GUIDELINES FOR CONTROL OF SLOPE INSTABILITY

ADVICE FOR DEVELOPMENT AND REDEVELOPMENT OF STEEP SLOPE AREAS.
The City of Gold Coast is a vibrant and thriving city with a diverse and enviable natural environment. The topography of the City is generally composed of coastal plains in the east and a hilly hinterland of increasing elevation and steeper slopes towards the west, which carries an associated risk of slope instability or landslide.

Our City is committed to building resilience to natural hazards and managing their risks. The information contained within this booklet addresses landslide risk that is relevant to some residents who live on, or adjacent to landslide prone areas.

What is a landslide?
A landslide is the movement of a mass of rock, debris or earth down a slope. It is the result of failure of the soil and/or rock materials and is driven by gravity.

What types of landslide occur?
Once a landslide is triggered, material is transported in three ways:
- sliding along a failure surface
- falling down a steep slope
- flowing as a suspended mass, usually in water, for example, a mudslide or debris flow.

The rate of landslide movement varies from extremely slow (millimetres or centimetres per year) to sudden and extremely rapid (metres per second), as with rock falls or debris flows. Sudden and rapid events are the most dangerous due to the lack of warning, the speed at which they can travel down the slope and the force of impact that may cause damage to properties and even loss of life.

Landslide types

Creep slides
Failure occurs as a gradual down-slope progression of material (often at extremely slow rates). The slide area may appear relatively undisturbed and identification of the slide is often reliant on surface features.

Flows
Failure along a planar or concave surface where materials transform into a viscous fluid consisting of soil and rock particles suspended in water.

Topple
Failure occurs from the end-over-end motion of rocks down a slope, often resulting from closely-spaced sub-vertical jointed rock outcrops.

Translational slides
Failure occurs on a planar surface or surfaces, usually due to natural defects in the material such as fissures, joints or bedding. Material within the sliding mass can remain relatively undisturbed.

Rotational slides
Failure occurs through the material commonly on a concave surface. Material within the sliding mass is disturbed.

Falls
Failure where the movement is by free-falling/rolling of fragments down steep slopes with outcrops of closely jointed rock.

Complex
Failure where there is a combination of one or more of the above mechanisms.
Figure 1: Common types of landslides

Creep
- Partially covered
- Titled
- Layered bedrock bending down

Flow
- Original
- Moving

Topple

Transitional
- Original position
- Moving block

Rotational
- Original
- Slumped mass

Fall
- Original position
- Falling rock
- Waves

Courtesy of the Geosciences Australia website (www.ga.gov.au)
What surface features indicate landslides?

Progressive development of hill slopes by weathering and erosion involves a gradual incision of the stream beds into higher ground and results in the formation of slope surfaces that are essentially uniform, convex or planar.

The occurrence of natural landslides on these slopes produces an irregular profile, often concave, accompanied by features reflecting the disturbance that has taken place. In the case of recent landslides, these features are usually sharp and distinct.

With time, the effects of weathering and erosion modify these features which become indistinct, but which can usually be recognised by close observation. Individually, the features may not be related to landslides, but the presence of several features at one location indicates that some mass movement of material may have occurred.

Features that indicate existing natural slope instability include:

- irregular surfaces – areas of hummocky ground and depressions indicating disturbed material
- benches – anomalous flat areas in uniform sloping areas
- scars – areas where vegetation has been stripped during slope movement
- scarps – linear features showing the location of vertical displacement of the ground surface
- cracks – linear features showing lateral displacement of the ground surface
- debris mounds – deposits of loose soil and rock on, or at the base of, slopes
- disturbed vegetation – tilted trees
- seepage – presence of springs and dense vegetation regrowth.

Features that indicate lateral mass movement of material may have occurred in developed areas include:

- cracking or tilting of walls and retaining structures
- cracking or slumping of embankment slopes
- cracking and fall of material from excavated slopes
- broken/fractured water pipes and underground facilities
- tilted (or offset) powerlines, retaining walls and fences
- sunken or cracked road surfaces.

What causes landslides?

The stability of sloping ground depends on four main factors:

- the angle of the ground surface
- the strength of the materials below the ground surface
- the level of water within the slope
- the loading and disturbance on the slope.

The influence of each of these factors is illustrated by the stability analysis of a range of situations. Parameters used for this analysis are given below:

- slope angle of 25, 30 and 35 degrees
- material with an effective friction angle of 20, 25 and 30 degrees
- low strength material to depths of two, four and six metres
- groundwater with depth of one, two and four metres.

These results indicate that the Factor of Safety against landsliding:

- increases on average by approximately 20 per cent by flattening the slope angle by five degrees
- increases on average by approximately 26 per cent by increasing the material effective friction angle by five degrees
- increases on average by approximately 36 per cent by permanently lowering the groundwater table by two metres
- the effects of human development on sloping sites can significantly change slope stability (see figures 2 and 3).
Table 1: Implications of hazard classification

<table>
<thead>
<tr>
<th>Hazard Rating</th>
<th>Description</th>
<th>Implications</th>
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<tbody>
<tr>
<td>VH – Very High</td>
<td>The event is expected to occur.</td>
<td>Extensive investigation, planning and implementation of treatment options essential to reduce risk to acceptable levels.</td>
</tr>
<tr>
<td>H – High</td>
<td>The event will probably occur under adverse conditions.</td>
<td>Detailed investigation, planning and implementation of treatment options essential to reduce risk to acceptable levels.</td>
</tr>
<tr>
<td>M – Moderate</td>
<td>The event could occur under adverse conditions.</td>
<td>May be acceptable provided treatment plan is implemented to maintain or reduce risk level.</td>
</tr>
<tr>
<td>L – Low</td>
<td>The event might occur under very adverse conditions.</td>
<td>Can be accepted. Treatment to reduce risk level should be defined.</td>
</tr>
<tr>
<td>VL – Very Low</td>
<td>The event is conceivable but only under exceptional circumstances.</td>
<td>Accepted. Managed by routine procedures.</td>
</tr>
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</table>

Courtesy of the Australian Geomechanics Society.
Guidelines for Control of Slope Instability

Guidance for proposed, or modification to existing developments in Landslide hazard areas

All proposed developments or redevelopments in areas classified moderate or higher landslide hazard should undertake a landslide hazard assessment.

All landslide hazard assessment reports will require the following elements to appropriately assess the existing site and the impacts of the proposed development:

- A description of the site and the proposed development including a site plan showing locations of the proposed development including vehicle access, swimming pools, rainwater tanks and other ancillary structures, earthworks, retaining walls, existing structures and features on the site and adjoining areas, all services existing and proposed including stormwater, sewerage, water, gas, electricity, telephone etc. vegetation, identified geotechnical hazards and contours across the site at a maximum of 0.5 metre vertical intervals.

- A description of the existing conditions on the site including slope angle, slope shape and features, parent rock type/soil type, engineering properties of sub-surface materials, concentration of surface water, concentration of groundwater, evidence of instability, available history of instability on the site or adjoining areas, land form modifications present and proposed, and geotechnical model of the site.

- Suitability of the proposed development that includes assessment of likely impacts and effects of the development on the landslide risk of the site and adjoining areas and likely impact of the development on the drainage of the slope.

- Landslide susceptibility rating analysis using the landslide susceptibility analysis form available in the City Plan policy - Geotechnical stability assessment guidelines.

- Outlining of restrictions and precautions that should be incorporated into the development, for example, buildings of light frame construction, suspended or split-level structures, earthworks minimisation, drainage provisions, effluent disposal locations and avoidance of particular areas.

- If the results of the landslide susceptibility rating analysis is moderate or higher, a risk assessment using the Australian Geomechanics Society (AGS) Landslide Risk is required.

- Management (LRM) 2007 guidelines will also be required to determine whether the risk to property and the public is acceptable. The risk assessment will also need to detail any design measures required to be included within the development to mitigate the risk to an acceptable level.

- All stability assessment reports must be signed off by a Registered Professional Engineer of Queensland (RPEQ).

- If the risk assessment report has been prepared for the final version of the design for a proposed development, it should also include a certification by an RPEQ that the proposed lot or allotments will have stable building areas and vehicular access.

Expertise required to prepare a Stability Assessment Report

The preparation of stability assessment reports require specialised skills. It is recommended in order to prepare these reports that a person should be qualified in civil engineering or engineering geology and be currently registered as a professional engineer of Queensland (RPEQ).

Their main area of business should be geotechnical engineering or engineering geology, and they should have a minimum of five years demonstrable experience in the assessment of steeply sloping and unstable land. It is desirable that the person also has local experience in the assessment of steep and unstable slopes.

How can the slope stability assessment be used?

The classification of the landslide hazards can be used in:

- the planning of proposed development
- the design of proposed development
- the reduction of the likelihood of landsliding in existing developments
- the design of landslide remedial works.

This is applicable in developments such as material change of use, reconfiguring a lot, operational work or building applications.

The actions required following a geotechnical study should depend on:

- the level of hazard classification
- the specific hazards identified on-site.

Once landslide hazards have been identified, activities can be directed in the following areas:

- avoidance of the hazardous areas, where possible
- the reduction of slope angle
- an increase in material strength
- a lowering of the water table and improvement of drainage
- slope retention.

The nature and extent of the activity depends on the most appropriate and practical, cost-effective solution.

Examples of how to maintain slope stability when developing on a slope are shown in Figure 2.
How can the landslide potential be evaluated?

The entire area of Gold Coast City has been broadly zoned into five landslide hazard categories. To determine whether your property is within the zones, visit cityplanmaps.goldcoast.qld.gov.au

Enter your property details, view the map, choose the overlay “Landslide hazard” and view the legend in the left panel. A slope instability legend is found above the map. Finally, zoom out for a view of neighbouring properties.

The hazard rating is classified into Very Low, Low, Moderate, High and Very High (see Table 1), however only moderate and higher ratings are applicable for future development.

For further details on development requirements on properties with a moderate or higher landslide hazard, refer to Schedule 6.10 City Plan policy Geotechnical stability assessment guidelines.

Poor drainage is another contributing factor to landslide occurrence. Surface and sub-surface water must be managed in a way that avoids the likelihood of damage or nuisance to the subject and surrounding properties.

Landslide issues on the Gold Coast

Gold Coast City has been extensively developed with a number of significant areas subject to intense rainfall. Natural landslides have been recognised over large areas of the city. Natural landslides in the city are most commonly found:

• in volcanic areas
• on prominent ridges of quartzite and greenstone (metasediments).

These slides may be rotational, translational or debris flows. There is also an association between instability and steep slopes at the heads of erosion gullies and with the accumulation of soil downhill of these drainage features.

In general, wherever colluvium is found to be several metres thick on sloping ground, slope instability may be expected. These failures may not be deep-seated, but they can still cover large areas in plan, particularly where there is a combination of thick low strength material and high groundwater pressures.

This combination may occur on relatively gentle slopes.

The natural slope angles in the metasediments are generally between about five degrees and 15 degrees on the lower slopes and along ridge tops. The middle and upper slopes are predominantly between about 15 degrees and 30 degrees, with small areas in the western and southern hinterland where the natural slope exceeds 30 degrees, generally on upper slopes. The metasediments are widespread across the city and comprise greenstone, quartzite, argillite, greywacke, sandstone and siltstones.

In volcanic areas, the natural slope angles are generally between about 15 degrees and 45 degrees on the middle and upper slopes, with some slopes greater than 45 degrees, particularly along scarps around the plateau edge. On the top of the plateau, slope angles are usually less than 15 degrees.

Volcanic rocks comprised of rhyolite, tuff and basalt are found in southern and south-western areas and on some of the coastal headlands and ridges.

There is no obvious evidence of natural slope instability initiated from the gentle slopes less than 11 degrees, except for the volcanic areas with colluvial deposits - particularly on benches below steep scarps. The majority of instability noted within the city occurs on slopes steeper than 15 degrees. Instability within the metasediments and alluvium has been noted down to 11 degrees at a number of locations within the city and across south-east Queensland. ¹

Deforestation is a contributing factor to slope instability.³ ⁴ ⁵ Loss of vegetation is principally caused by human activity but may also be due to disease and bushfires.

Deforestation can result in the elevation of a near surface groundwater table. Studies in the Gold Coast area have found a significant correlation between deforestation and slope instability on volcanic benches. ²

When planning developments through areas zoned as having a moderate or higher landslide hazard, reference should be made to City Plan - Landslide hazard overlay code

Examples of how to maintain slope stability when developing on a slope are shown in figure 2.

Recommendations:

• If developments or redevelopments are proposed on sites classified moderate or higher, ensure that a landslide risk assessment is undertaken by a Registered Professional Engineer of Queensland (RPEQ).
• Good hillside practice is included in design, for example, minimum vegetation clearing, compacted fill, engineered structures, appropriate building type, good drainage and minimal cut and fill.
• Ensure the proposal complies with the Landslide hazard overlay code of the City Plan.
• Refer to the Schedule 6.10 City Plan policy Geotechnical stability assessment guidelines, for more information.

Footnotes

Figure 2: Examples of good hillside practice

Figure 3: Examples of poor hillside practice

Refer to the Gold Coast Planning Scheme for more information.
City of Gold Coast is working hard to build a vibrant city, maintain a high quality of life for the community and ensure our city will be thriving, sustainable and attractive into the future.

This booklet contains information that residents who live on, or adjacent to, landslide-prone areas need to be aware of.

Disclaimer

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This document is available at cityofgoldcoast.com.au or in hard copy at Council Administration Centres.

References

6. Granger, K. 2009 Natural Hazards and Risks they pose to South-East Queensland.