°	>12°

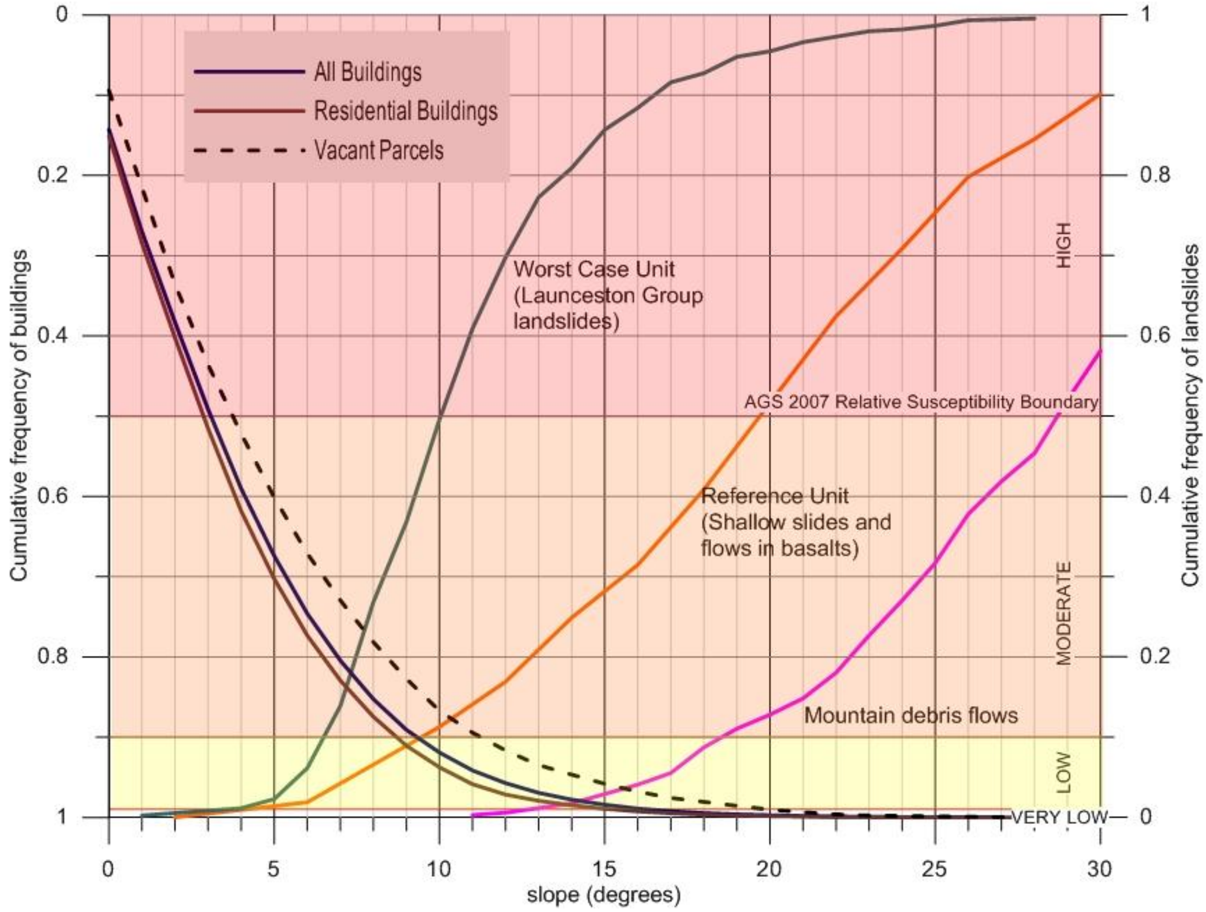

Figure 3. Cumulative frequency distribution of the three landslide associations on the natural general slopes (at right). Also shown is the cumulative frequency distribution of buildings and vacant parcels on the general slopes.

Figure 3 plots the cumulative frequency of landslides from each association in Tasmania against the natural slopes on which they occur – based on the mapped landslides within the MRT landslide database.

It is clear from Figure 3, and Table 3, that landslides generally occur on much lower slopes in association with the Launceston Group. There are some cases of landslides in basaltic soils that can also occur on similarly low slopes, but generally the landslides are expected on the steeper slopes.

As stated above, most of the Launceston Group and other equivalent Tertiary sediment units have been included on the modelled Launceston and Tamar Valley landslide susceptibility maps. This provides some justification for ignoring the slope thresholds derived for the Launceston Group in determining appropriate thresholds for the statewide slope categories. However, it will need to be accepted that there may be some cases of weak Tertiary clays, which can fail at low slope angles, within the State that will not be included in any of the slope categories or existing modelled landslide susceptibility.

Various investigations conducted by MRT and its predecessor, the Department of Mines, as well as other studies for forestry purposes, suggest that landslides associated with most other geological associations in Tasmania occur above slope thresholds that all exceed those for the basaltic soils and Launceston Group. So, on the basis that the slope thresholds for the Launceston Group do not need to be considered, it is reasonable to use the slope threshold for the basaltic soils as a lower threshold for the statewide slope categories.

Using the data summarised in Table 3 and Figure 3, a slope threshold of 11° has been chosen for the lower limit of a slope category that defines where a potential landslide hazard may exist. A second slope threshold of 20° was chosen to define an upper slope category where a greater potential landslide hazard may exist.

The justification for a 20° slope threshold is less well defined. However, for the susceptibility modelling for shallow slides and flows in the North-West of Tasmania, a threshold of 20° was used as the boundary between moderate and high susceptibility. That threshold was chosen on the basis of a statistical analysis of the known shallow landslides in the region. In addition, on slopes above 20° there is a significantly greater risk of debris flows and rock falls. Table 3 shows that 90 per cent of mapped debris flows occur on slopes greater than 19°. Figure 3 shows that about 99 per cent of existing buildings in Tasmania are on slopes less than about 15°, so it is expected that this upper slope category will have relatively little impact on future development in the 'Remaining Areas' of the State.

The slope values for the 'Remaining Areas' will largely be derived from a coarse 25 metre digital elevation model (DEM) supplemented with airborne laser scanning (LiDAR) surveys where available. The slope values derived from the 25 metre DEM, and relevant to this analysis, will tend to be underestimated (by around 2-5°). There will, therefore, be a slight underestimation of the area for each of the slope categories in the 'Remaining Areas'.

Because these slope categories do not consider the underlying geology, geomorphology or past instability, they will result in a large overestimation of the land potentially affected by landslides. Many of the steeper slopes around the State are steeper because they are underlain by more erosion-resistant, harder geology, and so may be quite stable in many cases. However, slopes greater than 42°, while generally not having any significant soil development and so cannot be the source of soil or debris slides, are quite prone to rock failures. Rock falls originating on these steep slopes can then move downslope to affect the lesser slopes at the base of the scarp.

Much of the steeper land included by these statewide slope categories is, in fact, land that is unlikely to ever be developed. That is, land on steep escarpments around dolerite mountains and mountainous land within existing parks and reserves. While about 99 per cent of existing buildings in Tasmania are on slopes less than about 15°, about 90 per cent are on slopes less than about 9° (Figure 3).

4.4.3 Components of Remaining Areas Susceptibility

The following slope categories are used for the remaining areas of the State not covered by detailed landslide susceptibility modelled by MRT:

1. Remaining Areas susceptibility, slopes >20° – slopes greater than 20°, based on a 25 metre digital elevation model (DEM) supplemented with airborne laser scanning (LiDAR) surveys

where available. Excluding areas of detailed landslide susceptibility modelling carried out by MRT, proclaimed Landslip Areas, and mapped slide-type landslides.

2. **Remaining Areas susceptibility, slopes 11-20°** – slopes from 11° to 20°, based on a 25 metre digital elevation model (DEM) supplemented with airborne laser scanning (LiDAR) surveys where available. Excluding areas of detailed landslide susceptibility modelling carried out by MRT, proclaimed Landslip Areas, and mapped slide-type landslides.

3. **Remaining Areas susceptibility, slopes 0-11°** – slopes less than 11°, based on a 25 metre digital elevation model (DEM) supplemented with airborne laser scanning (LiDAR) surveys where available. Excluding areas of detailed landslide susceptibility modelling carried out by MRT, proclaimed Landslip Areas, and mapped slide-type landslides. For the purpose of the Statewide Landslide Planning Map, this category is treated as having very low to no susceptibility to landslides.

5 MAINTENANCE OF THE STATEWIDE LANDSLIDE PLANNING MAP

As mentioned previously, an important consideration is the potential for differences to develop, over time, between the Known Landslide component of the Statewide Landslide Planning map and MRT's live landslide database as new landslide information is recorded. Each new landslide mapping programme usually results in a large number of new landslide records being added to the MRT database.

In addition, new landslide mapping programmes will usually produce new, or updated, modelled landslide susceptibility zones. Any new or updated landslide susceptibility zoning needs to be considered by the planning community.

The other potential area for significant change is with the increasing availability of airborne laser scanning (LiDAR) surveys. These surveys provide superior topographic detail that will greatly improve zoning for landslide susceptibility. In areas where it has not already been utilised, new LiDAR data could significantly improve some of the existing landslide susceptibility modelled by MRT, and LiDAR data would greatly improve the definition of the statewide slope categories used for 'Remaining Areas' where detailed landslide susceptibility modelling is not available.

These considerations suggest that there is a need for a process to regularly update the Landslide Planning Map, and any derived statutory maps, so that the planning community has the benefit of the latest landslide mapping and susceptibility modelling.

Pairwise assessment

Mineral Resources Tasmania coordinated the completion of the pairwise assessments. The results are shown below.

Pairwise Assessment 1

Y is 1000 N is 1 = is 100	Proclaimed "Landslip A areas"	Proclaimed "Landslip B areas"	Statewide slopes (25m DEM and LiDAR) 0-11deg	Statewide slopes (25m DEM and LiDAR) 11-20deg	Statewide slopes (25m DEM and LiDAR) >20deg	Rockfall susceptibility source + runout area 34deg	Rockfall susceptibility runout area 30deg	Shallow slide + flow susceptibility source-high	Shallow slide + flow susceptibility source-moderate	Shallow slide + flow susceptibility source-low	Debris flow susceptibility Mountain source + runout >30 Q1	Debris flow susceptibility Mountain runout 30-26 Q2	Debris flow susceptibility Mountain runout 26-22 Q3	Debris flow susceptibility Mountain runout 22 - 12 Q4a	Debris flow susceptibility Mountain runout - dam-burst	Deep-seated slide susceptibility (source-runout-regression)	Launceston Group slide susceptibility (large and small)	Mapped slides - deep-seated/Launc. Gp, recently active	Mapped slides - deep-seated/Launc. Gp, activity unknown	Mapped slides - other slides/flows, recently active	Mapped slides - other slides/flows, activity unknown
Proclaimed "Landslip A areas"		X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X	X
Proclaimed "Landslip B areas"	X		1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Statewide slopes (25m DEM and LiDAR) 0-11deg	1	X		1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000
Statewide slopes (25m DEM and LiDAR) 11-20deg	1	1	X		1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
Statewide slopes (25m DEM and LiDAR) >20deg	1	1	1000	X		1000	1000	1	100	1000	1	1	1	1000	1000	1000	1	1	1	1	1
Rockfall susceptibility source + runout area 34deg	1	1	1000	1000	X		1000	100	1000	1000	1000	1000	1000	1000	1000	1000	100	1	1	1000	1000
Rockfall susceptibility runout area 30deg	1	1	1000	1	1	X		100	100	1000	1	1	100	100	1000	1000	1	1	1000	1000	1000
Shallow slide + flow susceptibility source-high	1	1	1000	1	1	1	X		100	1000	1	1	1	100	1000	1000	1	1	1	1	1
Shallow slide + flow susceptibility source-moderate	1	1	1000	1000	100	100	100	X		1000	1	1	100	100	1000	1000	1	1	1	1	1
Shallow slide + flow susceptibility source-low	1	1	1000	100	1	100	100	1	X		1	1	1	1000	1000	1000	1	1	1	1	1
Debris flow susceptibility Mountain source + runout >30 Q1	1	1	1000	1	1	1	1	1	1	X		1	1	1	1000	1000	1	1	1	1	1
Debris flow susceptibility Mountain runout 30-26 Q2	1	1	1000	1000	1	1000	1000	1000	1000	1000	X		1000	1000	1000	1000	1	1	1	1	1
Debris flow susceptibility Mountain runout 26-22 Q3	1	1	1000	1000	1	1000	1000	1000	1000	1000	1	X		1000	1000	1000	1	1	1	1	1
Debris flow susceptibility Mountain runout 22 - 12 Q4a	1	1	1000	1000	1	100	1000	100	1000	1000	1	1	X		1000	1000	1	1	1	1	1
Debris flow susceptibility Mountain runout - dam-burst	1	1	1000	1	1	100	100	100	1	1000	1	1	1	X		1000	1	1	1	1	1
Deep-seated slide susceptibility (source-runout-regression)	1	1	1000	1	1	1	1	1	1	1	1	1	1	1	X		1	1	1	1	1
Launceston Group slide susceptibility (large and small)	1	1	1000	1000	1	1	1	1	1	1	1	1	1	1	1	X		1	1	1	1
Mapped slides - deep-seated/Launc. Gp, recently active	1	1	1000	1000	100	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	X		1	100	100
Mapped slides - deep-seated/Launc. Gp, activity unknown	1	1	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	X		1000	1000
Mapped slides - other slides/flows, recently active	1	1	1000	1000	1000	1	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1	X		1000
Mapped slides - other slides/flows, activity unknown	1	1	1000	1000	1	1	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	100	1	1	X	
Column Totals	19	18	18000	12105	4212	7407	11304	8406	10305	15003	7011	7011	8208	11304	16002	17001	4212	2016	3015	5112	6112

Pairwise Assessment 2

Y is 1000 N is 1 = is 100	Proclaimed "Landslip A areas"	Proclaimed "Landslip B areas"	Statewide slopes (25m DEM and LiDAR) 0-11deg	Statewide slopes (25m DEM and LiDAR) 11-20deg	Statewide slopes (25m DEM and LiDAR) >20deg	Rockfall susceptibility source + runout area 34deg	Rockfall susceptibility runout area 30deg	Shallow slide + flow susceptibility source-high	Shallow slide + flow susceptibility source-moderate	Shallow slide + flow susceptibility source-low	Debris flow susceptibility Mountain source + runout >30 Q1	Debris flow susceptibility Mountain runout 30-26 Q2	Debris flow susceptibility Mountain runout 26-22 Q3	Debris flow susceptibility Mountain runout 22 - 12 Q4a	Debris flow susceptibility Mountain runout - dam-burst	Deep-seated slide susceptibility (source-runout-regression)	Launceston Group slide susceptibility (large and small)	Hobart-Glenorchy deep-seated slide susceptibility (Rosetta scenario)	Mapped slides - deep-seated/Launc. Gp, recently active	Mapped slides - deep-seated/Launc. Gp, activity unknown	Mapped slides - other slides/flows, recently active	Mapped slides - other slides/flows, activity unknown
Proclaimed "Landslip A areas"		1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	100	1000
Proclaimed "Landslip B areas"	1		1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	100	1000	100	1000
Statewide slopes (25m DEM and LiDAR) 0-11deg	1	1		1	1	1	1	1	1	1	1	1	1	1	100	100	1	1	1	1	1	1
Statewide slopes (25m DEM and LiDAR) 11-20deg	1	1	1000		1	1	100	1	1	100	1	1	1	100	1000	1000	1	100	1	1	1	1
Statewide slopes (25m DEM and LiDAR) >20deg	1	1	1000	1000		1	100	1	100	1000	1	1	100	100	1000	1000	1	1000	1	1	1	100
Rockfall susceptibility source + runout area 34deg	1	1	1000	1000	1000		1000	1	100	1000	100	100	1000	1000	1000	1000	1	1000	1	1000	1	1000
Rockfall susceptibility runout area 30deg	1	1	1000	100	100	1		1	1	1000	1	1	100	100	1000	1000	1	1000	1	100	1	100
Shallow slide + flow susceptibility source-high	1	1	1000	1000	1000	1000	1000		1000	1000	1000	1000	1000	1000	1000	1000	100	1000	100	1000	100	1000
Shallow slide + flow susceptibility source-moderate	1	1	1000	1000	100	100	1000	1		1000	100	100	1000	1000	1000	1000	1	1000	1	1000	1	1000
Shallow slide + flow susceptibility source-low	1	1	1000	100	1	1	1	1	1		1	1	100	100	1000	1000	1	1	1	100	1	100
Debris flow susceptibility Mountain source + runout >30 Q1	1	1	1000	1000	1000	100	1000	1	100	1000		1000	1000	1000	1000	1000	1	1000	1	1000	1	1000
Debris flow susceptibility Mountain runout 30-26 Q2	1	1	1000	1000	1000	100	1000	1	100	1000	1		1000	1000	1000	1000	1	1000	1	1000	1	1000
Debris flow susceptibility Mountain runout 26-22 Q3	1	1	1000	1000	100	1	100	1	1	100	1	1		1000	1000	1000	1	100	1	100	1	100
Debris flow susceptibility Mountain runout 22 - 12 Q4a	1	1	1000	100	100	1	100	1	1	100	1	1	1		1000	1000	1	1	1	100	1	100
Debris flow susceptibility Mountain runout - dam-burst	1	1	100	1	1	1	1	1	1	1	1	1	1	1		1000	1	1	1	1	1	1
Deep-seated slide susceptibility (source-runout-regression)	1	1	100	1	1	1	1	1	1	1	1	1	1	1	1		1	1	1	1	1	1
Launceston Group slide susceptibility (large and small)	1	1	1000	1000	1000	1000	1000	100	1000	1000	1000	1000	1000	1000	1000	1000		1000	1	1000	1	1000
Hobart-Glenorchy deep-seated slide susceptibility (Rosetta scenario)	1	1	1000	100	1	1	1	1	1	1000	1	1	100	1000	1000	1000	1		1	100	1	1
Mapped slides - deep-seated/Launc. Gp, recently active	1	100	1000	1000	1000	1000	1000	100	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000		1000	100	1000
Mapped slides - deep-seated/Launc. Gp, activity unknown	1	1	1000	1000	1000	1	100	1	1	100	1	1	100	100	1000	1000	1	100	1		1	1000
Mapped slides - other slides/flows, recently active	100	100	1000	1000	1000	1000	1000	100	1000	1000	1000	1000	1000	1000	1000	1000	1000	1000	100	1000		1000
Mapped slides - other slides/flows, activity unknown	1	1	1000	1000	100	1	100	1	1	100	1	1	100	100	1000	1000	1	1000	1	1	1	
Column Totals	**120**	**1218**	**19200**	**14403**	**10506**	**6312**	**10605**	**2316**	**6411**	**13503**	**6213**	**7212**	**10605**	**12603**	**19101**	**20100**	**4116**	**13305**	**1317**	**10506**	**417**	**11505**

6.4 *Appendix 4: Statewide and LGA Indicators*

Table 8: Landslide hazard planning bands by LGA and Area (Ha)

Council		Landslide hazard band Proportion of Council / Area (Ha)									
	Total (Ha)	Acceptable		Low		Medium		**Medium - active**		High	
Break O'Day Council	352 177	60.93 per cent	214 573	22.49 per cent	79 198	16.58 per cent	58 381	-	-	0.01 per cent	25
Brighton Council	17 023	69.29 per cent	11 795	20.88 per cent	3 554	9.83 per cent	1 674	-	-	-	-
Burnie City Council	61 247	76.17 per cent	46 652	15.34 per cent	9 396	8.49 per cent	5 200	2.29 per cent	14	-	-
Central Coast Council	93 782	63.66 per cent	59 706	20.13 per cent	18 880	16.20 per cent	15 197	1.81 per cent	17	-	-
Central Highlands Council	797 702	76.33 per cent	608 852	16.38 per cent	130 693	7.29 per cent	58 157	-	-	-	-
Circular Head Council	489 813	85.37 per cent	418 162	10.35 per cent	50 686	4.28 per cent	20 964	-	-	-	-
Clarence City Council	37 704	76.15 per cent	28 710	16.46 per cent	6 206	7.39 per cent	2 788	0.21 per cent	0.8	-	-
Derwent Valley Council	410 252	48.09 per cent	197 307	23.92 per cent	98 135	27.99 per cent	114 811	-	-	-	-
Devonport City Council	11 556	88.19 per cent	10 192	5.96 per cent	689	5.83 per cent	674	11.25 per cent	13	0.02 per cent	2
Dorset Council	322 835	80.22 per cent	258 970	13.22 per cent	42 692	6.56 per cent	21 173	-	-	-	-

Flinders Council	198 006	87.84 per cent	173 921	7.75 per cent	15 340	4.42 per cent	8 745	-	-	-	-
George Town Council	65 765	90.02 per cent	59 205	7.95 per cent	5 228	2.03 per cent	1 333	6.23 per cent	41	-	-
Glamorgan-Spring Bay Council	258 121	62.95 per cent	162 478	23.32 per cent	60 187	13.74 per cent	35 457	-	-	-	-
Glenorchy City Council	12 148	69.06 per cent	8 389	13.76 per cent	1 672	17.14 per cent	2 083	0.82 per cent	1	0.04 per cent	5
Hobart City Council	7 796	79.32 per cent	6 184	9.93 per cent	774	10.75 per cent	838	1.28 per cent	1	-	-
Huon Valley Council	550 614	45.53 per cent	250 668	26.92 per cent	148 221	27.56 per cent	151 724	-	-	-	-
Kentish Council	115 915	59.56 per cent	69 042	23.66 per cent	27 424	16.78 per cent	19 448	-	-	-	-
King Island Council	109 575	97.96 per cent	107 338	1.73 per cent	1 897	0.31 per cent	339	-	-	-	-
Kingborough Council	71 888	59.07 per cent	42 463	27.53 per cent	19 788	13.41 per cent	9 637	2.09 per cent	15	-	-
Latrobe Council	60 208	78.90 per cent	47 504	14.13 per cent	8 508	6.97 per cent	4 196	0.66 per cent	4	-	-
Launceston City Council	142 028	67.63 per cent	96 056	22.86 per cent	32 472	9.50 per cent	13 499	4.44 per cent	63	0.001 per cent	1
Meander Valley Council	332 726	69.49 per cent	231 221	16.79 per cent	55 862	13.72 per cent	45 642	-	-	-	-
Northern Midlands Council	513 729	76.72 per cent	394 124	16.73 per cent	85 937	6.55 per cent	33 668	-	-	-	-
Sorell Council	58 285	66.05 per cent	38 495	24.79 per cent	14 449	9.16 per cent	5 341	-	-	-	-
Southern Midlands Council	261 325	69.08 per cent	180 518	22.42 per cent	58 584	8.50 per cent	22 223	-	-	-	-
Tasman Council	65 907	60.85 per	40 104	28.09	18 514	11.06 per	7 289	0.02 per	0.1	-	-

		cent		per cent		cent		cent			
Waratah-Wynyard Council	353 821	58.59 per cent	207 300	22.32 per cent	78 972	19.07 per cent	67 471	0.40 per cent	14	0.02 per cent	78
West Coast Council	958 338	49.15 per cent	471 036	23.86 per cent	228 646	26.99 per cent	258 653	-	-	0.001 per cent	4
West Tamar Council	70 968	79.44 per cent	56 378	13.79 per cent	9 784	6.73 per cent	4 777	6.76 per cent	48	0.04 per cent	29
Grand Total	6 801 256	66.13 per cent	4 497 342	19.30 per cent	1 312 388	14.58 per cent	991 383	0.35 per cent	241	0.00 per cent	143

Table 9: Vacant parcels of land less than 2000 m^2

Row Labels	Number of Vacant parcels less than 2 000 sqm	Number of parcels impacted	Parcels impacted by more than 10 per cent of their area
Break O'Day Council	775	110	82
Brighton Council	381	6	3
Burnie City Council	291	162	142
Central Coast Council	451	108	93
Central Highlands Council	183	8	6
Circular Head Council	179	7	6
Clarence City Council	845	186	155
Derwent Valley Council	182	38	32
Devonport City Council	474	76	62
Dorset Council	254	33	29
Flinders Council	44	10	9
George Town Council	352	6	5
Glamorgan-Spring Bay Council	740	68	52
Glenorchy City Council	445	60	48
Hobart City Council	432	127	104
Huon Valley Council	571	83	73
Kentish Council	64	1	1
King Island Council	104	6	1
Kingborough Council	634	137	121
Latrobe Council	452		153
Launceston City Council	597	170	37
Meander Valley Council	278	39	1
Northern Midlands Council	267	2	98
Sorell Council	862	124	3
Southern Midlands Council	82	3	100
Tasman Council	432	113	29
Waratah-Wynyard Council	343	39	228
West Coast Council	800	248	76
West Tamar Council	570	88	82
Grand Total	12 084	2 058	1 749

Number of residential buildings impacted by Council area

Local Government Area	Total number of residential buildings	Acceptable		Low		Medium		Medium-active		High	
		Number	Per cent of residential buildings in each LGA	Number	Per cent of residential buildings in each LGA	Number	Per cent of residential buildings in each LGA	Number	Per cent of residential buildings in each LGA	Number	Per cent of residential buildings in each LGA
Break O'Day Council	3 440	3 281	0.95	90	0.03	26	0.01		0.00	43	0.01
Brighton Council	5 103	5 042	0.99	61	0.01		0.00		0.00		0.00
Burnie City Council	7 014	5 510	0.79	602	0.09	902	0.13		0.00		0.00
Central Coast Council	6 135	5 704	0.93	224	0.04	207	0.03		0.00		0.00
Central Highlands Council	1 720	1 635	0.95	78	0.05	7	0.00		0.00		0.00
Circular Head Council	2 175	2 085	0.96	62	0.03	22	0.01	6	0.00		0.00
Clarence City Council	18 904	18 103	0.96	793	0.04	8	0.00		0.00		0.00
Derwent Valley Council	3 383	3 164	0.94	212	0.06	7	0.00		0.00		0.00
Devonport City Council	9 625	9 411	0.98	131	0.01	81	0.01	1	0.00	1	0.00
Dorset Council	2 568	2 524	0.98	44	0.02		0.00		0.00		0.00
Flinders Council	635	619	0.97	13	0.02	3	0.00		0.00		0.00
George Town Council	2 660	2 611	0.98	16	0.01	33	0.01		0.00		0.00

Glamorgan-Spring Bay Council	3 146	3 041	0.97	101	0.03	4	0.00		0.00		0.00
Glenorchy City Council	16 245	15 682	0.97	520	0.03	14	0.00		0.00	29	0.00
Hobart City Council	16 857	14 704	0.87	2 092	0.12	60	0.00	1	0.00		0.00
Huon Valley Council	6 190	5 663	0.91	514	0.08	13	0.00		0.00		0.00
Kentish Council	1 481	1 398	0.94	39	0.03	44	0.03		0.00		0.00
King Island Council	931	928	1.00	3	0.00		0.00		0.00		0.00
Kingborough Council	13 129	11 409	0.87	1 598	0.12	76	0.01	46	0.00		0.00
Latrobe Council	3 591	3 586	1.00	4	0.00	1	0.00		0.00		0.00
Launceston City Council	23 229	19 940	0.86	5	0.00	3 280	0.14	4	0.00		0.00
Meander Valley Council	7 846	7 654	0.98	80	0.01	112	0.01		0.00		0.00
Northern Midlands Council	4 305	4 293	1.00	12	0.00		0.00		0.00		0.00
Sorell Council	6 317	6 000	0.95	315	0.05	2	0.00		0.00		0.00
Southern Midlands Council	1 214	1 177	0.97	37	0.03		0.00		0.00		0.00
Tasman Council	1 894	1 716	0.91	173	0.09	5	0.00		0.00		0.00
Waratah-Wynyard Council	4 777	4 590	0.96	46	0.01	115	0.02		0.00	26	0.01
West Coast Council	2 792	2 542	0.91	217	0.08	33	0.01		0.00		0.00
West Tamar Council	8 202	7 027	0.86	105	0.01	1003	0.12		0.00	67	0.01
Grand Total	**185 508**	**171 039**	**0.92**	**8 187**	**0.04**	**6 058**	**0.03**	**58**	**0.00**	**166**	**0.00**

6.5 *Appendix 5: Supporting Documents*

There is a need for a supporting document to the hazard matrix, mapping, and code to support the planners and community members to make decisions on landslide. The discussion noted that the Australian Geomechanics Guidelines provide a good base for this.

Item	Description
Landslide Risk Assessment	Stage and types of landslide site and risk assessment required for each band.
Hazard Management Plan	Sets out how the landslide hazard will be mitigated during construction and ongoing maintenance.
AGS Guide to Good Hillside Practices	Provides the AGS guide to good hillside practices and notes in a consolidated form.
Suitably Qualified Person	Sets out the test of what a suitably qualified person is.
Forms and Reports	Templates for forms and reports.

6.6 *Appendix 6: Landslide Mapping Update Schedule.*

This revision schedule sets out the intended updates to the statewide landslide planning maps. The timing of the updates will be dependent on resourcing, consequently three revisions are intended, and are outlined below.

Landslide mapping revision

Landslide planning map version	Region	Comments	Date
Version 1	Statewide	This Map	October 2012
Version 2	Glenorchy	Debris flow susceptibility based on a better understanding of the hazard	June 2013
	Hobart	Debris flow susceptibility based on a better understanding of the hazard	June 2013
	Tamar	Completion of mapping	June 2013
	Launceston	General revision of mapping based on LiDAR	June 2013
Version 3	Statewide (other areas)	Rockfall modelling	June 2014
	Glenorchy	General revision of mapping based on LiDAR	June 2014
	Hobart	General revision of mapping based on LiDAR	June 2014
Version 4	North-West	General revision of mapping based on LiDAR	June 2016

Further revisions of the mapping may be trigged either by a landslide event, improvements in the underlying science of landslide, changes in the cadastral base used to define landslip A and B areas, or improvements in the base data used to develop the mapping. This could include the movement from the statewide 25 metre digital elevation model to a LiDAR based digital elevation model.

The process for endorsement of the statewide landslide planning map by the State Government before referral to the Tasmanian Planning Commission for consideration will be outlined in the MRT Policy and the DPAC Policy on *The Sharing Of Hazard And Risk Information*.

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