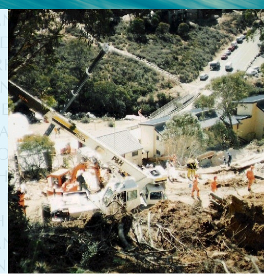
Australian Government
Geoscience Australia

TEACHER NOTES AND STUDENT ACTIVITIES

Landslides



RECORD 2011/25

APPLYING GEOSCIENCE TO AUSTRALIA'S MOST IMPORTANT CHALLENGES

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Australian Government
Geoscience Australia

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SECOND EDITION
RECORD 2011/25

GEOSCIENCE AUSTRALIA

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ABOUT THE BOOKLET
This booklet is intended to provide information for both science and geography teachers to support their work with pupils in both upper primary and secondary settings. Teachers should evaluate the student activities to ensure they are of appropriate difficulty for their cohort of students. If you have any further comments or feedback please email: education@ga.gov.au

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INTRODUCTION

Landslides are natural hazards that occur in localised areas. In Australia, they pose a serious threat to people and property. Between 1842 and 2010 there were more than 84 known landslide events, which were collectively responsible for the deaths of at least 110 people and injury to at least 156 people. During 2009 and 2010 alone there were three fatalities and 12 injuries. We need to be aware of the risks and effects of landslides due to their frequent and ongoing occurrence across the most populated regions of Australia (Figure 1).

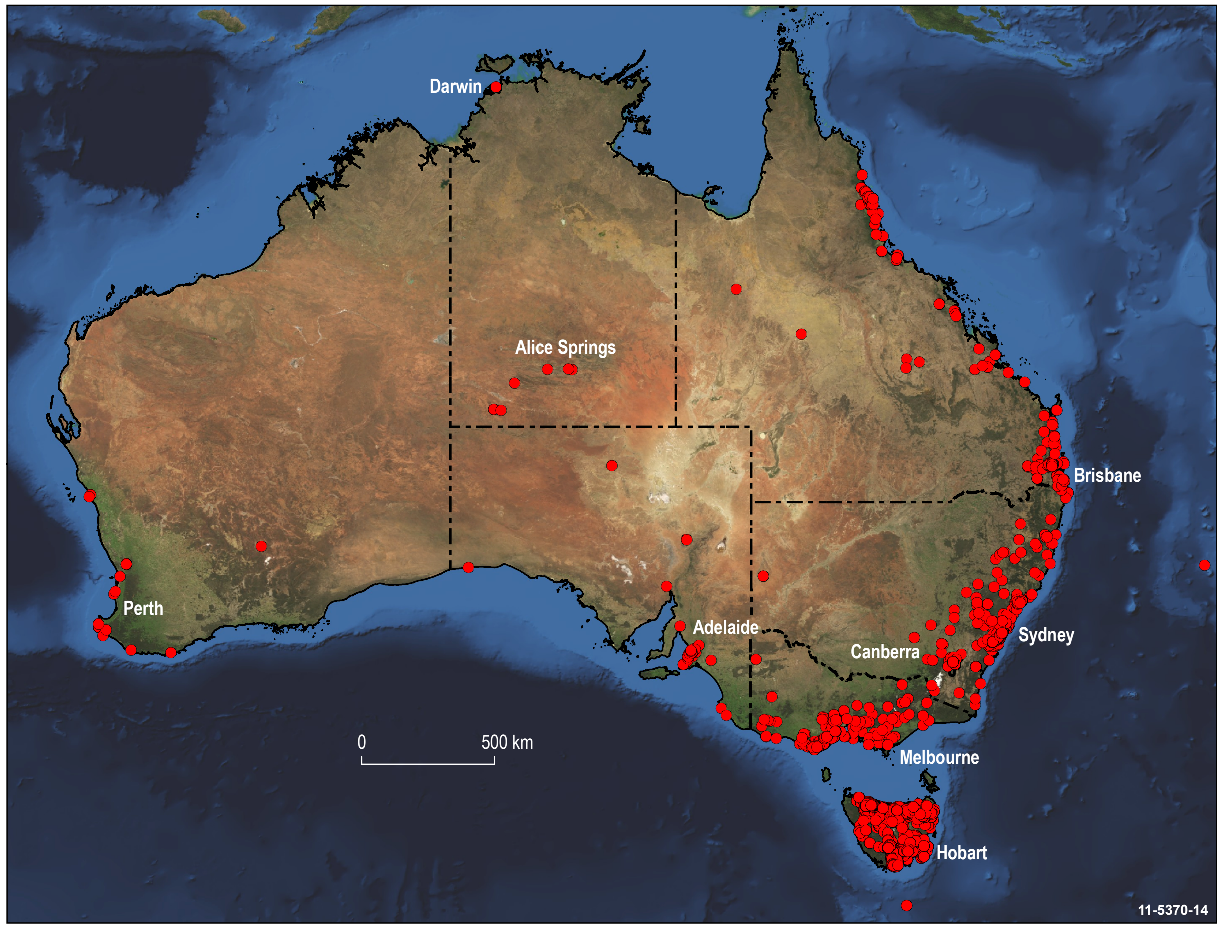

Figure 1: Recorded landslide events in Australia

Source: This map was compiled by Geoscience Australia in 2007 from data available in the Australian Landslide Database (incorporating records from Geoscience Australia, Mineral Resources Tasmania and the University of Wollongong). Data for southwest Victoria were supplied by Corangamite Catchment Management Authority in association with the University of Ballarat and A.S. Miner Geotechnical.

THE NATURE OF LANDSLIDES

1. DEFINITON

Landslides are a form of erosion as material (such as earth, rock, sand and mud) moves because of the effect of gravity. The general term for this movement is 'mass movement', which changes the angle of slopes and is important in the evolution of landscapes. Movement often occurs when water is involved and therefore more landslide events occur after heavy rainfall.

2. DANGER OF LANDSLIDES

Landslides can be incredibly dangerous and pose a serious threat to people's lives and property. While landslides are not as well recognised as other hazards in Australia they cause more injury or death, as well as economic loss, than many other hazards. The statistics show that more recorded deaths have resulted from landslides than from earthquakes. Until 2011 the worst landslide disaster in Australia's history was the Thredbo landslide, which occurred on 30 July 1997 and killed eighteen people (for more details see Significant landslides in Australia's history).

3. FACTORS THAT CAN CONTRIBUTE TO LANDSLIDES

- soil saturation
- heavy rainfall (Figure 4)
- vegetation removal
- seepage of water
- human activity
- blocked drains
- overgrazing
- earthquakes
- volcanoes
- vibrations from heavy machinery or traffic
- mining
- leaking water pipes or containers (Figure 5)
- construction of roads, railways, or buildings on steep terrain excavation (Figure 6)
- digging or working in trenches

4. RATE OF LANDSLIDE

The speed of a landslide varies considerably depending on the type of movement. Some landslides move extremely slowly at only millimetres per year, whereas others can travel at up to 100 kilometres per hour with a sudden avalanche of debris. Sudden and rapid landslide events are the most dangerous because of their speed, size and lack of warning. Human activities such as land clearing and excavations increase the risk of such catastrophic mass movements taking place.

The speed of a landslide is used to help to classify the types of mass movement that are described below and illustrated in Figure 2.

Creep: The gradual downhill movement of regolith (mass of weathered material resting above solid rock, particularly soil), at around one millimetre per year. Areas with soil creep may have trees with bent trunks, 'wrinkles' on the soil surface and areas where poles, walls and fence posts tilt down slope.

Flow: The fluid-like motion of debris is the most destructive and turbulent form of landslide. Debris flows are usually produced once a slope's surface has become saturated with water and the slope material loses its cohesion and turns into a slurry. The speed of movement varies depending on the slope angle, but some debris flows have accelerated to 100 kilometres per hour and may travel for many kilometres.

Slide: The sudden downhill movement of large sections of rock material and regolith. Unlike flows, the material has not been saturated and so the material moves as a large mass. A slide usually occurs along a surface of weakness, perhaps lubricated by water and/or when the toe of the slope is undercut. If a slide takes place along a curved rather than flat surface it is known as a **slump**.

Fall: The extremely rapid movement of rock associated with a steep slope, such as a cliff face. The rock material is generally weakened by weathering processes, such as freeze-thaw or by rainfall, and eventually friction can no longer hold the pieces in place and the material free falls or rolls downhill because of gravity. Evidence of a fall is the accumulations of broken material at the base of sea cliffs and in mountain areas.

Topple: The rapid end-over-end motion of rock, earth or debris down a slope. A topple usually takes place when blocks are quite tall compared to their width. A topple often creates a pile of debris at the bottom of the slope.

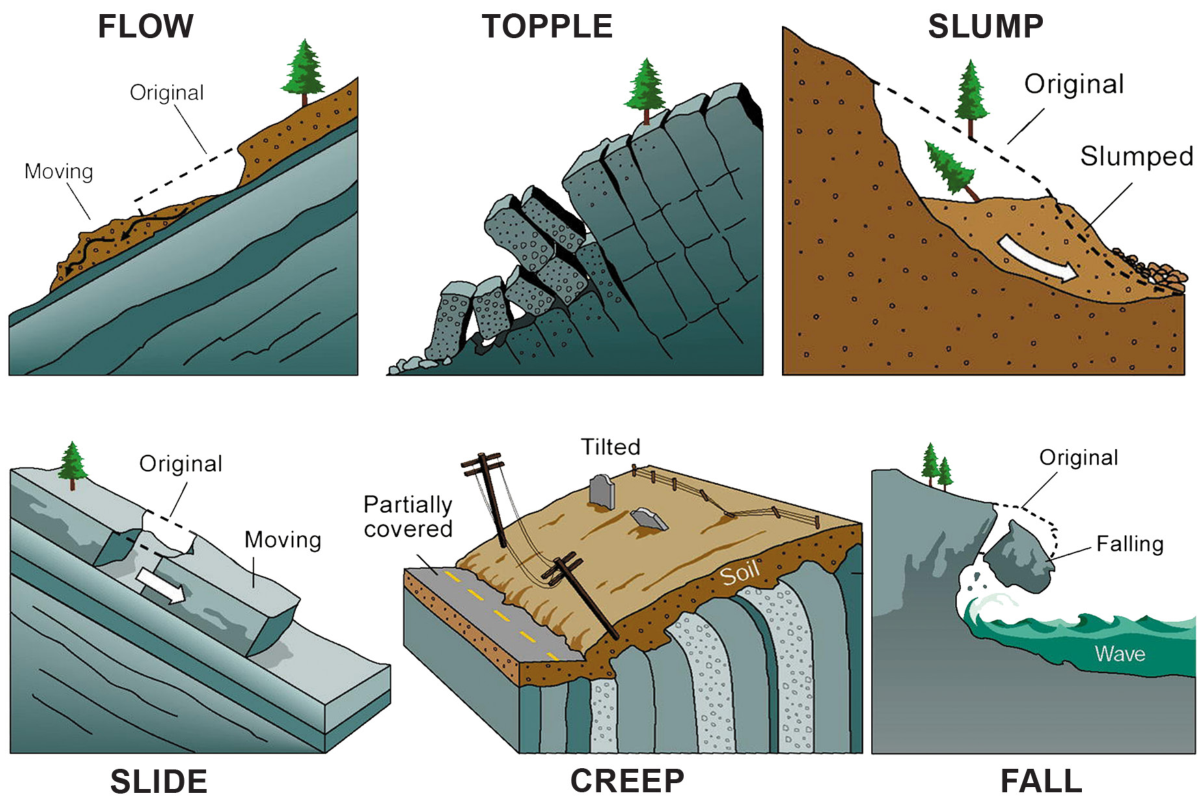

Figure 2: The different types of landslide movements.

Source: Reproduced with the permission of British Columbia Geological Survey, Ministry of Energy and Mines.

5. DISTANCE OF LANDSLIDE MOVEMENT

Landslides can travel over a range of distances, from centimetres for very slow-moving landslides to hundreds of kilometres for debris flows, depositing material well away from the original source. Figures 4 and 7 are examples of debris flow caused by torrential rain that carried material down-slope for hundreds of metres.

6. EVIDENCE OF LANDSLIDE MOVEMENT

Tell tale signs of land movement and slope processes can be observed in the landscape (Figure 3) and include:

- fresh rock faces (Figure 8)
- fallen rocks (Figure 9)
- lumpy topography (Figure 10)
- trees with the base of the trunk angled outwards from the slope (Figure 11)
- trees or poles tilting up or down the slope (Figures 10 and 13)
- water seepage
- breaks in the ground (Figures 5 and 10)
- cracks in the road and displaced kerbs (Figure 12)
- damage to building structures and roads

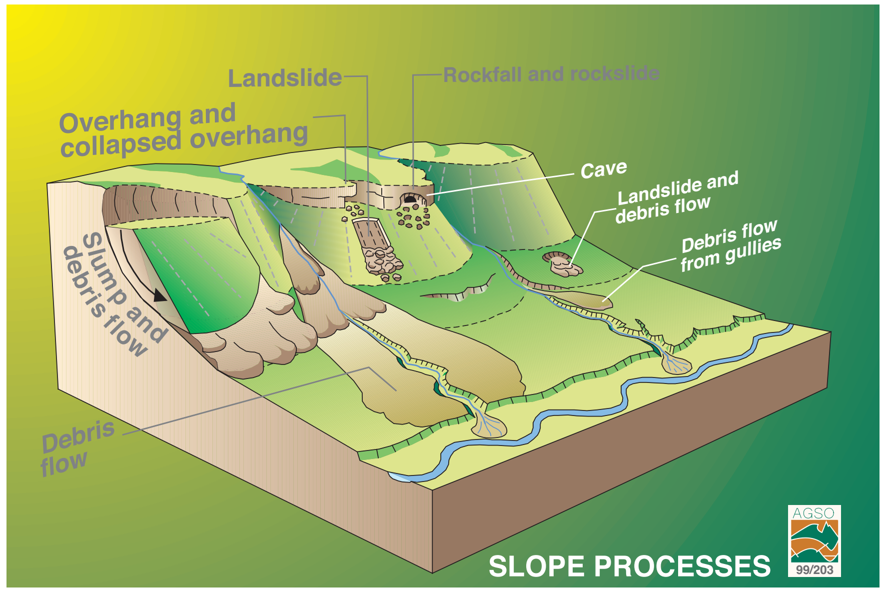

Figure 3: Areas prone to landslide movement reveal various types of slope processes.

7. ROCK TYPES SUSCEPTIBLE TO LANDSLIDE MOVEMENT

The types of rock usually involved in rock falls are sandstone, limestone and igneous rocks such as basalt (Figures 8 and 9). Sedimentary rocks with their layers dipping down slope and clays that absorb a lot of water are likely to slide or collapse due to their internal surfaces of weakness. Igneous rocks weather along joints (cracks) and form blocks and boulders that may easily move down a slope.

8. PROPERTY PROTECTION

Humans often trigger landslides by digging holes or building trenches in areas where the sands and soil collapse easily. These human-induced landslides often lead to significant injury or even loss of life. All building sites need to be thoroughly investigated before building developments are approved. Council officers are often sent into an area to assess the soil type, vegetation, weather conditions and land use before anyone can have permission to build on the site. The site will then be given a risk rating determining the level of restrictions to be placed on the building requirements.

IMAGES OF LANDSLIDE EVENTS

Figure 4: Debris flow deposit in Chapman, Canberra February 2007. The mud and hay bale were transported down the street by fast flowing water during a heavy downpour.

Source: Photograph by M Leiba.

Figure 5: Breaks in the ground at the head of a landslide at St Leonards, Launceston, Tasmania. This landslide was triggered by water leaking from one of the water tanks.

Source: Photograph by M Leiba.

Figure 6: Landslide along the wall of a building site excavation near Northbourne Avenue, Canberra in 2001.

Source: Photograph by M Leiba

Figure 7: Debris flow which ran into houses near the base of Castle Hill, Townsville.

Source: Photograph by M Leiba

Figure 8: The fresh rock face and rock fall on Barrengary Mountain, south coast of New South Wales in 1997.

Source: Photograph by M Leiba

Figure 9: A boulder travelled from the top to the base of this hill at Burleigh Heads, Queensland.

Source: Photograph by M Leiba

Figure 10: Lumpy topography and tilted telegraph pole following a landslide at Warbuton, Victoria.

Source: Photograph by M Leiba

Figure 11: The bent base of the tree trunk on the far right side is evidence of slow movement down-slope in that part of the creek bank. The tilted tree in the centre of the photo indicates rapid movement because of erosion from a debris flow in the creek.

Source: Photograph by M Leiba

Figure 12: Cracked road and displaced kerb as a result of a landslide in Lawrence Vale, Launceston, Tasmania.

Source: Photograph by M Leiba

Figure 13: Tilted trees at the edge of a landslide at Pelverata, Tasmania

Source: Photograph by M Leiba

SIGNIFICANT LANDSLIDES IN AUSTRALIA'S HISTORY[1]

Coledale – New South Wales, 30 April 1988

In Coledale, a northern suburb of Wollongong, two people were killed when a 17 metre high railway embankment slipped and buried a house. It was discovered that a blocked drainage system was a contributing factor to the landslide.

Port Campbell Coast – Victoria, 3 July 2005 and 15 January 1990

In 2005 one of the largest of the nine limestone stacks known as The Twelve Apostles collapsed. All that remained of the 45 metre high structure was a low pile of rubble.

In 1990 London Bridge, a double natural archway formed by marine erosion of limestone cliffs collapsed without warning. Two tourists were stranded on the outer archway for several hours until they were rescued by helicopter.

Figure 14: Behind the foremost pillar is the rubble remaining from the limestone stack (one of the 'Twelve Apostles') that collapsed along the Port Campbell Coast on 3 July 2005.

Source: Wikimedia Commons, photograph by B Wade 2005.

Gracetown – Western Australia, 27 September 1996

A 14 metre high limestone sea cliff collapsed on spectators at Cowaramup Bay near Gracetown in the Margaret River region. The spectators had been sheltering from the rain under an overhang when about 30 tonnes of rock and sand fell. Nine people were killed and another three injured. One survivor, a 10 year old girl, was dug from beneath the rubble by emergency workers after being trapped for 90 minutes. She received relatively minor injuries.

1 For earlier examples of Australian landslides please refer to the Geoscience Australia website.

Thredbo – New South Wales, 30 July 1997

Australia's most lethal landslide occurred when a large section of the mountainside, below the Alpine Way (highway) and directly above Thredbo Village, collapsed. As a result 1000 tonnes of material (trees, earth and rock) rapidly slid down the steep slope into a section of Thredbo Village. Two multi-level buildings were destroyed and debris and cars were scattered and buried in the lower 250 metres of the 400 metre landslide. The rescue efforts were hindered because of further minor slides and the unstable mass of debris, damaged buildings and vehicles. The disaster caused eighteen deaths, however, one man was rescued from the wreckage after being entombed for 65 hours.

Figure 15: The Thredbo landslide, 30 July 1997.

Source: http://commons.wikimedia.org/wiki/File:Thredbo_landslide.jpg#filelinks

Figure 16: SES volunteers assist at the Thredbo landslide of 1997.

Source: © NSW SES

Magnetic Island – Queensland, 10 January 1998

On the 10 January 1998, torrential rain triggered a debris flow, containing loose granite boulders and sand, which roared down one of Magnetic Island's hillsides. The landslide split at the base of the slope with one part following the creek bed west, and the other progressing straight ahead. Sand and boulders were deposited in and around the buildings of the Magnetic Island International Resort. Three buildings at the resort were destroyed as a result. Fortunately no one was injured, however, the area was scattered with boulders (up to several metres in diameter), sand, mud, and wreckage.

Cradle Mountain National Park – Tasmania, 18 February 2001

Four people died and fourteen people were injured when the soft shoulder of Dove Lake Road gave way under the weight of a stationary bus as it edged to the side of the road to make way for an oncoming vehicle. The bus plunged into a ravine below.

Binalong Bay – North East Tasmania, 7 January 2005

An ABC News article reported that an 18 year old man was buried under two metres of sand at Cosy Corner campsite after the hole he had been digging caved in. He was unable to breathe for about 10 minutes due to the compression of sand against his chest. It took almost an hour to rescue him because the sand kept caving in as people attempted to dig him out. He was lucky to survive; a number of people in Australia have died in similar sand cave-ins.

Somersby – Central Coast, New South Wales, 8 June 2007

A part of the Old Pacific Highway collapsed at Piles Creek and resulted in the deaths of five people after their car drove into a 10 metre wide and 30 metre deep gap in the road. The collapse occurred because of corrosion of the steel pipes of a culvert. The soil had eroded and undermined the tarmac of the highway. An inquest revealed that it was known in 1984 that the steel pipes of the culvert were corroding, and that evidence of slumping in the road had been known since 2000.

Yallourn East Field Mine – Victoria, 14 November 2007

Yallourn East Field Mine is an open cut coal mine. The landslide occurred on a steep slope 80 metres high and 500 long in the middle of the night. The landslide contained approximately six million cubic metres of coal and soil and travelled over 500 metres. As a result of the slope failure, the Latrobe River flooded into the mine. The main cause for the devastation was water pressure in joints in the coal block and in the clays underlying the coal. Increased water pressure thus reduced the resistance that had previously prevented the block of coal from sliding along its base. The loss of coal supplies from the mine forced the Yallourn Power Station to reduce electricity generation.

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http://www.ga.gov.au/education

GLOSSARY

Bedding plane: Line parallel to the surface of deposition of sedimentary rocks which was usually horizontal.

Creep: Very slow movement of soil at the surface, caused by the expansion or shrinking of soil (usually clay soils). Freezing or thawing of water in the soil, or salt crystallisation can also cause the slow movement of soil. Other causes of creep may relate to animal burrowing or trampling, plant-root penetration, or tree collapse. Gravity helps to move the material down the slope.

Debris avalanche: These are debris and mud flows of catastrophic proportions. The high speed of debris avalanches is due to a cushion of air below the debris which assists the flow to travel like a hovercraft.

Debris flow: Water is a major constituent of a debris flow. It is like a flash flood with more solid material. Giant boulders can be carried along in a torrent of very wet mud.

Fall (rock fall): Relatively free falling segments of rock of any size. The rocks can fall from cliffs, steep slopes, caves, or arches.

Freeze-thaw: A form of weathering where water seeps into cracks in a rock, then freezes and expands causing the crack to grow bigger.

Landslide (mass movement): The movement of a mass of soil, rock, debris, or mud which usually occurs on a steep slope due to the pull of gravity.

Mud flow: Water is a major constituent in a mud flow. Very small clay sediments are carried in the moving water. The unconsolidated sediments behave like a liquid when there is excess water.

Regolith: Literally means 'rock blanket'. It is weathered material (loose particles of rock fragments, eruptive volcanic material, soil, blown sand, gasses, and water) which rests above solid rock.

Rock mechanics: The study of the physical properties of rocks, especially those properties that affect the rocks ability to support a load.

Slump: Occur when the landslide moves on a curved surface, rather than a flat bedding plane.

Slurry: A mixture of water and an insoluble solid material, such as clay or cement.

Soil mechanics: The study of the physical properties of soils especially those properties that affect the soils ability to support a load.

Landslides

STUDENT ACTIVITIES

STUDENT ACTIVITIES

LANDSLIDE COMPREHENSION (THREE-LEVEL GUIDE)

Recommended Age: Upper primary to secondary

Instructions

Read "The Nature of Landslides" pages 2-4. Now that you have read the text, look at the following statements. Put a tick in the last column if you agree with the statement. List some words or phrases from the text that support your answer, and record the number of the section of text that contains your evidence. The first line has been completed for you.

Level l: Literal Level

Answer the following questions finding the evidence from the text and recording the key facts.

Question Number	Statement	Section Number	Key Facts/ Evidence	Agree
Example:	There have been more deaths caused by earthquakes than landslides in Australia.	2	15 people have died from earthquakes versus at least 110 deaths caused by landslides.	✓
1.	All landslides travel fast.			
2.	Earthquakes can cause landslides.			
3.	Heavy rainfall is not a cause of landslides.			
4.	The distance travelled by landslides is usually the same – usually about 500 metres.			
5.	Up until 2010 the worst landslide disaster in Australia occurred at Thredbo in NSW.			

Level 2: Interpretative Level

Read these statements. Does the text give you these ideas?
What words and phrases from the text support your answer?

Question Number	Statement	Section Number/s	Key Facts/ Evidence	Agree
6.	All ledges on cliffs are equally stable.			
7.	Children at the beach should never dig into high sand cliffs.			

Level 3: Applied Statements

Read the following opinions and think about them,helped by your new knowledge about landslides. Then write your personal response to the statement. You can include quotes from the text, or draw on your own experience in your answer.

Possible ways to begin a response:

This connects to my life in this way…

I wonder…

This is important because…

I don't understand _____ because ______ .

Question Number	Statement	Justification/discussion	Agree
8.	In heavy rain a tour guide instructs a group of holiday makers to shelter under the base of a cliff which collapses killing four people. The tour operator should have known better.		
9.	A visiting geologist stands on a forested hillside. Some of the trees have fallen or are tilted down hill. He says that this land should not be built on because it is too unstable. He has given good advice.		
10.	A house built on flat land on a valley floor is safe from landslides.		

SLIPPERY SLOPES = RISKY BUSINESS

Recommended Age: Lower secondary

Building on a slope can be a risky business. Before beginning to build, scientists, engineers and architects must test and measure how stable the slope is. Buildings and roads can weaken the stability of a slope.

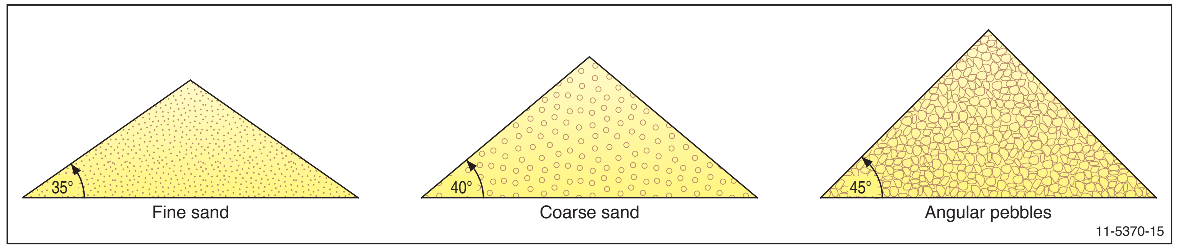
If material is excavated from the bottom of the slope in the process of building a road or house, the chance of a landslide event increases. This is also the case when the top of a slope is loaded down by a new house or material and the slope is unable to support the additional weight.

Nevertheless, preventative measures can be taken to reduce the risk of landslides. For example, the side/s of an excavation or road cut can be strengthened by retaining walls, concrete or gabions (hard rock fragments in a wire basket good for stabilising cut slopes). Additionally, installing good drainage and reducing the angle of the cut slope to make it less steep can help prevent a potential disaster.

The angles of slopes are measured when assessing the risk of landslides. Different materials naturally rest at different angles. For example, fine sand sits at about 35 degrees but sharp, pointy pebbles are stable at a steeper angle of 45 degrees. This means that it would be dangerous to build on sand that was at 40 degrees, but if the material was pointy pebbles, it would be safe to build here.

Local authorities are responsible for assessing construction sites. These assessments then effect the strictness of the building requirements. For instance, the riskier a slope is to build on, the stricter the building requirements need to be.

Even so, figuring out risk ratings is a costly and time consuming task and often ratings may not be entirely accurate. One must first explore the soil type, vegetation, land use and weather conditions before calculating the risk.



Precautions when building on a risky slope

Using the words below copy and complete the following sentences:

drainage	excavate	stabilise	friction	vegetation

1. **When benching (cutting) into the slope, you may need to ___________ the cut slope.**
2. **Provide good ___________ to direct water away from the site.**
3. **___________ existing soil and replace it with granular rock pieces which offer better ___________ and drainage.**
4. **Keep ___________ whose root system will stabilise the slope.**

Complete ONE of the following as a paragraph in your book:

a) Understanding the dangers of landslides is important because …

b) After reading about landslides, I'm wondering …

c) The story about landslides reminds me of …

CAN YOU OUTRUN A LANDSLIDE?

Recommended Age: Lower secondary

Can you outrun a landslide? How about a rockfall? You will find out in this activity!

First of all, find out how fast you can sprint 100 metres. To do this, use a stopwatch to time how many seconds it takes you to run 100 metres, then use the following equation:

$$\text{speed} = \frac{\text{distance}}{\text{time}}$$

For example, if Cathy Freeman runs 100 metres in 11.24 seconds, her sprinting speed is:

$$\frac{100}{11.24} = 8.9 \text{ m/s}$$

Repeat your measurement three times, and record the numbers in a table.

Distance (m)	Time (s)	Speed (m/s)

1. Calculate your average sprinting speed over 100 metres.

2. a) Using your answer from question 1, estimate how long it would take you to run 500 metres.

b) Describe how you made your estimate.

Now, work out if you could outrun landslides in each of the given scenarios.
Show all of your workings.

Scenario 1

Watch out! A mud flow (called a 'lahar' in Indonesian) caused by a volcanic eruption is heading your way! It is 50 metres upslope from where you are standing and travelling at 100km/h! You can run at 2 metres per second. Will you outrun it?

First step: How fast is 100 km/h in m/s? (Remember there are 1000 metres in 1 kilometre, and 3600 seconds in 1 hour).

$$1\text{km/h} = \frac{1\text{km}}{1\text{h}} = \frac{1000\text{m}}{3600\text{s}}$$

Second step: Fill in the table showing how far you and the mud will travel over time.

	0 seconds	1 s	10 s	20 s	30 s
You (2 m/s)	0 metres				
Mud (__m/s)	0 metres				834

Third step: Remember that the mud started 50 metres behind you, so now subtract 50m from each of the figures for distance for the mudslide.

	0 seconds	1 s	10 s	20 s	30 s
You (2 m/s)	0 metres				
Mud (corrected)	-50 metres				834

Fourth step: Using graph paper, draw up axes. Put distance (m) on the y-axis using a range of -100m to 800m. Put time (s) on the x-axis. Plot the data for how far you run in 30 seconds.
Now plot the data for the mudslide.

Fifth step: Does your line intersect the mudslide line? Y / N
If your answer is yes, how many seconds after you started running did the mudslide catch up with you?

Scenario 2

Oh dear, I think you may be in a spot of trouble! A landslide is heading your way at 0.000576 km/h. You can run at 2 m/s, but it's already 30 metres away from where you're standing. Can you escape?

First step: (Conversion from km/h to m/s.)

Second step:

	0 seconds	1 s	10 s	20 s	30 s
You (2 m/s)	0 metres				
Landslide (__m/s)	0 metres				

Third step:

	0 seconds	1 s	10 s	20 s	30 s
You (2 m/s)	0 metres				
Landslide (corrected)	metres				

Fourth step: Graph the data for you and the landslide. Use the range -40 to 70 (in metres) on the y-axis, and time (in seconds) on the x-axis.

Fifth step: Do your two lines intersect? Do you manage to outrun the landslide?

Scenario 3

Your house has been built on clay which is subject to soil creep. This is putting stress on the footings of the house. Some of the footings rest on the clay while other footings are on hard rock. The clay is creeping at 1 cm/y. A movement of only 5 centimetres may damage your house! You will need to stabilise and strengthen the footings in clay before your house is damaged. How much time do you have to fix your house before it becomes damaged?

VEGETATION MARKERS

Recommended Age: Lower secondary

A local amateur plant collector, Jayne Murek, has sent you a map of an area close to her home. Jayne has marked on this map the position of five different plant species that she has identified. She has also noted that the cliffs in this area have some fresh rock faces, or scars, which she thinks are the result of landslides that have occurred in the past.

From your experience in searching for evidence of landslides you know that some plant species are very quick to colonise the disturbed ground after a landslide, while others are very slow to colonise the new area. In an area close to where Jayne lives, you have recognised that the five plants Jayne has mapped tend to colonise disturbed land in the following order

First to colonise	Tussock grass
	Wattle
	Mallee bush
	Red barked gum
Last to colonise	Native Pine

You also have noticed that over time many species die off and often only the gum trees and wattles survive.

To discover the extent and relative age of possible landslides in Jayne's mapped area follow these steps:

1. **Draw a line on the map which divides those areas which only contain red barked gum and wattles from those areas containing other species. Colour the areas where only red barked gums and wattles are found with a green pencil.**

   How many landslide 'scars' can you recognise from this level of evidence?

2. **Recent landslides will have only tussock grass and wattles growing on the disturbed materials. Draw a line around any area where only these species can be found. Colour this area in with a red pencil.**

   How far from the cliff has the most recent landslide altered the vegetation?

3. **Medium aged landslides will have tussock grass, wattles, mallee bush and red barked gums but no native pines. Find any of these areas which Jayne has marked and colour this area in with an orange pencil.**
   How far from the cliff has the medium-aged landslide altered the vegetation?

4. **The oldest landslides will have all the species growing on them. Find any of these areas which Jayne has marked and colour this area in with a yellow pencil.**

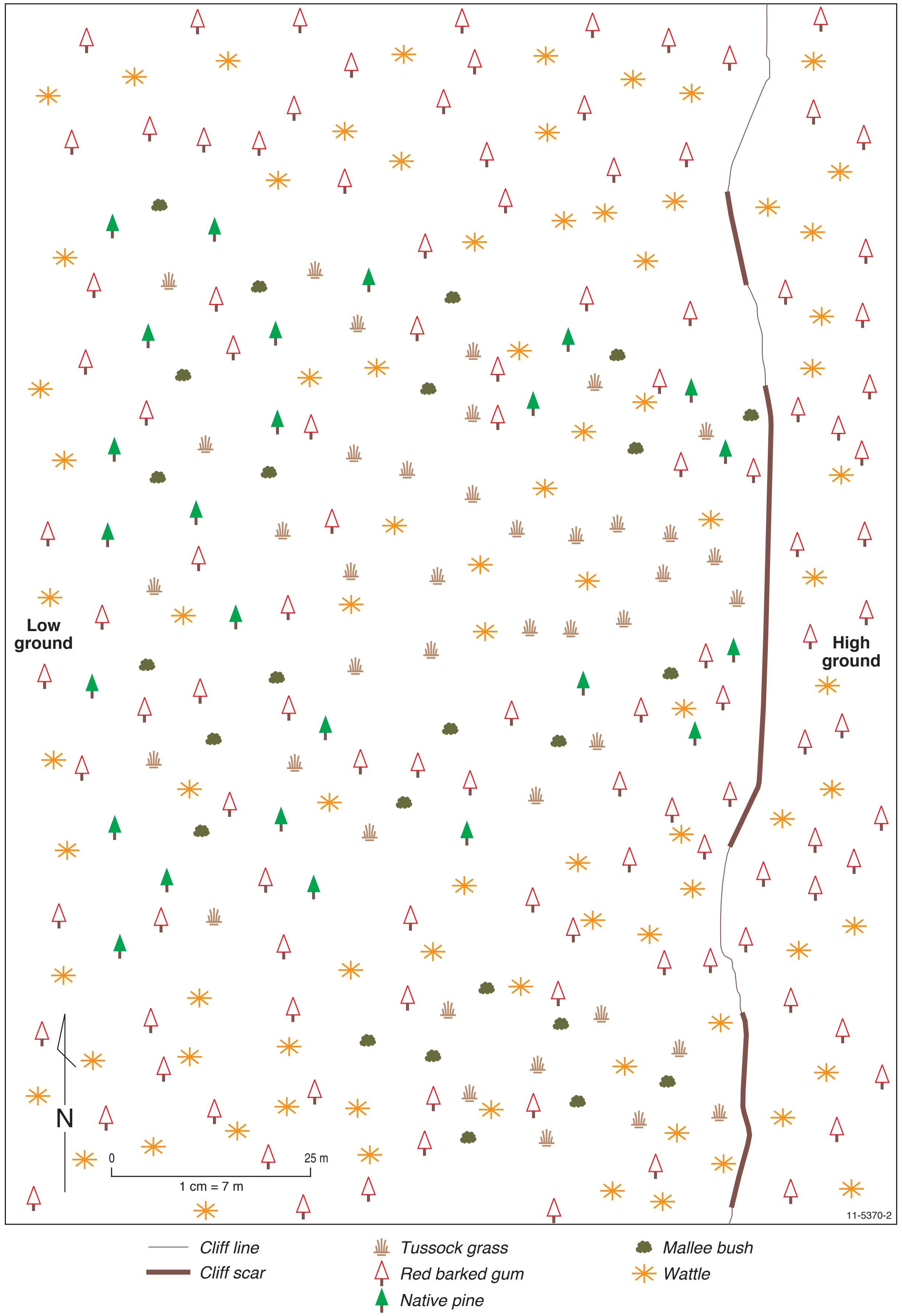
5. **How many landslide scars can you now recognise?**

6. **How far from the cliff has the largest landslide altered the vegetation?**

7. **How many cliff scars can you find which do not appear to have vegetation evidence for a landslide?**

8. **Why do you think that no vegetation evidence can be found here?**

JAYNE'S VEGETATION MAP



LANDSLIDE DEBATE ISSUES

Recommended Age: Upper primary to secondary

In groups debate the following five issues involving landslides. It is important that you justify your responses with a carefully considered argument. That is, you will have to be able to explain your reasons. You will be told whether you are to argue for or against the topic. The first topic suggests some example arguments for both sides. For the other topics you will have to work out the possible arguments for and against each statement.

1. House foundations move — should the council pay?

The council of Bimbdoon advertised, 'A 4 acre block of land in Bimbdoon's picturesque hinterland, with magnificent northerly views over mountains and valleys', in their local newspaper. Mr. and Mrs. Rafelli who were planning to build their dream home were excited about the prospect of living with such magnificent scenery, and therefore bought the land and built on it. After 13 months of living in their house it was discovered that the foundations had moved, resulting in cracking of their walls. To repair the damage to the house it will cost them $30 000. However, even after the house is fixed they have been given no guarantee that the foundations will remain stable.

Should the Council have to pay for the damage to their house?

Arguments For

The council should pay, because they sold a block of land which was unsuitable to build on.

Arguments Against

The Rafellis should have investigated the block of land more thoroughly. If unsure of the stability of the land they should have called geotechnical experts in to assess the site before purchasing the land.

2. Should councils increase funding to ensure all drains are free from blockages?

Phil, a ratepayer in the Mogdon Valley is concerned that the council is not keeping the drains clean enough. Phil suggests that the council make drain cleaning a higher priority in the valley, rather than spending so much time on tree planting. The Mogdon Valley is surrounded by three very steep slopes. Maddie, another ratepayer, wants to see more trees planted to prevent the drains from becoming blocked with sediments that flow off the slopes.

Identify the arguments for and against Phil's view on keeping the drains clean, rather than tree planting.

Should the council make cleaning the drains a higher priority than tree planting?

3. Is farmer Tom to blame?

One day a farmer named Tom decided to clear his land to improve the pasture for his sheep. His property was located at the top of a steep slope above another farmer's property. Paul's land was down slope from Tom's, and was valuable because it included a large dam. However, when Tom cleared his land of vegetation it altered the flow of water in the area. The water, instead of being captured by vegetation and soaking into the soil, flowed down the steep slope onto Paul's property. The change in water flow caused erosion and an undercut to develop on Paul's property.

A year after Tom's property had been cleared of vegetation, the undercut slope crumbled, resulting in a significant landslide. The debris caused significant damage to the dam and Paul is now struggling to provide adequate water for his sheep.

Paul is suing Tom for causing a landslide that has ruined his dam.

First, draw a mind map of your interpretation of the two properties and then work out the arguments for and against Paul's claim.

Should farmer Tom have to pay compensation for damaging farmer Paul's dam?

4. Should councils provide approval for building before a risk map of the area is completed by the government?

Whister and White Constructions Pty Ltd want to build a small housing development on the Great Pinnacles, a sandstone cliff top which has fantastic views of the ocean.

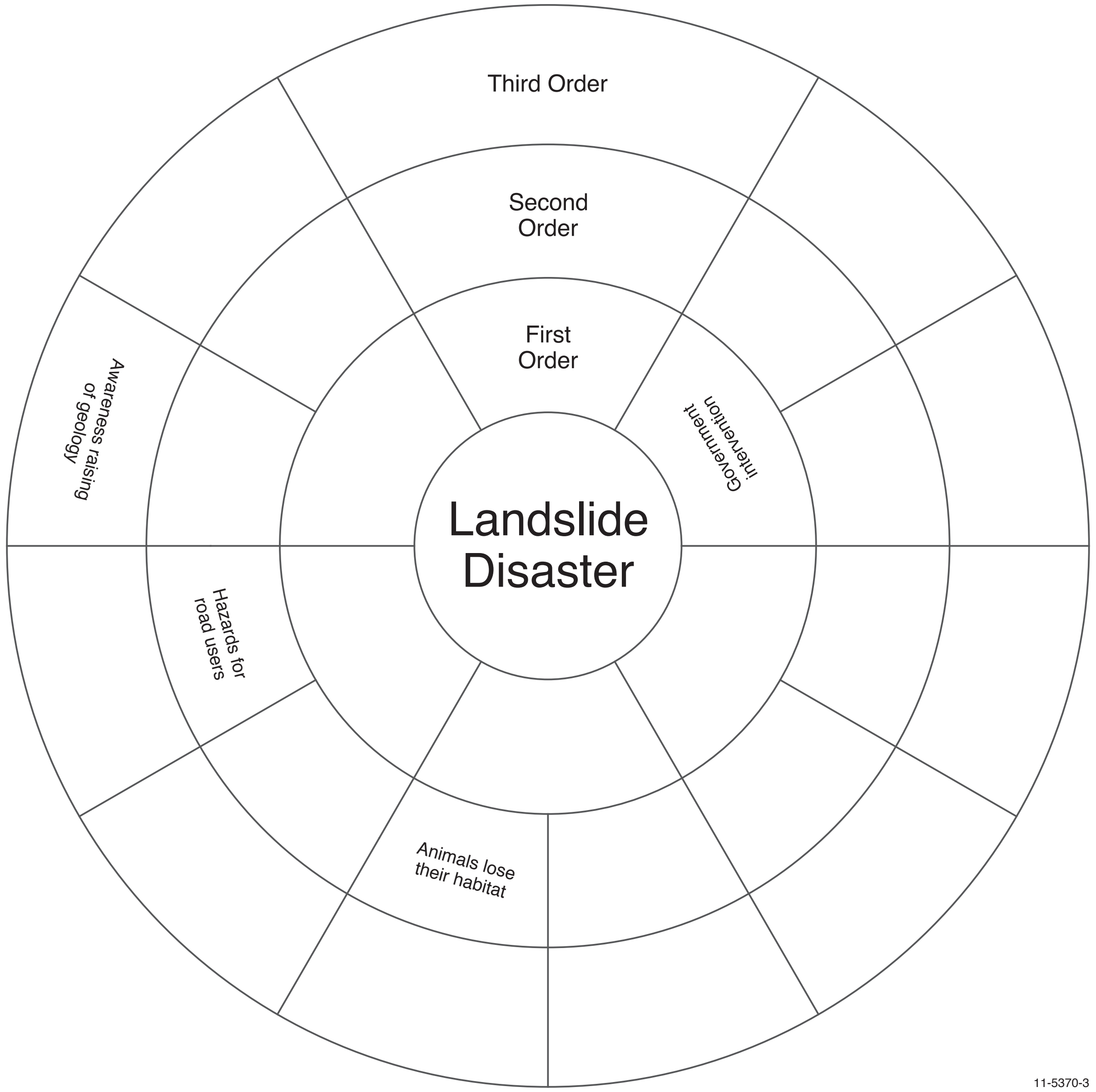
They argue that the area is safe because it has not recorded any natural disasters in the last 50 years. The government agrees that the land would fetch a high price, but insists that no construction can begin until a risk assessment is completed which includes the potential for the cliff to collapse.

Identify the arguments for and against the council granting permission for construction before the risk assessment is completed.

Should the developers have to wait for permission from the council before they can start developing?

LANDSLIDES EFFECTS WHEEL

Recommended Age: Middle to senior secondary



How to use the Landslides Effect Wheel

This circular structure is called an effects wheel. There are three orders or parts to this landslides effects wheel: first order, second order, and third order. You can turn the wheel around so you can read the writing easily.

First order effects: follow immediately from the landslide event.

Second order effects: follow from the first order effects.

Third order effects: follow from the second order effects.

Effects after a landslides disaster

The list below includes first, second and third order effects of a landslide disaster.

- Animals lose their habitat
- Chance of more road accidents
- Cost of damage (generally) not recovered from insurance agencies
- Cost of structural damage estimated
- Engineering and architectural design re-evaluated
- Earth flow
- Emergency Management Plan
- Human lives threatened
- Immediate reduction in animal population size
- Increased traffic on other roads
- Increased danger during rainfall
- Increased turbidity into rivers
- Insurance agencies involved
- Media coverage
- New plant and animal life
- Police guard public safety
- Regeneration of area
- Rescuers search for people
- Road blocked
- Sediments into waterway
- Vegetation lost
- Water redirected

Your task

1. Identify the five first order effects. (One is already provided for you in the wheel).
   Write them into the wheel. For each first order effect there are two second order, and two third order effects. They will all relate to each other.
   Eg [first order] = earth flow. [second order] = sediments in waterways
   [third order] = increased turbidity into rivers.
2. Organise all of these effects into their orders, then fill in the wheel.
3. Analyse the effects of landslides by exploring their social, political, economic and scientific consequences. Do this by grouping the first order effects into social, political, economic and scientific consequences. Write your answers into the table below. For example, Human lives threatened would be a social concern so write 'human lives threatened' under the social column.

   Note: first order effects can have multiple consequences, so may appear in more than one column.

	Social	Political	Economic	Scientific
First Order Effects	Human lives threatened			

GREAT GEOTECHNICAL GADGETS

Recommended Age: Secondary

Writing an article for a local newspaper

You are a highly respected geotechnical expert with experience in landslide processes.

There has been a landslide in a steep region of your local area. The landslide killed two young children and injured three people.

As a geotechnical expert you know that it is too early to speculate because investigations are only just beginning. You have a few hunches though, so you have ordered a range of investigations and studies.

- climate data (including rainfall over a long time)
- collection of soil data
- investigation of underground water courses
- assessment of existing drainage systems
- inspection of the remaining foundations
- use of monitoring devices (inclinometers and piezometers)

Note: **Inclinometers** are instruments which can measure angles. An inclinometer can be used to measure slopes and the movement of soils.
Piezometers are designed to measure fluid pressure. Ground water level and pore pressure can provide valuable information which can be interpreted along with rainfall data, water courses and drainage systems to indicate stability of the ground.

Your task

A journalist wants you, the geotechnical expert, to explain why these investigations are important. You have been asked to write an article for the local newspaper, which explains what may be discovered from the investigations and studies. You may use your own starting/topic sentence or the one below.

"Investigations are beginning, but, it is far too early for me to comment on the cause of this terrible disaster. Let me explain the importance of these investigations…"

OR

Prepare a transcript of an interview between you and the journalist for television or radio to present in front of the class.

OR

Video a television interview between you and the journalist. You may include interviews with members of the community who have been affected by the landslide.

GO BUSH ON SLIDE ISLAND

Recommended Age: Secondary

Brett and Bettina are planning to go bushwalking on Slide Island, a tropical island in the Pacific Ocean. They plan to camp out for about a week. They have heard reports from their friends of all the great spots to see, but they are a little concerned about the risk of rockfalls and landslides in the area. They have a geological map, a topographic map and the monthly rainfall data for Slide Island. Their goal is to get to the top of both Slump Peak and Mt Debris, and to see as much of the island as possible. Help Brett and Bettina to plan their walk, so that they avoid the risk of landslides.

Your tasks

1. Study the topographic and geological maps and the rainfall chart. Then read the reports from their friends.

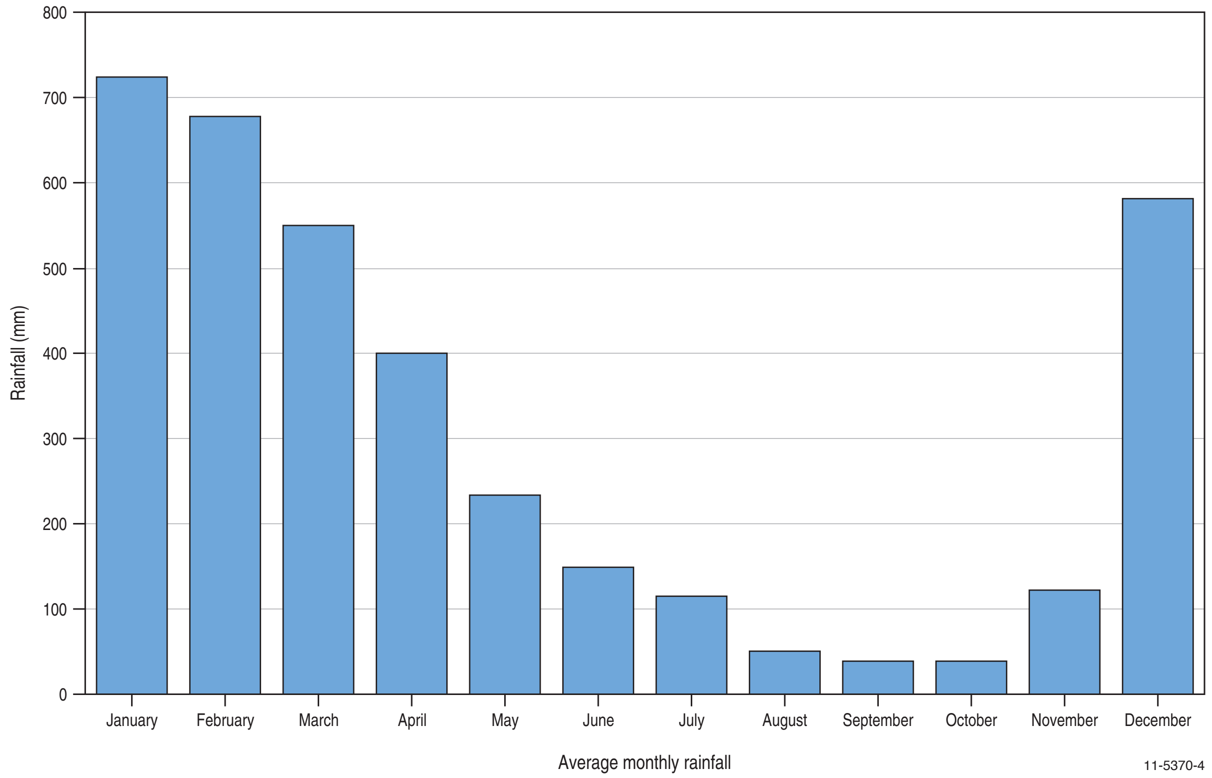
2. Choose the safest month (in terms of landslide risk) for Brett and Bettina to go on their walk.

3. Draw Brett and Bettina's walking route on to the topographic map. Note that they start their walk from the 'drop off point' on the east side of the island.

4. Put crosses on the topographic map where, in your opinion, the places of greatest risk of landslides are located.

5. Write a one page report about why you have chosen this route, and which month you have chosen.

Average Monthly Rainfall for Slide Island



Reports from friends

Before Brett and Bettina went on their bushwalk around Slide Island their friends wrote about various sites they had explored. Brett and Bettina marked these sites out on their topographic map. Recorded below are the comments that their friends made about each location.

Site A

"There are huge big boulders here, some seem to be just balancing on top of each other. It's very eerie here. We wondered if this place was culturally significant to the local inhabitants of the island."

Site B

"A spectacular view of the ocean from here, well worth climbing down the cliffs to sit on some big rocks right next to the ocean."

Site C

"Here we collected some beautiful rocks with big black crystals in them."

Site D

"We had to use ladders to climb to the top of Mt Debris, but the view at the top is worth it."

Site E

"The trees seem to be growing horizontally here!"

Site F

"We saw some lovely orchids here."

Site G

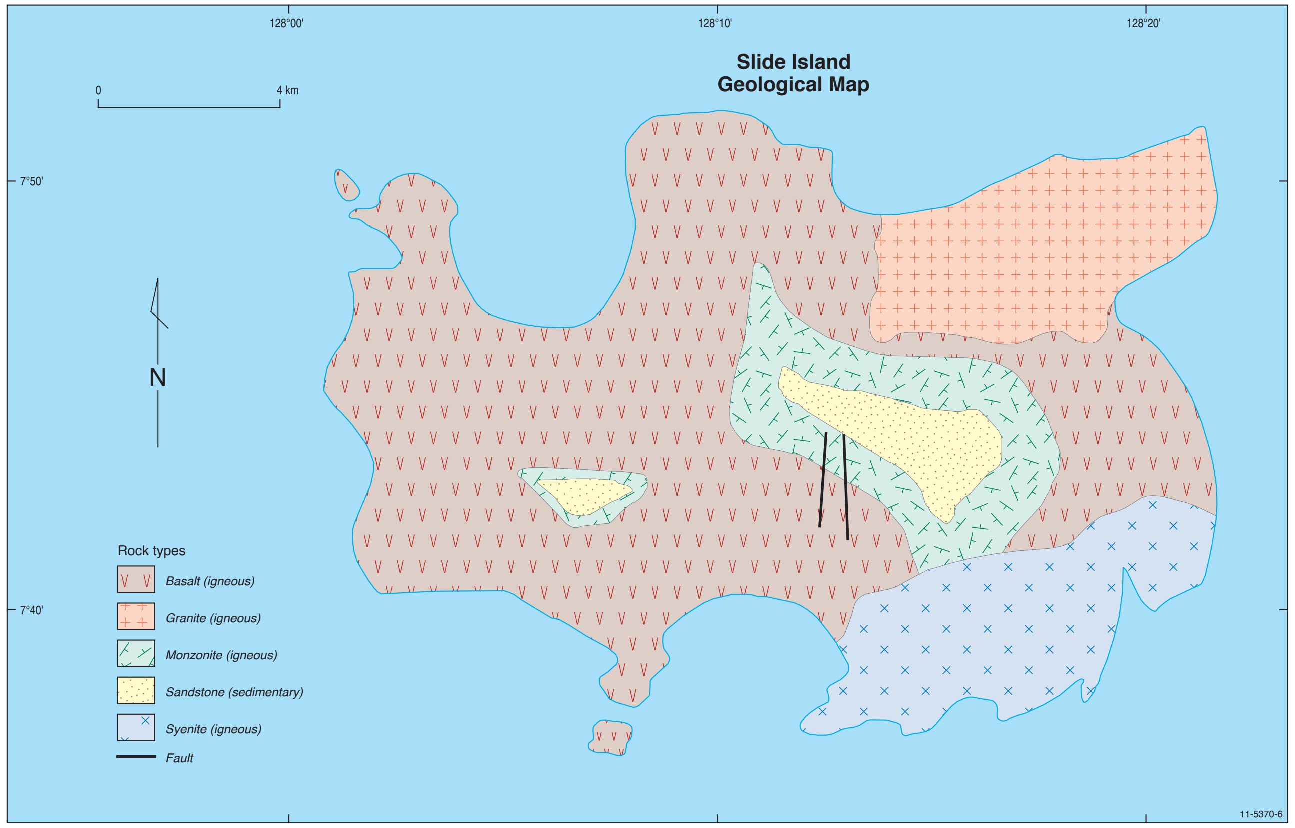
"A very steep climb from here to the top of Slump Peak. There are lots of cracks and joints in the rock."

Site H

"Beautiful white sandy beaches here."

SLIDE ISLAND – TOPOGRAPHIC MAP

SLIDE ISLAND – GEOLOGICAL MAP



RISKVILLE'S NEW HOSPITAL

Recommended Age: Secondary

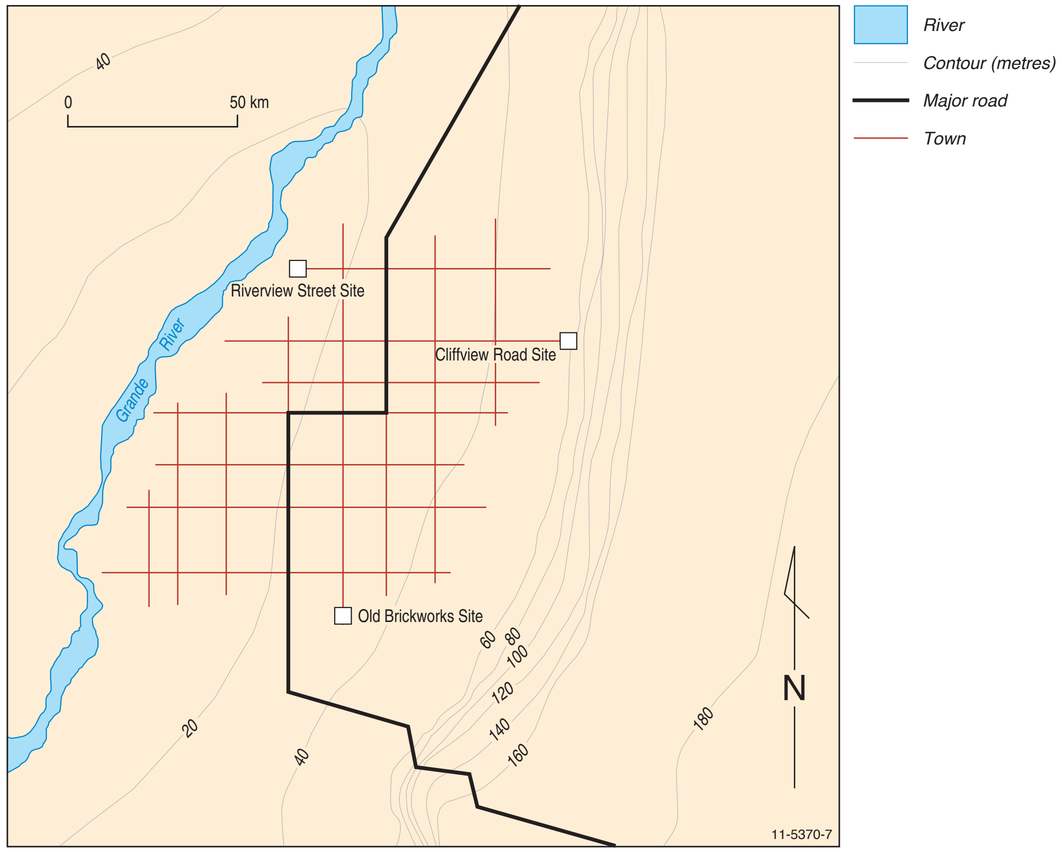
Riskville is a town with a population of 100 000 people, located a few kilometres from the Australian coast. The government has decided to build a new hospital in the town and has asked a number of scientists for information about the area to assist the town planners in deciding on a suitable location.

It is your job, as the landslide expert, to provide advice to the town planners about the landslide risk for the town and where you feel is the best site for the new building. There are three sites available:

1. Riverside Street Site
2. Cliffview Road Site
3. Old Brickworks Site

Below is the town map provided to you by the town planners with their proposed sites. The map also shows the main roads in the town, the topography (shown by contours) and the position of the Grande River.

Topography of Riskville Area

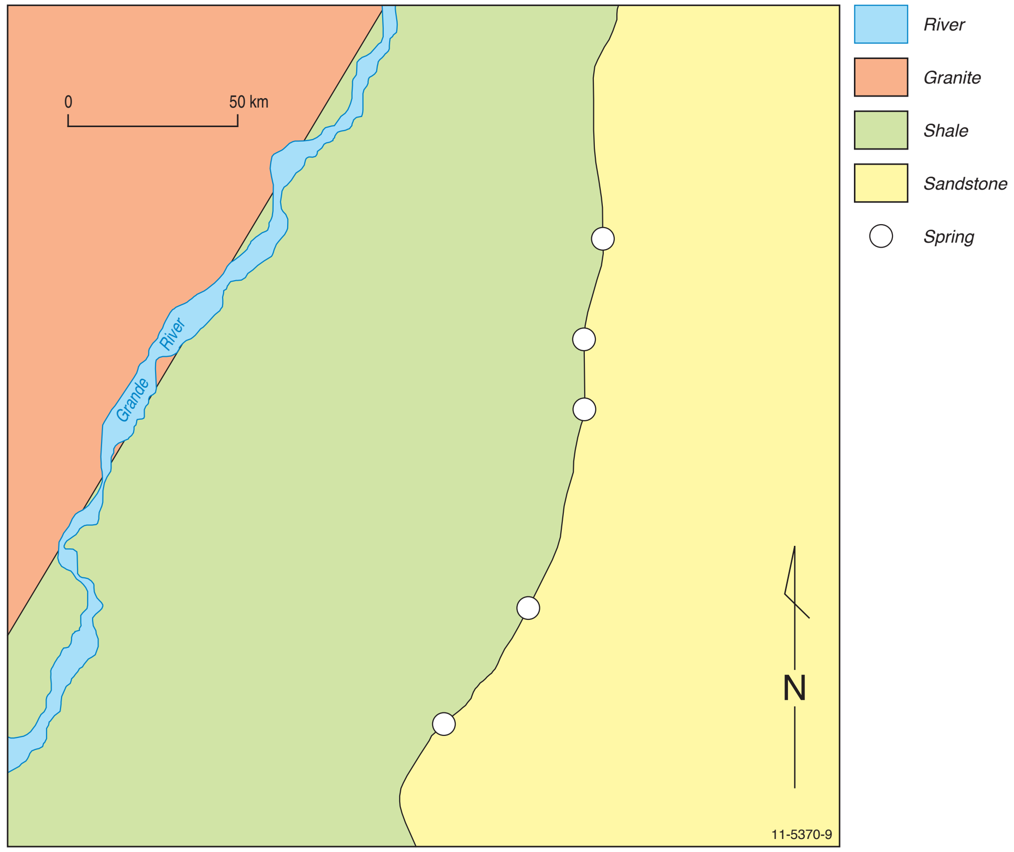


The scientists (a geologist and meteorologist) have each provided information about the town in one page reports. The town planners have asked you to provide them with a map of the town which shows the high landslide risk area.

The main factors in determining landslide risk in this region are rock type, rainfall patterns, groundwater and past landslide history. A high risk area will be one which has 'unstable' geology (for example loose rocks that are lying on top of soil comprised of clay material), numerous groundwater seeps or springs, heavy rainfall and some history of landslides.

GEOLOGIST REPORT

Geology of Riskville Area



Three major rock types outcrop in the Riskville Area.

Sandstone

This rock type makes up the cliffs and the plateau to the east of the town.

This rock type is quite strong. However, it tends to break along joints which can make parts of the cliffs east of Riskville quite unstable.

Shale

Most of Riskville is built on shale which underlies the sandstone. The shale tends to break up into flat sheets. When the shale becomes saturated with water it decomposes to a clay. In some places this clay has been used for making bricks.

A number of permanent springs have formed at the boundary between the sandstone and the shale. Around these springs the shale has completely decomposed and there is evidence for numerous small landslides.

Granite

This rock type is only found to the west of the Grande River. Some tors (rounded boulders) have developed from the granite to the west of the area.

METEROLOGIST REPORT

Rainfall in the Riskville Area

Low Zone

The lowest rainfall zone occurs to the west of the Grande River. This area receives less than 200 millimetres a year and most of this falls in January. The area could be considered as desert.

Medium Zone

This zone occurs between the Grande River and the base of the cliffs to the east of the town. Rainfall in this zone occurs mainly in January-February with smaller falls evenly distributed throughout the year.

High Zone

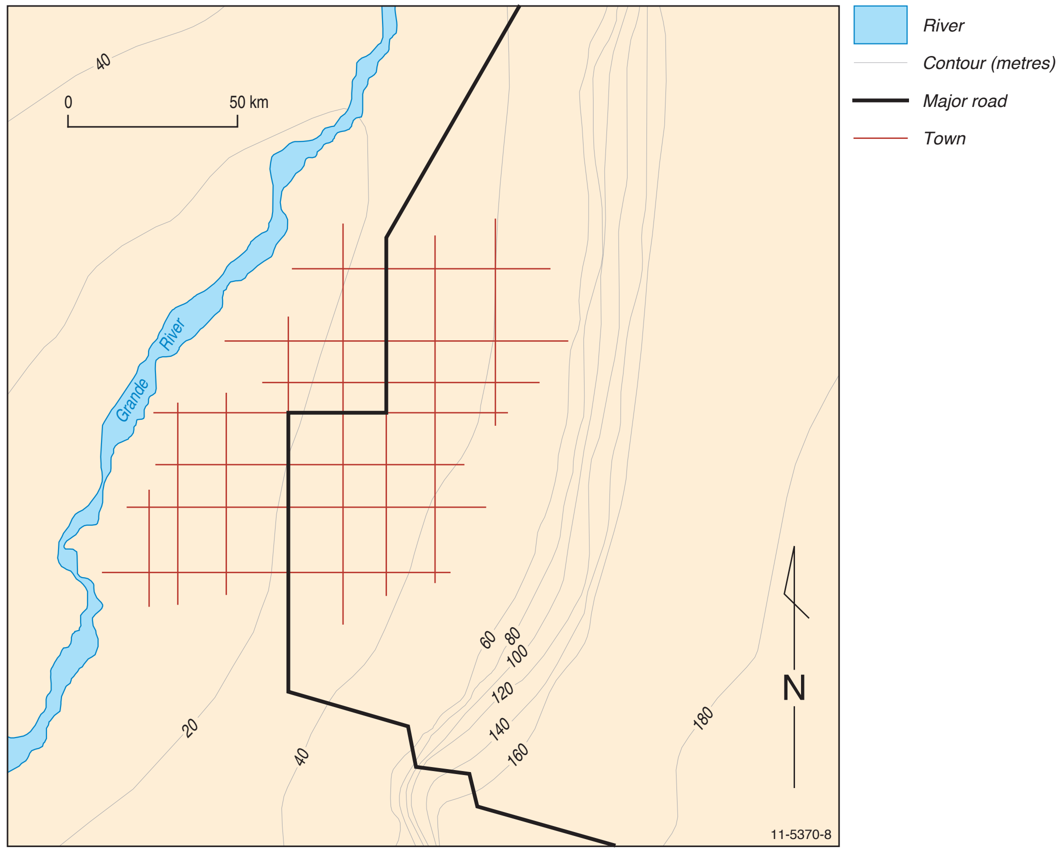
This zone occurs along the cliffs and extends well to the east of the area. The rainfall here is known as orographic rainfall, which is formed as air rises over the cliff, and occurs throughout the year

Flood Season

The Grande River has a flood season in January each year. The flood waters have been known to extended well into Riskville town.

The task

On the map below shade and label the area that you consider to be at highest risk from landslides. This map is the same scale as the other maps so you can place it on top of the other maps to help you.



1. **Based on your landslide risk map, which of the three proposed sites would you suggest would be best for the new hospital and why?**

____

____

____

____

2. **What other hazard factors might the government town planners need to take into consideration when making the final decision?**

____

____

____

____

Landslides

ANSWER SHEETS

LANDSLIDE COMPREHENSION (THREE-LEVEL GUIDE)

Recommended Age: Upper primary to secondary

Instructions

You are to read the background information called 'The Nature of Landslides' (on pages 2 to 4) . Put a tick in the last column if you agree with the statement. Write down the key facts or evidence in the column provided. Write down the number of the section from which you got the facts. Follow the example given.

Level I: Literal Level

Answer the following questions finding the evidence from the text and recording the key facts.

Question No.	Statement	Section Number	Key Facts/ Evidence	Agree
Example	There have been more deaths caused by earthquakes than landslides in Australia.	2	15 people have died from earthquakes versus at least 110 deaths caused by landslides.	
1.	All landslides travel fast.	4	**The speed of landslides vary considerably, such as debris flows that can travel up to 85 km/yr versus creep movement that move extremely slowly at mm/yr.**	
2.	Earthquakes can cause landslides.	3	**Earthquakes can certainly trigger a landslide.**	✓
3.	Heavy rainfall is not a cause of landslides.	3	**Heavy rainfall can be a contributing factor in a landslide.**	
4.	The distance travelled by landslides is usually the same - about 500 metres.	5	**In a landslide the land can move from a short distance (centimetres) to an extremely long distance (kilometres).**	
5.	Up until 2010 the worst landslide disaster in Australia occurred in NSW.	2	**18 people were killed in Thredbo disaster in NSW on 30 July 1997.**	

Level 2: Interpretative Level

Use the information within the text to make your decision, that is interpret the information given. The answers may not be obvious. Record your key facts or evidence and section number or numbers in the appropriate column.

Question No.	Statement	Section Number/s	Key Facts/ Evidence	Agree
6.	All ledges on cliffs are equally stable.	4 & 8	**Some rock types are more as susceptible to landslides than other rock types. Materials are also often weakened by weathering.**	
7.	Children at the beach should never dig into high sand cliffs.	8	**It is true that there is safety risks involved digging into the side of sand cliffs. Sands can collapse readily when trenches and holes are dug into them. For example, at Binalong Bay.**	✓

Level 3: Applied Statements

Read the following opinions and think about them, helped by your new knowledge on landslides. Now write your personal response to the statement. You can include quotes from the text, or draw on your own experience in your answer.

Possible ways to begin a response:

This connects to my life in this way…
I wonder …
This is important because …
I don't understand _______ because _______

Question No.	Statement	Justification or Discussion
8.	A tour guide instructs a group of holiday makers to shelter under the base of a cliff which collapses killing four people. The tour operator should have known better.	**It may be unsafe to sit at the bottom of a cliff, especially if there is evidence of fallen debris. There would be less chance of a group being injured if they were to take shelter in a building rather than under a cliff.**
9.	A visiting geologist stands on a forested hillside. Some of the trees have fallen and are tilted down hill. He says that this land should not be built on because it could have a serious landslide. He has given good advice.	**Yes – observing trees tilting down the slope is usually evidence of a previous landslide or creep.**
10.	A house built on flat land on a valley floor is safe from landslides.	**No, because there may be a landslide risk on or near the mountain and the run-off may flow through the valley.**

SLIPPERY SLOPES = RISKY BUSINESS

Recommended Age: Upper primary

Building on a slope can be a risky business. Before beginning to build, scientists, engineers and architects must test and measure how stable the slope is. Buildings and roads can weaken the stability of a slope.

If material is excavated from the bottom of the slope in the process of building a road or house, the chance of a landslide event increases. This is also the case when the top of a slope is loaded down by a new house or material and the slope is unable to support the additional weight.

Nevertheless, preventative measures can be taken to reduce the risk of landslides. For example, the side/s of an excavation or road cut can be strengthened by retaining walls, concrete or gabions (hard rock fragments in a wire basket good for stabilising cut slopes). Additionally, installing good drainage and reducing the angle of the cut slope to make it less steep can help prevent a potential disaster.

The angles of slopes are measured when assessing the risk of landslides. Different materials naturally rest at different angles. For example, fine sand sits at about 35 degrees but sharp, pointy pebbles are stable at a steeper angle of 45 degrees. This means that it would be dangerous to build on sand that was at 40 degrees, but if the material was pointy pebbles, it would be safe to build here.

Local authorities are responsible for assessing construction sites. These assessments then effect the strictness of the building requirements. For instance, the riskier a slope is to build on the stricter the building requirements need to be.

Even so, figuring out risk ratings is a costly and time consuming task and often ratings may not be entirely accurate. One must first explore the soil type, vegetation, land use and weather conditions before calculating the risk

Precautions when building on a risky slope

Using the words below copy and complete the following sentences: drainage, excavate, stabilise, friction, vegetation

When benching (cutting) into the slope, you may need to **stabilise** the cut slope.

Provide good **drainage** to direct water away from the site.

Excavate existing soil and replace it with granular (pointy) rock pieces which offer better **friction** and drainage.

Keep **vegetation** whose root system will stabilise the slope.

Complete ONE of the following as a paragraph in your book:

a) Understanding the dangers of landslides is important because …

b) After reading about landslides, I'm wondering …

c) The story about landslides reminds me of …

CAN YOU OUTRUN A LANDSLIDE?

Recommended Age: Lower secondary

Please show all workings!

Scenario 1

Watch out! A mud flow ("called a 'lahar' in Indonesian) caused by a volcanic eruption is heading your way! It is 50 metres upslope from where you are standing and travelling at 100km/h. Will you outrun it?

First step: = so multiply km/h by 1000, and divide by 3600 to obtain the result in $1\text{km/h} = \frac{1\text{km}}{1\text{h}} = \frac{1000\text{m}}{3600\text{s}}$ m/s

$$\frac{\text{km}}{\text{h}} \div \frac{\text{min}}{\text{h}} \div \frac{\text{s}}{\text{min}} \times \frac{\text{m}}{\text{km}}$$

$$\therefore \frac{\text{km}}{\text{h}} \times \frac{\text{h}}{\text{min}} \times \frac{\text{min}}{\text{s}} \times \frac{\text{m}}{\text{km}}$$

$\therefore$ m/s

Answer: 27.8 m/s

Second step: Draw a table showing how far you, and the mud, will have travelled over time.

	0 seconds	1 s	10 s	20 s	30 s
You (2 m/s)	0 metres	2	20	40	60
Landslide (27.8m/s)	0 metres	27.8	278	556	834

Third step: Remember that the mud started 50 metres behind you, so now subtract 50m from each of the figures for distance for the mud.

	0 seconds	1 s	10 s	20 s	30 s
You (2 m/s)	0 metres	2	20	40	60
Landslide (corrected)	-50 metres	-22.2	228	506	784

Fourth step: (Graph)

Fifth step: The two lines intercept after two seconds of running, when you have only run four metres. You didn't succeed in outrunning the mudslide.

Scenario 2

First step: so multiply km/h by 1000, and divide by 3600 to obtain the result in m/s.

0.000576km/h ÷ 60 min/h ÷ 60s/min x 1000 m/km = 0.00016 m/s

$$\frac{\text{km}}{\text{h}} \div \frac{\text{min}}{\text{h}} \div \frac{\text{s}}{\text{min}} \times \frac{\text{m}}{\text{km}}$$

$$\therefore \frac{\text{km}}{\text{h}} \times \frac{\text{h}}{\text{min}} : \frac{\text{min}}{\text{s}} \times \frac{\text{m}}{\text{km}}$$

$\therefore$ m/s

Second step:

	0 seconds	1 s	10 s	20 s	30 s
You (2 m/s)	0 metres	2	20	40	60
Mud (__m/s)	0 metres	0.00016	0.0016	0.0032	0.0048

Third step:

	0 seconds	1 s	10 s	20 s	30 s
You (2 m/s)	0 metres	2	20	40	60
Landslide (__m/s)	-30 metres	-29.9998	-29.9984	-29.9968	-29.9952

Third step: Yes, you easily outrun the landslide.

Scenario 3

At a speed of 1 centimetre every year, you have five years to fix your house. After five years, the ground will have moved five centimetres, which is the amount needed to do serious damage to your house.

VEGETATION MARKERS

Recommended Age: Lower secondary

A local amateur plant collector, Jayne Murek, has sent you a map of an area close to her home. Jayne has marked on this map the position of five different plant species that she has identified. She has also noted that the cliffs in this area have some fresh rock faces, or scars, which she thinks are the result of landslides that have occurred in the past.

From your experience in searching for evidence of landslides you know that some plant species are very quick to colonise the disturbed ground after a landslide while others are very slow to colonise the new area. In an area close to where Jayne lives, you have recognised that the five plants Jayne has mapped tend to colonise disturbed land in the following order

First to colonise	Tussock grass
	Wattle
	Mallee bush
	Red barked gum
Last to colonise	Native Pine

You also have noticed that over time many species die off and often only the gum trees and wattles survive.

JAYNE'S VEGETATION MAP

To discover the extent and relative age of possible landslides in Jayne's mapped area follow these steps:

1. Draw a line on the map which divides those areas which only contain red barked gum and wattles from those areas containing other species.

How many landslide 'scars' can you recognise from this level of evidence?
There is evidence for two landslides.

2. Colour the areas where only red barked gums and wattles are found with a green pencil. Recent landslides will have only tussock grass and wattles growing on their recently disturbed materials. Then draw a line around any areas which Jayne has marked that only these species can be found. Colour this area in with a **red** pencil.

How far from the cliff has the landslide altered the vegetation?
Approximately 55 metres

3. Medium aged landslides will have tussock grass, wattles, mallee bush and red barked gums but no native pines. Find any of these areas which Jayne has marked and colour this area in with an orange pencil.

How far from the cliff has the landslide altered the vegetation? **Approximately 50 metres**

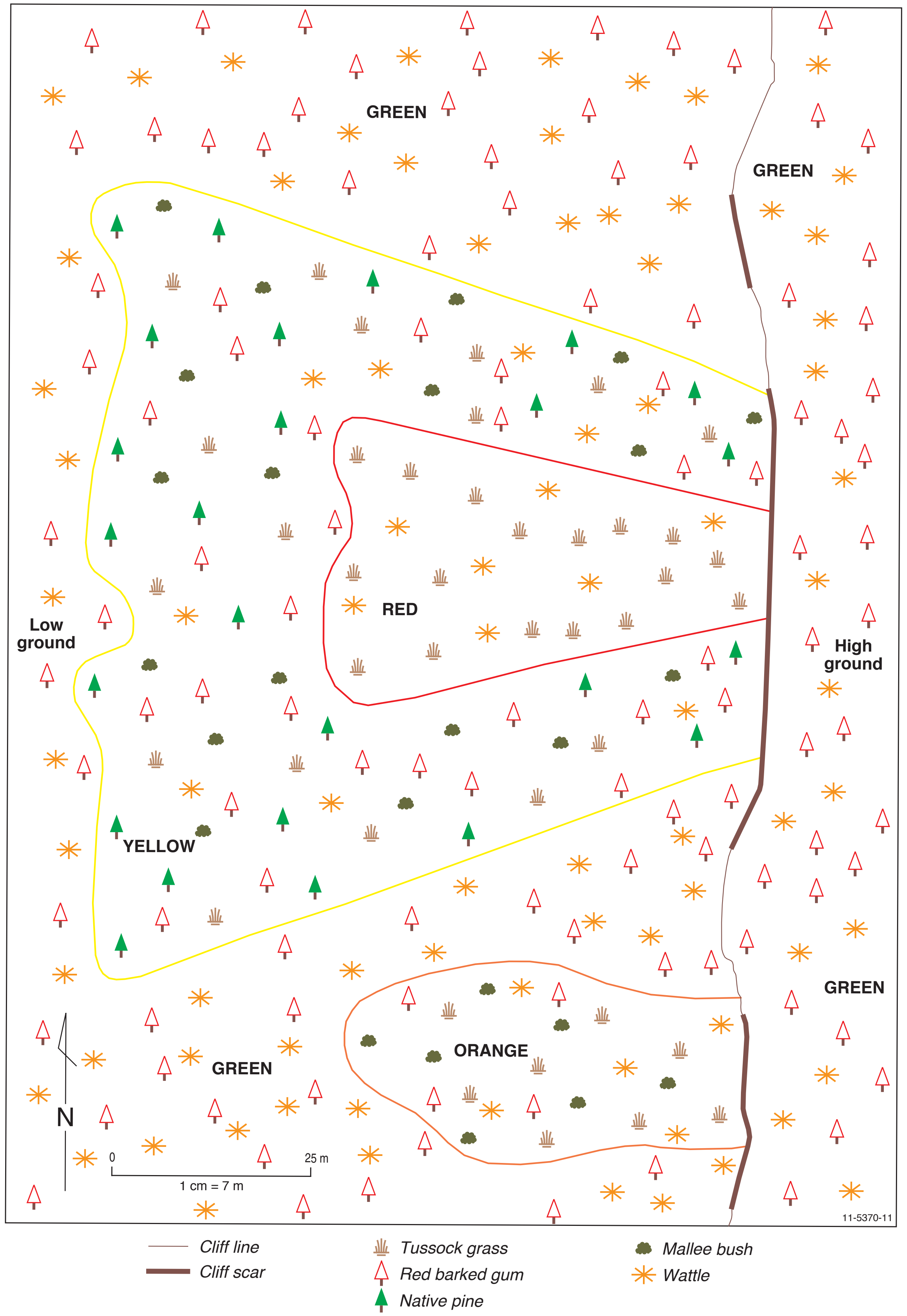
4. The oldest landslides will have all the species growing on them. Find any of these areas which Jayne has marked and colour this area in with a **yellow** pencil.

5. How many landslide scars can you now recognise? **There is evidence for three landslides.**

6. How far from the cliff has the largest landslide altered the vegetation? **Approximately 85 metres.**

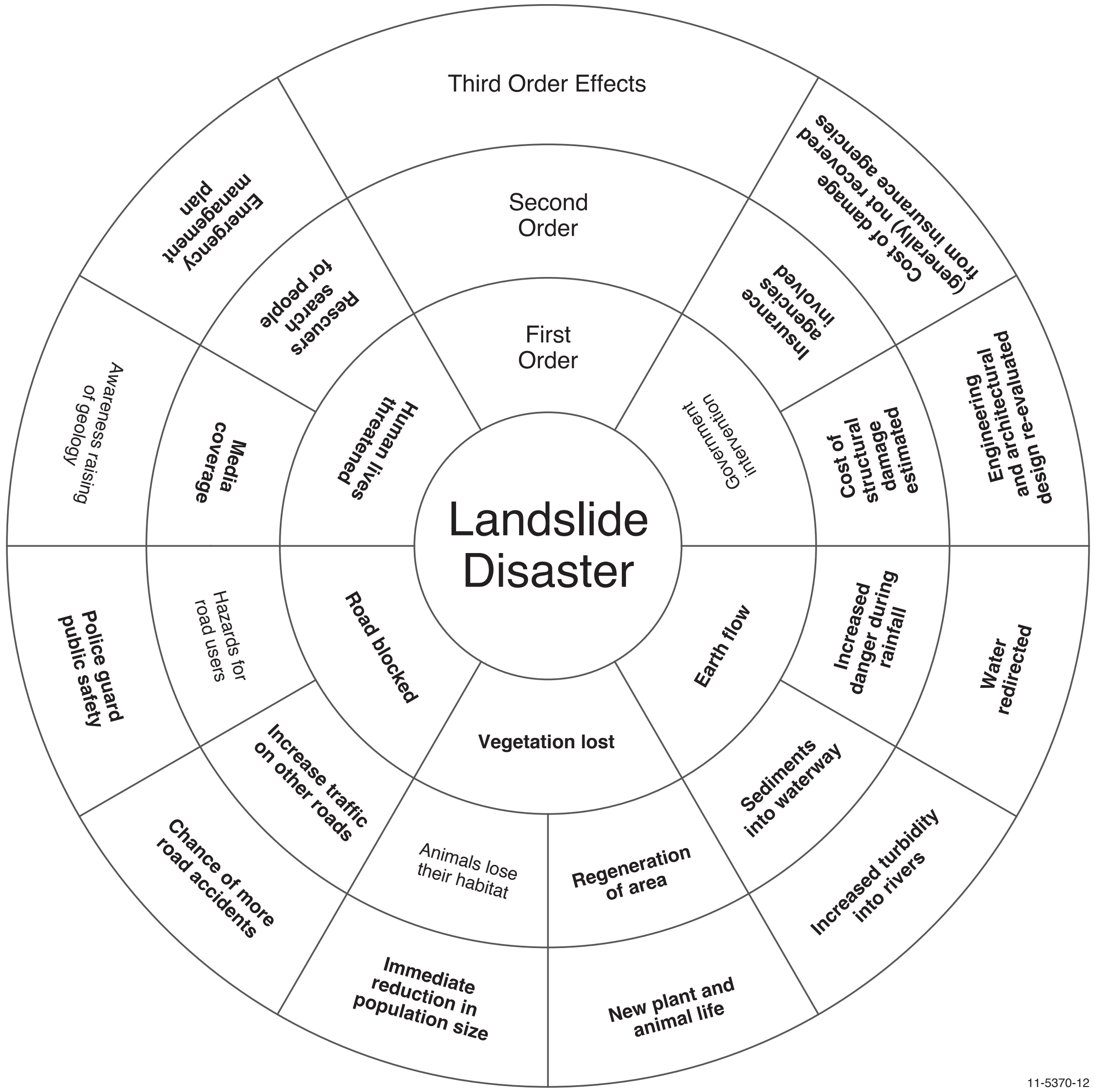
7. How many cliff scars can you find which do not appear to have vegetation evidence for a landslide? **Only one cliff scar has no evidence of a landslide.**

8. Why do you think that no vegetation evidence can be found here? **The landslide which caused the rock scar may be very old and so the vegetation evidence has changed so that it appears the same as the background vegetation, in other words, only wattles and red barked gums. Or, the scar may be the result of a rock fall which had minimal effect on the vegetation.**



LANDSLIDES EFFECTS WHEEL

Recommended Age: Middle to senior secondary



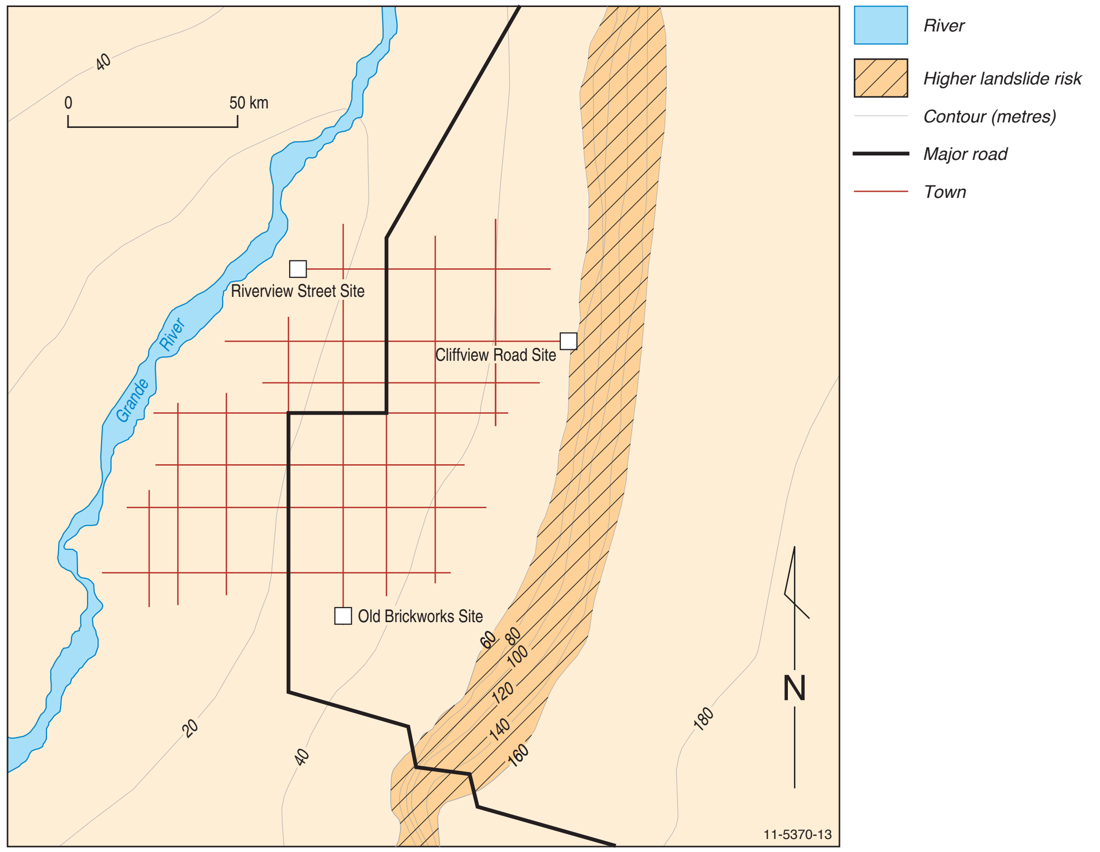
	Social	Political	Economic	Scientific
First Order Effects	Human lives threatened Road blocked	Government intervention	Road blocked	Earth flow Vegetation loss

RISKVILLE'S NEW HOSPITAL

Recommended Age: Secondary

The task

Using the information you have been given, on the map below draw a line around the area that you consider to be at highest risk from landslides in the Riskville area. This map is the same scale as the other maps so you can place it on top of the other maps to help you.



1. **Based on your landslide risk map, which site would you suggest would be best for the new hospital and why?**
   The best site based on landslide risk alone would be the Riverview site. The other two sites are close to steep slopes with springs and consequent landslide risk. Riverview is relatively flat.
2. **What other hazard factors might the government town planners need to take into consideration when making the final decision?**
   If the hospital was built on the Riverview site flood waters could possibly cut off access to the hospital.