Geotechnical Engineering Office, Civil Engineering and Development Department
The Government of the Hong Kong Special Administrative Region

GEO Technical Guidance Note No. 15 (TGN 15) Guidelines for Classification of Consequence-to-Life Category for Slope Features

1. SCOPE

1.1 This Technical Guidance Note (TGN) provides technical guidelines for the classification of the consequence-to-life (CTL) category for slopes and retaining walls (hereafter referred to as slope features). This TGN is intended to supplement the guidance given in the Geotechnical Manual for Slopes (GCO, 1984) and Works Bureau Technical Circular (WBTC) No. 13/99 (Works Bureau, 1999).

1.2 Any feedback on this TGN should be directed to the Chief Geotechnical Engineer/Standards & Testing of the GEO.

2. TECHNICAL POLICY

2.1 The guidelines promulgated in this TGN were agreed by the GEO's Geotechnical Control Conference (GCC).

3. RELATED DOCUMENTS

3.1 Geotechnical Control Office (1984). *Geotechnical Manual for Slopes. (Second Edition)*. Geotechnical Control Office, Hong Kong, 295 p.

3.2 Geotechnical Engineering Office (2000). *Highway Slope Manual*. Geotechnical Engineering Office, Hong Kong, 114 p.

3.3 Wong, C.K.L. (1998). *New Priority Classification for Slopes and Retaining Walls (GEO Report No. 68)*, Geotechnical Engineering Office, Hong Kong, 117 p.

3.4 Wong, H. N. & Ho, K.K.S. (1996). Travel distance of landslide debris. *Proceedings of the Seventh International Symposium on Landslides*, Balkema, Vol. 1, pp 417- 422.

3.5 Wong, H.N., Ho, K.K.S. & Chan, Y.C. (1997). Assessment of consequence of landslides. *Proceedings of the Workshop on Landslide Risk Assessment,* IUGS Working Group on Landslides, Balkema, pp 111-149.

3.6 Works Bureau (1999). *Geotechnical Manual for Slopes Guidance on Interpretation and Updating (Works Bureau Technical Circular No. 13/99).* Works Bureau, Government Secretariat, Hong Kong, 12 p.

4. BACKGROUND

4.1 The Geotechnical Manual for Slopes (GCO, 1984) gives recommendations on the appropriate factor of safety against failure of a slope in relation to the consequence of failure. It provides typical examples of slope failure situations for each consequence category. The consequence of failure is assessed based on the likelihood of loss of life and economic loss.

4.2 WBTC No. 13/99 provides further guidelines on the assessment of the CTL category of slope features. It stipulates that due consideration should be given to "such factors as possible failure mechanisms, site condition, scale of failure, proximity of the buildings and facilities to the slope, their likely density of occupation and frequency of usage in the event of failure, travel distance of the landslide debris, resistance of the buildings and facilities to debris impact and vulnerability of occupants and users".

4.3 WBTC No. 13/99 emphasises that the examples given in the Geotechnical Manual for Slopes refer to situations where the facilities lie within the expected travel distance of debris. If the facilities of a particular CTL category, e.g. CTL Cat "1" lie beyond the expected travel distance of the debris, the severity in terms of loss of life in the event of failure is less, and the CTL category may be downgraded to "2". Similarly, where the facilities lie beyond the possible extreme travel distance of landslide debris, the CTL category may be taken as "3". Similar considerations apply to buildings and facilities located behind the crest.

4.4 In the New Priority Classification System for Slopes and Retaining Walls (Wong, 1998), the types of facilities are subdivided into five facility groups. The possible CTL categories corresponding to each facility group are given in Table 1.

4.5 Guidance on assessing the facility grouping of slope features affecting roads is given in the Highway Slope Manual (GEO, 2000).

5. GUIDELINES

5.1 GENERAL

5.1.1 Guidelines to further illustrate the application of the principles of WBTC No. 13/99 as mentioned in paragraphs 4.2 and 4.3 above are given below.

5.2 PROXIMITY OF FACILITIES AT SLOPE TOE AND TRAVEL DISTANCE OF LANDSLIDE DEBRIS

5.2.1 An assessment of whether a facility would be within or beyond the travel distance of landslide debris, and hence downgrading or upgrading of the CTL category, can be made by comparing the shadow angle of the slope feature with respect to the facility with the travel angle of debris (see Figure 1). The shadow angle of the slope feature is the angle between the horizontal and a line drawn from the nearest point of the facility affected to the point (generally the crest of the slope feature) on the slope feature that gives a clear line of sight and maximum obliquity. The travel angle of debris is the angle between the horizontal and a line joining the crest of the landslide scarp to the distal end of the debris. A reasonable estimate of the potential debris travel distance can be made by projecting the travel angle from a point (normally the crest of the slope feature) on the slope feature that can give a clear line of sight to the toe facility and yields the farthest debris travel distance rather than the crest of an assumed failure scarp. The travel angle concept provides a reasonable prediction of debris travel distance for man-made slope features where the downslope gradient is fairly flat.

5.2.2 Figure 1 shows the relationship between the travel angle and volume of landslide debris for some slope failures in Hong Kong. The travel angle of debris varies with the nature of the slope-forming material, and the mechanism and scale of failure. The data in Figure 1 include landslides in soil cut slopes, rock cut slopes, fill slopes and retaining walls. By reference to Figure 1, a suitably conservative estimate of the expected and possible extreme travel distance of the landslide debris can be made as follows:

Type of Feature	Travel Angle for Estimation of the Expected Travel Distance of Landslide Debris	
	Debris Volume $\leq$ 300 m^3	Debris Volume > 300 m^3
Cut Slopes and Retaining Walls	35°	25°
Fill Slopes	25°	15°

Type of Feature	Travel Angle for Estimation of the Possible Extreme Travel Distance of Landslide Debris	
	Debris Volume ≤ 300 m^3	Debris Volume > 300m^3
Cut Slopes and Retaining Walls	30°	20°
Fill Slopes	20°	10°

5.2.3 The scale of failure depends on, among other things, the height of the slope feature. Past failure records (see Figure 2) indicate that those with volume of more than 300 m^3 mostly occurred in slope features with height greater than 10 m.

5.2.4 For high slope features (e.g. slope features higher than 15 m), users and occupants of facilities which lie outside the expected travel distance of debris could still be vulnerable to casualty from potential large-scale failures. When dealing with high slope features, extreme care should be exercised in assessing the consequence of failure before it is decided to downgrade the CTL category of the slope feature.

5.2.5 For gentle cut slopes whose gradient is less than the above recommended travel angles, the consideration of the expected travel distance of debris by means of travel angle alone may not be adequate in assessing their CTL category for cases where the feature can give rise to large failures and the toe facility lies very close to the feature. Under such circumstances, it is prudent to consider the presence of an adequate buffer space at the toe to accommodate debris before the CTL category can be downgraded (e.g. a 3 m wide buffer zone in front of a 10 m high cut slope is generally considered adequate).

5.2.6 In some cases, the height of a feature may vary along its length and the location of the affected facility may not coincide with the maximum feature height. Under such circumstances, the assessment of the CTL category for the feature should take account of the likely failure scenarios, site conditions and characteristics of that part of slope where debris from it could reach the facility. Where several facilities exist, the potential consequence of failure in relation to each facility should be assessed to determine which facility gives rise to the most severe situation.

5.3 PROXIMITY OF FACILITIES AT THE FEATURE CREST AND EXTENT OF FAILURE

5.3.1 The back scarp of a failure may extend beyond the crest of the slope feature thereby affecting the crest facility. Figure 3 shows the relationship between the crest

influence zone (see Figure 1 for definition) and landslide volume. The extent of the crest influence zone has been normalised with respect to the slope height. The accuracy of the information of the crest influence zone may have been hampered in some cases where the original feature profile prior to failure was not reliably known at the time of landslip inspection. Nevertheless, it is adequately conservative to assume that the expected crest influence zone is not larger than 0.4 times the slope height. For the extreme limit of the crest influence zone, it can be taken as the slope height.

5.3.2 In assessing the effects of landslides on building located at the crest, the nature of the building's foundation should also be taken into account. For example, the degree of damage to a building founded on piles is expected to be small if its foundation does not rely on the slope feature for stability. In such a case, the CTL category may still be downgraded even if the building lies within the expected crest influence zone of the landslide.

5.4 SCALE OF FAILURE

5.4.1 Landslides from small soil cut slopes, fill slopes and retaining walls are generally of small failure volume and are unlikely to cause severe damage to substantial structures. Hence, when a slope feature is small and in the judgement of the inspecting engineer, the toe facilities are structures that have sufficient structural strength to withstand debris impact without collapse, and that casualties due to intrusion of debris through openings such as windows or doors are unlikely, the CTL category of the feature may be downgraded by one category following the guidance in WBTC No. 13/99. Figure 2 shows that the failure volume of landslides on slope features with a height of 4 m or less have all been less than 50 m^3. Based on these data, a reasonably conservative assumption of a small slope feature is one that is not higher than 4 m.

5.4.2 A small piece of falling rock could cause severe injury or fatalities. As such, the above principle is not applicable to rock slopes and soil cut slopes with potential boulder fall or fall of rock blocks.

5.4.3 In the event where steep natural terrain locates above the feature crest, due consideration should be given to the potential for large failures in the assessment of the CTL category. Each case should be judged on its own merits.

5.5 MECHANISM OF FAILURES AND SITE CONDITIONS OF DISTURBED TERRAIN

5.5.1 Most disturbed terrain (DT) are agricultural terraces with relatively gentle overall slope gradient (less than 30°). Unlike man-made slopes where the facilities are mostly located at the toe or on the slope crest, there are a number of cases where the facilities

lie on the DT. Past landslide data indicate that for DT comprising agricultural terraces with gentle overall slope gradient (less than 30°), the likelihood of large-scale failure is low and the landslide incidents in these DT are mainly related to localised small cuttings or masonry walls. Under such circumstances, it is more appropriate to assess the CTL classification based on the proximity of any facility located within the influence zone with respect to the localised slope features. The considerations on the proximity and scale of failures as given in Sections 5.2, 5.3 and 5.4 are also applicable to DT.

5.6 **EXAMPLES**

5.6.1 Examples are given in Annex TGN15 A5 to illustrate how the assessment of CTL is carried out following the principles given in WBTC No. 13/99. It should be cautioned that the guidance and examples should not be mechanically applied. Due consideration of the site conditions should be given and each case needs to be examined on its own merits. It is worth noting that if the key facilities are found to lie beyond the expected or possible extreme travel distance of debris, other intervening facilities (e.g. roads) should be considered and may become the dictating facility in the assessment of the CTL category of the feature.

6. ANNEXES

6.1 TGN15 A1 – Typical Examples of Facilities Affected by Landslides in Each Consequence-to-Life Category

6.2 TGN15 A2 – Figure 1 - Relationship between Travel Angle and Landslide Volume for Selected Slope Failures in Hong Kong

6.3 TGN15 A3 – Figure 2 - Relationship between the Height of Slope Features and Scale of Failures

6.4 TGN15 A4 – Figure 3 - Relationship between the Crest Influence Zone (D/H) and Landslide Volume

6.5 TGN15 A5 – Illustrative Examples for Assessing CTL Category of Features

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Table 1 – Typical Examples of Facilities Affected by Landslides in Each Consequence-to-Life Category

Group	Facilities	Consequence-to-life Category[1]
1	(a) Heavily Used Buildings – residential building, commercial office, store and shop, hotel, factory, school, power station, ambulance depot, market, hospital, polyclinic, clinic, welfare centre	1
	(b) Others – cottage, licensed and squatter areas – bus shelter, railway platform and other sheltered public waiting area – dangerous goods storage site (e.g. petrol stations) – road with very heavy vehicular or pedestrian traffic density	
2	(a) Lightly Used Buildings – indoor car park, building within barracks, abattoir, incinerator, indoor games' sport hall, sewage treatment plant, refuse transfer station, church, temple, monastery, civic centre, manned substation	
	(b) Others – major infrastructure facility (e.g. railway, tramway, flyover, subway, tunnel portal, service reservoir) – construction site (if future use not certain) – road with heavy vehicular or pedestrian traffic density	2
3	– heavily used open space and public waiting area (e.g. heavily used playground, open car park, heavily used sitting out area, horticulture garden) – road with moderate vehicular or pedestrian traffic density	
4	– lightly used open-air recreation area (e.g. district open space, lightly used playground, cemetery, columbarium – non-dangerous goods storage site – road with low vehicular or pedestrian traffic density	3
5	– remote area (e.g. country park, undeveloped green belt, abandoned quarry) – road with very low vehicular or pedestrian traffic density	

Note: (1) The consequence-to-life category refers to situation where the facilities are located within the expected travel distance of landslide debris or the expected crest influence zone of failure. Any indirect consequences should also be taken into consideration, e.g. debris falling into a catchwater can travel long distance and affect other facilities. Situations where the CTL category can be downgraded are given in Section 5 of this TGN.

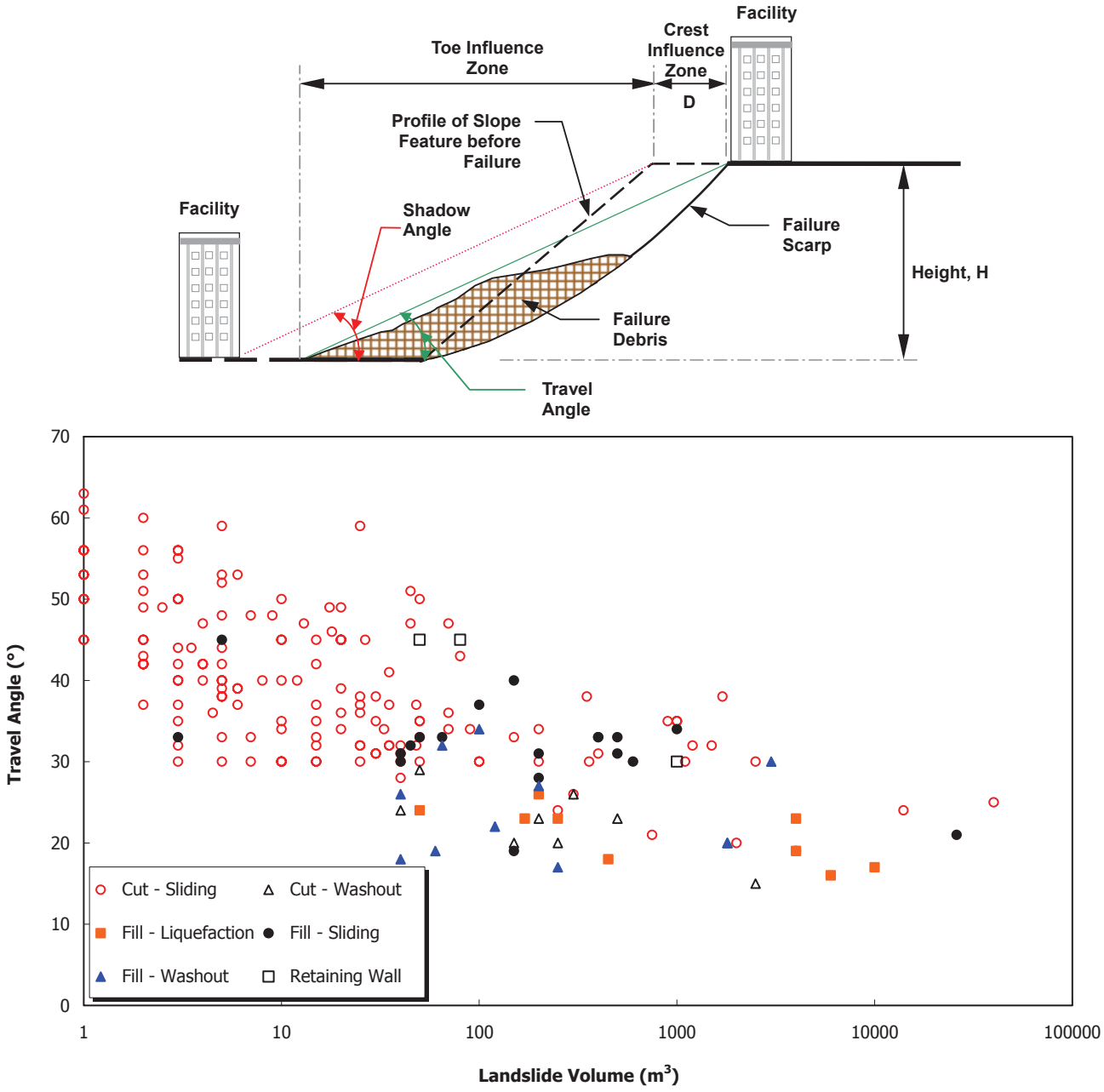
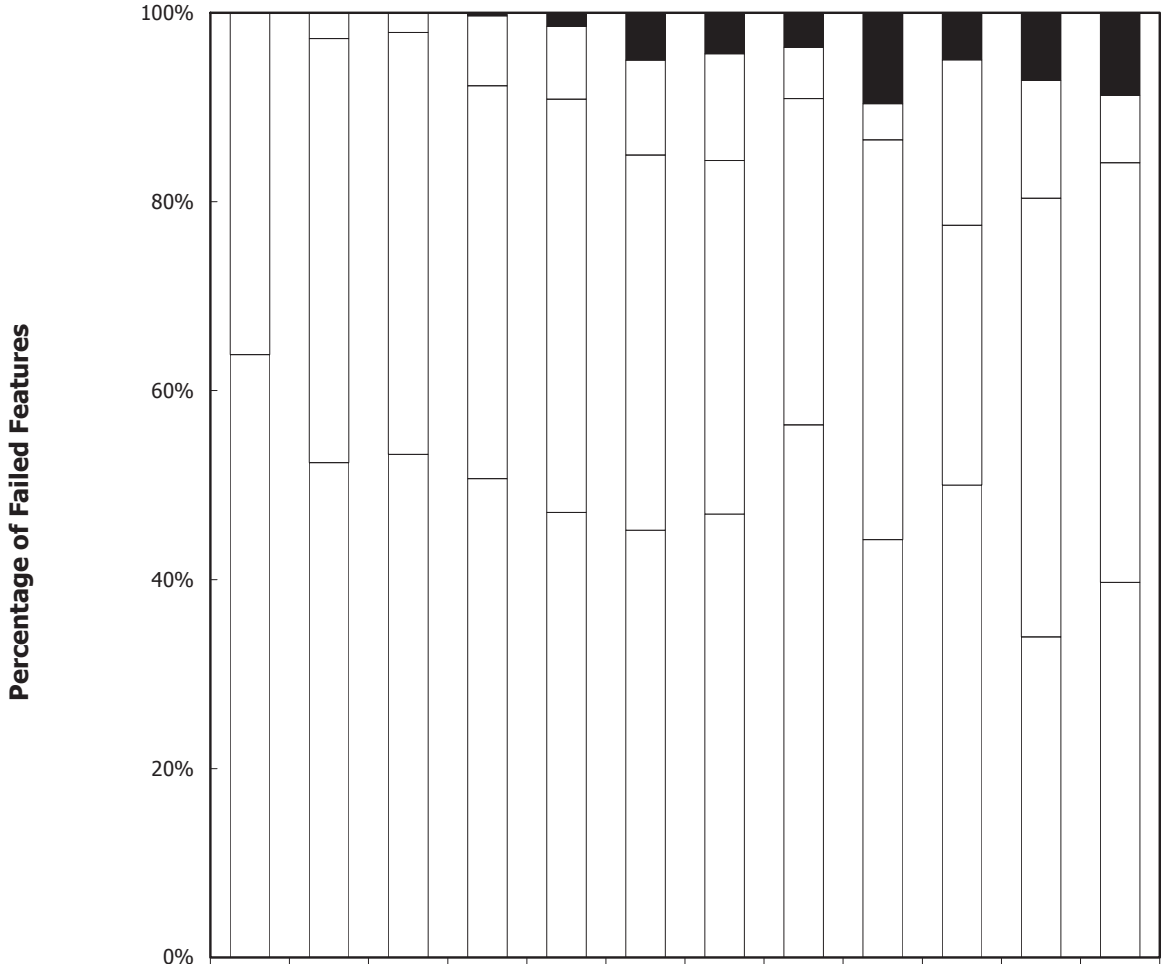


Figure 1 – Relationship between Travel Angle and Landslide Volume for Selected Slope Failures in Hong Kong

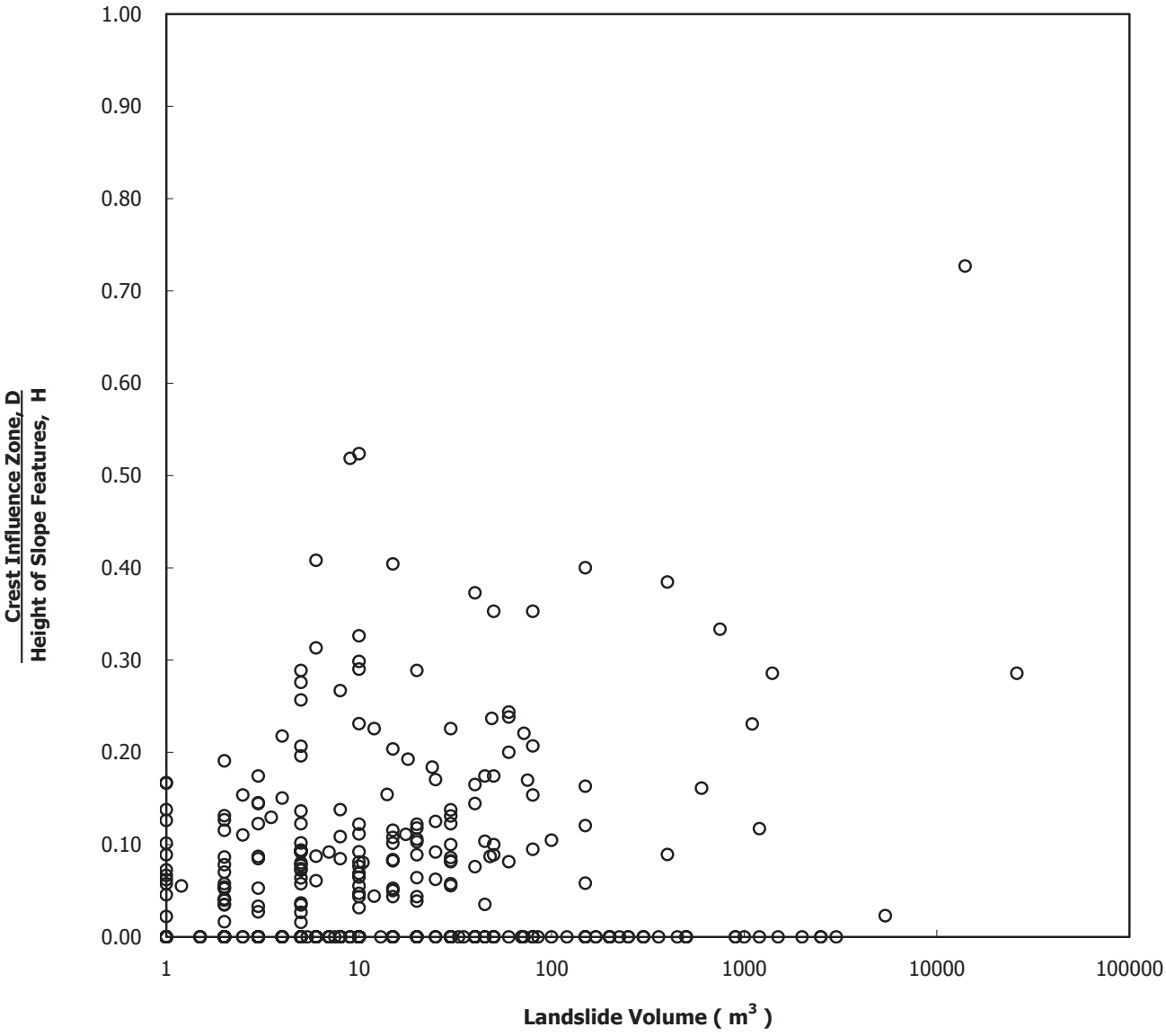


Volume of Debris, V (m^3)	H≦4	4 < H ≦6	6 < H ≦8	8 < H ≦10	10 < H ≦12	12 < H ≦15	15 < H ≦18	18 < H ≦21	21 < H ≦24	24 < H ≦27	27 < H ≦30	H > 30
■ V > 300	0	0	0	1	3	10	5	4	5	2	4	11
▧ 50 < V ≦300	0	15	9	22	16	20	13	6	2	7	7	9
▥ 5 < V ≦50	106	245	192	124	91	79	43	38	22	11	26	56
□ V ≦5	187	286	229	151	98	90	54	62	23	20	19	50
SubTotal	293	546	430	298	208	199	115	110	52	40	56	126

Height of Failed Features, H (m)

Note: Based on landslide incidents at registered slopes (soil and rock cut slopes, fill slopes and retaining walls) reported to GEO between 1984 and 2002.

Figure 2 – Relationship between the Height of Slope Features and Scale of Failures



Notes:
1. Based on notable landslides between 1992 and 2002 and landslide incidents reported to the GEO between 1999 and 2002.
2. Refer to Figure 1 for definitions of D and H.

Figure 3 – Relationship between the Crest Influence Zone (D/H) and Landslide Volume

Illustrative Examples for Assessing CTL Category of Features

- Height of retaining wall : 8 m
- A residential building is located at 14 m from the toe of the retaining wall
- Shadow angle ≈ 27° (< 30°) from the crest of retaining wall

The residential building belongs to Facility Group 1(a) but is located beyond the possible extreme travel distance of the debris. The CTL category of the feature should be either "2" or "3" depending on the nature of the intervening facilities.

- Height of cut slope : 13.5 m
- A residential building is located at 8.5 m from the toe of the slope
- Shadow angle ≈ 24° (< 25°) from the slope crest

The residential building is located beyond the expected travel distance of the debris. The CTL category of the feature should be "2" depending on the nature of the intervening facilities.

Illustrative Examples for Assessing CTL Category of Features

- Height of fill slope : 10 m
- A factory is located at 5 m from the toe of the slope
- Shadow angle ≈ 21° (< 25°) from the slope crest

The factory belongs to Facility Group 1(a) but is located beyond the expected travel distance of the landslide debris. The CTL category of the feature should be "2" depending on the nature of the intervening facilities.

- Height of fill slope : 7 m
- A house is located at about 4 m from the toe of the slope
- Shadow angle ≈ 18° (< 20°) from the slope crest

The house belongs to Facility Group 1(b) but is located beyond the possible extreme travel distance of the landslide debris. The CTL category of the feature should be either "2" or "3" depending on the nature of the intervening facilities.

Illustrative Examples for Assessing CTL Category of Features

- Height of cut slope : 6 m
- A dangerous goods store is located at 10 m from the toe of the slope
- Shadow angle ≈ 23° (< 30°) from the slope crest

The dangerous goods store (petrol station) belongs to Facility Group 1(b) but is located beyond the possible extreme travel distance of the landslide debris. The CTL category of the feature should be either "2" or "3" depending on the nature of the intervening facilities.

- Height of cut feature : 5 m
- A house is located at about 3 m from the crest of the slope
- Distance of the house from the slope crest ≈ 0.6 x slope height

The house belongs to Facility Group 1(b) but is located away from the expected crest influence zone of the failure. The feature may be assessed as CTL Cat "1" or "2" depending on the proximity of the toe facility.

Illustrative Examples for Assessing CTL Category of Features

- Height of cut feature : 3.5 m
- A house at the toe of the slope is made of substantial structure
- Open space at crest

The scale of failure from the feature is likely to be small and the structure will provide protection against small landslides. The feature can be assessed to be CTL Cat "2".

- Feature type : agricultural terraces in disturbed terrain
- Overall height of feature : 24 m
- Overall slope angle : 25° (< 30°)

The CTL category of the disturbed terrain depends on the proximity of facility from the localised slope features. In this case, if a Group 1 or 2(a) facility lies beyond the expected travel distance of debris from the localised slope, the CTL category should be "2".