



Mornington Peninsula Shire

Flinders Township and Tanti Creek Geotechnical Information Pack

Document 4

Geotechnical assessment for landslip susceptibility and investigation zoning: Flinders
Foreshore Mornington Peninsula, January 2008

LanePiper

Geotechnical & Environmental Engineers
Hydrogeologists & Environmental Scientists

GEOTECHNICAL ASSESSMENT FOR LANDSLIP SUSCEPTIBILITY AND INVESTIGATION ZONING

**FLINDERS FORESHORE
MORNINGTON PENINSULA**

For

**MORNINGTON PENINSULA SHIRE
COUNCIL**

JANUARY 2008

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FLINDERS FORESHORE MORNINGTON PENINSULA

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GEOTECHNICAL ASSESSMENT OF LANDSLIP SUSCEPTIBILITY AND INVESTIGATION ZONING

FLINDERS FORESHORE MORNINGTON PENINSULA

1 INTRODUCTION

At the request of Mr John Ault-Connell of Mornington Peninsula Shire Council in Purchase Order No. 053370 dated 30th May 2007 a limited geotechnical assessment was undertaken to assess the areas of potential landslip and provide landslip susceptibility and investigation zoning of the Flinders Foreshore area. The work was conducted in accordance with our fee proposal 24063-2.0 dated 26th September 2006. The work was slightly delayed whilst waiting for the latest digital terrain model to be completed together with the low-level aerial photography of the Flinders area.

Landslip susceptibility zoning involves the classification, area and spatial distribution of the existing and potential landslips in the study area. Landslide susceptibility zoning usually involves developing an inventory of landslides, which have occurred in the past together with an inventory of areas that have the potential to experience landsliding in the future. No assessment of the frequency of the occurrence of landslides was undertaken nor any assessment of the areas of the debris flow, but an allowance for landslip regression was made.

Due to the lack of definitive geotechnical information or history of movements or landslips in the area, it was decided to limit the assessment to areas of different geotechnical investigation with landslip susceptibility mapping within the study area rather than develop a map of landslide zoning or risk zoning. It is proposed that these assessments would be made for the individual property owners for the proposed development. In some areas within the study area, ancient or active landslides were identified, while in other areas, there was little evidence of landslip despite being steeper with similar geology. A geotechnical investigation may reveal that due to different geotechnical soil profiles such as shallow bedrock or absence of shallow groundwater, there is a tolerable risk to landslip and we were not able to assess this risk with definitive site-specific geotechnical information. This report does not include any assessment of risk to either property or life.

A glossary of the terminology of landslips is included in Appendix D.

The assessment consisted of the following:

- Review of the previous literature
- Review of any further geotechnical reports that the council have in their records
- Further geotechnical inspections and analysis to define the different zones
- Preparation of documentation to support the preparation of an Erosion Management Overlay for inclusion in the Mornington Peninsula Planning Scheme by way of a future Planning Scheme Amendment. The

documentation includes the designation of three investigation areas with specified requirements for geotechnical assessment.

1.1 LIMITATIONS OF THE REPORT

The purpose of this report is to provide a landslide inventory and susceptibility to inform the Council and the public and provide guidance on the level of geotechnical investigation to be conducted. It is not a detailed landslip assessment of individual sites and detailed examination may reveal the potential and susceptibility of landslip may be greater or less than indicated. The report indicates the level of investigation required together with the landslip potential. General limitations of geotechnical investigations are in Appendix G.

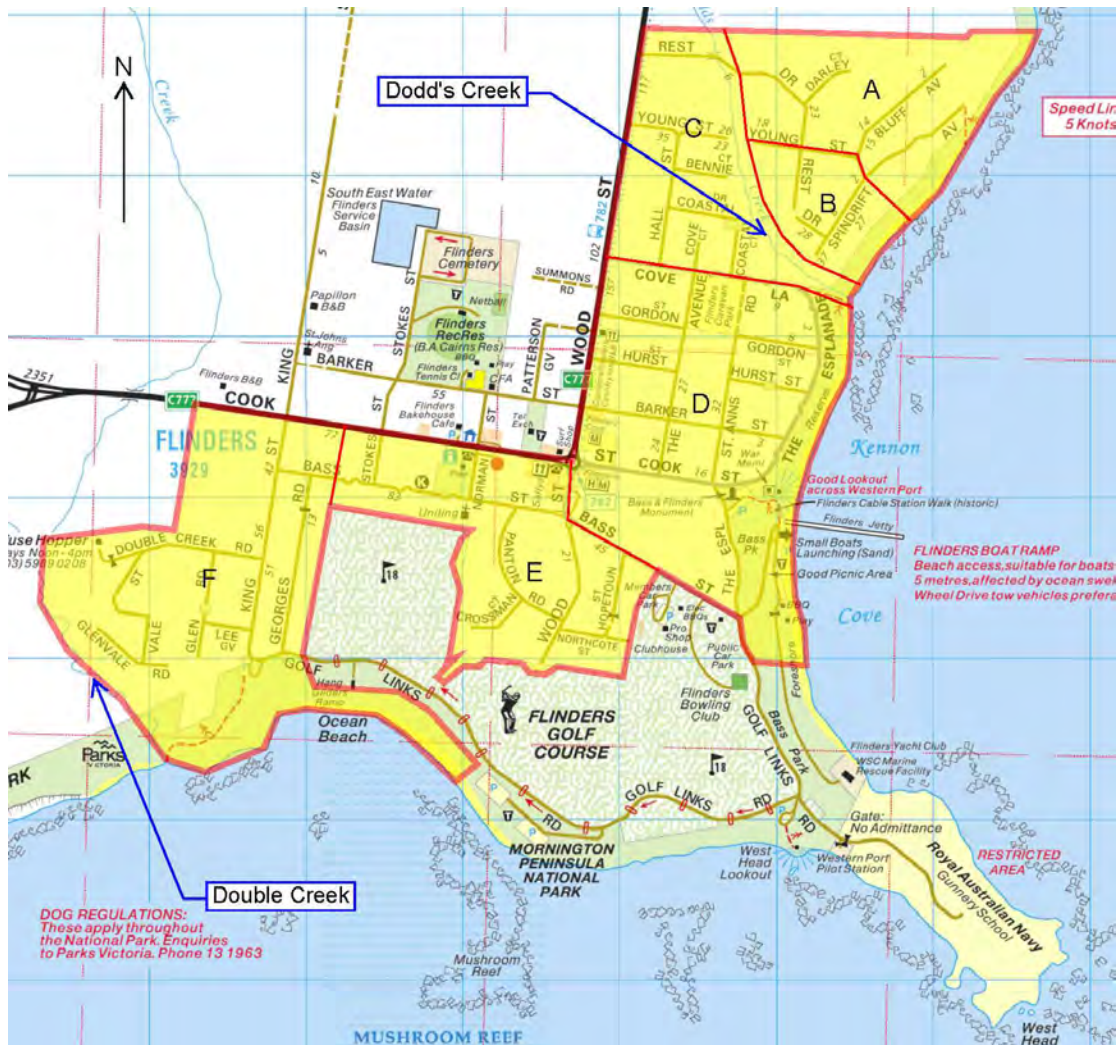
1.2 AREAS ASSESSED

The areas assessed are as follows:

- A. The northern end of Spindrift Avenue, north of its intersection with Young Street
- B. The southern end of Spindrift Avenue, south of the intersection with Young Street
- C. The banks of Dodd's Creek and the area between Dodd's Creek and Wood Street
- D. The area between Wood Street and The Esplanade (including the foreshore) from Cove Lane to Bass Street
- E. The residential area between Cook Street and the golf course
- F. The area to the west of the golf course bounded by Double Creek, Double Creek Road and Cook Street.

The approximate location of the study is shown in Figure 1.1 together with the designated areas A – F.

Figure 1.1: Area of the Study



1.3 REVIEW OF EXISTING INFORMATION

The initial part of the assessment involved the following:

- Review of the geotechnical reports prepared by Piper and Associates and others in the Flinders area
- Review of the geological maps and previous geological reports in the area

2 GEOSPATIAL SURVEY

Geocomp-Suntac Pty. Ltd. as sub-contractors to Lane Piper Pty. Ltd. used computer modeling to create the following:

- A digital terrain model using the data supplied by the Mornington Peninsula Shire Council (MPSC)
- Assign the surface slope and direction values to the DTM triangles

3 PREVIOUS REPORTS

A number of geotechnical and geological reports have been prepared over the years that are applicable to this area, including those as follows (in chronological order):

Golder Moss Associates Pty. Ltd., *Letter report for Residence, 5 Spindrift Avenue, Flinders*, dated 19 December 1974

Lawrence C.E., & Associates (Vic.) Pty. Ltd., *Site Investigation No. 19 Spindrift Avenue, Flinders*, 3 April 1996

A.S. James Pty. Ltd., *Geotechnical Investigation for proposed Residence, Lot 2, Spindrift Avenue, Flinders*, Report No. 80638 dated 27 August 1996.

Dolphin P., *Onsite Observation at 9 Spindrift Avenue, Flinders since 1965*, dated 14 July 1998.

Piper & Associates Pty. Ltd., *Geotechnical Investigation for proposed Cable Station Boardwalk, The Esplanade, Flinders*, Report No. 99011 dated 2 September 1998.

Piper & Associates Pty. Ltd., *Geotechnical and Geological investigation of proposed Street Scheme, Spindrift Avenue, Flinders*, Ref. No. 99005 dated 14 September 1998

Piper & Associates Pty. Ltd., *Geotechnical Assessment of Inclinator Readings, Mt. Eliza, Mt. Martha & Flinders*, Ref. No. 98109 dated 7 March 2001

Piper & Associates Pty. Ltd., *Landslip Movement Measurement Installation of Two Additional Inclinator Readings, Spindrift Avenue, Flinders*, Ref. No. 21109 dated 15 June 2001

Piper & Associates Pty. Ltd., *Geotechnical Review of the Inclinator Readings, Mornington Peninsula Shire*, Job No. 22033 dated 25 July 2001

Piper & Associates Pty. Ltd., *Geotechnical Comments of Lot 2 on Plan of Sub-division, LP222189D, Spindrift Avenue, Flinders*, Ref. No. 22034 dated 26 September 2001

BFP Consultants Pty. Ltd., *3 Spindrift Avenue, Flinders, Geotechnical Investigation*, Job No. 41035 dated September 2002

Piper & Associates Pty. Ltd., *Geotechnical Inspection of the Property, 17 Spindrift Avenue, Flinders*, Ref No. 23016 dated 23 September 2002

Piper & Associates Pty. Ltd., *Extent of Geotechnical Investigation for proposed Dwelling Extensions, 2A Spindrift Avenue, Flinders*, Ref. No. 23105 dated 24 March 2003

A.S. James Pty. Ltd., *Proposed Residential Development, 5 Spindrift Avenue, Flinders*, Report No. 104610Rev2., dated 10 December 2003

A.S. James Pty. Ltd., *Proposed New Residence, 17 Spindrift Avenue, Flinders*, Report No. 104933/A dated 30 March 2004

Connell Wagner Pty. Ltd., *Inclinometer Readings, Spindrift Avenue*, June 2004.

A.S. James Pty. Ltd., *Proposed Residential Development, 5 Spindrift Avenue, Flinders*, Report No. 104610/G1., dated 16 July 2004.

Piper & Associates Pty. Ltd., *Geotechnical Assessment for Landslip Risk, Flinders Foreshore (Draft)*, Report No. 24063/1 dated 9 September 2004.

BFP Consultants, *Geotechnical Investigation for Dodd's Creek Crossing, Flinders*, Job No. 1003384 dated March 2005

Connell Wagner Pty Ltd *Inclinometer Readings, Spindrift Avenue*, June 2004 and June 2005

BFP Consultants Pty. Ltd., *Geotechnical Investigation for Flinders Sewerage Project, Stage 2*, Job No. M6041 dated 7 November 2005.

Piper & Associates Pty. Ltd. *Geotechnical Assessment of the Inclinometer Readings for Mornington Peninsula Shire*, Report No. 24115-1.1 dated 23 December 2005

Piper & Associates Pty. Ltd., *Geotechnical Assessment for Proposed Sewer Construction, Flinders Backlog Sewerage Project*, Report No. 26049-1.2 dated 24 March 2006.

Lane Piper Pty Ltd., *Geotechnical Comments for Underground Power Line, Lot 2A Spindrift Avenue, Flinders*, Ref. No. 27082-Report1.1 dated 15 November 2006

4 AERIAL PHOTOGRAPHS

A copy of the aerial photograph of the area under investigation is shown below in Figure 4.1. The photographs used were part of the 2006-07 survey of the Mornington Peninsula by the Department of Sustainability and Environment *CIP 2006-07 Mornington Peninsula*.

The approximate locations of the different areas assessed are shown on the photograph.

Figure 4.1: Aerial Photograph of the Site (2003)



5 GEOLOGY OF THE FLINDERS AREA

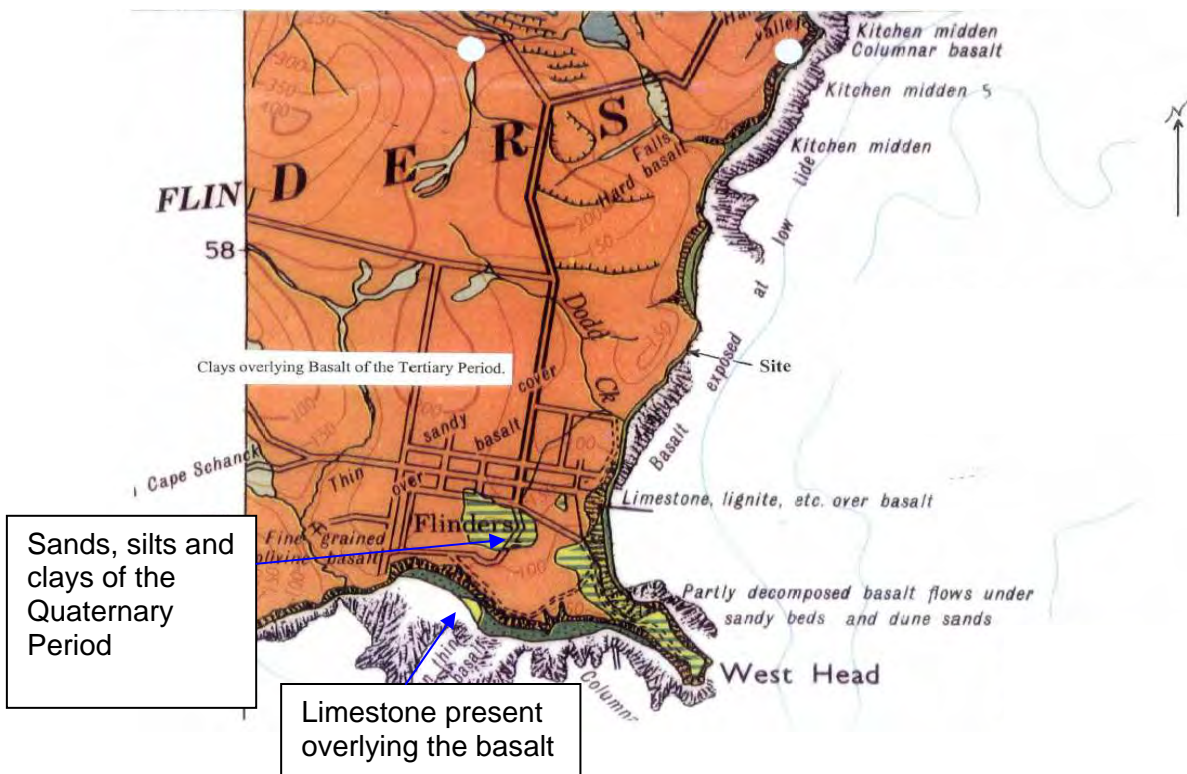
The Western Port 1: 63 360 Geological Survey map (1967) shows basaltic materials of the Lower Tertiary *Older Volcanics* to occur both at the surface and underlying the area being studied, with the words "Thin sandy cover over basalt" recorded on the map in the Flinders township area. A narrow beach of (quartz) sand is shown fringing the basaltic coastal cliffs, with basalt below the beach exposed at low tide. Neither the map nor the related Geological Survey Memoir 17 on the Mornington Peninsula (Keble, 1950) give any data on the degree of weathering of the basalt.

At the southern end of Flinders within the cliff faces, there is the presence of limestone breccia overlying the basalt rock and underlying basaltic clays.

There are two areas of silts, sands and clays of the Quaternary Period, probably alluvium overlying the Tertiary Basalt at the southern end of Flinders.

The geological map of the area is shown below in Figure 5.1.

Figure 5.1: Excerpt of the Geological Map of the Area



Along the foreshore, there are beach and coastal dune sands overlying the Lower Tertiary *Older Volcanics*.

In 1911, the Geological Survey of Victoria drilled a bore to 1300ft (396m) near the mouth of Dodd's creek, north of the jetty, commencing at about 4m above the sea water level. This bore revealed 6.25m thickness of clay, overlying 34m of decomposed basalt and overlying 'hard, jointy basalt' of 257m thickness. (Keble,

1950). The deep weathering and decomposed basalt layers of the shallower soils are consistent with the borings (Piper & Associates, BFP Partners, Golder Moss, & A.S. James)

South of Dodd's Creek on the eastern foreshore, the coastal cliffs show low strength moderately weathered basalt in parts of the top portion of the cliffs but this is far from universal. A borehole at the cliff summit above the Flinders jetty found 9.4 m of very stiff basaltic clay immediately sub-surface (Piper & Associates, 1998). The cliffs in this section of the coast have been eroded and steepened by marine erosion but there are no major slope failures apart from an extensive *probable* past landslide directly behind the Flinders jetty. Elsewhere there are shallow down-slope movements and towards Dodd's Creek, a rockfall zone: none of these threaten the properties along The Esplanade and private property to the west.

6 EXISTING SLOPE FAILURES

6.1 AERIAL PHOTOGRAPHIC INTERPRETATION

The aerial photographs were studied for evidence of slope instability. Areas that were identified as possible landslips were then confirmed on site.

The slope failures identified after the field visit are shown on the accompanying plan, Figures No. 1 - 8, Appendix A.

North of Dodd's Creek hard basalt is commonly not visible in the coastal cliffs, with basaltic clay as the common material seen. Drilling along Spindrift Avenue (Piper & Associates, 1998) found at least 9.0 m of basaltic clay in landslips there and this is probably typical for this part of the coast. Major old landslides with earth-flow type features at their toes characterize this coastal zone, with somewhat near level, benched areas forming the surface of failed areas.

The lower reaches of Dodd's Creek display steep slopes, which are even with few undulations present. No indications of major slope instability were found, although there are minor failures and creep movements in close proximity of the creek.

The southern foreshore is similar to the eastern foreshore with coastal cliffs along the entire length within the study area. There are several small and medium size slips within this area as well as erosion gullies and rockfall zones. There is one large *probable* past landslide within the cliff at the end of Georges Road that appears to be active although to our knowledge, no detailed investigation of this slip has been conducted.

The banks along Double Creek show significant signs of movement, especially creep and translational slides. East of the creek there are several large *probable* past landslips although again we are not aware of any detailed investigation of these slips.

The areas away from the coastline, Dodd's Creek and Double Creek tend to have gentle to moderate slopes with minimal sign of instability although in between Bass Street and the golf course there are several ridges with associated steep slopes.

Moderate and gentle slopes are characteristic of the study area behind the coast away from Dodd's Creek.

The landslide earth-flows shown north of Dodd's Creek are the most serious failures in the area. They are, with one exception, classed as *certain*. There is a possibility that some of them might be in danger of further movement. The landslide shown curving around near the mouth of Dodd's Creek is classified as *probable*.

South of Dodd's Creek near the mouth of Dodd's Creek a landslide, curving westwards without an earth-flow toe, is shown as *possible* only. Adjoining it to the south, a rockfall with topple and shallow slide features is active but presents no medium-term threat to The Esplanade and private property to the west. A fan-like feature composed apparently of clayey material and probably some concealed hard basalt boulders is adjacent as a *certain* slope failure.

The steep slope of about 70° extending south towards the Flinders monument has an irregular profile, with minor rock fall and wasting of clayey materials still active at a very low rate. It is a *certain*, but shallow failure zone. The major triangular scar in the cliff behind the Flinders jetty has an uneven profile and is classed as a *probable* past landslide. Any earth-flow zone at its toe has been removed by wave action.

Along the southern foreshore there are several *possible* landslides and one large *probable* past landslide at the end of Georges Road. The earth-flow zones of these slips have been removed by wave action.

There are two large bowl shaped landslips with zones of depletions with associated accumulation zones to the east of Double Creek. One between Vale Street and Glen Road, the other to the south of the southern end of Glen Road. Both of these are classed as *probable* past landslips. There is a *possible* shallow slip to the north of Double Creek Road. Between Vale Street and the creek there are some smaller *possible* slips.

Along the creek itself there are numerous slumps and minor slips while directly east of the creek to the south-west of the 'Hopper' there is a significant *probable* past landslide.

6.2 FIELD WALKOVER

A field walkover of the study area was conducted on 17 August 2007 and 28 September 2007. The purpose of the walkover was to confirm the presence of landslips that were identified in the aerial photographs as well as to locate other potential slips that were not identified in the photographs.

The landslips were identified by features such as scarps and accumulation zones with associated features such as hummocky ground, leaning trees, boggy ground and tension cracks.

Details of the findings of the walkover are shown on Figures 2 to 8, Appendix A and are discussed in Sections 7 to 12.

7 NORTH SPINDRIFT AVENUE (AREA 'A')

The northern section of Spindrift Avenue extends from Young Street to the end of Spindrift Avenue to the north. This area has been the subject of considerable geotechnical investigations and monitoring over the last 10 years.

7.1 REVIEW OF THE DATA AND REPORTS FOR NORTHERN SPINDRIFT AVENUE

The review is based on several letters and geotechnical reports from private sources (dated between 1974 and 2004) and inclinometer monitoring, which concern a number of allotments along Spindrift Avenue, were examined. They reveal the following information of importance:

- The possibility of localised slips occurring at 5 Spindrift Avenue was mentioned in the Golder Moss Associates Pty. Ltd. geotechnical investigation in December 1974, and a borehole log recorded about 3m of residual basaltic clay above very variably weathered basalt down to 17.0m. They recommended that the dwelling be founded on piles founded at least 1.5m into the highly weathered basalt.
- An area of slip of undefined size at 15 Spindrift Avenue was recorded in a Council letter dated February 1989, with flow of water down an adjacent gully thought to be the major cause.
- At 17 Spindrift Avenue, Statewide Geotechnical Services carried out a site classification for a proposed dwelling in April 1989. The boreholes were drilled to a depth of between 0.25 - 0.40m of fill overlay silty clay down to at least 1.5m; slope instability was not mentioned. The site was classified as "M" in accordance with AS2870.1 – 1988, possibly incorrectly.
- A high-risk area of slope instability was recognised at 19 Spindrift Avenue by C.E. Lawrence and Associates in April 1996. They emphasised the need to avoid cuts and filling and recommended a cut-off drain. The site was classified as "P" (Problem) due to slope instability. The house was recommended to be founded on a driven pile and beam system with the garage founded on a stiffened raft. The piles were to be founded at a depth of at least 6.5m.
- At 1A Spindrift Avenue, A.S. James Pty. Ltd. conducted a geotechnical investigation in August 1996. They recognised significant past slope instability, thought to have occurred more than 30 years ago, and indicated a potential problem of shallow movement or creep. Drilling to 6.2m found 2.0m of stiff to very stiff, residual, basaltic clay above extremely to highly weathered basalt. A.S. James Pty. Ltd. recommended that the site be classified as "P" (Problem) due to slope instability and recommended that the structures be founded on bored piers within the weathered basalt.
- In 1998, Piper and Associates conducted a geotechnical and geological investigation and assessment of the area for a proposed street scheme and retaining walls. Slope instabilities were identified and a monitoring system of the ground movement was commenced. The street scheme was postponed.

- The owner of 9 Spindrif Avenue in a letter dated July 1998 suggested that the road in the front of 7 and 9 Spindrif Avenue rests on an extensive clay landslide, with observations of down slope movements since 1965 of 0.64 - 0.76m at No. 7 and 0.45-0.76m at No. 9. They also indicate that a landslide occurred at the northern end of Nos. 7 and 9, with gradual soil movement at the base of No. 9.
- BFP Consultants Pty. Ltd. conducted a geotechnical investigation for a new dwelling at 3 Spindrif Avenue Flinders in 2002. They concluded that the ancient landslide to the north of this site has apparently occurred due to differing subsurface ground conditions than the site at 3 Spindrif Avenue. The shallow depth of the rock on the subject site is somewhat less (1 – 4.5m compared with 11.8m). They concluded that the site is relatively stable as a result of computer analysis and appropriate sensitivity analyses.
- In 2004, AS James conducted a geotechnical investigation for a new dwelling at 5 Spindrif Avenue. They identified the presence of active creep but concluded that the house can be constructed at this location with an appropriate risk.
- Also in 2004, AS James conducted a geotechnical investigation for a new dwelling at 17 Spindrif Avenue. Due to the presence of an excavation for the tennis court below this steep site, considerable retaining works with ground anchors are proposed for the house development.

7.2 SITE DESCRIPTION

Spindrif Avenue runs along the edge of the steep sloping hillside running down to the beach, north of Flinders. The area of this investigation is confined to the area north of Young Street. The street is mostly an unsealed gravel road cut into the existing hillside. The slopes of the sites to the west and east of the road are variable, but generally steep. The sites are mostly vegetated with trees, shrubs and blackberries. At either end of the street, there are large pine trees. Most of the sites contain dwellings. The dwellings were not available for inspection, nor was it part of the scope of this investigation to see if there is any distress in the existing structures.

7.3 GEOLOGY AROUND NORTHERN SPINDRIFT AVENUE

The geological unit exposed from the inter-tidal zone to the ridge top north-west of Spindrif Avenue is weathered basalt of the Lower Tertiary aged Older Volcanics. Exposures are very limited and mainly confined to road cuts, which reveal brown to dark grey residual basaltic clays, mainly very stiff and with fissuring. Some of the fissuring was pronounced and suggestive of material that had once moved under slope failure. Several boulders of hard moderately weathered basalt were seen between the road and the sand line, but the clayey surface soil is ubiquitous.

There are no observable structural features to indicate any tectonic disturbance and good exposures of basalt along the coast west of Flinders indicate conditions of flat-lying flows of basalt, which should continue at the site.

The boreholes along Spindrif Avenue and on the slope, north-west of the street, recorded very stiff basaltic clay to the depth of drilling at about 9.0m in the four boreholes. When extruded, the samples commonly showed fabric weaknesses associated with fissuring, indicative of possibly structurally weak and failed materials.

The depth of hard basaltic rock and the shape of the interface between surface clay and hard rock in this area remain unknown. The boreholes along or adjacent to Spindrift Avenue indicate a deeply weathered clay and extremely or completely weathered basalt.

Capping the ridge top immediately north-west of Spindrift Avenue are some dark grey slightly clayey fine to medium quartz sands, which are estimated to be about 3 metres thick, but the thickness is uncertain and may be irregular: if important it would need to be established by drilling. The sands are of wind-blown origin of the Quaternary period.

Normal slope processes have caused some sand to migrate down the upper part of the slopes and mix with basaltic clay in the upper soil profile.

Slumped materials from slope failures found below Spindrift Avenue include some quartz sand, which probably originated from the ridge top referred to above by slope failure. This sand appears to be limited in occurrence to slumped material, making its origin through slope failure more likely rather than from wind-blown beach sand.

7.4 TOPOGRAPHY AND SLOPE INSTABILITY IN NORTH SPINDRIFT AVENUE AREA

The slopes above and below Spindrift Avenue, to the northeast of its junction with Young Street, are initially steep but generally become rather flat to gently undulating in the vicinity of Spindrift Avenue. Below Spindrift Avenue, the slopes are irregular and finally fairly steep towards the beach, with some almost flat benches interrupting this steep descent.

There are several steep cusped scarps rising above Spindrift Avenue with the typical appearance of elements of a *main scarp* at the head of a *landslide*. The gently undulating surface below the cusped main scarp elements is the surface of *displaced material*, which has slid by shear failure on a *surface of rupture*. The surface of rupture begins at the complex main scarp exposed above. Spindrift Avenue crosses the main scarp about 50m north-east of Young Street and continues thereafter on the surface of displaced material. There is a fairly wide but uneven *zone of accumulation* of the displaced failed material, on which houses are built, with the *toe*, marking the down slope limit of the landslide, well below the road towards the sea. The landslide is complex, and may represent several slides in combination. The nomenclature used above is from Turner and Schuster (1996), based on the IAEG Commission (1990) after Varnes (1978) and is shown below.

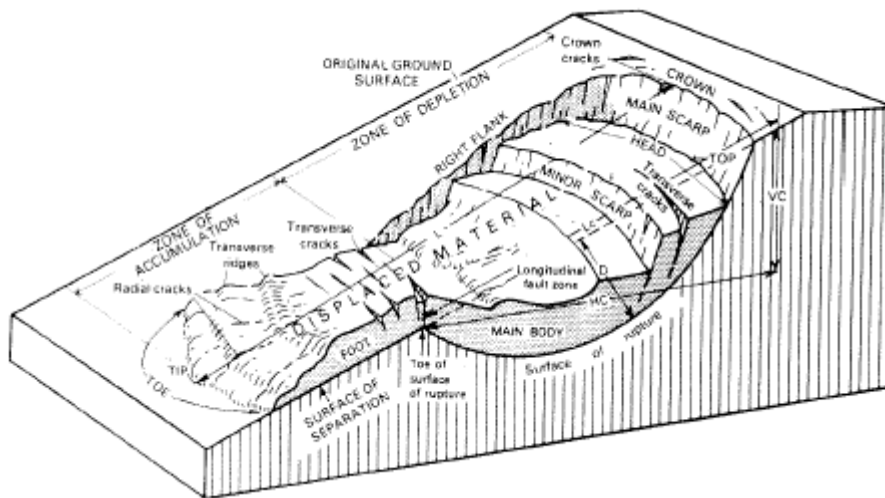


Figure 7.1: Landslide Features.

The Figure No. 8, Appendix A shows the extents of the landslips in the area. No attempt has been made to show the extent of the down slope limit of the failure or debris flow, but often this has been removed by sea erosion. Boundaries are shown as approximations only, based on field notes and examination of aerial photographs. The failures are generally arcuate type of failures with a zone of accumulation on the slopes below.

The visible failed and displaced materials in the *zone of accumulation* are basaltic clays, apparently more than 9m thick and there is no evidence to indicate whether or not some extremely or highly weathered basalt might also be included amongst the failed materials.

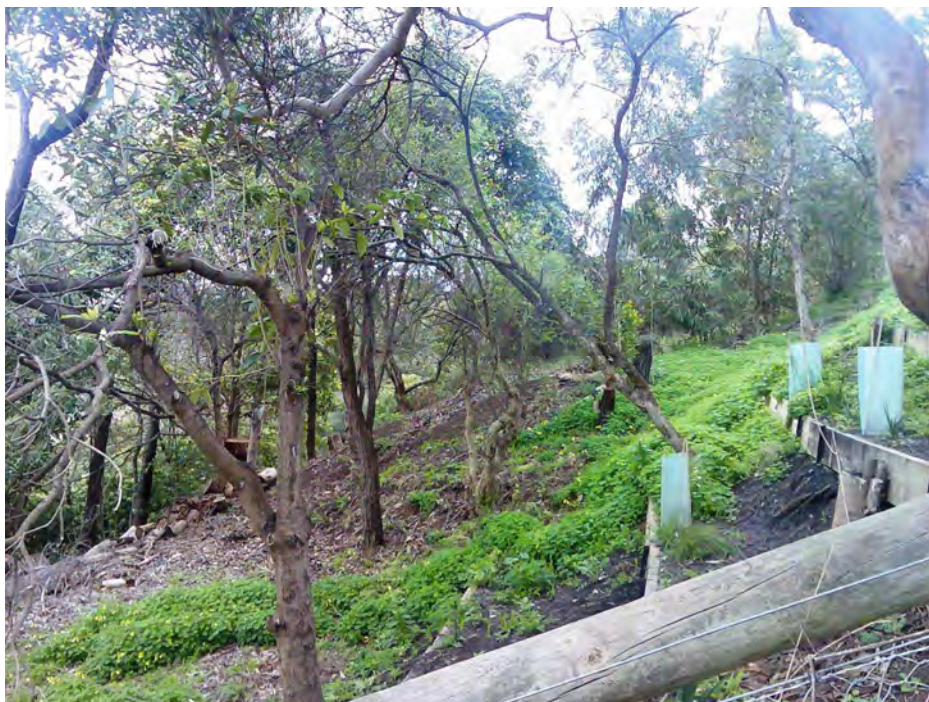
One of the four boreholes (Bore 4, Piper & Associates, 1998) was located on one of the cusped *main scarp* elements. This borehole indicated at least 9.0m of basaltic clay there, still in the unfailed material. Another borehole (Bore 5, Piper & Associates, 1998) appears to be above the main scarp (but might still be on it, because the scarp has not been accurately mapped), and likewise revealed at least 9.0m of basaltic clay. Fabric weaknesses in bore samples are possibly indications of structural weakness in these steep slopes above the failed material of the zone of accumulation.

The depth and shape of the *surface of ruptures* are also unknown, but they are likely to be deep and arcuate. Some quartz sand among the basaltic clay in parts of the lower zone of displaced material appears to have originated from near the ridge top above the head scarp and is suggestive of complex shear movements and probable flow subsequent to the initial stage of failure.

Local information indicates that minor and irregular movement of at least parts of displaced material (comprising the *zone of accumulation*) is still taking place. The extent, direction, rate and variability with time and water content of any ground movements remain unknown in the absence of monitoring.

The steep slopes of the main scarp elements at the head of the landslide are probably potentially unstable. No cuts into their profiles should be made. Any cuts into slopes in the area of displaced material of the zone of accumulation would endanger their stability. The ground water conditions on the site have not been studied, but the groundwater is below 10m. To maximise ground stability, good drainage is nonetheless essential.

Plate 7.1: Scarp of landslide between Spindrift Avenue and Bluff Avenue



7.5 INCLINOMETERS ALONG NORTHERN SPINDRIFT AVENUE

Three inclinometers have been installed along and adjacent to Spindrift Avenue, north of Young Street. The results of the movements are summarised in the Piper & Associates report 24116-1.1 dated 23rd December 2005 as well as the more recent inclinometer reading in January 2006. The surveyors took the readings using an inclinometer supplied and operated by Connell Wagner. The Inclinometer No 1 at the southern end of Spindrift Avenue has been destroyed in 2005 as a result of road grading. This inclinometer was installed to a depth of 15m and first read in February 1998 and has been read annually to June 2004. The movements are small and do not indicate any shear planes present. However, there appears to be creep movement of about 9mm towards the sea over this period. This equates to movement in the upper 3 – 4m of about 1.4mm per year.

Inclinometer No 2 was installed to a depth of 18m and first read in June 2001. This inclinometer is showing greater movement with some 27mm of movement at the head of the inclinometer towards the beach from June 2001 to June 2005. Again this appears to be creep movement over the upper 8 – 9m. This equates to about 6.75mm per year, but decreased to about 2mm per year from June 2005 to January 2006.

Inclinometer 3 is showing very little movement and movement from June 2001 to June 2005 has shown movement of less than 1 – 1.5mm and is too small to be accurate. The incremental displacements are not showing any distinct pattern and it can be considered that little, if any, movement has occurred since June 2001. This inclinometer was not able to be read in 2006 due to construction materials being placed over the head of the inclinometer.

Overall, the inclinometer results support the conclusion that movements towards the sea can be expected. There is no evidence of any slope failure planes and the movements are typically creep, varying from nil to 6.75 mm per year. Such movement is consistent with the identified ancient landslips present along Spindrift Avenue. The movements are likely to be intermittent and in part a reflection of the recent rainfalls.

7.6 CONCLUSIONS FOR NORTHERN SPINDRIFT AVENUE

The investigations to date have highlighted that Spindrift Avenue in the section north of Young Street is located within a previous landslip(s). This landslip(s) has been identified by aerial photograph interpretation, site inspections, geological mapping and computer slope stability analyses. The area is part of an ancient landslip formation.

Beyond about 50m from Young Street, Spindrift Avenue lies on failed material of a former landslide(s). Limited drilling has revealed at least 10.0m of very stiff basaltic clay, but deeper drilling might show a more complex pattern of basaltic materials including some hard rock. Borehole 1 (P & A, 98033 dated February 1998) showed completely weathered rock at a depth of 14.8m to the full depth explored of 15.4m. The depth and shape of the surface of rupture beneath are unknown.

Some continuing movement of the failed material of the landslide is occurring, but the precise areas of such movement and their rates are almost unknown. The inclinometer installed is indicating ground creep movement in the upper 3 – 4m but could be as great as 8m. However, insufficient time has elapsed for this movement to be conclusive or determine the rate of movement with any accuracy relative to the age of the landslip. Nonetheless, the inclinometer suggests a maximum rate of movement of the order of 6 - 7mm per year. Therefore over a 30-year period, the expected movement could be as great as 210mm, which is similar to the previous owner's observations at 7 and 9 Spindrift Avenue and could be greater towards the steeper section of the Lots.

The steep slopes above the zone of accumulation of the landslide are believed to be in a weakened condition and cuts into these should be avoided. The geological mapping has indicated major and minor scarps, which suggest that the soils in some areas are approaching the residual condition with increasing strain. Further movements can be expected to continue to occur, albeit erratically, and could be associated with sustained rainfall events.

Any engineering works involving cuts into the surface of the failed material in the zone of accumulation of the landslide could be in material that could be reduced to the residual strength. It is expected this will induce some movement, particularly in the slopes above the road. In some locations, Spindrift Avenue is located within the failed displaced material and unloading of the toe of this material must be avoided.

The failed displaced material is probably undergoing creep movement and any disturbance to these failed materials could induce accelerated creep movements.

8 SOUTHERN SPINDRIFT AVENUE, BETWEEN YOUNG STREET AND DODD'S CREEK (AREA 'B')

The section of Flinders township between southern Spindrift Avenue and the strandline is typically at a grade of 40 - 50% to the base of the cliff with some areas at a slope of 60 – 70% with a few sections up to a grade of 80 – 90%. Apart from either end of this section of Spindrift Avenue, many of the lots are graded at 10 – 30%. See Figure No. 3, Appendix B.

Two arcuate landslips have been detected along this section at either end of southern Spindrift Avenue. These landslips have a benched area of failed material with minor earth flow in the lower section. It is likely that some of the lower section has been eroded in the past.

These landslips do not extend to Spindrift Avenue. However, in the area to just south of Young Street intersection with Spindrift Avenue and the southern end of Spindrift Avenue on the banks of Dodd's Creek, there is the potential for landslips due to the steepness of the ground.

In our opinion, there is likely to be little likelihood of a slope failure extending to Spindrift Avenue in this location, although creep movement to the south could occur.

9 DODD'S CREEK TO WOOD STREET (AREA 'C')

There are two landslips to the east of Spindrift Avenue in the vicinity of Dodd's Creek. There are signs of landslip movement in the area of 39 Spindrift Avenue but these are mostly creep movements in recent times. There is evidence of toe erosion in the creek bed, tending to destabilise the slope.

There is no evidence of major landslips west of Spindrift Avenue along Dodd's Creek despite the steepness of the slope. However there is evidence of near surface small landslips in the vicinity of the creek and creep movement within the creek banks. Erosion of the bed of Dodd's Creek is causing increased slope instability.

The southern creek banks are very steep with undulations indicative of shallow creep movements and shallow slope failures. On the southern bank, there appears to be evidence of debris flow at the base of the creek bank.

BFP Consultants drilled five boreholes in the location of the Dodd's Creek crossing in March 2005. Refusal was encountered in all of the boreholes on basalt bedrock at a depth of between 1m and 13.7m.

Groundwater was encountered in boreholes 1 and 5 on either side of Dodd's Creek at a depth of 12.7m and 10.7m respectively.

The basalt rock is likely to be close to base of the creek bed, typically moderately to highly weathered.

BFP Consultants consider slope instability on the banks of the creek unlikely even with creek bank slopes of 25° (45 – 50%). We agree generally with this conclusion provided the groundwater remains suppressed, but cannot preclude creep movements in the near surface soils.

Whilst we agree that a major global instability of the creek banks is unlikely due to the presence of the basalt rock in or close to the creek bed, it cannot be precluded as there are slopes elsewhere in the Flinders locale, that have failed at similar or even less steep slopes. It is more likely that a shallow slope failure may result, particularly on the southern steep banks, but the depth of groundwater is critical to the slope stability.

With increased development of the area in the last few decades and increased size of dwellings and surrounding paving, the intensity of the runoff of the stormwater within Dodd's Creek has probably increased. This can result in increased erosion of the toe of the creek banks, with potential deepening of the creek bed and undermining of the creek banks. However, the deepening of the creek bed is likely to be limited in parts by the presence of the basalt bedrock.

The areas away from Dodd's Creek towards Wood Street tend to have gentle to moderate slopes. These areas are unlikely exhibit any large scale landslip and creep movement is considered to be minimal.

10 THE AREA INCLUDING THE ESPLANADE TO WOOD STREET, & SOUTH OF DODD'S CREEK TO BASS STREET (AREA 'D')

This section includes the area from the Esplanade from Cove Lane to Bass Street along the foreshore and inland to Wood Street. The Esplanade is set back from the cliff edge that overlooks the foreshore.

The aerial photograph interpretation of this area identified landslips on the eastern side of the Esplanade to the foreshore. Whilst no landslips encroach into the road reserve, in two locations, the scarp of the landslips appears to become close to the Esplanade between Cove Lane and Gordon Streets and between Cook and Bass Streets. The landslips are variable in type from arcuate slope failures, rock falls and topples, earth flow fans and minor falls with down slope movements.

BFP Consultants drilled one borehole to a depth of 3m in October 2005 in this area (BFP, Nov 2005). Very stiff, red-brown, silty CLAY(CH), presumably basaltic, was encountered to a depth of at least 3m which was the full depth explored. No basalt rock was encountered.

10.1 BOARDWALK INVESTIGATION ABOVE THE PIER

Piper & Associates conducted a geotechnical investigation for the timber boardwalk in September 1998. The boardwalk followed a pre-existing track from the Esplanade to the footpath leading to the pier access road. Borehole 1 close to the Esplanade was drilled to a depth of 9.8m. Dark brown, silty CLAY(CH) was encountered to a depth of 5m, whereupon remnant rock structures were present with the clay to a depth of 7m. Below 7m, completely weathered BASALT(CW) was encountered with visible remnant rock structure, becoming highly weathered toward the full depth explored of 9.8m. A further 4 handauger holes were drilled along the proposed boardwalk.

The borehole at the top of the slope revealed 9.4m of very stiff dark grey-brown clay, which is a residual clay derived from the weathering of basalt. Several of the lower samples had a distinctive basaltic texture. No trace of hard or moderately weathered basaltic rock was found.

The hand augering went to depths of between 1.0m and 1.7m. The samples were fairly uniform, very stiff, dark grey-brown clays with some variegation and minor changes of colour. Some showed basaltic texture. The minor content of quartz sand noted in the surface soils was completely absent, apart from in the highest auger hole (HA-A), where the top sample at 0.7m depth contained a minor content of rounded fine quartz grains.

The sub-surface work has found very stiff basaltic clay to a minimum depth of between 1.0m and 1.7m on the slope. The thickness of more than 9.4m of basaltic clay found at the summit of the slope indicates that the thickness of clay down the slope might be at least 9.4m. The absence of the hard basaltic rock detritus on the slope suggests that such rock will, at a minimum, be of moderate depth, but there is a lack of firm data on which to base any conclusion on the weathering profile beneath the slope.

The aerial photographs reveal a U-shaped depression down the slope and some

slope irregularity in the area to be crossed by the then proposed boardwalk. This is suggestive of a scar from an old slope failure, which had a mechanism of shear failure or flowage of basaltic clay, or a combination of these. No failed material at the foot of the slope is to be found, although such material would have been readily removed by wave action. The presence of a former slope failure here remains uncertain due to the eroded features.

No cracks or fissures in the soil were seen on the slope, nor were any notable slope irregularities found. There are no signs of any existing slope weakness.

It is possible that “*creep*”, i.e. the down-slope movement of the colluvial basaltic clay in the surface zone at an infinitesimal or imperceptible rate, is taking place, but in the absence of slope monitoring over a period of years nothing definitive can be said about its occurrence.

Our site inspection of the Esplanade Road itself did not reveal the presence of major ground movement although there is one location near Gordon Street where there are thin cracks in the road surface running parallel to the escarpment. These cracks are possibly due to movement within the escarpment but could also possibly be attributed to other causes such as trees.

Movement was also possibly detected in the area of Cove Road adjacent to the tributary to Dodd’s Creek.

There are also a few confined areas away from the Esplanade where the slope increases to greater than 20% and in the south east where Bass Street and the Esplanade meet the slope becomes greater than 20%. These areas are unlikely to exhibit large scale movements. However, creep movement in these areas can not be precluded.

As with the area between Dodd’s Creek and Wood Street, the majority of the area west of The Esplanade is generally gently to moderately sloping, especially to the north of Cook Street. These areas are unlikely to exhibit any large scale landslip and creep movement is considered to be minimal.

11 COOK STREET TO THE GOLF COURSE (AREA 'E')

There is a residential area that is inset into the northern boundary of the golf course and bounded by Bass Street to the north. The properties in this area are well developed with houses on nearly all of the properties. Although there are trees throughout the area there are areas that have been cleared of trees and the natural slopes have been altered in several locations with features such as retaining walls.

Minimal previous geotechnical investigation information was available for this area and there are no reported landslips in the area.

The area is undulating and typified by moderate slopes increasing to steep along the slopes of a series of ridges. The geological map of the area indicates that the area is partially underlain by Quaternary Age sands, silts and clays. Observations of road cuttings in the area confirmed this geology with sands of at least 1.0m deep observed in several locations. It is possible that the ridges are a series of sand dunes or they are basalt hills overlain by Quaternary sands. However, neither of these stratigraphies has been confirmed.

Signs of creep such as leaning trees were observed on the steep sides of the ridges at several locations indicating the potential for further creep movement. However, no significant signs of movement were observed.

In our opinion, there is likely to be little likelihood of a slope failure occurring within this area, although creep movement could occur, especially along the steep slopes of the ridges.

The area between Cook Street and Bass Street tends to have gentle to moderate slopes. This area is unlikely to exhibit any large-scale landslip and any creep movement is likely to be minimal.

Plate 11.1: Steep Slope below Ridge



12 DOUBLE CREEK AREA (AREA 'F')

The Double Creek area extends from Double Creek in the west to the golf course in the east and from the southern coastline to Cook Street. The topography of this area is highly variable.

Minimal investigation has been conducted to date in this area and as such there is little information on the landslips that were identified as part of this investigation. Should detailed information on any of these landslips be required then it is recommended that further investigation be carried out for each particular landslip.

12.1 GEOLOGY AROUND DOUBLE CREEK

As with a majority of the Flinders area, the geological map identifies this area as being underlain by soils weathered from the basalt of the Lower Tertiary aged Older Volcanics. At the time of the preparation of this report there were no records of boreholes conducted in the area so the depth to rock is unknown.

Along the coastline limestone breccias are noted in several locations overlying the basalt. This was confirmed on site with several outcrops of limestone within the cliffs.

Plate 12.1: Exposed Limestone Breccias



In general the cliffs and creek beds in these areas are overgrown with vegetation and little basalt bedrock was observable. However, around the mouth of Double Creek basalt outcrops were visible in varying degrees of weathering.

12.2 TOPOGRAPHY AND SLOPE INSTABILITY IN DOUBLE CREEK AREA

The slopes in the Double Creek area can be separated into four distinct types as discussed below.

Cliffs

The cliffs along the southern coastline are very similar to those along the eastern coastline in the vicinity of Spindrift Avenue and The Esplanade. The cliffs tend to have an average slope of approximately 70%. However there is a large variability in the cliffs ranging from as little as 25% up to greater than 100%. The cliffs are typified by small shallow slumps and numerous erosion gullies.

There were several minor landslips observed with widths in the order of 20-30m. In addition there were two large slips, one with a width of approximately 70m and the other with a width of approximately 100m.

These landslips typically had evident scarps. However the zone of accumulation was generally not present, most probably due to wave erosion of the cliffs.

There are numerous leaning trees along the cliffs and narrow cracks were observed in the surface of Golf Links Road where the road was in the vicinity of the cliffs. A possible tension crack was observed in vicinity of the larger landslip and a recent slump was observed within the scarp of that slip.

There is significant evidence that movement is still occurring within the cliffs. This movement is most probably predominantly creep. However, larger scale arcuate landslips can not be ruled out, especially in the vicinity of the two larger landslips.

As well as the potential for landslides along the cliffs there is potential for toppling and block failures of the cliffs in the vicinity of the limestone breccias.

Creek Banks

The creek banks of Double Creek from its mouth north to Double Creek Road show significant signs of instability. The creek itself was generally inaccessible by foot, however observations from the nearby properties indicated numerous slumps within the creek itself and a significant creep zone above the creek banks. In particular, there were two vacant properties in between Glenvale Road and the creek where the lower reaches of the property showed significant signs of creep, including hummocky and boggy ground.

In addition, a property near the mouth of the creek had evidence of a landslip with a width of approximately 65m. The scarp and zone of accumulation of this slip were evident although there appears to have been some earthworks around the scarp by either the existing or previous owners of the property. There are several large pine trees to the rear of the scarp that are leaning away from the scarp, possibly indicating that some movement has occurred during the life of the trees.

There are possibly other slips and scarps along the banks of the creek. However at the time of the investigation these areas were inaccessible.

Escarpment Area

There is a large escarpment that extends from near the coast at the southern end of King Street and runs parallel to Double Creek in a north-westerly direction until No. 4 Glen Road where it turns toward the creek in a westerly direction and eventually joins the creek bank at No. 6 Vale Street.

The escarpment is tiered into several terraces with the main upper escarpment as mentioned above and several smaller lower escarpments. The upper escarpment tends to have a slope in the order of 30-40% with localised areas increasing to 50%. The lower escarpments tend to have similar slopes. The benches in between the escarpments tend to be much flatter with slopes in the order of 0-10%.

There are three large possible to probable past landslips associated with the upper escarpment while the lower escarpments have less evidence of landslip. No detailed investigation has been conducted of these landslips. However, the field observations are included below.

The first probable past landslip is to the south of Glen Road. This slip has a width of approximately 180m and extends over several properties. The general direction of the slip is to the south. The scarp extends from No. 16 Glen Road to No. 82 King Street while the zone of accumulation possibly extends as far south as No. 92 King Street. In the vicinity of the scarp there were numerous leaning trees while downslope from the scarp the ground was hummocky and there were boggy zones. There is at least one dwelling within this probable past landslip. The age of the landslip is unknown but there is evidence that some movement, possibly creep as a minimum, is still occurring.

The second probable past landslip is to the west of Glen Road. This slip has a width of approximately 150m and extends over at least 10 properties. The slip forms a large bowl with a general direction to the south-west. The scarp extends from No. 1 Vale Street to No. 6 Glen Road in an easterly direction and then to No. 14 Glen Road and No. 18 Glenvale Road in a southerly direction. The zone of accumulation covers the southern part of Vale Street with several properties within the zone. Considerable development has occurred within the landslip so it is possible that evidence of the landslip has been removed and the slopes modified. However, there are still hummocky zones and leaning trees evident at several locations. This probable past landslip has the potential of affecting several dwellings.

The third probable past landslip is to the south of Double Creek Road and to the rear of Nos. 2 – 6 Vale Street. This slip is smaller than the above two slips with a width of approximately 80m. The slip is generally located within one undeveloped property identified as No. 21 Double Creek Road. The scarp forms a bowl around the north-east of the property and approaches the rear of Nos. 4 – 6 Vale Street and No. 39 Glenvale Road. The zone of accumulation possible extends to Double Creek. There is no development within. However, the houses within the properties to the rear of the scarp have the potential to be affected if the scarp regresses.

The age of these landslips is unknown but does not appear to be recent. There is evidence that some movement, possibly creep as a minimum, is still occurring.

Above the Escarpment

The areas above and away from the escarpment are typically gently to moderately sloping and show minimal signs of slope instability.

12.3 CONCLUSIONS FOR DOUBLE CREEK AREA

The different areas within the Double Creek Area are each affected differently by landslip varying from significant movement in the vicinity of the cliffs, creek and upper escarpment to minimal movement above and away from the upper escarpment. Each of the different areas should be treated on a case by case basis.

Cliffs

There are no houses in the immediate vicinity of these slips, with the main amenities being Golf Links Road and the golf course.

The field study identified numerous locations where movement may still be occurring. At this stage this movement is expected to have minimal impact on the residential properties. However, Golf Links Road and the golf course have the potential to be affected should the movement continue.

Plate 12.2: Scarp with Active Erosion and Movement



Should further development be required in the vicinity of the cliffs, then a high level of geotechnical investigation is recommended.

Creek Banks

The properties along the banks of the creek show a moderate level of development with approximately half of the properties having existing dwellings. None of the dwellings were inspected for evidence of damage due to slope instability. However

where these houses are in the vicinity of the creep affected zone or any existing landslips it is possible that some distress may occur in the future, if it has not already occurred.

Future development on these properties can be expected to be similarly affected without appropriate development constraints and therefore a high level of geotechnical investigation is recommended prior to such development occurring.

Escarpment Area

Significant development has occurred within the escarpment area. The houses within this area were not inspected but there is a possibility that some of the houses have already some evidence of damage due to slope instability. There is a possibility that houses in this area will be affected to some extent by future movement, especially those either within or in the vicinity of the existing landslips.

Future development on these properties can be expected to be similarly affected without appropriate development constraints and therefore a high level of geotechnical investigation is recommended prior to such development occurring.

Above the Escarpment

The areas above and away from the escarpment, especially to the north-east of Glen Road and Lee Grove are unlikely to exhibit any large scale landslip and creep movement is considered to be minimal.

13 PREVIOUS EROSION MANAGEMENT OVERLAY

The Mornington Peninsula Planning Scheme includes an Erosion Management Overlay (EMO) that has two schedules. : The classification 'EMO1' within the EMO relates 'Erosion Prone Slopes' while 'EMO2' relates to 'Unstable Slopes'. This overlay was translated into the Planning Scheme from former Planning Schemes applying in the area that had their genesis in the Westernport Regional Planning Authority's "Conservation Plan" for the southern Peninsula. The "erosion prone slopes" and "unstable slopes" classifications were based on studies that are referred to in Environmental Resources of Australia (1974) A Natural Systems Study of the Southern Mornington Peninsula,.

The EMO was inspected for any EMO1 or EMO2 classifications within the study area, however none were identified.

14 CONCLUSIONS AND RECOMMENDATIONS

The Flinders area is characterised by geological and geotechnical issues and topographic features that affect the stability of the foreshore area. The major features affecting the slope stability are:

1. Pre-existing slope failures, mostly ancient, although some more recent.
2. Variably steep slopes from gentle to very steep
3. The often considerable depth of the residual highly plastic clay overlying the extremely and deeply weathered basalt. However, the depth to the basalt does vary
4. Heavy rainfalls over a sustained period
5. The direction of the slope
6. Undermining of the toe of the slope by construction or erosion
7. The placement of fills and cut and heavily loaded structures
8. The height of the slope
9. Mostly uncontrolled discharge of stormwater on the ground areas and road gutters, soakage pits and the use of septic tanks often with absorption trenches to raise the groundwater.
10. The presence of underground services that can be a source of water ingress
11. An accumulation of surface runoff on roads
12. Seismic activity

In recent times, there have been no large documented landslips in the study area, although there is considerable evidence of creep movements and smaller slope failures. There is evidence of ancient large landslips in the study area

Appropriate management controls are required to ensure that no significant landslips occur within the study area. The likelihood of a significant landslip could increase if uncontrolled development should occur.

The geology in the area of the foreshore is relatively consistent across the study area and with residual highly plastic clays weathered from the underlying Tertiary aged basalt. At the southern end of the study area, there is limestone between the basalt layers.

It is important to understand that the assessment to date is to determine the zoning of landslip susceptibility. It does not consider the hazard of the landslip, which can change over time and with the particular land use of a site, or the risk of the landslip which involves an assessment of the potential damage to persons or property after accounting for temporal, and spatial probability and vulnerability. See Appendix D for terminology.

The purpose of the study is to define areas for appropriate geotechnical investigation across the study area alone. Furthermore, debris flows or other issues have not been considered and should form part of a detailed risk assessment for a particular property.

14.1 TYPES OF LANDSLIPS

The landslips are mostly of four types:

- Rotational Landslip
- Rockfall and possible Toppling Failure
- Earth Flow
- Creep

The types of the landslips are discussed in Appendix E.

14.2 RATIONALISATION FOR THE LANDSLIP SUSCEPTIBILITY CLASSIFICATION

The selection of the zones for the particular classifications are based on the following criteria in order of importance:

- Presence of pre-existing slope failure
- Documented or anecdotal evidence of movement from site inspections, maps and aerial photographs
- The slope of the land
- The depth of the groundwater
- The height of the slope
- The direction of the slope
- Other factors such as the potential for toe erosion.

14.3 PROPOSED LANDSLIP SUSCEPTIBILITY ZONES FOR THE FLINDERS FORESHORE

The geotechnical investigation level required for the different zones of landslip susceptibility has been determined. The survey and inspection from the roads and aerial photography are not sufficiently accurate to define the precise extent of each of the zones. Therefore, the nominated boundaries are based on limited information. In most cases, a conservative approach has been adopted with a buffer of approximately 20m applied between any identified landslips and the zone boundaries.

The classification is not to restrict development on any lot. The purpose is to define the extent of geotechnical investigation required based on defined criteria. It is considered possible that the detailed geotechnical investigation and risk assessment may reveal that some areas are classified conservatively and the risk of landslip is less than the limited interpretation to date has revealed. A review of the classifications should be conducted after a period of 5 years to include the investigations conducted over the next few years. The Council should maintain an inventory of geotechnical investigations conducted within the study area.

It is important that the owners understand that lots classified as ‘Higher level of Investigation’ of landslip may not indicate that the lot is in imminent risk of landslip, but does indicate that in certain unfavourable circumstances, a landslip could occur and creep movements may already be occurring and is therefore susceptible to landslip. Furthermore higher risk does not preclude development of these lots, but needs to be considered in the development.

The proposed classification system adopted is as follows:

Low Susceptibility of Landslip – These areas are shown as ‘green’ on the plan showing the areas of ‘Low Level Investigation Requirements’, see Figure No 1, Appendix B. The dwellings or structures located within these green areas need not consider slope stability issues in detail, except to the extent as nominated by Australian Standard 2870-1996 *Residential Slabs and Footings – Construction* and providing that the development does not precipitate unstable slope conditions. Slope stability issues can be restricted to a site inspection and possibly, a limited geotechnical assessment

Medium Susceptibility of Landslip - These areas are shown as ‘yellow’ on the plan showing the areas of ‘Medium level Investigation Requirements’, see Figure No. 1, Appendix B. In this area, a more detailed geotechnical investigation is required consisting of deeper boreholes, piezometers, appropriate sampling, limited geotechnical testing, slope stability analysis and reporting. Peer review and formal risk assessments are not required.

Higher Susceptibility of Landslip - These areas are shown as ‘red’ on the plan showing the areas of ‘High Level Investigation Requirements’, see Figure No. 1, Appendix B. These areas are considered to be the highest risk of landslip within the study area. It emphasised again that it does not preclude any development in these areas nor does it always indicate that a landslip is evident. However, it does indicate that slope stability needs to be seriously considered in the geotechnical design and on-going management of the sites.

In these areas, a detailed geotechnical investigation is essential. The geotechnical investigation will need to consist of deep boreholes, appropriate sampling and insitu testing, geotechnical laboratory testing, slope stability analysis and reporting, risk assessment and an on-going site management plan.

The geotechnical requirements for each of the classified areas are shown in the following section.

14.4 GEOTECHNICAL INVESTIGATION REQUIREMENTS FOR EACH CLASSIFICATION

The geotechnical investigation relates to the requirements for slope stability and the other geotechnical issues such as fill and soil reactivity need to be considered as well.

Low Level of Investigation

The geotechnical investigation should consist as a minimum of the following:

- Site classification in accordance with AS2870- Residential Slabs and Footings
- 3 boreholes to a typical depth of 2m

- Appropriate sampling
- A site inspection by an experienced geotechnical professional to assess whether there are any slope stability issues and a statement to this effect should be included in the report.

Medium Level of Investigation

The geotechnical investigation should consist of at a minimum, the following:

- Develop a site history from previous owners
- Review the aerial photographs and any other relevant literature
- At least 3 boreholes to a minimum depth of 5m but may need to be considerably deeper on some sites
- Appropriate undisturbed sampling, Standard Penetrometer testing and coring of the rock, if encountered
- Appropriate geotechnical testing in a NATA accredited soil laboratory to confirm the geotechnical shear strength design parameters, at least by established correlations
- Computer modelling of the slope with the imposed structures, fill and cuts to determine that there is an adequate factor of safety for the proposed development
- Conduct a detailed inspection of the site for any signs of movement or other geomorphological features
- Reporting and discussion of any site restrictions or on-going site management as required by the geotechnical engineer. The analysis and reporting to be conducted by an experienced geotechnical engineer or engineering geologist who is experienced in slope stability assessments. Appropriate geotechnical declarations are required

High Level of Investigation

A detailed and comprehensive geotechnical investigation is considered to be mandatory in these lots. The geotechnical investigation should consider at a minimum, the following:

- Develop a site history from previous owners
- Review the aerial photographs and any other relevant literature
- Assess the likelihood of any pre-existing slope failures on the site, even if disguised by onsite developments and erosion
- Conduct a detailed inspection of the site for any signs of movement or other geomorphological features
- Conduct deep and detailed geotechnical investigation
- Drill at least 3 boreholes to a minimum depth of 12m (but may need to be greater) with appropriate undisturbed sampling and insitu testing
- Conduct appropriate geotechnical testing in a NATA accredited soils laboratory and may typically consist of direct shear tests, appropriate triaxial compression tests, Atterberg limits and others
- Conduct a computer slope stability assessment of the site including the proposed development, any cuts or filled areas
- Conduct a quantitative risk assessment of the site in accordance with the AGS(2007) procedures. The robustness of the risk assessment for the proposed development for the particular geotechnical conditions needs to be considered
- Develop an on-going site management plan including consideration of site creep, stormwater and sewerage disposal and implications on the slope

stability, any vegetation removal and the impact or restrictions on any works at the toe of the slopes.

- The assessment should be approved by an experienced geotechnical engineer who is a registered building practitioner, NPER accredited and experienced in slope stability. In medium to higher level investigation areas, the geotechnical declaration and verification for the development, construction certificate application, geotechnical application minor impact and final structural and final geotechnical certificates should be provided.
- In most circumstances, the Council may consider that a peer review is warranted.

A typical checklist for a slope stability assessment is included in Appendix C.

14.5 SITE MANAGEMENT REQUIREMENTS

In all the areas, and in particular in the areas of medium to high levels of landslip susceptibility, development controls are required to ensure that the stability of the site does not deteriorate. The development controls should consist of (at a minimum):

- Professional geotechnical engineering advice on the site prior to starting work
- Limitations on the fills and cut slopes within the site and any retaining walls. Maximum unsupported cut depths and fill thicknesses of not greater than 2m should be battered at a slope of not greater than 1V:2H. Prior to the placement of any fill, the vegetation, rootmatter and any upper silts should be stripped and fill keyed into the underlying natural clays or sands as appropriate and compacted to a level suitable for the proposed use
- On the more sensitive sites, the depth of unsupported fills or cuts should be limited to less than 1.5m or 1m as appropriate. Deeper fills and the cuts should be supported with appropriately designed retaining walls
- Any retaining walls or structures should be drained and designed by a professional engineer
- Limitations on changes to the natural site profile
- Minimise any vegetation removal
- Control surface water and sub-surface groundwater and direct the water collected in addition to the roof and pavement runoff, into pipes to the stormwater system. The pipes should be flexible to accommodate creep or ground movements and be designed to prevent blockage and energy dissipators may be required
- Avoid structures that are sensitive to movement, such as pools and spas
- Consider carefully the location of the soakage pits and any absorption trenches
- Specific details are often required for water retention structures such a swimming pools, spas, and water tanks. Depending on the site, these structures may need to be piled or with foundation designed to accommodate movement. An under-drainage system is often needed

Within some lots, the risk of landslip is higher on some sections than others. The development of these lots should avoid the higher risk areas.

The Australian Geomechanics Geoguides LR1 – LR5, LR7 & LR8 and LR10 are included in Appendix E. These are also downloadable from the AGS website www.australiangeomechanics.org.

If you have any questions, Lane Piper Pty Ltd would be pleased to answer your queries.

15 REFERENCES

Australian Geomechanics Society, *Landslide Risk Management*, Vol. 42, No. 1, Australian Geomechanics March 2007.

Australian Standard 2870 – 1996 *Residential Slabs and Footings – Construction*

Australian Geomechanics Society, *Landslide Risk Management Concepts and Guidelines*, Australian Geomechanics Society, Vol. 35, No. 1, March 2000.

Crawford S.A., & Millar P.J., *The Design of Permanent Slopes for Residential Development*, 8th Aust & NZ Conference on Geomechanics, 1999.

Keble R.A., *Memoirs of the Geological Survey of Victoria, No. 17, The Mornington Peninsula*, 1950, Victoria (Dept. of Mines.)

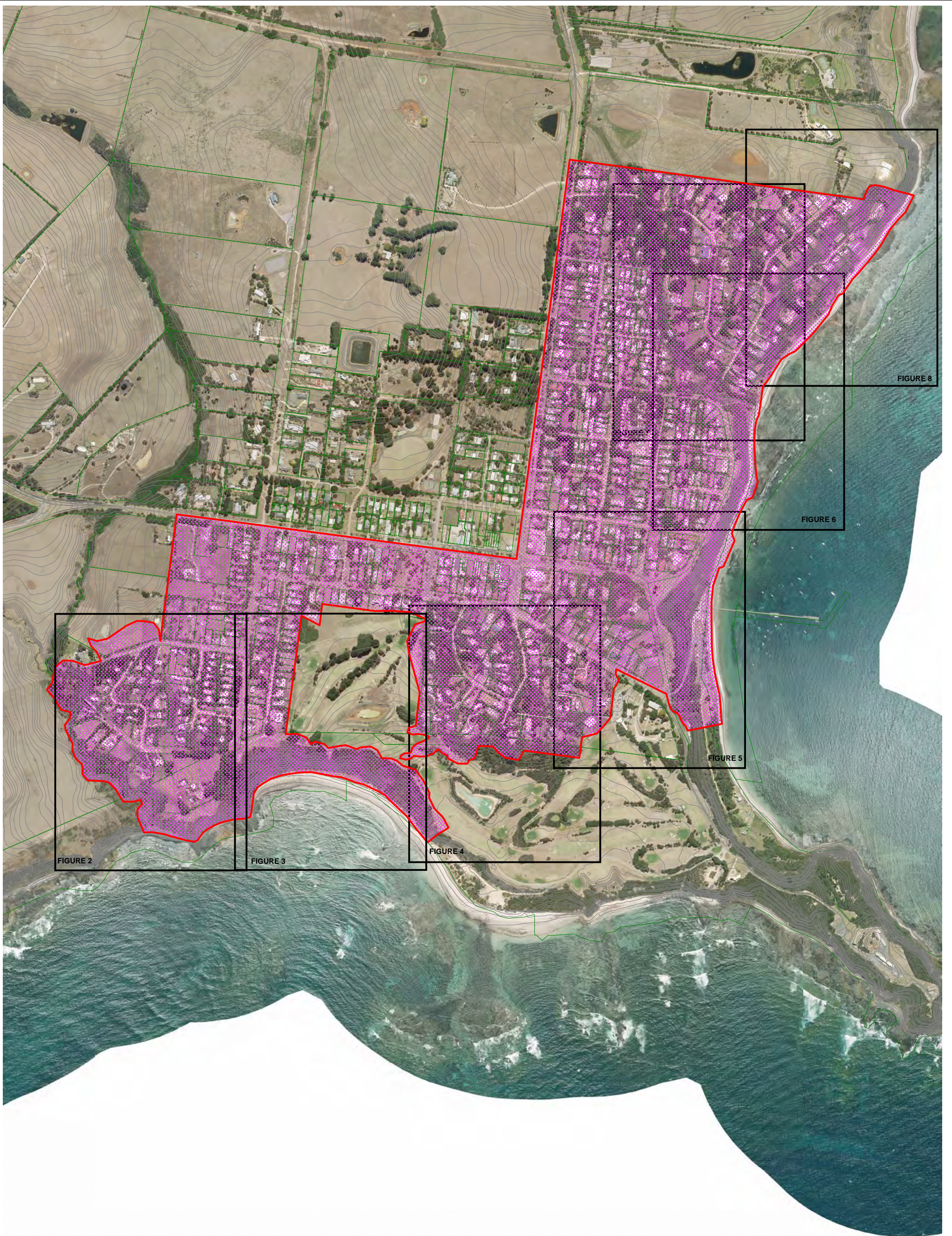
Stark, T. D., Choi, H. and McCone, S., “Drained Shear Strength Parameters for Analysis of Landslides”, in *Journal of Geotechnical and Geoenvironmental Engineering*, ASCE, May 2005, Volume 131, Number 5

Turner, A.K. and R.L. Schuster (Edts.), 1996: *Landslides, investigation and mitigation*, Special Report 247, Transport Research Board, National Research Council, Washington, D.C.



Varnes, D.J., 1978 Slope Movement Types and Processes. In *Special Report 176: Landslides: Analysis and Control*, editors R.L. Schuster and R.J. Krizek, TRB, National Research Council, Washington, D.C., 11-33

APPENDIX A

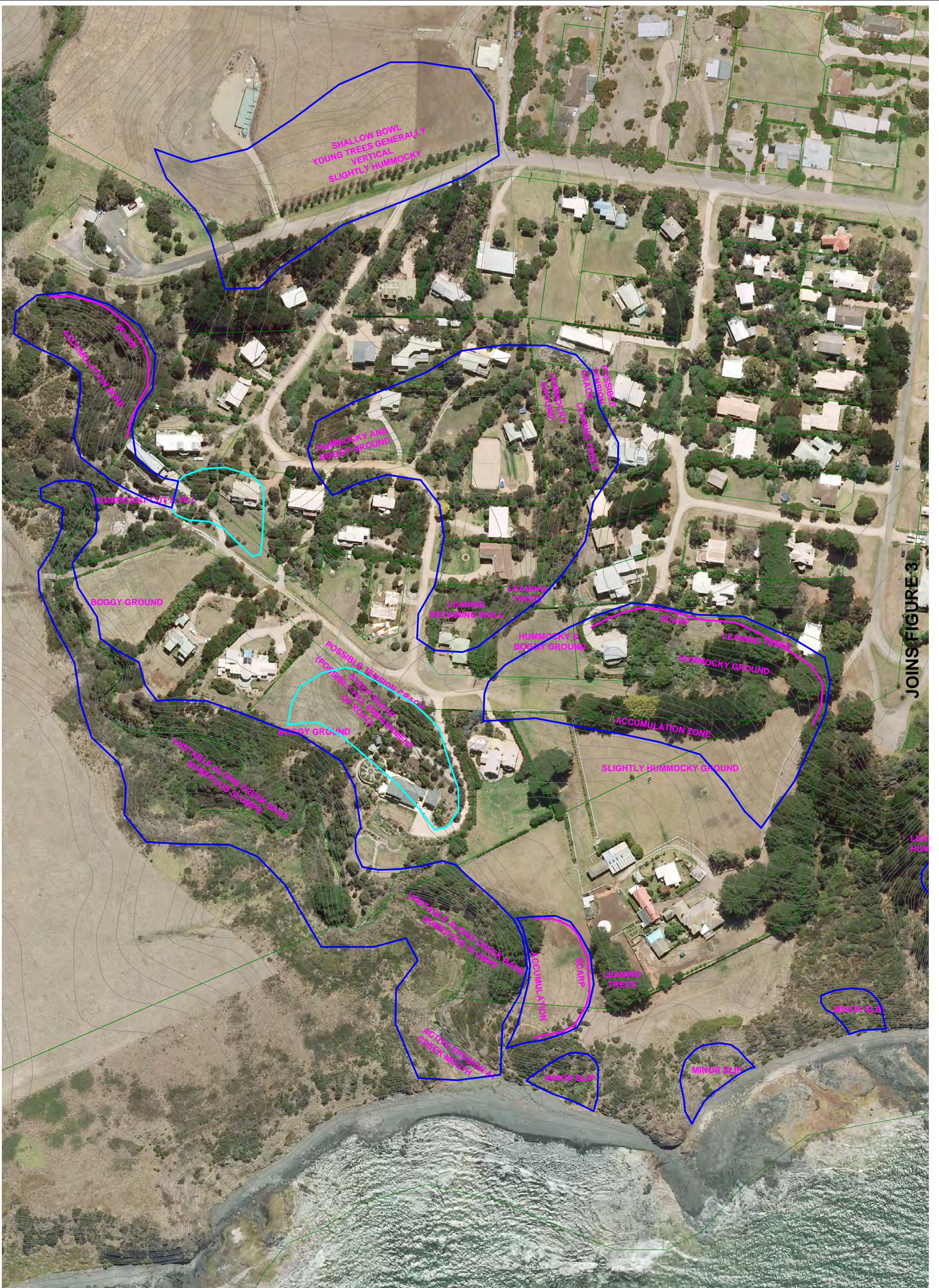
On-Site Observations (Area Plan) On-Site Observations (Details)



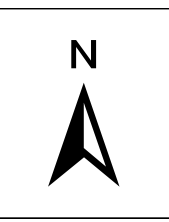
LEGEND

-  Area of Study
-  Figure Locations

TITLE	ON SITE OBSERVATION PLAN	JOB NO.	27005	DATE	22 NOV 2007
PROJECT	FLINDERS FORESHORE LANDSLIP ASSESSMENT	SCALE (A3)	1:10,000	REV NO.	0
FILE REFERENCE	FLINDERS.WOR	DRAWN	DBS	FIG NO.	1



JOINS FIGURE 3



LEGEND

—	Probable Landslips
—	Potential Landslip or Area with Potential for Landslip
TEXT	On Site Observations

TITLE	ON SITE OBSERVATION PLAN	JOB NO.	27005	DATE	22 NOV 2007
PROJECT	FLINDERS FORESHORE LANDSLIP ASSESSMENT	SCALE (A3)	1:2,000	REV NO.	0
FILE REFERENCE	FLINDERS.WOR	DRAWN	DBS	FIG NO.	2



LEGEND	
—	Probable Landslips
—	Potential Landslip or Area with Potential for Landslip
—	On Site Observations

TITLE	ON SITE OBSERVATION PLAN	JOB NO.	27005	DATE	22 NOV 2007
PROJECT	FLINDERS FORESHORE LANDSLIP ASSESSMENT	SCALE (A3)	1:2,000	REV NO.	0
FILE REFERENCE	FLINDERS.WOR	DRAWN	DBS	FIG NO.	3



JOINS FIGURE 3

JOINS FIGURE 5



LEGEND

- Probable Landslips
- Potential Landslip or Area with Potential for Landslip
- TEXT On Site Observations

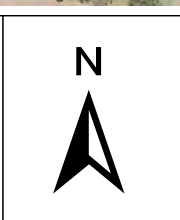
TITLE	ON SITE OBSERVATION PLAN	JOB NO.	27005	DATE	22 NOV 2007
PROJECT	FLINDERS FORESHORE LANDSLIP ASSESSMENT	SCALE (A3)	1:2,000	REV NO.	0
FILE REFERENCE	FLINDERS.WOR	DRAWN	DBS	FIG NO.	4



LEGEND

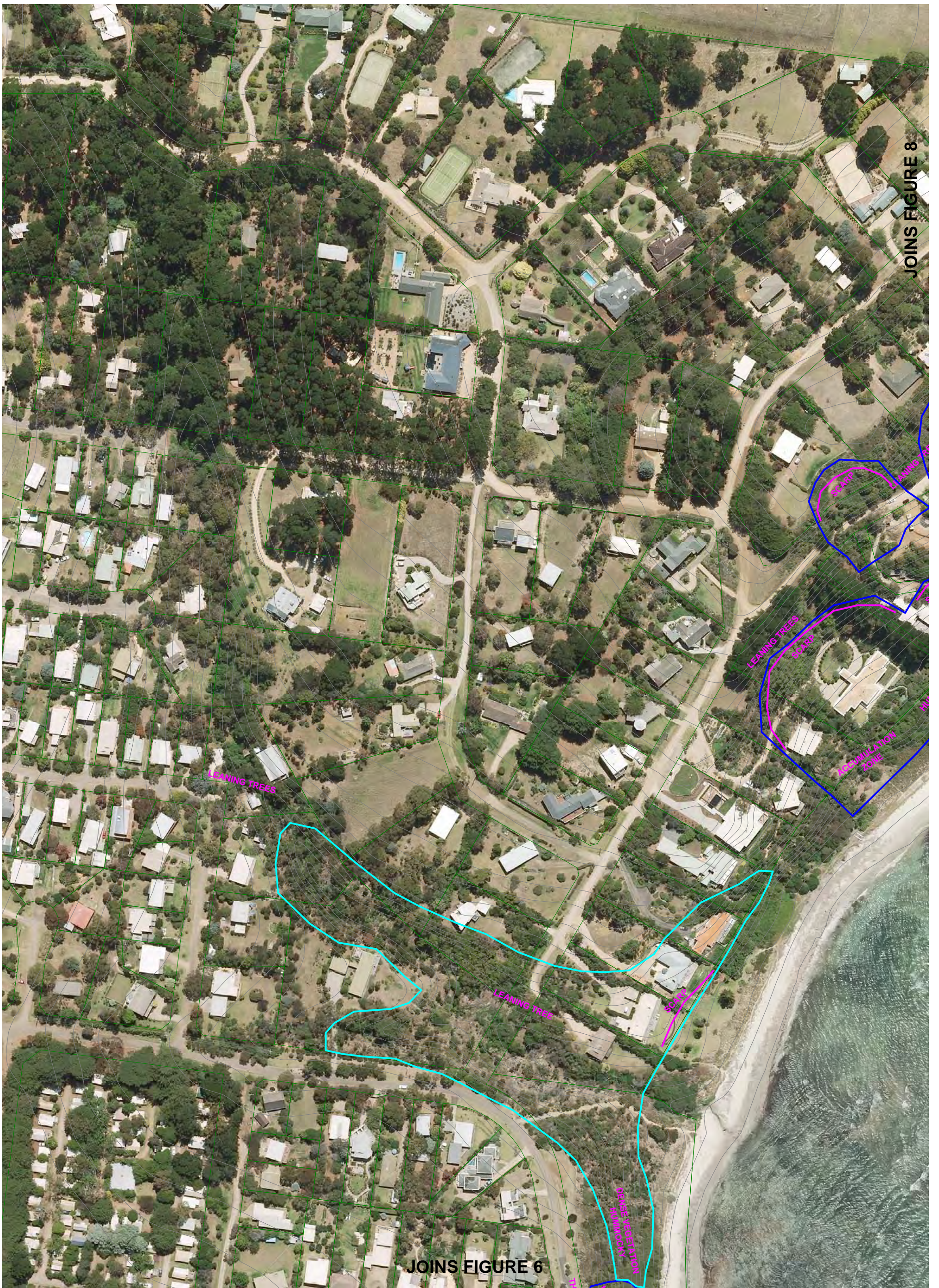
- Probable Landslips
- Potential Landslip or Area with Potential for Landslip
- TEXT On Site Observations

TITLE	ON SITE OBSERVATION PLAN	JOB NO.	27005	DATE	22 NOV 2007
PROJECT	FLINDERS FORESHORE LANDSLIP ASSESSMENT	SCALE (A3)	1:2,000	REV NO.	0
FILE REFERENCE	FLINDERS.WOR	DRAWN	DBS	FIG NO.	5



LEGEND	
—	Probable Landslips
—	Potential Landslip or Area with Potential for Landslip
TEXT	On Site Observations

TITLE	ON SITE OBSERVATION PLAN	JOB NO.	27005	DATE	22 NOV 2007
PROJECT	FLINDERS FORESHORE LANDSLIP ASSESSMENT	SCALE (A3)	1:2,000	REV NO.	0
FILE REFERENCE	FLINDERS.WOR	DRAWN	DBS	FIG NO.	6

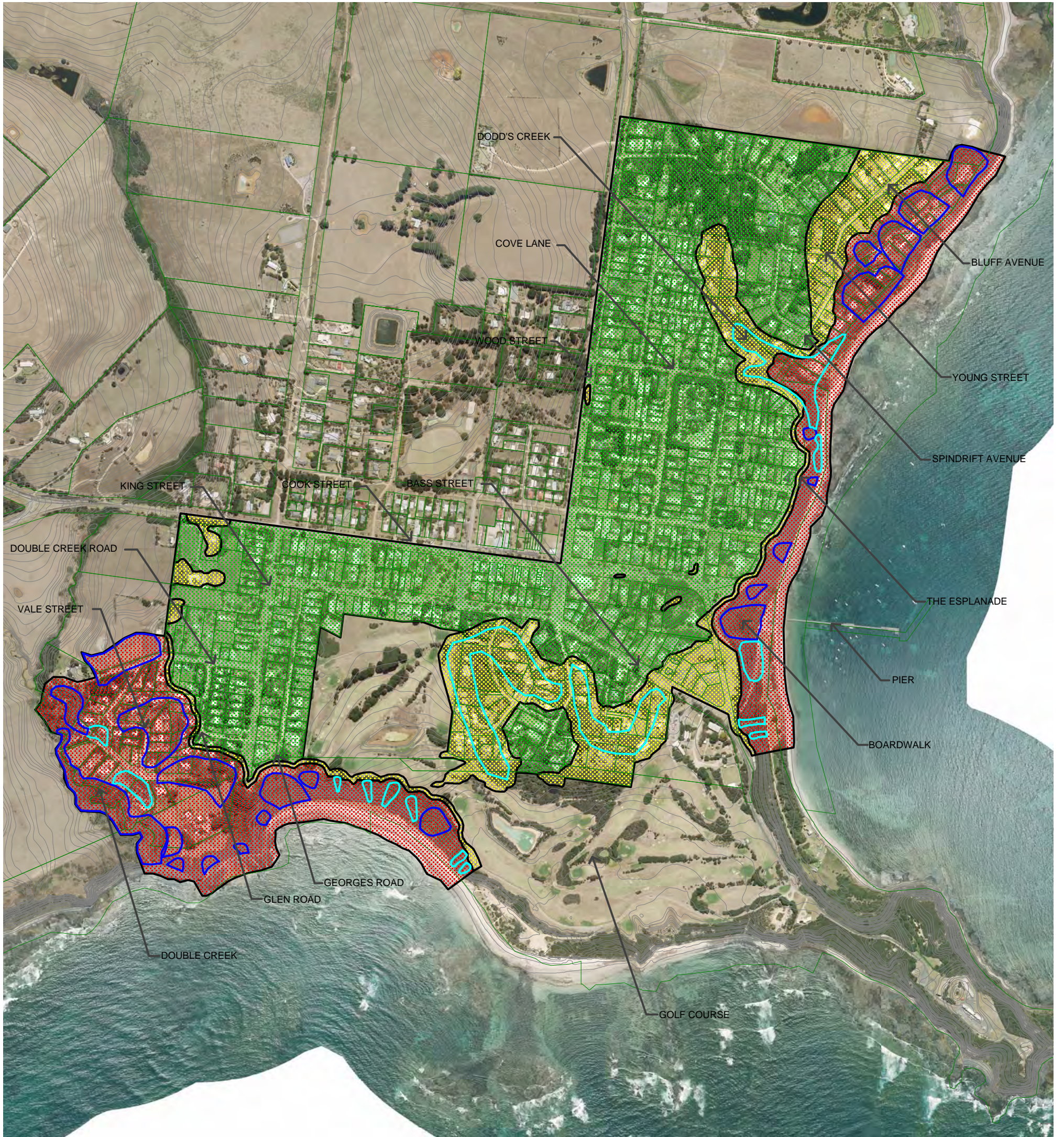


LEGEND	
	Probable Landslips
	Potential Landslip or Area with Potential for Landslip
	On Site Observations

TITLE	ON SITE OBSERVATION PLAN	JOB NO.	27005	DATE	22 NOV 2007
PROJECT	FLINDERS FORESHORE LANDSLIP ASSESSMENT	SCALE (A3)	1:2,000	REV NO.	0
FILE REFERENCE	FLINDERS.WOR	DRAWN	DBS	FIG NO.	7

APPENDIX B

Areas of Different Geotechnical Investigation Zone Plan Digital Terrain Plan Slopes and Aspect Plan



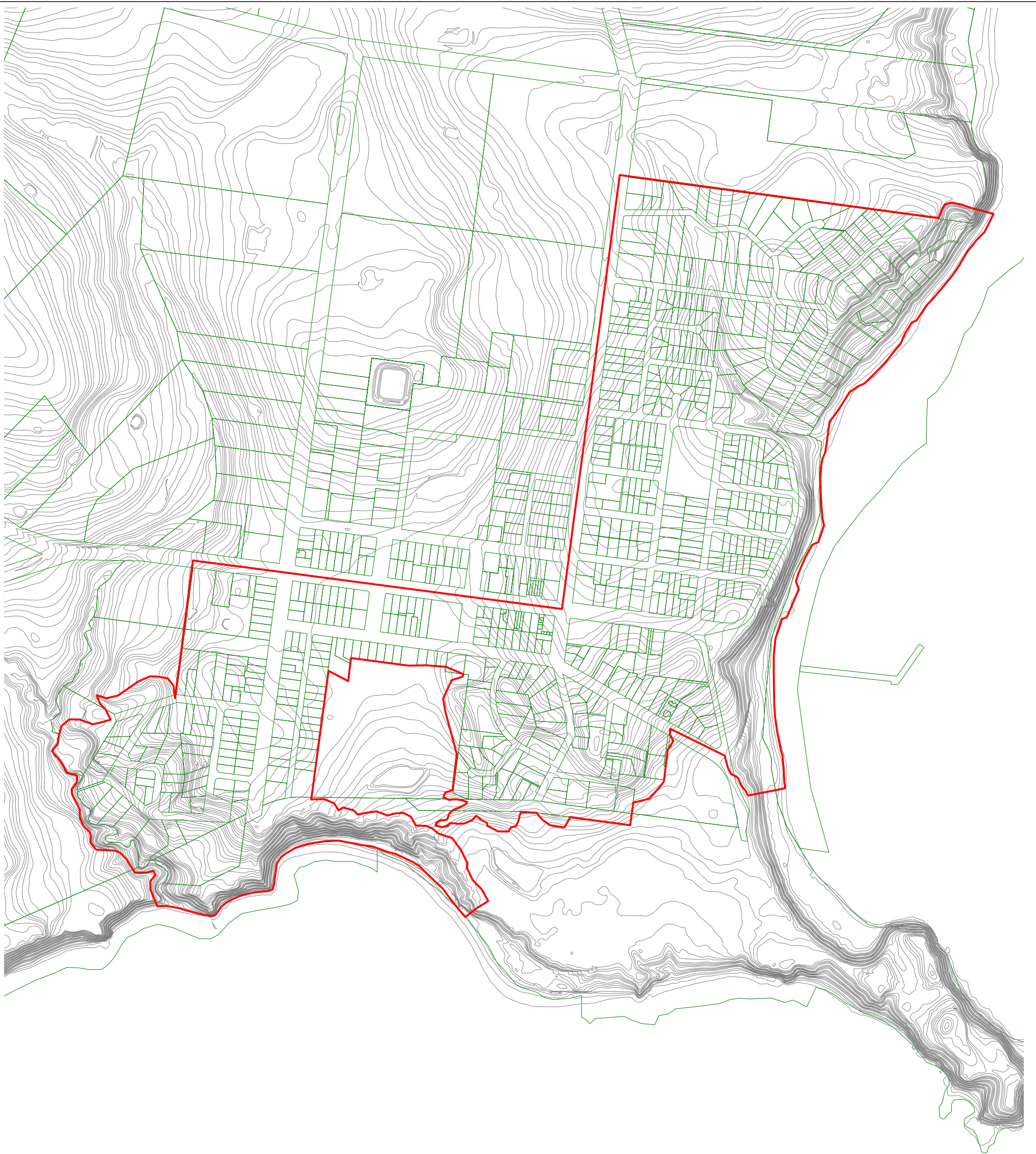
NOTE: Study area does not include golf course or Commonwealth land including parks and gunnery school

The survey and inspection from the roads and aerial photography are not sufficiently accurate to define the precise extent of each of the zones. Therefore, the nominated boundaries are based on limited information. In most cases, a conservative approach has been adopted with a buffer of approximately 20m applied between any observed landslips and the zone boundaries.



LEGEND	
	High Level of Geotechnical Investigation Required
	Moderate Level of Geotechnical Investigation Required
	Site Classification in Accordance with AS2870
	Probable Landslips
	Potential Landslip or Area with Potential for Landslip
Note: Unshaded areas not covered by the investigation	

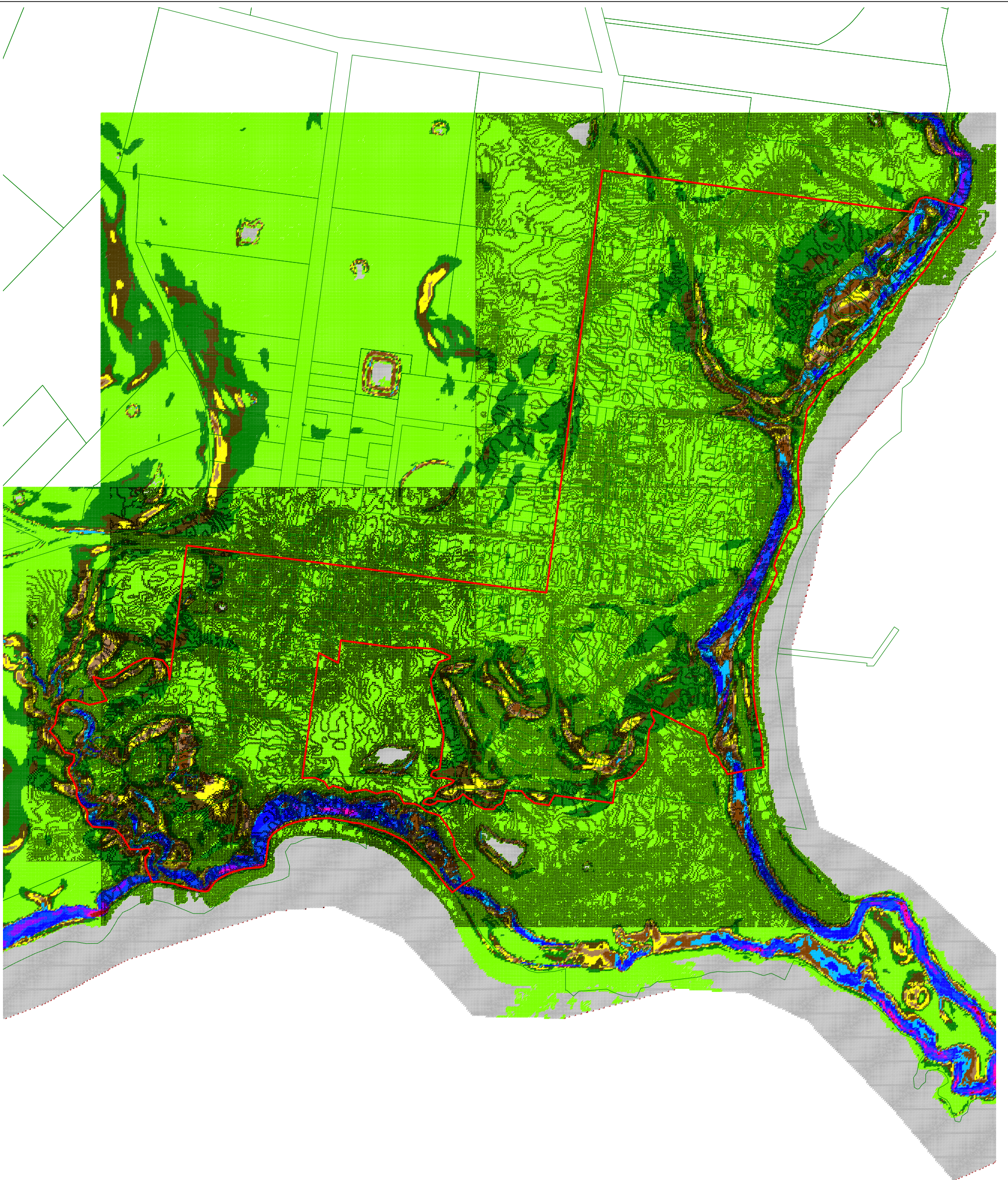
TITLE	AREAS OF DIFFERENT GEOTECHNICAL INVESTIGATION ZONE PLAN	JOB NO.	27005	DATE	12 DEC 2007
PROJECT	FLINDERS FORESHORE LANDSLIP ASSESSMENT	SCALE	(A3) 1:10,000	REV NO.	1
FILE REFERENCE	FLINDERS-ZONES.WOR	DRAWN	DBS	FIG NO.	1



LEGEND

- Area of Study
- Cadastre
- Contours (1m interval)

TITLE	DIGITAL TERRAIN PLAN	JOB NO.	27005	DATE	14 DEC 2007
PROJECT	FLINDERS FORESHORE LANDSLIP ASSESSMENT	SCALE (A3)	1:10,000	REV NO.	0
FILE REFERENCE	FLINDERS-DIGITAL TERRAIN.WOR	DRAWN	DBS	FIG NO.	2



LEGEND
 Area of Study

TITLE	SLOPE AND ASPECT PLAN	JOB NO.	27005	DATE	14 DEC 2007
PROJECT	FLINDERS FORESHORE LANDSLIP ASSESSMENT	SCALE (A3)	1:10,000	REV NO.	0
FILE REFERENCE	FLINDERS-SLOPES & ASPECTS.WOR	DRAWN	DBS	FIG NO.	3

APPENDIX C

Checklist for Slope Stability Assessments

CHECKLIST FOR STABILITY ASSESSMENTS

Factual Information

1. INFORMATION
 - Report prepared for who?
 - Site Location
 - Outline of proposed development^(b)
 - Comment on need for earthquake assessment
 2. TOPOGRAPHY
 - Outline current landform (slope, shape, height gradient, irregularities, erosion, soil creep/terraces)
 - Outline surface drainage patterns^(b)
 - Review aerial photos
 - Comment on any previous earthworks
 - Comment on any existing instability^(c)
 - Additional site features (eg. Vegetation/trees structures^(b) retaining walls, roads/driveways, services)
 3. SITE HISTORY
 - Outline current/previous landuse
 - Comment on previous siteworks^(b)
 - Reference “District Hazard Map”/GIS
 - Comment on previous instability^(c)
 - Performance of existing structures
 - Review aerial photos
 - Comment on previous contamination^(c)
 4. GEOLOGY
 - Describe geological setting
 - Refer to relevant maps
 - Geological influences on stability (eg. bedding, weak materials, faults)
 - Describe seismic setting
 5. INVESTIGATIONS
 - ◆ FIELD
 - Inspections by geotechnical specialist
 - Descriptions of soils/rock in borelogs (Ref. 1)
 - Outcrop/cutting descriptions^(c)
 - Record Extent of any cracking^(c)
 - Other field tests (eg. EPT, etc)
 - Monitoring of ground movements^(c)
 - Groundwater measurements and observations (seepage, subsurface erosion) ^(c)
 - ◆ LABORATORY
 - Outline tests undertaken
 - Summarise results
 - Previous testing in local area
 6. SUBSURFACE CONDITIONS
 - Geological interpretation^(c)
 - Summarise subsoil conditions, eg. extent of fill^(c) topsoil, nature and distribution of soils/rock
 - Describe soil strengths/density, likely behaviour – refer to tests and logs
 - Highlight weak/sensitive/loose soils or rock defects
 - Describe groundwater conditions, subsurface drainage, expected seasonal fluctuation
- ## Interpretation/Discussion
7. SLOPE STABILITY (Ref. 2,3,4,5)
 - ◆ ENGINEERING GEOLOGICAL ASSESSMENT
 - Discuss site features
 - Discuss geological setting/influences^(c)
 - Influence of rainfall/groundwater
 - Reasons for landform (local, regional)
 - Likely slope failure mechanisms
 - Potential for instability
 - Effects of the development on slopes^(f)
 - Consequence of instability
 - Empirical assessment (qualitative)
 - Risk rating applied^(g)
 - State whether stability analyses are required
 - ◆ GEOLOGICAL ENGINEERING ANALYSES
 - Geotechnical slope model correct?
 - Analytical method stated
 - Determination of critical section of slope
 - Assessment of strength parameters
 - Assessment of groundwater profile/rainfall
 - Back analysis of any existing failures
 - External loads due to the development
 - State need for seismic analysis
 - Normal FOS requirements:
 - Static (Design gwt) FOS ≥ 1.5
 - Static (Extreme gwt) FOS ≥ 1.2
 - Seismic (150 year EQ) FOS ≥ 1.2
 - Sensitive analyses for parameters required?
 - Results and comments.

CHECKLIST FOR STABILITY ASSESSMENTS

- | | |
|--|--|
| <p>8. GEOTECHNICAL EFFECTS OF DEVELOPMENT</p> <ul style="list-style-type: none"> ○ Slope stability risk increased or reduced? ○ Is the development feasible? ○ Need to drain slopes (surface/subsurface)? ○ Subsurface drainage beneath fills? ○ Need to retain slopes/secure rock faces? ○ Foundation conditions/requirements ○ Effect of stormwater/effluent disposal ○ Effect of service lines rupture (eg. SW, sewer) ○ Effect of river/coastal erosion ○ Seismic effects on development and slope ○ Maintenance requirements for life of the development | <p>9. CONCLUSIONS AND RECOMMENDATIONS</p> <p>10. STATEMENT
Statement by geotechnical assessor as to their ability & qualifications to prepare this geotechnical assessment</p> |
|--|--|

APPENDICES

- Borelogs, Testpit Logs, Logs of Exposures (Ref.1)
- Laboratory Results
- Specifications for Remedial Works/Fills
- Site Photos

DRAWINGS/FIGURES

- Site Plan^(d): ○ Borehole/Testpit Locations
○ Outline of Proposed Development
- Site Engineering Geological Maps^(d)
- Site Contours Maps^(d)) Cuts and fills
- Cross Sections) Indicated
- Geotechnical Model
- Stability Analyses Results

REFERENCES

1. Australian Standard 1726 – 1993, Geotechnical Site Investigations
2. Assessment of Slope Stability at Building Sites, BRANZ Study SR4, (1997)
3. Slope Stability in Urban Development, DSIR Series 122 (1981)
4. Stability of House Sites & Foundations, Earthquake & War Damages Commission, NZ Geomechanics Society (1980)
5. Landslide Risk Management Concept & Guidelines AGS, Sub-committee on Landslide Risk Management Australian Geomechanics Vol. 35, Vol. 35 March 2000
Land Assessment for Development Suitability, Burns & Farquhar, NZ Geotechnical Symposium (1996)

NOTES

- (a) This checklist is intended as a guide for typical stability investigation & assessments for residential developments. There may be additional requirements for specifically difficult sites, large scale developments and regional hazards
- (b) Indicate on site plan
- (c) Indicate on site engineering geological map
- (d) These plans/maps are best combined if possible
- (e) Ref.3 provides a valuable outline of stability problems peculiar to selected areas of NZ
- (f) Refer BRANZ document Fig 3 (ref 2 above), Stability House Sites and Foundations (ref. 4 above)
- (g) See Table 1. Design of Permanent Slopes for Residential Development, Crawford & Millar (1999)

EXCERPT

from Crawford SA & Millar P.J.
The Design of Permanent Slopes for Residential Development, 8th Aust & NZ Conference on Geomechanics, Vol. 1999

APPENDIX D

Glossary of Terminology

LANDSLIDE SUSCEPTIBILITY DEFINITIONS AND TERMINOLOGY

The following definitions and terminology are based on those in the *Guideline for Landslide Susceptibility, Hazard And Risk Zoning For Land Use Planning* by Australian Geomechanics Society Landslide Zoning Working Group.

These definitions are based on IUGS (1997), with some amendments in matters of detail based on internationally adopted definitions prepared by The International Society of Soil Mechanics and Geotechnical Engineering (ISSMGE) Technical Committee 32. These definitions should be used for all zoning, reports and land use planning documents. It is recommended that the definitions are attached to these documents so there is no misunderstanding of the terms.

Definitions of the main terms are:

- **Landslide:** The movement of a mass of rock, debris, or earth (soil) down a slope.
- **Landslide Inventory:** An inventory of the location, classification, volume, activity and date of occurrence of individual landslides in an area.
- **Landslide Susceptibility:** A quantitative or qualitative assessment of the classification, volume (or area) and spatial distribution of landslides which exist or potentially may occur in an area. Susceptibility may also include a description of the velocity and intensity of the existing or potential landsliding.
- **Hazard:** A condition with the potential for causing an undesirable consequence. The description of landslide hazard should include the location, volume (or area), classification and velocity of the potential landslides and any resultant detached material and the probability of their occurrence within a given period of time. Landslide hazard includes landslides which have their source in the area or may have their source outside the area but may travel on to or regress into the area.
- **Risk:** A measure of the probability and severity of an adverse effect to health, property or the environment. Risk is often estimated by the product of probability and consequences. However, a more general interpretation of risk involves a comparison of the probability and consequences in a non-product form.
- **Elements at Risk:** The population, buildings and engineering works, economic activities, public services utilities, infrastructure and environmental features in the area potentially affected by the landslide hazard.
- **Vulnerability:** The degree of loss to a given element or set of elements within the area affected by the landslide hazard. It is expressed on a scale of 0 (no loss) to 1 (total loss). For property, the loss will be the value of the damage relative to the value of the property; for persons, it will be the probability that a particular life (the element at risk) will be lost, given the person(s) is (are) affected by the landslide.
- **Zoning:** The division of land into homogeneous areas or domains and their ranking according to degrees of actual or potential landslide susceptibility, hazard or risk.

In this report use of the word 'landslide' implies both existing (or known landslides) and potential landslides which a practitioner might reasonably predict based on the relevant geology, geometry and slope forming processes. Such potential landslides may be of varying likelihood of occurrence.

The term landslip is sometimes used to describe landslides but is not the recommended term.

It is noted that the term “zoning” has particular application by planners in Australia. This document uses the term as it best describes the process and is used internationally. To avoid confusion, those preparing landslide zoning using this document should always refer to “ landslide susceptibility zoning”, “landslide hazard zoning” and “landslide risk zoning”.

It is important that those carrying out landslide mapping use consistent terminology to classify and describe the landslides. It is recommended that the classifications of Cruden and Varnes (1996), Varnes (1978) or Hutchinson (1988) and terminology described in IAEG (1990) be used. These are reproduced in AGS (2007c).

APPENDIX E
AGS Geoguides



**Australian
Geomechanics
Society**

Extract from

Australian Geomechanics

Journal and News of the Australian Geomechanics Society
Volume 42 No 1 March 2007

Extract containing:

“The Australian GeoGuides for Slope Management and Maintenance”

Ref: AGS (2007e)



Landslide Risk Management



ISSN 0818-9110

Figure 1

THE AUSTRALIAN GEOGUIDES FOR SLOPE MANAGEMENT AND MAINTENANCE

AGS Landslide Taskforce, Slope Management and Maintenance Working Group

The Australian Geomechanics Society (AGS) presents on the following pages a guideline on slope management and maintenance, as part of the landslide risk management guidelines developed under the National Disaster Funding Program (NDMP). This Guideline is aimed at home owners, developers and local councils, but also has applicability to a larger audience which includes builders and contractors, consultants, insurers, lawyers, government departments and in fact any person, or organisation, with a responsibility for the management or maintenance of a slope. The objective is to inform those with little or no knowledge of geotechnical engineering about landslides.

Each GeoGuide is a stand-alone document, which is formatted so that it can be printed on two sides of a single A4 sheet. It is expected that the set of GeoGuides will increase with time to cover a range of topics. As things stand:

- **GeoGuide LR1** is an introductory sheet that should be read by all users, since it explains what the LR (landslide risk) series is about and defines terms.
- **GeoGuides LR2, 3 and 4** explain why landslides occur and provide information on different types of landslide.
- **GeoGuide LR5** discusses the critical part that water often plays in relation to landslide occurrence and discusses measures that can be adopted to limit its effect.
- **GeoGuide LR6** refers to retaining walls and their maintenance.
- **GeoGuide LR7** puts the concept of landslide risk into an everyday context, so users can relate a particular landslide risk to other risks that they know they are prepared to take, sometimes on a daily basis.
- **GeoGuide LR8** retains the ideas of good and poor hillside construction practice originally provided by an AGS sub-committee in 1985.
- **GeoGuide LR9** concentrates specifically on effluent and surface water disposal, which is an important topic in some development areas.
- **GeoGuide LR10** is specifically aimed at those who have property on the coast and could be susceptible to coastal erosion processes.
- **GeoGuide LR11** provides information about the benefits of keeping records on inspection and maintenance activities and provides a proforma record sheet for users.

It is recognised that the GeoGuides are likely to be upgraded from time to time. Feedback on use and suggested changes should be sent to the National Chair of the Australian Geomechanics Society. The latest versions of the GeoGuides will be downloadable from the AGS website www.australiangeomechanics.org

Through the NDMP, Australian governments (at Commonwealth, State and Local Government levels) are also funding the development of a Landslide Zoning Guideline (AGS 2007a), and a Practice Note Guideline (AGS 2007c) to which interested readers seeking in-depth information should refer.

ACKNOWLEDGEMENTS

These guidelines have been prepared by The Australian Geomechanics Society with funding from the National Disaster Mitigation Program, the Sydney Coastal Councils Group, and The Australian Geomechanics Society.

The Australian Geomechanics Society established a Working Group within a Landslide Taskforce to develop the guidelines. The development of the guidelines was managed by a Steering Committee. Membership of the Working Group, Taskforce and Steering Committee is listed in the Appendix.

Drafts of these GeoGuides have been subject to review by members of the AGS Landslide Taskforce, members of the geotechnical profession and local government.

REFERENCES

- AGS (2007a) Guideline for Landslide Susceptibility, Hazard and Risk Zoning for Land Use Management. Australian Geomechanics Society, *Australian Geomechanics*, Vol 42, No1.
- AGS (2007c). Practice Note Guidelines for Landslide Risk Management. Australian Geomechanics Society. *Australian Geomechanics*, Vol 42, No1,
- AGS (2007e). The Australian GeoGuides for slope management and maintenance –. Australian Geomechanics Society. *Australian Geomechanics*, Vol 42, No 1, - this paper.

AUSTRALIAN GEOGUIDE LR1 (INTRODUCTION)

INTRODUCTION TO LANDSLIDE RISK

Photographs courtesy of Greg Kotze and Tony Phillips



AUSTRALIAN GEOGUIDES

The **Australian GeoGuides (LR series)** are a set of information sheets on the subject of landslide risk management and maintenance, published by the Australian Geomechanics Society (AGS). They provide background information intended to help people without specialist technical knowledge understand the basic issues involved. Topics covered include:

LR1 - Introduction	LR2 - Landslides	LR3 - Landslides in Soil
LR4 - Landslides in Rock	LR5 - Water & Drainage	LR6 - Retaining Walls
LR7 - Landslide Risk	LR8 - Hillside Construction	LR9 - Effluent & Surface Water Disposal
LR10 - Coastal Landslides	LR11 - Record Keeping	

The GeoGuides explain why slopes and retaining structures can be a hazard and what can be done with appropriate professional advice and local authority approval (if required) to remove, or reduce, the risk they represent.

Preparation of the GeoGuides has been funded by Australian governments through the National Disaster Mitigation Program (NDMP). This is a national program aimed at identifying and addressing natural disaster risk priorities across Australia. Technical input has been provided by experienced geotechnical engineers, engineering geologists and local government and government agency representatives from around Australia.

BACKGROUND

A number of landslides and cliff collapses occurred in Australia in the 1980's and 1990's in which lives were lost. Of these the Thredbo landslide probably received the most publicity, but there were several others. During this period the AGS issued a number of advisory notes to practitioners in relation to the assessment of landslide risk and its reduction. Building on these notes, and responding to changes in technology, a technical paper known as AGS2000 was prepared. It was followed in 2002 by an intensive nation-wide educational campaign attended by a large number of interested professionals from government departments and private industry. This resulted in an increased awareness of the risks associated with unstable slopes and a changed approach in many government departments responsible for regional planning, domestic development, roads, railways and the maintenance of natural features such as cliffs.

STATUS OF THE GEOGUIDES

The GeoGuides reflect the essence of good practice as perceived by a large number of geotechnical engineers, engineering geologists and other practitioners such as local government planners. **The GeoGuides are generic and do not, and cannot, constitute advice in relation to a specific situation. This must be sought from a geotechnical practitioner with first hand knowledge of the site.** It is expected that some local councils will refer to the GeoGuides and their companion publications in planning and building legislation. Check with your local council to see how it regards these documents. Companion publications to the GeoGuides are:

- AGS (2007a) Guideline for Landslide Susceptibility, Hazard and Risk Zoning for Land Use Management Australian Geomechanics Society, *Australian Geomechanics*, Vol 42, No1 and its associated commentary (AGS 2007b).
- AGS (2007c). Practice Note Guidelines for Landslide Risk Management. Australian Geomechanics Society. *Australian Geomechanics*, Vol 42, No1 2007, and its associated "Commentary" (AGS 2007d).

Copies of the above documents are available on the AGS website www.australiangeomechanics.org

AUSTRALIAN GEOGUIDE LR1 (INTRODUCTION)

TERMINOLOGY

Terminology tends to change with time and place and with the context in which it is used. The terms listed below have the following meanings in the GeoGuides:

Consequence	the outcome, or potential outcome, arising from the occurrence of a landslide expressed quantitatively, or qualitatively, in terms of loss, disadvantage, damage, injury, or loss of life.
Discontinuity	in relation to the ground is a crack, a bedding plane (a boundary between strata) or fault (a plane along which the ground has sheared) which forms a plane of weakness and reduces the overall strength of the ground.
Equilibrium	the condition when the forces on a mass of soil or rock in the ground, or on a retaining structure, are equal and opposite.
Factor of safety (FOS)	theoretically the forces available to prevent a part of the ground, or a retaining structure, from moving divided by those trying to move it. A FOS of one or less indicates that failure is likely to occur, but not how likely it is. To allow for unknowns and to limit movements engineers always aim to achieve a FOS significantly larger than one.
Failure	when part of the ground experiences movement as a result of the out of balance forces on it. Failure of a retaining structure means it is no longer able to fulfil its intended function.
Geotechnical practitioner	when referred to in the Australian GeoGuides (LR series), is a professional geotechnical engineer, or engineering geologist, with chartered status in a recognised national professional institution and relevant training, experience and core competencies in landslide risk assessment and management. In some government departments, technical officers are specifically trained to undertake some of the functions of a geotechnical practitioner.
Hazard	a condition with the potential for causing an undesirable consequence. In relation to landslides this includes the location, size, speed, distance of travel and the likelihood of its occurrence within a given period of time.
Landslide	the movement, or the potential movement, of a mass of rock, debris, or earth down a slope.
Likelihood	a qualitative description of probability, or frequency, of occurrence.
Partial saturation	the condition in the ground above the water table where both air and water are present as well as soil, or rock.
Perched water table	a water table above the true water table supported by a low permeability stratum.
Permeability	a measure of the ability of the ground to allow water to flow through it.
Risk	a measure of the probability and severity of an adverse effect to life, health, property or the environment.
Slip failure	landslide.
Stable	the condition when failure will not occur. Over geological time no part of the ground can be considered stable. Over short periods (eg the life of a structure) stability implies a very low likelihood of failure.
Retaining structure	anything built by humans which is intended to support the ground and inhibit failure.
Structure	in relation to rock, or soil, means the spacing, extent, orientation and type of discontinuities found in the ground at a particular location.
Tension crack	a distinct open crack that normally develops in the ground around a landslide and indicates actual, or imminent, failure.
Water table	the level in the ground below which it is saturated and the voids are filled with water.

Photograph courtesy of Phil Flentje



AUSTRALIAN GEOGUIDE LR2 (LANDSLIDES)

LANDSLIDES

What is a Landslide?

Any movement of a mass of rock, debris, or earth, down a slope, constitutes a "landslide". Landslides take many forms, some of which are illustrated. More information can be obtained from Geoscience Australia, or by visiting its Australian Landslide Database at www.ga.gov.au/urban/factsheets/landslide.jsp. Aspects of the impact of landslides on buildings are dealt with in the book "Guideline Document Landslide Hazards" published by the Australian Building Codes Board and referenced in the Building Code of Australia. This document can be purchased over the internet at the Australian Building Codes Board's website www.abcb.gov.au.

Landslides vary in size. They can be small and localised or very large, sometimes extending for kilometres and involving millions of tonnes of soil or rock. It is important to realise that even a 1 cubic metre boulder of soil, or rock, weighs at least 2 tonnes. If it falls, or slides, it is large enough to kill a person, crush a car, or cause serious structural damage to a house. The material in a landslide may travel downhill well beyond the point where the failure first occurred, leaving destruction in its wake. It may also leave an unstable slope in the ground behind it, which has the potential to fail again, causing the landslide to extend (regress) uphill, or expand sideways. For all these reasons, both "potential" and "actual" landslides must be taken very seriously. They present a real threat to life and property and require proper management.

Identification of landslide risk is a complex task and must be undertaken by a geotechnical practitioner (GeoGuide LR1) with specialist experience in slope stability assessment and slope stabilisation.

What Causes a Landslide?

Landslides occur as a result of local geological and groundwater conditions, but can be exacerbated by inappropriate development (GeoGuide LR8), exceptional weather, earthquakes and other factors. Some slopes and cliffs never seem to change, but are actually on the verge of failing. Others, often moderate slopes (Table 1), move continuously, but so slowly that it is not apparent to a casual observer. In both cases, small changes in conditions can trigger a landslide with serious consequences. Wetting up of the ground (which may involve a rise in ground water table) is the single most important cause of landslides (GeoGuide LR5). This is why they often occur during, or soon after, heavy rain. Inappropriate development often results in small scale landslides which are very expensive in human terms because of the proximity of housing and people.

Does a Landslide Affect You?

Any slope, cliff, cutting, or fill embankment may be a hazard which has the potential to impact on people, property, roads and services. Some tell-tale signs that might indicate that a landslide is occurring are listed below:

- open cracks, or steps, along contours
- ground water seepage, or springs
- bulging in the lower part of the slope
- hummocky ground
- trees leaning down slope, or with exposed roots
- debris/fallen rocks at the foot of a cliff
- tilted power poles, or fences
- cracked or distorted structures

These indications of instability may be seen on almost any slope and are not necessarily confined to the steeper ones (Table 1). Advice should be sought from a geotechnical practitioner if any of them are observed. Landslides do not respect property boundaries. As mentioned above they can "run-out" from above, "regress" from below, or expand sideways, so a landslide hazard affecting your property may actually exist on someone else's land.

Local councils are usually aware of slope instability problems within their jurisdiction and often have specific development and maintenance requirements. **Your local council is the first place to make enquiries if you are responsible for any sort of development or own or occupy property on or near sloping land or a cliff.**

TABLE 1 - Slope Descriptions

Appearance	Slope Angle	Maximum Gradient	Slope Characteristics
Gentle	0° - 10°	1 on 6	Easy walking.
Moderate	10° - 18°	1 on 3	Walkable. Can drive and manoeuvre a car on driveway
Steep	18° - 27°	1 on 2	Walkable with effort. Possible to drive straight up or down roughened concrete driveway, but cannot practically manoeuvre a car.
Very Steep	27° - 45°	1 on 1	Can only climb slope by clutching at vegetation, rocks etc.
Extreme	45° - 64°	1 on 0.5	Need rope access to climb slope
Cliff	64° - 84°	1 on 0.1	Appears vertical. Can abseil down.
Vertical or Overhang	84° - 90±°	Infinite	Appears to overhang. Abseiler likely to lose contact with the face.

Some typical landslides which could affect residential housing are illustrated below:

AUSTRALIAN GEOGUIDE LR2 (LANDSLIDES)

Rotational or circular slip failures (Figure 1) - can occur on moderate to very steep soil and weathered rock slopes (Table 1). The sliding surface of the moving mass tends to be deep seated. Tension cracks may open at the top of the slope and bulging may occur at the toe. The ground may move in discrete "steps" separated by long periods without movement. More rapid movement may occur after heavy rain.

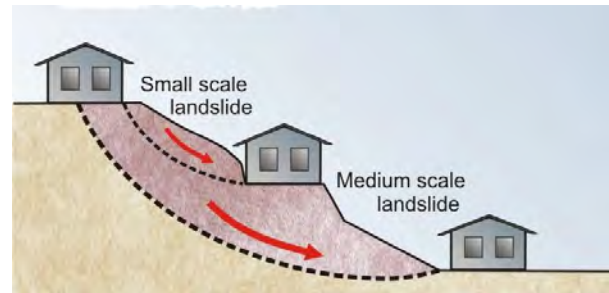


Figure 1

Translational slip failures (Figure 2) - tend to occur on moderate to very steep slopes (Table 1) where soil, or weak rock, overlies stronger strata. The sliding mass is often relatively shallow. It can move, or deform slowly (creep) over long periods of time. Extensive linear cracks and hummocks sometimes form along the contours. The sliding mass may accelerate after heavy rain.



Figure 2

Wedge failures (Figure 3) - normally only occur on extreme slopes, or cliffs (Table 1), where discontinuities in the rock are inclined steeply downwards out of the face.

Rock falls (Figure 3) - tend to occur from cliffs and overhangs (Table 1).

Cliffs may remain apparently unchanged for hundreds of years. Collections of boulders at the foot of a cliff may indicate that rock falls are ongoing. Wedge failures and rock falls do not "creep". Familiarity with a particular local situation can instil a false sense of security since failure, when it occurs, is usually sudden and catastrophic.

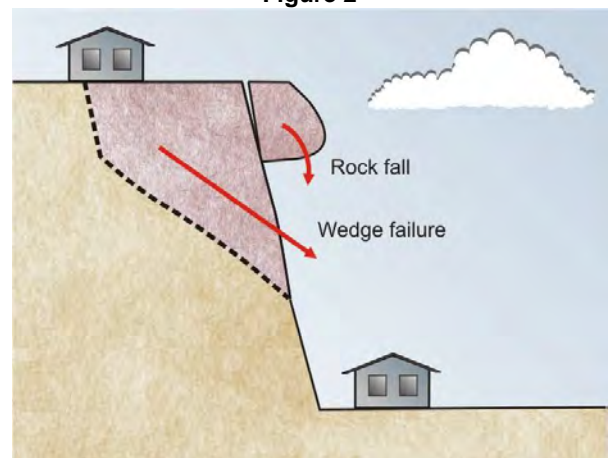


Figure 3

Debris flows and mud slides (Figure 4) - may occur in the foothills of ranges, where erosion has formed valleys which slope down to the plains below. The valley bottoms are often lined with loose eroded material (debris) which can "flow" if it becomes saturated during and after heavy rain. Debris flows are likely to occur with little warning; they travel a long way and often involve large volumes of soil. The consequences can be devastating.

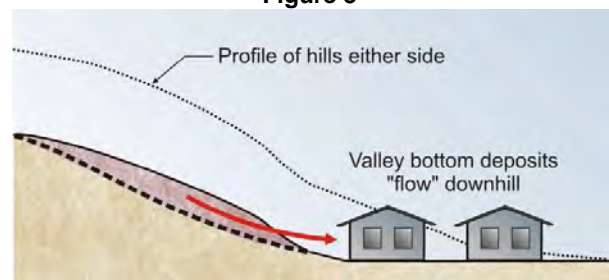


Figure 4

More information relevant to your particular situation may be found in other Australian GeoGuides:

- GeoGuide LR1 - Introduction
- GeoGuide LR3 - Soil Slopes
- GeoGuide LR4 - Rock Slopes
- GeoGuide LR5 - Water & Drainage
- GeoGuide LR6 - Retaining Walls
- GeoGuide LR7 - Landslide Risk
- GeoGuide LR8 - Hillside Construction
- GeoGuide LR9 - Effluent & Surface Water Disposal
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AUSTRALIAN GEOGUIDE LR3 (LANDSLIDES IN SOIL)

LANDSLIDES IN SOIL

Landslides occur on soil slopes and the consequences can include damage to property and loss of life. Soil slopes exist in all parts of Australia and can even occur in places where rock outcrops can be seen on the surface. If you live on, or below, a soil slope it is important to understand why a landslide might occur and what you can do to reduce the risk it presents.

It is always worth asking the question "why is this slope here?", because the answer often leads to an understanding of what might happen in the future. Slopes are usually formed by weathering (breakdown) and erosion (physical movement) of the natural ground - the "parent material". Many factors are involved including rain, wind, chemical change, temperature variation, plant growth, animal activity and our own human enthusiasm for development. The general process is outlined in Figure 1.

The upper levels of the parent material progressively weather over thousands, or millions, of years, losing strength. This can result in a surface layer which looks similar to the parent material (although its colour has probably changed) but has the strength of a soil - this is called "residual soil". At some stage the weathered surface layer is exposed to the elements and fragments are transported down the slope. In this context a fragment could be a single sand grain, a boulder, or a landslide. The time scale could be anything from a few seconds to many thousands of years. The transported fragments often collect on the lower slopes and form a new soil layer that blankets the original slope - "colluvium". If material reaches a river or the sea it is deposited as "alluvium" or as a "marine deposit". With appropriate changes in river and sea level this material can again find itself on the surface to commence another cycle of weathering and erosion. In places often, but not only, near the coast, this can include sand sized fragments which form beaches and are sometimes blown back onto the land to form dunes.

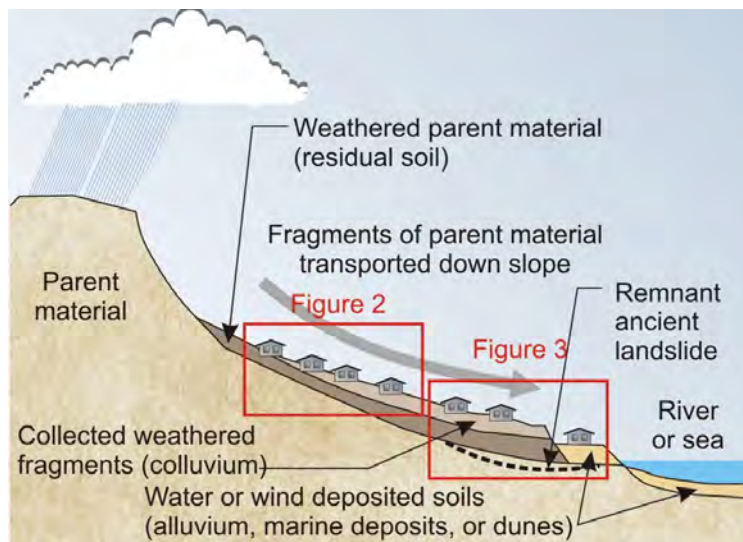


Figure 1

Landslides can occur almost anywhere on a soil slope. Slides can be rotational, translational, or debris flows (see GeoGuide LR2) and may have a number of causes.

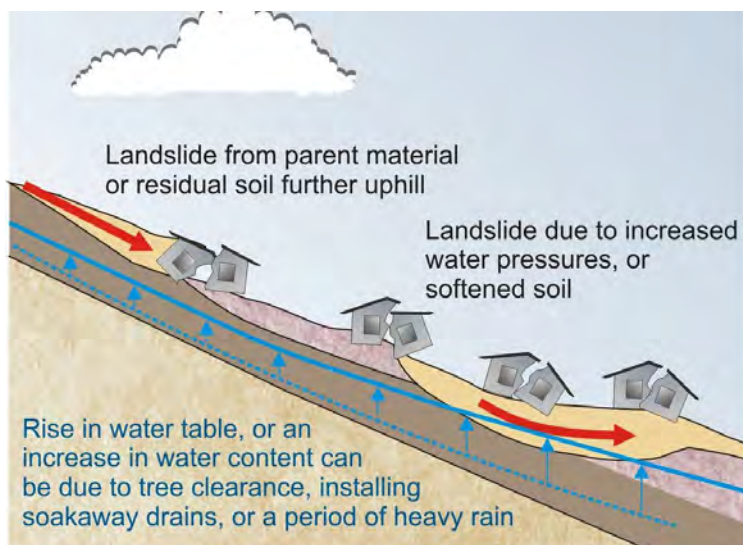


Figure 2

AUSTRALIAN GEOGUIDE LR3 (LANDSLIDES IN SOIL)

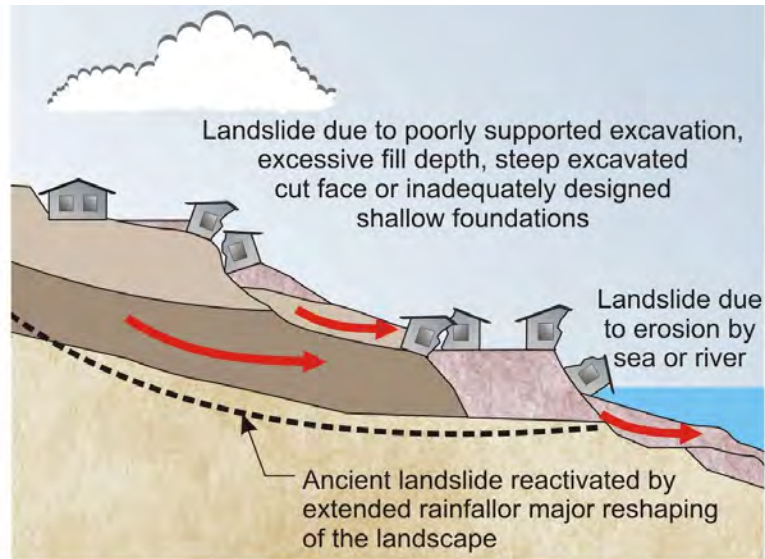


Figure 3

Some of the more common causes of landslides in soil are:

- 1) Falls of the parent material or residual soil from above, due to natural weathering processes (Figure 2).
- 2) Increased moisture content and consequent softening of the soil, or a rise in the water table. These can be due to excessive tree clearance, ill-considered soak-away drainage or septic systems, or heavy rainfall (Figure 2).
- 3) Excavation without adequate support, increased surface load from fill placement, or inadequately designed shallow foundations (Figure 3).
- 4) Natural erosion at the toe of the slope due to scour by a river or the sea (Figure 3).
- 5) Re-activation of an ancient landslide (Figure 3).

Most soil slopes appear stable, but they all achieved their present shape through a process of weathering and erosion and are often sensitive to minor changes in the factors that affect their stability. As a general rule, human activities only improve the situation if they have been designed to do so. Once this idea is understood, it is probably easy to see why the following basic rules are so important and should not be ignored without seeking site specific advice from a geotechnical practitioner:

- Do not clear trees unnecessarily.
- Do not cut into a slope without supporting the excavated face with an engineer designed structure.
- Do not add weight to a slope by placing earth fill or constructing buildings with inadequately designed shallow foundations (Note: in certain circumstances weight is added to the toe of a slope to inhibit landslide movement, but this must be carried out in accordance with a proper engineering design).
- Do not allow water from storm water drains, or from septic waste or effluent disposal systems to soak into the ground where it could trigger a landslide.

More information in relation to good and poor hillside construction practice is given in GeoGuide LR8. With appropriate engineering input it is often possible to reduce the likelihood, or consequences, of a landslide and so reduce the risk to property and to life. Such measures can include the construction of properly designed storm water and sub-soil drains, surface protection (GeoGuide LR5) and retaining walls (GeoGuide LR6). **Design should be undertaken by a geotechnical practitioner and will normally require local council approval.**

More information relevant to your particular situation may be found in other Australian GeoGuides:

- GeoGuide LR1 - Introduction
- GeoGuide LR2 - Landslides
- GeoGuide LR4 - Landslides in Rock
- GeoGuide LR5 - Water & Drainage
- GeoGuide LR6 - Retaining Walls
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LANDSLIDES IN ROCK

Rocks have been formed by many different geological processes and may have been subjected to intense pressure, large scale distortion, extreme temperature and chemical change. As a result there are many different rock types and their condition varies enormously. Rock strength varies and is often significantly reduced by the presence of discontinuities (GeoGuide LR1). You may think that rock lasts forever, but in reality it weathers under the combined effects of water, wind, chemical change, temperature variation, plant growth and animal activity and erodes with time. Rock is often the parent material that ends up forming soil slopes (GeoGuide LR3). Inevitably different rocks have different physical and chemical characteristics and they weather and erode to form different types of soil.

Weathering can lead to landslides (GeoGuide LR2) on rock slopes. The type of landslide depends on the nature of rock, the way it has weathered and the presence or absence of discontinuities. It is hard to generalise, though normally a specific combination of discontinuities and material types will be the determining factor and these are often underground and out of sight. Typical examples are provided in the figures 1 to 4. A geotechnical practitioner can assess the landslide risk and propose appropriate maintenance measures. This often entails making geological observations over an area significantly larger than the site and a review of available background information, including records of known landslides and aerial photographs. Depending on the amount of information available, geotechnical investigation may or may not be needed. Every site is different and every site has to be assessed individually.

It is impossible to predict exactly when a landslide will occur on a rock slope, but failure is normally sudden and the consequences can be catastrophic.

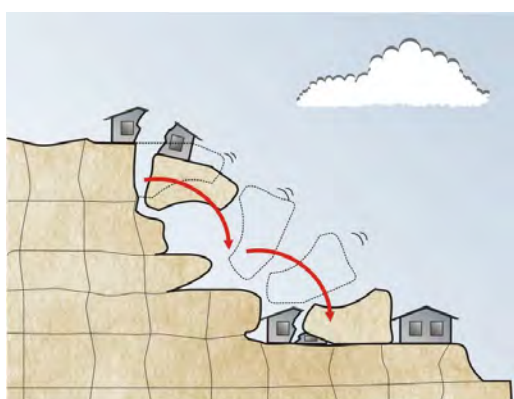


Figure 1 - Failure of an undercut block

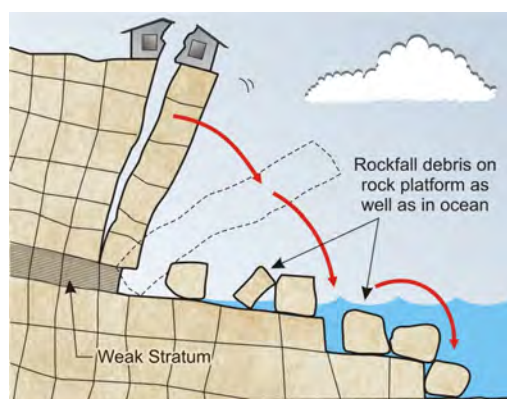


Figure 2 - Toppling failure

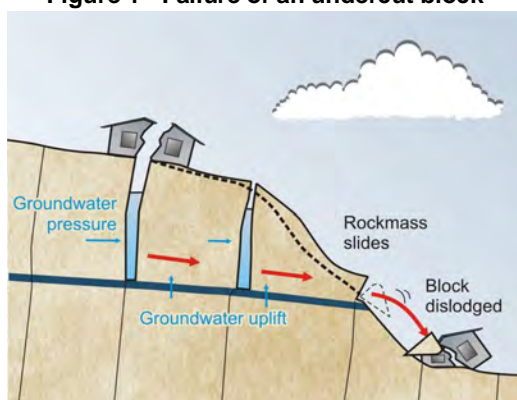


Figure 3 - Block slide on weak layer

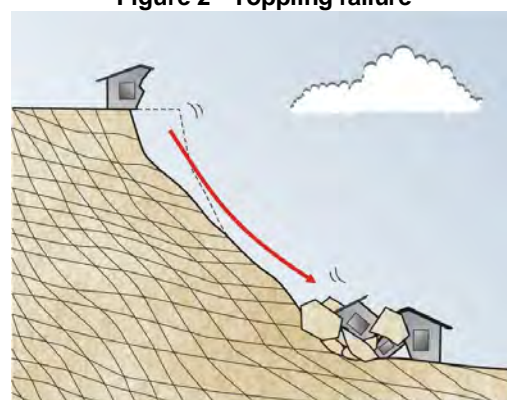


Figure 4 - Wedge failure along discontinuities

If the landslide risk is assessed as being anything other than Low, or Very Low, (GeoGuide LR7) it may be possible to carry out work aimed at reducing the level of risk.

The most common options are:

- 1) Trimming the slope to remove hazardous blocks of rock.
- 2) Bolting, or anchoring, to fix hazardous blocks in position and prevent movement.
- 3) Installation of catch fences and other rockfall protection measures to limit the impact of rockfalls.
- 4) Deep drainage designed to limit changes in the ground water table (GeoGuide LR5).

Although such measures can be effective, they need inspection and on-going maintenance (GeoGuide LR11) if they are to be effective for periods equivalent to the life of a house. **Design should be undertaken by a geotechnical practitioner and will normally require local council approval.** It should be appreciated that it may not be viable to carry out remedial works in all circumstances: for example where the landslide is on someone else's property, where the cost is out of proportion to the value of the property, or where the risk inherent in carrying out the work is actually greater than the risk of leaving things as they are. In situations such as these, development may be considered inappropriate.

AUSTRALIAN GEOGUIDE LR4 (LANDSLIDES IN ROCK)

ROCK SLOPE HAZARD REDUCTION MEASURES

Removal of loose blocks - may be effective but, depending on rock type, ongoing erosion can result in more blocks becoming unstable within a matter of years. Routine inspection, every 5 or so years, may be required to detect this.

Rock bolts and rock anchors (Figure 5) - can be installed in the ground to improve its strength and prevent individual blocks from falling. Rock bolts are usually tightened using a torque wrench, whilst rock anchors carry higher loads and require jacking. Both can be designed to be "permanent" using stainless steel, or sheathing, to inhibit corrosion, but the cost can be up to 10 times that of the "temporary" alternative. You should inspect rock bolts and rock anchors for signs of water seepage, rusting and deterioration around the heads at least once every 5 years. If you notice any of these warning signs, have them checked by a geotechnical practitioner. It is recommended that you keep copies of design drawings and maintenance records (GeoGuide LR11) for the anchors on your site and pass them on to the new owner should you sell.

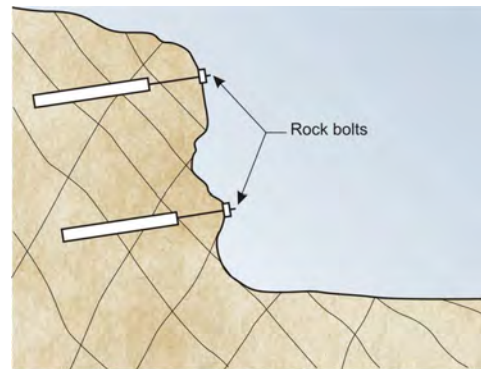


Figure 5

Rock fall netting, catch fences and catch pits (Figure 6) - are designed to catch or control falling rocks and prevent them from damaging nearby property. You should inspect them at least once every 5 years, and after major falls, and arrange for fallen and trapped rocks to be removed if they appear to be filling up. Check for signs of corrosion and replace steel elements and fixings before they lose significant strength.

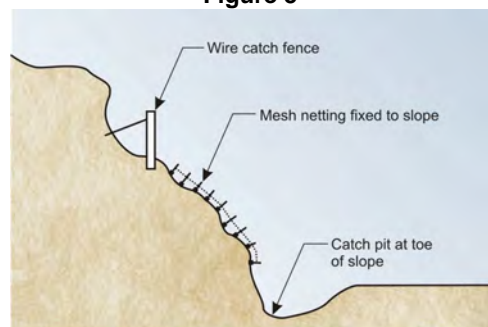


Figure 6

Cut-off drains (Figure 7) - can be used to intercept surface water run-off and reduce flows down the cliff face. Suitable drains are often excavated into the rock, or constructed from mounds of concrete, or stabilised soil, depending on conditions. Drains must be laid to a fall of at least 1% so they drain adequately. Frequent inspection is needed to ensure they are not blocked and continue to function as intended.

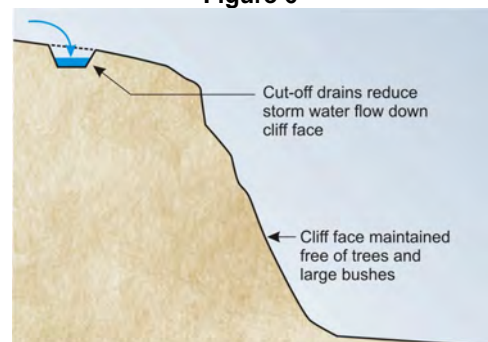


Figure 7

Clear trees and large bushes (Figure 7) - from slopes since roots can prize boulders from the face increasing the landslide hazard.

Natural cliffs and bluffs - often present the greatest hazard and yet are easily overlooked, because they have "been there forever". They can exist above a building, road, or beach, presenting the risk of a rock falling onto whatever is below. They also sometimes support buildings with a fine view to the horizon. Cliffs should be observed frequently to ensure that they are not deteriorating. You may find it convenient to use binoculars to look for signs of exposed "fresh" rock on the face, where a recent fall has occurred, or to go to the foot of the cliff from time to time to see if debris is collecting. A thorough inspection of a cliff face is often a major task requiring the use of rope access methods and should only be undertaken by an appropriately qualified professional. If tension cracks are observed in the ground at the top of a cliff take immediate action, since they could indicate imminent failure. **If you have any concerns at all about the possibility of a rock fall seek advice from a geotechnical practitioner.**

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WATER, DRAINAGE & SURFACE PROTECTION

One way or another, water usually plays a critical part in initiating a landslide (GeoGuide LR2). For this reason, it is a key factor to be controlled on sites with more than a low landslide risk (GeoGuide LR7).

Groundwater and Groundwater Flow

The ground is permeable and water flows through it as illustrated in Figure 1. When rain falls on the ground, some of it runs along the surface ("surface water run-off") and some soaks in, becoming groundwater. Groundwater seeps downwards along any path it can find until it meets the water table: the local level below which the ground is saturated. If it reaches the water table, groundwater either comes to a halt in what is effectively underground storage, or it continues to flow downwards, often towards a spring where it can seep out and become surface water again. Above the water table the ground is said to be "partially saturated", because it contains both water and air. Suctions can develop in the partially saturated zone which have the effect of holding the ground together and reducing the risk of a landslide. Vegetation and trees in particular draw large quantities of water out of the ground on a daily basis from the partially saturated zone. This lowers the water table and increases suctions, both of which reduce the likelihood of a landslide occurring.

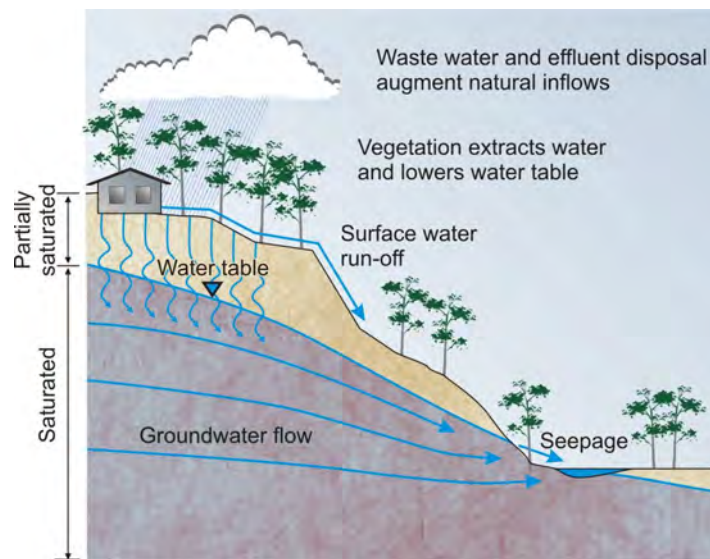


Figure 1 - Groundwater flow

Groundwater Flow and Landslides

The landslide risk in a hillside can be affected by increase in soak-away drainage or the construction of retaining walls which inhibit groundwater flow. The groundwater is likely to rise after heavy rain, but it can also rise when human interference upsets the delicate natural balance. Activities such as felling trees and earthworks can lead to:

- a reduction in the beneficial suctions in the partially saturated zone above the water table.
- increased static water pressures below the water table,
- increased hydraulic pressures due to groundwater flow,
- loss of strength, or softening, of clay rich strata,
- loss of natural cementing in some strata,
- transportation of soil particles.

Any of these effects, or a combination of them, can lead to landslides like those illustrated in GeoGuides LR2, LR3 and LR4.

Limiting the Effect of Water

Site clearance and construction must be carefully considered if changes in groundwater conditions are to be limited. GeoGuide LR8 considers good and poor development practices. Not surprisingly much of the advice relates to sensible treatment of water and is not repeated here. Adoption of appropriate techniques should make it possible to either maintain the current ground water table, or even cause it to drop, by limiting inflow to the ground.

If drainage measures and surface protection are relied on to keep the risk of a landslide to a tolerable level, it is important that they are inspected routinely and maintained (GeoGuide LR11).

The following techniques may be considered to limit the destabilising effects of rising groundwater due to development and are illustrated in Figure 2.

AUSTRALIAN GEOGUIDE LR5 (WATER & DRAINAGE)

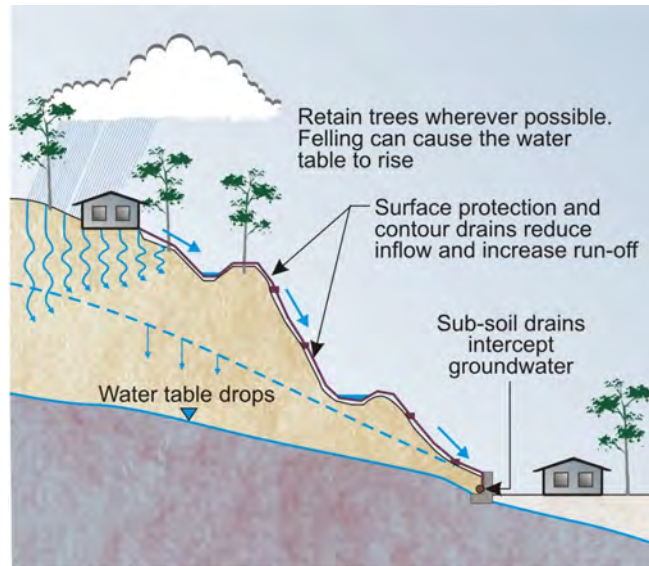


Figure 2 - Techniques used to control groundwater flow

Surface water drains (dish drains, or table drains) - are often used to prevent scour and limit inflow to a slope. Other than in rock, they are relatively ineffective unless they have an impermeable lining. You should clear them regularly, and as required, and not less than once a year. If you live in an area with seasonal rainfall, it is best to do this near the end of the dry season. If you notice that soil or rock debris is falling from the slope above, determine the source and take appropriate action. This may mean you have to seek advice from a geotechnical practitioner.

Surface protection - is sometimes used in addition to surface water drainage to prevent scour and minimise water inflow to a slope. You should inspect concrete, shotcrete or stone pitching for cracking and other signs of deterioration at least once a year. Make sure that weepholes are free of obstructions and able to drain. If the protection is deteriorating, you should seek advice from a geotechnical practitioner.

Sub-soil drains - are often constructed behind retaining walls and on hillsides to intercept groundwater. Their function is to remove water from the ground through an appropriate outlet. It is important that subsoil drains are designed to complement other measures being used. They should be laid in a sand, or gravel, bed and protected with a graded stone or geotextile filter to reduce the chance of clogging. Sub-soil drains should always be laid to a fall of at least 1 vertical on 100 horizontal. Ideally the high end should be brought to the surface, so it can be flushed with water from time to time as part of routine maintenance procedures.

Deep, underground drains - are usually only used in extreme circumstances, where the landslide risk is assessed as not being tolerable and other stabilisation measures are considered to be impractical. They work by permanently lowering the water table in a slope. They are not often used in domestic scale developments, but if you have any on your site be aware that professional maintenance is essential. If they are not maintained and stop working, the water table will rise and a landslide may even occur during normal weather conditions. Both an increase or a reduction in the normal flow from deep drains could indicate a problem if it appears to be unrelated to recent rainfall. If changes of this sort are observed, you should have the drains and your site checked by a geotechnical practitioner.

Documentation - design drawings and specifications for geotechnical measures intended to minimise landslide risk can be of great assistance to a geotechnical specialist, or structural engineer, called in to inspect and report on them. Copies of available documentation should be retained and passed to the new owner when the property is sold (GeoGuide LR11). You should also request details of an appropriate maintenance program for drainage works from the designer and keep that information with other relevant documentation and maintenance records.

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AUSTRALIAN GEOGUIDE LR7 (LANDSLIDE RISK)

LANDSLIDE RISK

Concept of Risk

Risk is a familiar term, but what does it really mean? It can be defined as "a measure of the probability and severity of an adverse effect to health, property, or the environment." This definition may seem a bit complicated. In relation to landslides, geotechnical practitioners (GeoGuide LR1) are required to assess risk in terms of the likelihood that a particular landslide will occur and the possible consequences. This is called landslide risk assessment. The consequences of a landslide are many and varied, but our concerns normally focus on loss of, or damage to, property and loss of life.

Landslide Risk Assessment

Some local councils in Australia are aware of the potential for landslides within their jurisdiction and have responded by designating specific "landslide hazard zones". Development in these areas is often covered by special regulations. If you are contemplating building, or buying an existing house, particularly in a hilly area, or near cliffs, go first for information to your local council.

Landslide risk assessment must be undertaken by a geotechnical practitioner. It may involve visual inspection, geological mapping, geotechnical investigation and monitoring to identify:

- potential landslides (there may be more than one that could impact on your site)
- the likelihood that they will occur
- the damage that could result
- the cost of disruption and repairs and
- the extent to which lives could be lost.

Risk assessment is a predictive exercise, but since the ground and the processes involved are complex, prediction tends to lack precision. If you commission a

landslide risk assessment for a particular site you should expect to receive a report prepared in accordance with current professional guidelines and in a form that is acceptable to your local council, or planning authority.

Risk to Property

Table 1 indicates the terms used to describe risk to property. Each risk level depends on an assessment of how likely a landslide is to occur and its consequences in dollar terms. "Likelihood" is the chance of it happening in any one year, as indicated in Table 2. "Consequences" are related to the cost of repairs and temporary loss of use if a landslide occurs. These two factors are combined by the geotechnical practitioner to determine the Qualitative Risk.

TABLE 2: LIKELIHOOD

Likelihood	Annual Probability
Almost Certain	1:10
Likely	1:100
Possible	1:1,000
Unlikely	1:10,000
Rare	1:100,000
Barely credible	1:1,000,000

The terms "unacceptable", "may be tolerated", etc. in Table 1 indicate how most people react to an assessed risk level. However, some people will always be more prepared, or better able, to tolerate a higher risk level than others.

Some local councils and planning authorities stipulate a maximum tolerable level of risk to property for developments within their jurisdictions. In these situations the risk must be assessed by a geotechnical practitioner. If stabilisation works are needed to meet the stipulated requirements these will normally have to be carried out as part of the development, or consent will be withheld.

TABLE 1: RISK TO PROPERTY

Qualitative Risk		Significance - Geotechnical engineering requirements
Very high	VH	Unacceptable without treatment. Extensive detailed investigation and research, planning and implementation of treatment options essential to reduce risk to Low. May be too expensive and not practical. Work likely to cost more than the value of the property.
High	H	Unacceptable without treatment. Detailed investigation, planning and implementation of treatment options required to reduce risk to acceptable level. Work would cost a substantial sum in relation to the value of the property.
Moderate	M	May be tolerated in certain circumstances (subject to regulator's approval) but requires investigation, planning and implementation of treatment options to reduce the risk to Low. Treatment options to reduce to Low risk should be implemented as soon as possible.
Low	L	Usually acceptable to regulators. Where treatment has been needed to reduce the risk to this level, ongoing maintenance is required.
Very Low	VL	Acceptable. Manage by normal slope maintenance procedures.

AUSTRALIAN GEOGUIDE LR7 (LANDSLIDE RISK)

Risk to Life

Most of us have some difficulty grappling with the concept of risk and deciding whether, or not, we are prepared to accept it. However, without doing any sort of analysis, or commissioning a report from an "expert", we all take risks every day. One of them is the risk of being killed in an accident. This is worth thinking about, because it tells us a lot about ourselves and can help to put an assessed risk into a meaningful context. By identifying activities that we either are, or are not, prepared to engage in we can get some indication of the maximum level of risk that we are prepared to take. This knowledge can help us to decide whether we really are able to accept a particular risk, or to tolerate a particular likelihood of loss, or damage, to our property (Table 2).

In Table 3, data from NSW for the years 1998 to 2002, and other sources, is presented. A risk of 1 in 100,000 means that, in any one year, 1 person is killed for every 100,000 people undertaking that particular activity. The NSW data assumes that the whole population undertakes the activity. That is, we are all at risk of being killed in a fire, or of choking on our food, but it is reasonable to assume that only people who go deep sea fishing run a risk of being killed while doing it.

It can be seen that the risks of dying as a result of falling, using a motor vehicle, or engaging in water-related activities (including bathing) are all greater than 1:100,000 and yet few people actively avoid situations where these risks are present. Some people are averse to flying and yet it represents a lower risk than choking to death on food. Importantly, the data also indicate that, even when the risk of dying as a consequence of a particular event is very small, it could still happen to any one of us any day. If this were not so, no one would ever be struck by lightning.

Most local councils and planning authorities that stipulate a tolerable risk to property also stipulate a tolerable risk to life. The AGS Practice Note Guideline recommends that 1:100,000 is tolerable in newly

developed areas, where works can be carried out as part of the development to limit risk. The tolerable level is raised to 1:10,000 in established areas, where specific landslide hazards may have existed for many years. The distinction is deliberate and intended to prevent the concept of landslide risk management, for its own sake, becoming an unreasonable financial burden on existing communities. Acceptable risk is usually taken to be one tenth of the tolerable risk (1:1,000,000 for new developments and 1:100,000 for established areas) and efforts should be made to attain these where it is practicable and financially realistic to do so.

TABLE 3: RISK TO LIFE

Risk (deaths per participant per year)	Activity/Event Leading to Death (NSW data unless noted)
1:1,000	Deep sea fishing (UK)
1:1,000 to 1:10,000	Motor cycling, horse riding, ultra-light flying (Canada)
1:23,000	Motor vehicle use
1:30,000	Fall
1:70,000	Drowning
1:180,000	Fire/burn
1:660,000	Choking on food
1:1,000,000	Scheduled airlines (Canada)
1:2,300,000	Train travel
1:32,000,000	Lightning strike

More information relevant to your particular situation may be found in other AUSTRALIAN GEOGUIDES:

- GeoGuide LR1 - Introduction
- GeoGuide LR2 - Landslides
- GeoGuide LR3 - Landslides in Soil
- GeoGuide LR4 - Landslides in Rock
- GeoGuide LR5 - Water & Drainage
- GeoGuide LR6 - Retaining Walls
- GeoGuide LR8 - Hillside Construction
- GeoGuide LR9 - Effluent & Surface Water Disposal
- GeoGuide LR10 - Coastal Landslides
- GeoGuide LR11 - Record Keeping

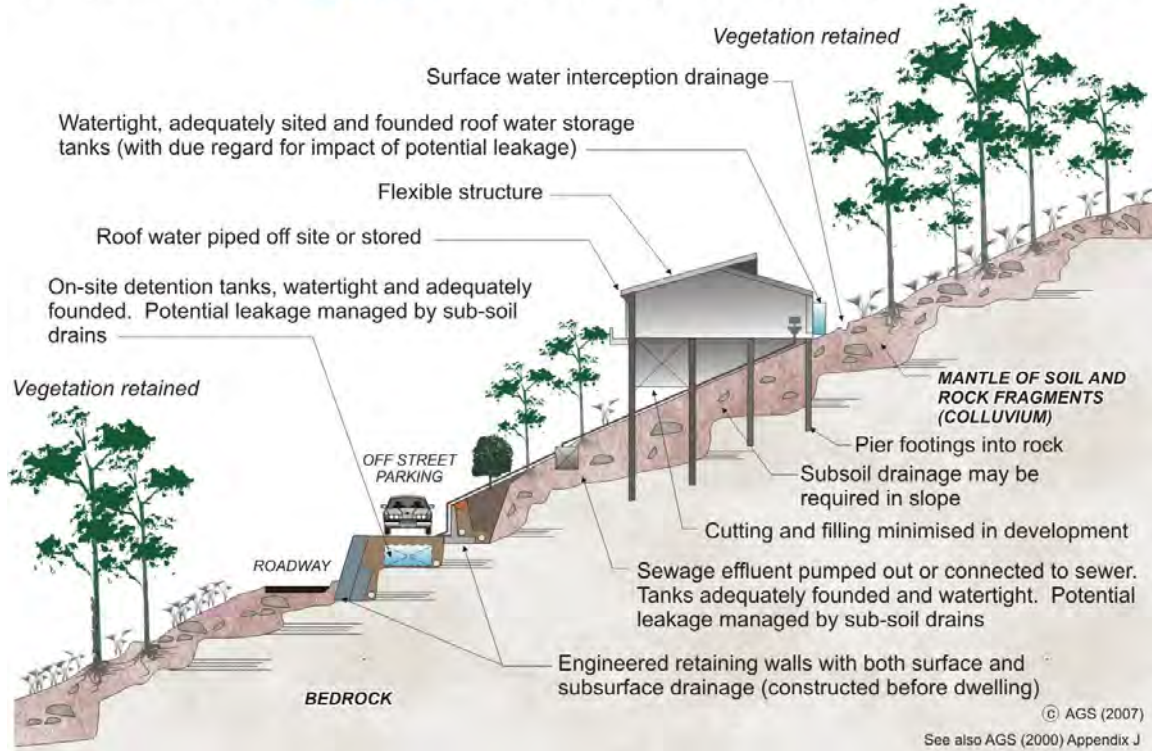
The Australian GeoGuides (LR series) are a set of publications intended for property owners; local councils; planning authorities; developers; insurers; lawyers and, in fact, anyone who lives with, or has an interest in, a natural or engineered slope, a cutting, or an excavation. They are intended to help you understand why slopes and retaining structures can be a hazard and what can be done with appropriate professional advice and local council approval (if required) to remove, reduce, or minimise the risk they represent. The GeoGuides have been prepared by the [Australian Geomechanics Society](#), a specialist technical society within Engineers Australia, the national peak body for all engineering disciplines in Australia, whose members are professional geotechnical engineers and engineering geologists with a particular interest in ground engineering. The GeoGuides have been funded under the Australian governments' National Disaster Mitigation Program.

AUSTRALIAN GEOGUIDE LR8 (CONSTRUCTION PRACTICE)

HILLSIDE CONSTRUCTION PRACTICE

Sensible development practices are required when building on hillsides, particularly if the hillside has more than a low risk of instability (GeoGuide LR7). Only building techniques intended to maintain, or reduce, the overall level of landslide risk should be considered. Examples of good hillside construction practice are illustrated below.

EXAMPLES OF GOOD HILLSIDE CONSTRUCTION PRACTICE



WHY ARE THESE PRACTICES GOOD?

Roadways and parking areas - are paved and incorporate kerbs which prevent water discharging straight into the hillside (GeoGuide LR5).

Cuttings - are supported by retaining walls (GeoGuide LR6).

Retaining walls - are engineer designed to withstand the lateral earth pressures and surcharges expected, and include drains to prevent water pressures developing in the backfill. Where the ground slopes steeply down towards the high side of a retaining wall, the disturbing force (see GeoGuide LR6) can be two or more times that in level ground. Retaining walls must be designed taking these forces into account.

Sewage - whether treated or not is either taken away in pipes or contained in properly founded tanks so it cannot soak into the ground.

Surface water - from roofs and other hard surfaces is piped away to a suitable discharge point rather than being allowed to infiltrate into the ground. Preferably, the discharge point will be in a natural creek where ground water exits, rather than enters, the ground. Shallow, lined, drains on the surface can fulfil the same purpose (GeoGuide LR5).

Surface loads - are minimised. No fill embankments have been built. The house is a lightweight structure. Foundation loads have been taken down below the level at which a landslide is likely to occur and, preferably, to rock. This sort of construction is probably not applicable to soil slopes (GeoGuide LR3). If you are uncertain whether your site has rock near the surface, or is essentially a soil slope, you should engage a geotechnical practitioner to find out.

Flexible structures - have been used because they can tolerate a certain amount of movement with minimal signs of distress and maintain their functionality.

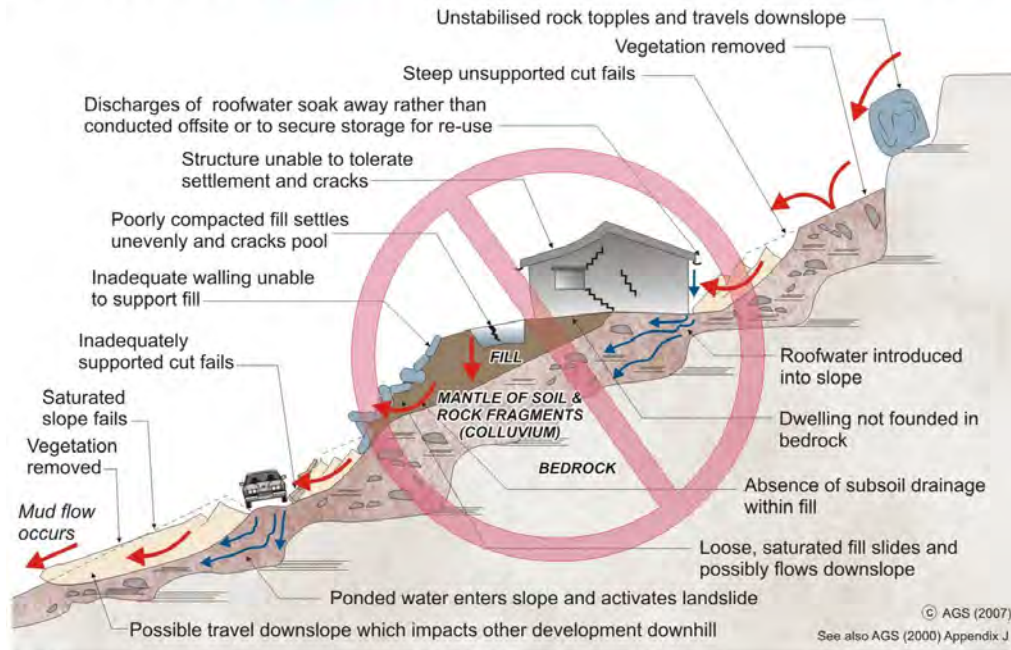
Vegetation clearance - on soil slopes has been kept to a reasonable minimum. Trees, and to a lesser extent smaller vegetation, take large quantities of water out of the ground every day. This lowers the ground water table, which in turn helps to maintain the stability of the slope. Large scale clearing can result in a rise in water table with a consequent increase in the likelihood of a landslide (GeoGuide LR5). An exception may have to be made to this rule on steep rock slopes where trees have little effect on the water table, but their roots pose a landslide hazard by dislodging boulders.

Possible effects of ignoring good construction practices are illustrated on page 2. Unfortunately, these poor construction practices are not as unusual as you might think and are often chosen because, on the face of it, they will save the developer, or owner, money. You should not lose sight of the fact that the cost and anguish associated with any one of the disasters illustrated, is likely to more than wipe out any apparent savings at the outset.

ADOPT GOOD PRACTICE ON HILLSIDE SITES

AUSTRALIAN GEOGUIDE LR8 (CONSTRUCTION PRACTICE)

EXAMPLES OF **POOR** HILLSIDE CONSTRUCTION PRACTICE



WHY ARE THESE PRACTICES POOR?

Roadways and parking areas - are unsurfaced and lack proper table drains (gutters) causing surface water to pond and soak into the ground.

Cut and fill - has been used to balance earthworks quantities and level the site leaving unstable cut faces and added large surface loads to the ground. Failure to compact the fill properly has led to settlement, which will probably continue for several years after completion. The house and pool have been built on the fill and have settled with it and cracked. Leakage from the cracked pool and the applied surface loads from the fill have combined to cause landslides.

Retaining walls - have been avoided, to minimise cost, and hand placed rock walls used instead. Without applying engineering design principles, the walls have failed to provide the required support to the ground and have failed, creating a very dangerous situation.

A heavy, rigid, house - has been built on shallow, conventional, footings. Not only has the brickwork cracked because of the resulting ground movements, but it has also become involved in a man-made landslide.

Soak-away drainage - has been used for sewage and surface water run-off from roofs and pavements. This water soaks into the ground and raises the water table (GeoGuide LR5). Subsoil drains that run along the contours should be avoided for the same reason. If felt necessary, subsoil drains should run steeply downhill in a chevron, or herring bone, pattern. This may conflict with the requirements for effluent and surface water disposal (GeoGuide LR9) and if so, you will need to seek professional advice.

Rock debris - from landslides higher up on the slope seems likely to pass through the site. Such locations are often referred to by geotechnical practitioners as "debris flow paths". Rock is normally even denser than ordinary fill, so even quite modest boulders are likely to weigh many tonnes and do a lot of damage once they start to roll. Boulders have been known to travel hundreds of metres downhill leaving behind a trail of destruction.

Vegetation - has been completely cleared, leading to a possible rise in the water table and increased landslide risk (GeoGuide LR5).

DON'T CUT CORNERS ON HILLSIDE SITES - OBTAIN ADVICE FROM A GEOTECHNICAL PRACTITIONER

More information relevant to your particular situation may be found in other Australian GeoGuides:

- GeoGuide LR1 - Introduction
- GeoGuide LR2 - Landslides
- GeoGuide LR3 - Landslides in Soil
- GeoGuide LR4 - Landslides in Rock
- GeoGuide LR5 - Water & Drainage
- GeoGuide LR6 - Retaining Walls
- GeoGuide LR7 - Landslide Risk
- GeoGuide LR9 - Effluent & Surface Water Disposal
- GeoGuide LR10 - Coastal Landslides
- GeoGuide LR11 - Record Keeping

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LANDSLIDES IN THE COASTAL ENVIRONMENT

Coastal Instability

The coast presents a particularly dynamic environment where change is often the norm. Hazards exist in relation to both cliffs and sand dunes. The coast is also the most heavily populated part of Australia and always regarded as "prime" real estate, because of the views and access to waterways and beaches.



Photo courtesy Greg Kotze

Waves, wind and salt spray play a significant part, causing dunes to move and cliff-faces to erode well above sea level. Our response is often to try to neutralise these effects by doing such things as dumping rock in the sea, building groynes, dredging, or carrying out dune stabilisation. Such works can be very effective, but ongoing maintenance is usually needed and total reconstruction may be necessary after a relatively short working life.

Of particular significance are extreme events that cause destruction on a scale that ignores our efforts at coastal protection. Records show that cliffs have collapsed, taking with them backyards which had been relied upon as a buffer between a house and the ocean. Sand dunes have also been washed away resulting in the dramatic loss of homes and infrastructure. As with most landslide issues, even though such events may be infrequent, they could happen tomorrow. It is easy to be lulled into a false sense of security on a calm day.

In coastal areas, typical landslide hazards (GeoGuides LR1 to LR4) are compounded by coastal erosion which, over time, undercuts cliffs and eventually results in failure. In the case of sand dunes, dune erosion and dune slumping have equally dramatic effects. Coastal locations are subject to particular processes relating to fluctuating water tables, inundation under storm tides and direct wave attack. Large sections of our more sandy coastline are receding under present sea conditions. The hazards are progressive and likely to be exacerbated through climate change.

Coastal Development

If you own, or are responsible for, a coastal property it is important that you understand that, where the shore line is receding, there is a greater landslide risk than would be the case on a similar site inland. The view may make the risk worthwhile, but does not reduce it.

Coastal Landslides

Coastal landslides are little different from other landslides in that the signs of failure (GeoGuides LR2) and the causes (LR3, LR4 & LR5) are largely the same. The main difference relates to the overriding influence of wave impact, tidal movement, salt spray and high winds.

Cliff failures

In addition to the processes that produce cliff instability on inland cliffs, coastal cliffs are also subjected to repeated cycles of wetting and drying which can be accompanied by the expansive effect of salt crystal growth in gaps in the rocks. These processes accelerate the deterioration of coastal cliffs. At the base of cliffs, direct wave attack and the impact of boulders moved by wave action causes undercutting and hence instability of the overall face. Figure 2 of GeoGuide LR4 provides an example. Whilst the processes leading to coastal cliff collapse may take years, failure tends to be catastrophic and with little warning. In many cases, waves produced by large oceanic storms are the trigger assisted by rainfall to produce collapse. These are also the conditions in which you are more likely to be inside your home and oblivious to unusual noises or movements associated with imminent failure.

Sand dune escarpment and slope failures

An understanding of coastal processes is essential when determining beach erosion potential. Waves produced by large oceanic storms can erode beaches and cut escarpments into dunes. These may be of relatively short duration, when beach rebuilding happens after the storm, but can be a permanent feature where long term beach recession is taking place. In many locations, houses and infrastructure are sited on or immediately behind coastal dunes. After an escarpment has eroded, those assets may be lost or damaged by subsequent slumping of the dune. It is important that, on erodible coastal soils, the potential for landward incursion of an erosion escarpment is determined. Having done this, the likelihood of slope instability can be established as part of the landslide risk management process. Injury, death and structural damage have occurred around the Australian coast from collapsing sand escarpments.



Photo courtesy DNR NSW

AUSTRALIAN GEOGUIDE LR10 (COASTAL LANDSLIDES)

The large scale and potentially high speed of coastal erosion processes means that major civil engineering work and large cost is normally involved in their control. The installation of rock bolts (LR4), drainage (LR5), or retaining walls (LR6) on a single house site may be necessary to provide local stability, but are unlikely to withstand the attack of a large storm on a beach or cliff-line.

BUILDING NEAR CLIFFS AND HEADLANDS

Coastal cliffs and headlands exist because the rock that they are made from is able to resist erosion. Even so, cliff-faces are not immune and will continue to collapse (Figure 1) by one or other of the mechanisms shown on GeoGuide LR4. If you live on a coastal cliff, you should undertake inspection and maintenance as recommended in LR4 and the other GeoGuides, as appropriate. The top of the cliff, its face, and its base should be inspected frequently for signs of recent rock falls, opening of cracks, and heavy seepage which might indicate imminent failure. Since the sea can remove fallen rocks rapidly, inspections should be made shortly after every major storm as a matter of course. **If collapses are occurring seek advice from an appropriately experienced geotechnical practitioner. Advise you local council if you believe erosion is rapid or accelerating.**

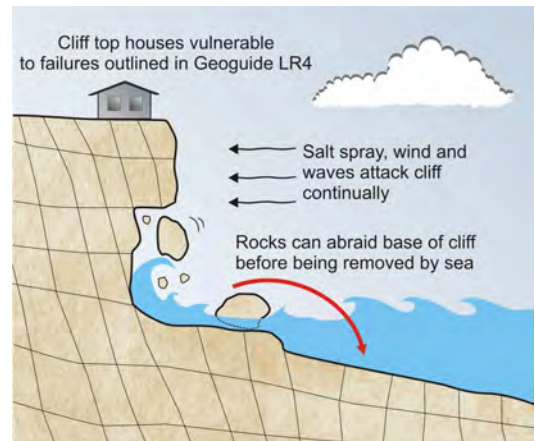


Figure 1

Building on Coastal Dunes

Any excavation in a natural dune slope is inherently unstable and must be supported and maintained (GeoGuide LR6). Dunes are particularly susceptible to ongoing erosion by wind and wave action and extreme changes can occur in a single storm. Whilst vegetation can help to stabilise dunes in the right circumstances, unfortunately a single storm has the potential to cut well into dunes and, in some cases, remove an entire low lying dune system or shift the mouth of a river. **As for cliffs, it is appropriate to observe the effects of major storms on the coastline. If erosion is causing the coastline to recede at an appreciable rate, seek advice from suitably experienced geotechnical and coastal engineering practitioners and bring it to the attention of the local council.**



CLIMATE CHANGE

The coastal zone will experience the most direct physical impacts of climate change. A number of reviews of global data indicate a general trend of sea level rise over the last century of 0.1 - 0.2 metres. Current rates of global average sea level rise, measured from satellite altimeter data over the last decade, exceed 3 mm/year and are accelerating. The most authoritative and recent (at the time of writing) report on climate change (IPCC, 2007) predicts a global average sea level rise of between 0.2 and 0.8 metres by 2100, compared with the 1980 - 1999 levels (the higher value includes the maximum allowance of 0.2 m to account for uncertainty associated with ice sheet dynamics).

In addition to sea level rise, climate change is also likely to result in changes in wave heights and direction, coastal wind strengths and rainfall intensity, all of which have the capacity

to impact adversely on coastal dunes and cliff-faces. A Guideline for responding to the effects of climate change in coastal areas was published by Engineers Australia in 2004.

References

- Engineers Australia 2004 'Guidelines for responding to the effects of climate change in coastal and ocean engineering.' The National Committee on Coastal and Ocean Engineering, Engineers Australia, updated 2004.
- IPCC (2007) *Climate Change 2007: The Physical Science Basis*. Summary for Policy Makers. Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC).
- Nielsen, A.F., Lord D.B. and Poulos, H.G. (1992). 'Dune Stability Considerations for Building Foundations', *Aust. Civil Eng. Transactions* CE No.2, 167-174.

More information relevant to your particular situation may be found in other Australian GeoGuides:

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APPENDIX F

Geotechnical and other Engineering Declarations

FORM	A	Page 1 of 2	
Geotechnical Declaration and Verification Development Application		Regulator: <i><Add in or change to appropriate name></i>	
<p>To be submitted with a development application. If this form is not submitted with the geotechnical report the report will be refused. This form is essential to verify that the geotechnical report has been prepared in accordance with <i><Regulator's geotechnical DCP></i> and that the author of the geotechnical report is a geotechnical engineer or engineering geologist as defined by <i><Regulator's geotechnical DCP></i>. Alternatively, where a geotechnical report has been prepared for subdivision or is greater than two years old or by a professional person not recognised by <i><Regulator's geotechnical DCP></i>, then this form may be used as technical verification of the geotechnical report if signed by a geotechnical engineer or engineering geologist as defined by <i><Regulator's geotechnical DCP></i>.</p>			
Section 1		Related Application	
<i>Reference</i>	What is the Council development application number?		
<i>DA Site Address</i>			
<i>DA Applicant</i>			
Section 2		Geotechnical Report	
<i>Details</i>	Title:		
	Author's Company/ Organisation Name:		Report Reference No:
	Author:		Dated: / /
Section 3		Checklist	
Geotechnical Requirements (Tick as appropriate, either Yes or No)		The following checklist covers the minimum requirements to be addressed in a geotechnical report. This checklist is to accompany the report. Each item is to be cross-referenced to the section or page of the geotechnical report which addresses that item.	
Yes No <input type="checkbox"/> <input type="checkbox"/>		A review of readily available history of slope instability in the site or related land as per <i><Add reference></i>	
<input type="checkbox"/> <input type="checkbox"/>		An assessment of the risk posed by all reasonably identifiable geotechnical hazards as per <i><Add reference></i>	
<input type="checkbox"/> <input type="checkbox"/>		Plans and sections of the site and related land as per <i><Add reference></i>	
<input type="checkbox"/> <input type="checkbox"/>		Presentation of a geological model as per <i><Add reference></i>	
<input type="checkbox"/> <input type="checkbox"/>		Photographs and/or drawings of the site as per <i><Add reference></i>	
<input type="checkbox"/> <input type="checkbox"/>		A conclusion as to whether the site is suitable for the development proposed to be carried out either conditionally or unconditionally as per <i><Add reference></i>	
<input type="checkbox"/> <input type="checkbox"/>		If any items above are ticked No, an explanation is to be included in the report to justify why. <i><Add reference></i>	
Yes No <input type="checkbox"/> <input type="checkbox"/>		Subject to recommendations and conditions relevant to:	
<input type="checkbox"/> <input type="checkbox"/>		selection and construction of footing systems,	
<input type="checkbox"/> <input type="checkbox"/>		earthworks,	
<input type="checkbox"/> <input type="checkbox"/>		surface and sub surface drainage,	
<input type="checkbox"/> <input type="checkbox"/>		recommendations for the selection of structural systems consistent with the geotechnical assessment of the risk,	
<input type="checkbox"/> <input type="checkbox"/>		any conditions that may be required for the ongoing mitigation and maintenance of the site and the proposal, from a geotechnical viewpoint,	
<input type="checkbox"/> <input type="checkbox"/>		highlighting and detailing the inspection regime to provide the <PCA> and builder with adequate notification for all necessary inspections.	
<input type="checkbox"/> <input type="checkbox"/>		State Design life adopted: Years	

Note: *<Add reference>*: Add in the relevant section or page number of the listed geotechnical report which addresses each item.

FORM	A	Page 2 of 2			
Geotechnical Declaration and Verification Development Application					
Section 4 List of Drawings referenced in Geotechnical Report					
Design Documents	Description	Plan or Document No.	Revision or Version No.	Date	Author
Section 5 Declaration					
Declaration (Tick all that apply) Yes <input type="checkbox"/> No <input type="checkbox"/> <input type="checkbox"/> N/A <input type="checkbox"/> <input type="checkbox"/> N/A <input type="checkbox"/> <input type="checkbox"/> No <input type="checkbox"/> <input type="checkbox"/> No <input type="checkbox"/> <input type="checkbox"/> No <input type="checkbox"/>	I am a geotechnical engineer or engineering geologist as defined by the <Regulator's geotechnical DCP> and on behalf of the company below, I: am aware that the geotechnical report I have either prepared or am technically verifying (referenced above) is to be submitted in a support of a development application for the proposed development site (referenced above) and its findings will be relied upon by <the Regulator> in determining the development application. prepared the geotechnical report referenced above in accordance with the AGS (2007c) as amended and <Regulator's geotechnical DCP>. am willing to technically verify that the Geotechnical Report referenced above has been prepared in accordance with the AGS (2007c) as amended and <Regulator's geotechnical DCP>. am willing to technically verify that the geotechnical report prepared for the development application for the site confirms the land will achieve the level of <tolerable risk> of slope instability as a result of the considerations described in <add reference to specific section of> <Regulator's geotechnical DCP> taking into account the total development and site disturbances proposed. am willing to technically verify that the geotechnical report prepared for the site and related land being greater than two years old confirms the land will achieve the level of <tolerable risk> of slope instability as a result of the considerations described <add reference to specific section of> of <Regulator's geotechnical DCP> taking into account the total development and site disturbances proposed. have professional indemnity insurance in accordance with <Regulator's geotechnical DCP> of not less than \$.... million, being in force for the year in which the report is dated, with retroactive cover under this insurance policy extending back to the engineer's first submission to <the Regulator>.				
Section 6 Geotechnical Engineer or Engineering Geologist Details					
Company/ Organisation Name					
Name (Company Representative)	Surname:		Mr /Mrs /Other:		
	Given Names:				
	Chartered Professional Status:		Registration No:		
Signature					Dated: / /

Reference: AGS (2007c) "Practice Note Guidelines for Landslide Risk Management". Australian Geomechanics Society, Australian Geomechanics, V42, .N1, March 2007.

Note: N/A = Not Applicable.

FORM	B	Structural/Civil/Geotechnical Engineering Declaration – <Construction Certificate> Application				
Office Use Only				Regulator: <Add in or change to appropriate name>		
<p>To be submitted with the structural design forming part of an application for a <construction certificate>. This form must be attached with the submission of the structural documentation required for the determination of a <construction certificate> or combined development application and <construction certificate> submission. This form is essential, as it provides evidence to the <PCA> determining the <construction certificate>, that the structural design has been prepared or verified by a structural engineer or civil engineer as defined by <Regulator's geotechnical DCP> and that the structural design has been prepared in accordance with the recommendations given in the geotechnical report for the same development. This form also covers additional design documents required to cover other works not shown on the main structural/civil design drawings. This form is also essential to establish that the recommendations given in the geotechnical report have been interpreted and incorporated into the structural design as originally intended by the geotechnical engineer in preparing the geotechnical report.</p>						
Section 1 Related Application						
<i>Reference</i>		What is the <Regulator's> development application number?				
<i>DA Site Address</i>						
<i>DA Applicant</i>						
Section 2 Structural/Civil Design Documents						
<i>List of Structural/Civil Design Documents (More space on page two if required)</i>		Description	Plan or Document No.	Revision or Version No.	Date	Author
Section 3 Geotechnical Report						
<i>Details</i>		Title:				
		Author:		Dated: / /		
		Author's Company/ Organisation Name:		Report Reference No:		
Section 4 Declaration by Structural/Civil Engineer or Designer of Additional Design Documents in Relation to a Geotechnical Report						
Declaration (Tick all that apply) Yes No <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>		I am a structural or civil engineer as defined by the <Regulator's geotechnical DCP> and on behalf of the company below. I have prepared the structural designs listed in Section 2 above and/or Section 6 below, in accordance with the recommendations given in the above geotechnical report. I am a design engineer and have prepared Additional Design documents listed in Section 7 below in accordance with the recommendations given in the above geotechnical report. I am aware that the <PCA> will rely on this declaration in granting a <construction certificate> for works to which the above structural design documents and geotechnical report relate. I certify that any residential structure designed or erected in accordance with the structural design prepared by the structural engineer or civil engineer achieves the performance requirements of Clause 1.3 of the current version of AS 2870 (this must be ticked when accompanied by minimal impact certification). I have professional indemnity insurance in accordance with <Regulator's geotechnical DCP> of not less than \$... million, being in force for the year in which the report is dated, with retroactive cover under this insurance policy extending back to the engineer's first submission to <the Regulator>.				

FORM	B	Structural/Civil/Geotechnical Engineering Declaration – <Construction Certificate> Application				
Section 5 Structural/Civil/Design Engineer Details						
<i>Company/ Organisation Name</i>						
Name (Company Representative)						
Surname:		Mr /Mrs /Other:				
Given:						
Chartered Professional Status:			Registration No:			
Signature						
Dated: / /						
Section 6 Ancillary Structural/Civil Design Required Prior to Completion of Geotechnical Declaration						
<i>List of Structural Design Documents Required</i>						
Description		Company Responsible	Plan or Document No.	Revision or Version No.	Date of Additional Form B *	Author
eg. Landscaping retaining walls						
eg. Anchor design						
Section 7 Additional Design Documents Required Prior to Completion of Geotechnical Declaration						
<i>List of Design Documents Required</i>						
Description		Company	Plan or Document No.	Revision or Version No.	Date of Additional Form B *	Author
eg. Surface & subsoil drainage design						
eg. Infiltration or effluent disposal						
Section 8 and 9 are not to be completed until each relevant ancillary and additional Form B has been completed and forwarded to the geotechnical engineer/engineering geologist						
Section 8 Declaration in Relation to Structural/Civil Designs and Additional Design Drawings						
Declaration (Tick all that apply)		I am a geotechnical engineer or engineering geologist as defined by the <Regulator's geotechnical DCP> and on behalf of the company below:				
Yes No		I prepared and/or technically verified the above geotechnical report and now declare that I have viewed the above listed design documents prepared for the same development.				
<input type="checkbox"/> <input type="checkbox"/>		I am satisfied that the recommendations given in the above geotechnical report have been incorporated into the design documents as intended.				
<input type="checkbox"/> <input type="checkbox"/>		I consider no additional drawings are required to show all the required works listed in the Geotechnical Report.				
<input type="checkbox"/> <input type="checkbox"/>						
Section 9 Geotechnical Engineer or Engineering Geologist Details						
<i>Company/ Organisation Name</i>						
Name (Company Representative)						
Surname:		Mr /Mrs /Other:				
Given Names:						
Chartered Professional Status:			Registration No:			
Signature						
Dated: / /						

Note: * A separate Form B is required to be completed by the design engineer for those works listed in each of Sections 6 and 7 of this Form B.

PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

FORM	C	Page 1 of 2	
		Geotechnical Declaration Subdivision <Construction Certificate> Application	
Office Use Only			Regulator: <Add in or change to appropriate name>
<p>To be submitted with an application for an engineering <construction certificate> for subdivision of land. This form must be attached to the application for the <construction certificate>.</p> <p>This form is essential to verify that the geotechnical report has been prepared in accordance with <Regulator's geotechnical DCP> and that the author of the geotechnical report is a geotechnical engineer or engineering geologist as defined by <Regulator's geotechnical DCP>. Alternatively, where a geotechnical report has been prepared by a professional person not recognised by the <Regulator's geotechnical DCP>, then this form may be used as technical verification of the geotechnical report if signed by a geotechnical engineer or engineering geologist as defined by <Regulator's geotechnical DCP>.</p>			
Section 1		Related Application	
Reference	What is the Regulator's Development Application Number?		
DA Site Address			
DA Applicant			
Section 2		Geotechnical Report	
Details	Title:		
	Author:	Dated: / /	
	Author's Company/ Organisation Name:	Report Reference No:	
Section 3		Declaration	
Declaration (Tick all that apply) Yes No <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	I am a geotechnical engineer or engineering geologist as defined by the <Regulator's geotechnical DCP> and on behalf of the company below: I prepared the geotechnical report referenced above in accordance with the AGS (2007c) as amended and the <Regulator's geotechnical DCP>. I am willing to technically verify that the geotechnical report referenced above has been prepared in accordance with the AGS (2007c) as amended and <Regulator's geotechnical DCP>. I have professional indemnity insurance in accordance with <Regulator's geotechnical DCP> of not less than \$... million, being in force for the year in which the report is dated, with retroactive cover under this insurance policy extending back to the engineer's first submission to <the Regulator>. I am aware that the geotechnical report I have either prepared or am technically verifying (referenced above) is to be submitted in support of an engineering <construction certificate> for subdivision of land for the proposed development site (referenced above) and its findings will be relied upon by <the Regulator> determining the engineering <construction certificate>.		

FORM	C	Page 2 of 2																						
<h2 style="margin: 0;">Geotechnical Declaration</h2> <h3 style="margin: 0;">Subdivision <Construction Certificate> Application</h3>																								
Section 4 Checklist																								
<p>Geotechnical Requirements (Tick as appropriate, either Yes or No)</p> <table style="width: 100%; border: none;"> <tr> <td style="text-align: center;">Yes</td> <td style="text-align: center;">No</td> </tr> <tr> <td style="text-align: center;"><input type="checkbox"/></td> <td style="text-align: center;"><input type="checkbox"/></td> </tr> <tr> <td style="text-align: center;"><input type="checkbox"/></td> <td style="text-align: center;"><input type="checkbox"/></td> </tr> <tr> <td style="text-align: center;"><input type="checkbox"/></td> <td style="text-align: center;"><input type="checkbox"/></td> </tr> <tr> <td style="text-align: center;"><input type="checkbox"/></td> <td style="text-align: center;"><input type="checkbox"/></td> </tr> <tr> <td style="text-align: center;"><input type="checkbox"/></td> <td style="text-align: center;"><input type="checkbox"/></td> </tr> <tr> <td style="text-align: center;"><input type="checkbox"/></td> <td style="text-align: center;"><input type="checkbox"/></td> </tr> <tr> <td style="text-align: center;"><input type="checkbox"/></td> <td style="text-align: center;"><input type="checkbox"/></td> </tr> <tr> <td style="text-align: center;"><input type="checkbox"/></td> <td style="text-align: center;"><input type="checkbox"/></td> </tr> <tr> <td style="text-align: center;"><input type="checkbox"/></td> <td style="text-align: center;"><input type="checkbox"/></td> </tr> <tr> <td style="text-align: center;"><input type="checkbox"/></td> <td style="text-align: center;"><input type="checkbox"/></td> </tr> </table>	Yes	No	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<p>The following checklist covers the minimum requirements to be addressed in a geotechnical report in accordance with <Add reference to specific section of> <Regulator's geotechnical DCP>. This checklist is to accompany the report.</p> <p>The extent and stability of proposed embankments including those acting as retarding basins <Add reference></p> <p>Recommended Geotechnical testing requirements <Add reference></p> <p>Required level of geotechnical supervision for each part of the works as defined under AS3798 – Guidelines on Earthworks for Commercial and Residential Developments <Add reference></p> <p>Compaction specification for all fill within private subdivisions <Add reference></p> <p>The level of risk to existing adjacent dwellings as a result of a construction contractor using vibratory rollers anywhere within the site the subject of these works. In the event that vibratory rollers could affect adjacent dwellings, 'high risk' areas shall be identified on a plan and the engineering plans shall be amended to indicate that no vibratory roller shall be used within that zone <Add reference></p> <p>The impact of the installation of services on overall site stability and recommendations on short term drainage methods, shoring requirements and other remedial measures that may be appropriate during installation <Add reference></p> <p>The preferred treatment of any areas of unacceptable risk within privately owned allotments <Add reference></p> <p>Requirement for subsurface drainage lines <Add reference></p> <p>Overall suitability of the engineering plans for the proposed development <Add reference></p> <p>Risk mitigation plan defined <Add reference></p>	
Yes	No																							
<input type="checkbox"/>	<input type="checkbox"/>																							
<input type="checkbox"/>	<input type="checkbox"/>																							
<input type="checkbox"/>	<input type="checkbox"/>																							
<input type="checkbox"/>	<input type="checkbox"/>																							
<input type="checkbox"/>	<input type="checkbox"/>																							
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<input type="checkbox"/>	<input type="checkbox"/>																							
<input type="checkbox"/>	<input type="checkbox"/>																							
<input type="checkbox"/>	<input type="checkbox"/>																							
<input type="checkbox"/>	<input type="checkbox"/>																							
Section 5 Geotechnical Engineer or Engineering Geologist Details																								
Company/ Organisation Name																								
Name (Company Representative)	Surname:	Mr /Mrs /Other:																						
	Given Names:																							
	Chartered Professional Status:	Registration No:																						
Signature																								
	Dated: / /																							

Reference: AGS (2007c) "Practice Note Guidelines for Landslide Risk Management". Australian Geomechanics Society, Australian Geomechanics, V42, .N1, March 2007.

Note: <Add reference>: Add in the relevant section or page number of the listed geotechnical report which addresses each item.

PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

FORM	D	Page 1 of 2				
Geotechnical Declaration Minor Impact						
Office Use Only				Regulator: <i><Add in or change to appropriate name></i>		
<p>This form may be used where minor construction works present minimal or no geotechnical impact on the site or related land. A geotechnical engineer or engineering geologist must inspect the site and/or review the proposed development documentation to determine if the proposed development requires a geotechnical report to be prepared to accompany the development application. Where the geotechnical engineer determines that such a report is not required then they must complete this form and attach design recommendations where required. A copy of this form with design recommendation, if required, must be submitted with the development application.</p> <p>Note: In all situations, this form will need to be accompanied by Form B where the structural engineer or civil engineer certifies that any residential structure designed or erected in accordance with the plans and specifications prepared by the structural engineer or civil engineer achieve the performance requirements of Clause 1.3 of the current version of AS 2870.</p> <p>Note: The use of this form does not preclude the geotechnical consultant from requiring a Geotechnical Report.</p>						
Section 1 Related Application						
<i>Reference</i>		What is the Council Development Application Number?				
<i>DA Site Address</i>						
<i>DA Applicant</i>						
Section 2 Documentation						
<i>List of Documents Reviewed (More space on page two if required)</i>		Description	Plan or Document No.	Revision or Version No.	Date	Author
Section 3 Declaration						
Declaration (Tick all that apply)		I am a geotechnical engineer or engineering geologist as defined by the <i><Regulator's geotechnical DCP></i> and I have inspected the site and reviewed the proposed development at the DA Site Address described above. As a result of my consideration of the <i><Regulator's geotechnical DCP></i> , of my site inspection and review of the documentation listed above, I have determined and declare that, on behalf of the company below:				
Yes <input type="checkbox"/>	No <input type="checkbox"/>	The current load-bearing capacity of the site will not be exceeded or be adversely impacted on by the proposed development, and				
<input type="checkbox"/>	<input type="checkbox"/>	The proposed works are of such a minor nature that the requirement for geotechnical advice in the form of a geotechnical report, prepared in accordance with <i><Regulator's geotechnical DCP></i> is considered unnecessary for the adequate and safe design of the structural elements to be incorporated into the new works as there is no change to the current landslide risk on the site in accordance with AGS (2007c), and				
<input type="checkbox"/>	<input type="checkbox"/>	In accordance with AS 2870 Residential Slabs and Footings, the site is to be classified as a type: _____				
<input type="checkbox"/>	<input type="checkbox"/>	I have attached design recommendations to be incorporated in the structural design in accordance with this site classification.				
<input type="checkbox"/>	<input type="checkbox"/>	I have professional indemnity insurance in accordance with <i><Regulator's geotechnical DCP></i> of not less than \$.... million, being in force for the year in which the report is dated, with retroactive cover under this insurance policy extending back to the engineer's first submission to <i><the Regulator></i> .				
<input type="checkbox"/>	<input type="checkbox"/>	I am aware that this declaration shall be used by <i><The Regulator></i> as an essential component in granting development consent for a structure to be erected on the site or related land without requiring submission of a geotechnical report complying with the <i><Regulator's geotechnical DCP></i> in support of the development application.				

Reference: AGS (2007c) "Practice Note Guidelines for Landslide Risk Management". Australian Geomechanics Society, Australian Geomechanics, V42, .N1, March 2007.

FORM	D	Page 2 of 2			
		Geotechnical Declaration Minor Impact			
Section 4 Additional Documentation					
<i>List of Documents Reviewed</i>	Description	Plan or Document No.	Revision or Version No.	Date	Author
Section 5 Geotechnical Engineer or Engineering Geologist Details					
<i>Company/ Organisation Name</i>					
Name (Company Representative)	Surname:		Mr /Mrs /Other:		
	Given Names:				
	Chartered Professional Status:		Registration No:		
Signature			Dated: / /		

PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

FORM	E	Page 1 of 2	
Geotechnical Declaration Remediation			
Office Use Only		Regulator: <i><Add in or change to appropriate name></i>	
<p>This form must be submitted where development must be staged for geotechnical reasons and remediation of the site to a <i><tolerable risk></i> is necessary prior to any further development continuing on the site.</p> <p>This form is essential, as it provides verification at each stage of the development, prior to the next stage commencing, that the remediation of the site to a <i><tolerable risk></i> has been carried out in accordance with the requirements of the geotechnical report and <i><add reference to specific section></i> of <i><Regulator's geotechnical DCP></i> and that no unforeseen ground conditions have been encountered which could impact on the integrity of structures on site or related land or the landslide risk. The geotechnical engineer or engineering geologist who prepared and/or verified the report must carry out site inspections as determined by the report to ensure that the design(s) documented on Form(s) B have been completed prior to signing this form.</p>			
Section 1		Related Application	
<i>Reference</i>	What is the Development Application number?		
<i>DA Site Address</i>	<i>Development Stage (s):</i>		
<i>DA Applicant</i>			
Section 2		Geotechnical Report	
<i>Details</i>	Title:		
	Author:	Dated: / /	
	Author's Company/ Organisation Name:	Report Reference No:	
Section 3		Declaration	
Declaration (Tick all that apply) Yes No <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>	<p>I am a geotechnical engineer or engineering geologist as defined by the <i><Regulator's geotechnical DCP></i> and, on behalf of the company below:</p> <p>I inspected and am satisfied that the foundation materials upon which the structural elements of the development have been erected, complied with the requirements and recommendations specified in the geotechnical report for Stage (s) <i><add></i> of the development.</p> <p>To the best of my knowledge, I am satisfied that Stage(s) <i><add></i> of the development referred to above have been carried out in accordance with all the requirements and recommendations of the above geotechnical report, and conditions of development consent relating to geotechnical issues.</p> <p>To the best of my knowledge, I am satisfied that where changes to the development occurred during construction, those changes were carried out in accordance with all the requirements and recommendations of the above geotechnical report, conditions of development consent relating to geotechnical issues, and any site instructions or site reports issued by me as listed below.</p> <p>I am aware that the <i><PCA></i> requires this certificate at the end of stage of the development specified in the development approval and prior to any further development continuing on the site and related land.</p> <p>I am willing to technically verify that the site or related land will now achieve the level of <i><tolerable risk></i> of slope instability as defined by <i><Regulator's geotechnical DCP></i>.</p> <p>I have professional indemnity insurance in accordance with <i><Regulator's geotechnical DCP></i> of not less than \$.... million, being in force for the year in which the report is dated, with retroactive cover under this insurance policy extending back to the engineer's first submission to <i><the Regulator></i>.</p>		

Note: *<add>* relevant stage numbers to be inserted.

FORM	E	Page 2 of 2					
		Geotechnical Declaration Remediation					
Section 4		List of Site Instructions and/or Site Reports Issued					
<i>List of Documents Issued</i>	Description/Title	Reference No.	Date	Author	Associated Design Drawings (tick as appropriate)		
					Yes	No	
Section 5		Geotechnical Engineer or Engineering Geologist Details					
<i>Company/ Organisation Name</i>							
Name (Company Representative)	Surname:	Mr /Mrs /Other:					
	Given Names:						
	Chartered Professional Status:	Registration No:					
Signature	Dated: / /						

PRACTICE NOTE GUIDELINES FOR LANDSLIDE RISK MANAGEMENT 2007

FORM	F	Page 1 of 2				
Geotechnical Declaration Final Structural/Civil Certificate						
Office Use Only				Regulator: <i><Add in or change to appropriate name></i>		
<p>This form must be submitted to the <i><PCA></i> at the completion of a project and prior to the issue of an <i><occupation certificate></i>.</p> <p>This form is essential, as it provides evidence to the <i><PCA></i> that the development works have been carried out in accordance with the requirements of the structural design, any site inspections, and that any changes to the development occurring during construction, were carried out in accordance with all the requirements and recommendations of the structural design and geotechnical report, conditions of development consent relating to geotechnical issues, and any site instructions issued.</p>						
Section 1		Related Application				
<i>Reference</i>		What is <i><the Regulator's></i> Development Application number?				
<i>DA Site Address</i>						
<i>DA Applicant</i>						
Section 2		Geotechnical Report				
<i>Details</i>		Title:				
		Author:		Dated: / /		
		Author's Company/ Organisation Name:		Report Reference No:		
Section 3		Structural Civil Design Documents appropriate to the 'as constructed' development				
<i>List of Structural Civil Design Documents (More space on page two if required)</i>		Description	Plan or Document No.	Revision or Version No.	Date	Author
Section 4		Declaration				
Declaration (Tick all that apply) Yes No <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>		I am a structural or civil engineer as defined by the <i><Regulator's geotechnical DCP></i> and I prepared the above structural designs in accordance with the recommendations given in the geotechnical report described above on behalf of the company below. I: inspected and am satisfied that the structural elements of the above development have been erected, and complied with the requirements and recommendations specified in the structural design and geotechnical report. to the best of my knowledge, am satisfied that the above development has been carried out in accordance with all the requirements and recommendations of the structural design and above geotechnical report, and conditions of development consent relating to geotechnical issues. to the best of my knowledge, am satisfied that where changes to the development occurred during construction, those changes were carried out in accordance with all the requirements and recommendations of the structural design and above geotechnical report, conditions of development consent relating to geotechnical issues, and any site instructions issued by me as listed below. am aware that the <i><PCA></i> requires this certificate prior to issuing an <i><occupation certificate></i> for the above development and will rely on this certificate as verification that the above development has been erected, and complied with the requirements and recommendations specified in the structural design and geotechnical report as defined by <i><Regulator's geotechnical DCP></i> and in determining the <i><occupation certificate></i> . have professional indemnity insurance in accordance with <i><Regulator's geotechnical DCP></i> of not less than \$... million, being in force for the year in which the report is dated, with retroactive cover under this insurance policy extending back to the engineer's first submission to <i><the Regulator></i> .				

FORM F	Page 2 of 2					
Geotechnical Declaration Final Structural/Civil Certificate						
Section 5 List of Site Instructions Issued						
<i>List of Documents Issued</i>	Description/Title	Reference No.	Date	Author	Associated Design Drawings	
					Yes	No
Section 6 Additional Design Documents						
<i>List of Additional Design Documents</i>	Description	Plan or Document No.	Revision or Version No.	Date	Author	
Section 7 Structural Engineer or Civil Engineer Details						
<i>Company/ Organisation Name</i>						
Name (Company Representative)	Surname:			Mr /Mrs /Other:		
	Given Names:					
	Chartered Professional Status:			Registration No:		
Signature				Dated: / /		

FORM	G	<h2 style="margin: 0;">Geotechnical Declaration</h2> <h3 style="margin: 0;">Final Geotechnical Certificate</h3>					
Section 5 List of Site Reports or Site Instructions Issued							
<i>List of Documents Issued</i>	Description/Title	Reference No.	Date	Author	Associated Design Drawings		
					Yes	No	
Section 6 Additional Work as Executed Drawings and Ongoing Maintenance Plans relevant to Geotechnical Risk Management							
<i>List of Additional Documents</i>	Description	Plan or Document No.	Revision or Version No.	Date	Author		
Section 7 Geotechnical Engineer or Engineering Geologist Details							
<i>Company/ Organisation Name</i>							
Name (Company Representative)	Surname:		Mr /Mrs /Other:				
	Given Names:						
	Chartered Professional Status:		Registration No:				
Signature							
			Dated: / /				

FORM	H	Page 1 of 2	
	Geotechnical Declaration <i><Building Certificate> or Order</i>		
Office Use Only			Regulator: <i><Add in or change to appropriate name></i>
This form is to be submitted with Application for a <i><Building Certificate></i> or in response to an order.			
Section 1		Related Application	
<i>Reference</i>		What is the <i>Regulator's DA / BA / Order</i> number?	
<i>Site Address</i>			
<i>Applicant</i>			
Section 2		Geotechnical Report	
<i>Details</i>		Title:	
		Author:	Dated: / /
		Author's Company/ Organisation Name:	Report Reference No:
Section 3		Declaration	
Declaration (Tick all that apply) Yes No <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/> <input type="checkbox"/>		I am a geotechnical engineer or engineering geologist as defined by the <i><Regulator's geotechnical DCP></i> and I prepared or verified the geotechnical report as described above on behalf of the company below. I: <p>have inspected the site and existing development and am satisfied that both the site and development achieves <i><tolerable risk></i> level requirement of the <i><Regulator's geotechnical DCP></i>. The attached report provides details of the assessment in accordance with the <i><Regulator's geotechnical DCP></i>. The report also contains recommendations as to any reasonable and practical measures that can be undertaken to reduce foreseeable risk.</p> <p>have inspected the site of the existing development. The attached report details the remedial actions required to be undertaken prior to me being prepared to certify that the site and the development achieves the <i><tolerable risk></i> criteria required by the <i><Regulator's geotechnical DCP></i>.</p> <p>to the best of my knowledge, am satisfied that where changes to the development occurred during construction, those changes were carried out in accordance with all the requirements and recommendations of the above geotechnical report, conditions of development consent relating to geotechnical issues, and any site reports or site instructions issued by me as listed below.</p> <p>am aware that the <i><PCA></i> requires this certificate prior to issuing a <i><Building Certificate></i> for the above development and will rely on this certificate as verification that the development has achieved the necessary level of <i><tolerable risk></i> as defined by <i><Regulator's geotechnical DCP></i> and in determining the <i><occupation or subdivision certificate></i>.</p> <p>have professional indemnity insurance in accordance with <i><Regulator's geotechnical DCP></i> of not less than \$... million, being in force for the year in which the report is dated, with retroactive cover under this insurance policy extending back to the engineer's first submission to <i><the Regulator></i>.</p>	

FORM	H	Page 2 of 2				
		Geotechnical Declaration <i><Building Certificate> or Order</i>				
Section 4 List of Site Reports or Site Instructions Issued						
<i>List of Documents Issued</i>	Description/Title	Reference No.	Date	Author	Associated Design Drawings	
					Yes	No
Section 5 Geotechnical Engineer or Engineering Geologist Details						
<i>Company/ Organisation Name</i>						
Name (Company Representative)	Surname:		Mr /Mrs /Other:			
	Given Names:					
	Chartered Professional Status:		Registration No:			
Signature			Dated: / /			

APPENDIX G

Limitations of Geotechnical Investigations

LIMITATIONS OF GEOTECHNICAL REPORTS

The purpose of this report is to provide a geotechnical assessment of the sites examined. The information provided herein will reduce the exposure to risks, but no geotechnical assessment can eliminate them. Nonetheless, even a rigorous assessment may fail to detect all of the geotechnical conditions on a site. Site variations may have occurred in areas not investigated or sampled.

This geotechnical report should not be used when the nature of the proposed site usage changes, when the size, layout, or location of the development is modified, when the site ownership changes nor should it be applied to a nearby area. No environmental assessment has been undertaken nor is implied.

This site geotechnical assessment identifies actual subsurface conditions where the samples were taken and at the time they were taken. Any soil tests completed, were carried out in Lane Pipers NATA accredited soil laboratory. Geotechnical engineers then interpreted the laboratory results and field data and rendered an opinion about the overall subsurface conditions, including the soil type, extent of the soil layers, and their likely impact on the proposed development, with a discussion of the implications considered likely. The actual conditions may differ from the inferred conditions, as no person (no matter how qualified) or even the most detailed subsurface investigation can predict with confidence what may be hidden by soil or water or may have altered with time. Often the interface between different geotechnical areas may be more abrupt or gradual than anticipated. The actual conditions in an area may differ from those predicted.

Site assessments are limited by time, and natural processes such as erosion, or mankind altering the ground conditions, including the site levels or filled areas, may affect a site assessment. This geotechnical assessment is prepared in response to a client's specific requirements. No person other than the client should apply the report without first conferring with Lane Piper Pty Ltd.

Costly problems can occur if the report is misinterpreted. To avoid these problems, Lane Piper Pty Ltd should be retained to work with the appropriate design professionals and to review the adequacy of their plans and specifications relative to the geotechnical matters.

This report should only be reproduced in its entirety. Reproduction of borehole or testpit logs alone without the entire report should not be permitted. Redrafting of the borehole or testpit logs for inclusion in drawings or other reports should not be allowed as errors in the drafting can occur. It is recommended that the report be made available in entirety to persons and organisations involved in the project such as contractors. Simply disclaiming responsibility for the accuracy of the subsurface or geotechnical information does not insulate the organisation from liability. The more information a contractor has available to him, the better able he is to avoid costly construction problems and costly adversarial situations.

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