Review of Landslides in 2013

GEO Report No. 326

R.W.H. Lee & D.O.K. Lo

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

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Preface

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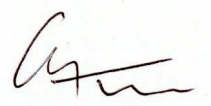

W.K. Pun
Head, Geotechnical Engineering Office
February 2017

Foreword

This report presents the findings of a detailed diagnosis of landslides in 2013 that were reported to the Government. It serves to review the performance of the Government's slope safety system and identify areas for improvement, as well as to further enhance the slope engineering practice in Hong Kong.

The review was carried out by Mr R.W.H. Lee and Dr D.O.K. Lo of Landslip Preventive Measures Division 1 under the supervision of Mr Y. Lam. Assistance was provided by the landslide investigation consultants engaged by the Geotechnical Engineering Office, namely Fugro Scott Wilson Joint Venture and AECOM Asia Company Limited respectively. Technical support provided by Mr T.F.O. Luk, Mr L.K.W. Hui and Mr C.M. Leung is gratefully acknowledged.

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Head of the Geotechnical Engineering Office

Abstract

This report presents the findings of a diagnostic review of the landslides in 2013 that were reported to the Government. The review forms part of the GEO's systematic landslide investigation programme, which is an integral component of the Government's slope safety system. The aims of this report are to review the performance of the Government's slope safety system and identify areas for improvement, as well as to further enhance the slope engineering practice in Hong Kong.

Altogether, 241 genuine landslides in 2013 were reported to the Government. There were nine major landslides (viz. failure volume of 50 m^3 or more) including one occurring on an engineered man-made slope. There were also 13 minor landslides (viz. failure volume of less than 50 m^3) occurring on engineered man-made slopes. The corresponding annual failure rate of engineered slopes is about 0.052% on a slope number basis (i.e. number of landslides relative to the total number of engineered slopes).

Overall, 99.95% of the engineered man-made slopes performed satisfactorily without occurrence of landslides in 2013.

Recommendations for further improvement of the slope safety system and slope engineering practice in Hong Kong are also given in this report.

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1 Introduction

This report presents the findings of a diagnostic review of the landslides in 2013 that were reported to the Geotechnical Engineering Office (GEO) of the Civil Engineering and Development Department (CEDD) and other government departments. The review forms part of GEO's systematic landslide investigation (LI) programme, which is an integral component of the Government's slope safety system. The LI programme has the following two principal objectives:

(a) to identify, through studies of landslides, slopes that are affected by inherent instability problems so that appropriate follow-up actions can be taken for integrated slope assessment and upgrading works, and

(b) to review the performance of Government's slope safety system and identify areas for improvement in slope engineering practice.

The present diagnostic review considers all the available landslide data in 2013. The review has been carried out by the Landslip Preventive Measures Division 1 (LPM1) of the GEO, with assistance provided by GEO's LI consultants, namely Fugro Scott Wilson Joint Venture (FSWJV) and AECOM Asia Company Limited (AECOM).

2 Rainfall and Landslides in 2013

The factual information, together with the relevant statistics on rainfall and reported landslides in 2013, was documented by Lee & Ting (2014).

In 2013, the annual rainfall recorded at the Principal Raingauge of the Hong Kong Observatory (HKO) in Tsim Sha Tsui was 2,847.3 mm, a surplus of about 19% comparing to the mean rainfall of 2,398.5 mm between 1981 and 2010. One Landslip Warning was issued on 22 May 2013. One Black Rainstorm Warning was issued on 22 May 2013; two Red Rainstorm Warnings were issued on 22 May and 24 June 2013; and 23 Amber Rainstorm Warnings were issued between 19 March and 4 September 2013.

Reported landslides are classified as follows:

(a) minor failure (i.e. failure volume < 50 m^3), and

(b) major failure (i.e. failure volume ≥ 50 m^3 or where a fatality has occurred).

In the present context, failure volume refers to the total sum of the volume of detached material and the volume of any deformed material that remains on the slope that may, or may not, have displaced significantly.

Of a total of 256 reported incidents in 2013, 241 were genuine landslides, discounting the non-landslide incidents (e.g. tree falls). There were nine major failures, corresponding to

about 4% of the number of genuine landslides.

The distribution of landslides, as classified by the types of slope failures, is given in Table 2.1. The range of facilities affected by the landslides is summarised in Table 2.2. The consequences of the landslides in relation to the types of slope failures are summarised in Table 2.3. The distribution of the different facility groups affected by the major landslide is presented in Table 2.4. The distribution of the scale of failures, as classified by the types of slopes involved, is given in Table 2.5.

Table 2.1 Breakdown of Landslides by Types of Slope Failures

Types of Slope Failures		Number	Percentage (%)
Fill Slopes		10 (2)	4.1
Cut Slopes	Soil	108 (4)	44.8
	Soil/Rock	48 (1)	19.9
	Rock	5 (0)	2.1
Retaining Walls		22 (1)	9.1
Natural Hillside		45 (1)	18.7
Registered Disturbed Terrain		3 (0)	1.3
Total		241 (9)	100

Legend:

48 (1) Forty-eight landslides, one of which was a major failure

Notes:
(1) Where a landslide involved more than one type of failure, the predominant type of failure has been considered in the above classification.
(2) Incidents that were not genuine landslides have been excluded.

Table 2.2 Breakdown of Landslides by Types of Affected Facilities

Types of Affected Facilities	Hong Kong Island	Kowloon	New Territories and Outlying Islands	All
Buildings (including village houses)	0	0	19 (1)	19 (1)
Registered Squatter Dwellings	0	0	13 (0)	13 (0)
Roads	9 (0)	6 (2)	28 (5)	43 (7)
Transportation Facilities (e.g. railways, tramways, etc.)	0	0	0	0
Pedestrian Pavements/Footways	3 (0)	0	2 (0)	5 (0)
Minor Footpaths/Access Paths/Access Roads	16 (0)	1 (0)	73 (0)	90 (0)
Construction Sites	0	2 (2)	0	2 (2)
Open Areas	5 (0)	0	40 (1)	45 (1)
Catchwaters	3 (0)	0	15 (0)	18 (0)
Others (e.g. carparks, parks, playgrounds, gardens, backyards, etc.)	3 (0)	1 (0)	19 (0)	23 (0)
Nil	1 (0)	1 (0)	2 (0)	4 (0)
Total	40 (0)	11 (4)	211 (7)	262 (11)

Legend:

19 (1) Nineteen landslides of which one was a major failure

Notes:
(1) Incidents that were not genuine landslides have been excluded.
(2) A given landslide may affect more than one type of facility.
(3) Nil consequence refers to incidents where the landslide debris came to rest on the slopes, not affecting any facilities.

Table 2.3 Breakdown of Landslide Consequences by Types of Slope Failures

Types of Slope Failures		Number of Squatter Dwellings [1] Evacuated		Number of Floors, Houses or Flats Evacuated or Partially Closed	Number of Incidents Involving Closure			Deaths	Injuries Reported to GEO
		Permanent	Temporary		Roads	Pedestrian Pavements	Footpaths, Alleyways or Private Access Paths		
Fill Slopes		0	0	0	3	0	1	0	0
Cut Slopes	Soil	1 (1)	0	0	9	0	5	0	0
	Soil/Rock	0	0	0	10	1	2	0	0
	Rock	0	0	0	0	0	0	0	0
Retaining Walls		0	1 (1)	2[3]	2	0	1	0	0
Natural Hillside		0	0	0	1	0	4	0	0
Registered Disturbed Terrain		0	0	0	0	0	0	0	0
Total		1 (1)	1 (1)	2	25	1	13	0	0

Legend:

1 (1) Number of squatter dwellings evacuated, with the number of tolerated squatter structures evacuated shown in brackets

Notes:

(1) A squatter dwelling is defined as a place of residence that contains one or more tolerated squatter structures, i.e. structures registered in the 1982 Housing Department's Squatter Structure Survey (GEO, 2010a).

(2) A failure may give rise to more than one type of consequence.

(3) A retaining wall failure (Incident No. 2013/06/1390) resulted in temporary evacuation of three residents from two village houses on a licensed land at Ma Tso Lung.

Table 2.4 Breakdown of Facility Groups Affected by Major Landslides

Types of Major Landslides	Facility Groups Affected by Major Landslides (Group No)						
	1a	1b	2a	2b	3	4	5
All Major Landslides	0	1	0	0	4	3	1
Major Landslides on Man-made Slopes	0	1	0	0	4	3	0
Major Landslides on Registered Disturbed Terrain	0	0	0	0	0	0	0
Major Landslides on Natural Hillside	0	0	0	0	0	0	1

Note: Facility groups are classified in accordance with the GEO Technical Guidance Note No. 15 (GEO, 2007).

Table 2.5 Breakdown of Scale of Failures by Types of Slopes

Types of Slopes	Number of Minor Landslides	Number of Major Landslides		Total
	(< 50 m^3)	(50 m^3 to < 500 m^3)	(≥ 500 m^3)	
Registered Man-made Slopes	122	6	0	128
Registered Disturbed Terrain	3	0	0	3
Unregistrable Man-made Slopes	51	0	0	51
Registrable Man-made Slopes Not Yet Registered at Time of Failure	12	0	2 (both cases involved slopes being formed at the time of failures)	14
Natural Hillside	44	1	0	45
Total	232	7	2	241

3 Severity of Rainstorms as Reflected by Landslide Potential Index

Experience has shown that the annual rainfall alone is not a good measure of the severity of the individual rainstorms in terms of their potential to trigger landslides. A more direct measure of the severity of the individual rainstorms in the context of landslides is given by the Landslide Potential Index (LPI), as promulgated by the GEO (2014a). The LPI is calculated for rainstorms that resulted in the issue of Landslip Warning and is used to depict the relative severity of the rainstorm with respect to its potential to cause landslides. The LPI, which is not a predictive index, is based on the 24-hour rainfall of a rainstorm. The LPI for rainstorms that resulted in the issue of Landslip Warnings from 1984 to 2013 is presented in Figure 3.1.

In 2013, one Landslip Warning was issued on 22 May 2013 and its corresponding LPI was assessed to be 2. In terms of its potential to cause landslides, the rainstorm of 22 May 2013 was one-fifth of the severity of the rainstorm of 23 July 1994 and 20 August 2005, both of which had an LPI of 10 and had triggered landslides resulting in fatalities (viz. the 23 July 1994 landslide at Kwun Lung Lau and the 20 August 2005 landslide at Fu Yung Shan Tsuen).

4 Overall Diagnostic Review of Landslides

4.1 General

An overall diagnostic review of the available 2013 landslide data has been carried out to appraise the slope performance, and facilitate the identification of areas in the slope safety system for further improvement.

The diagnostic review has mainly focused on the following aspects:

(a) coverage of the Catalogue of Slopes,

(b) performance of registered man-made slopes,

(c) observations from natural terrain landslides, and

(d) other areas of technical interest.

4.2 Coverage of the Catalogue of Slopes

4.2.1 General

Sizeable man-made slopes and retaining walls, including those compiled under the GEO's project entitled “Systematic Identification and Registration of Slopes in the Territory” (SIRST) that was completed in September 1998, together with newly formed or identified slope features after 1998, are registered in the Catalogue of Slopes. Any unregistered man-made slopes identified during slope maintenance inspections, landslide investigations and other geotechnical inspections or studies will also be registered in the Catalogue of Slopes should they satisfy the slope registration criteria (GEO, 2010b).

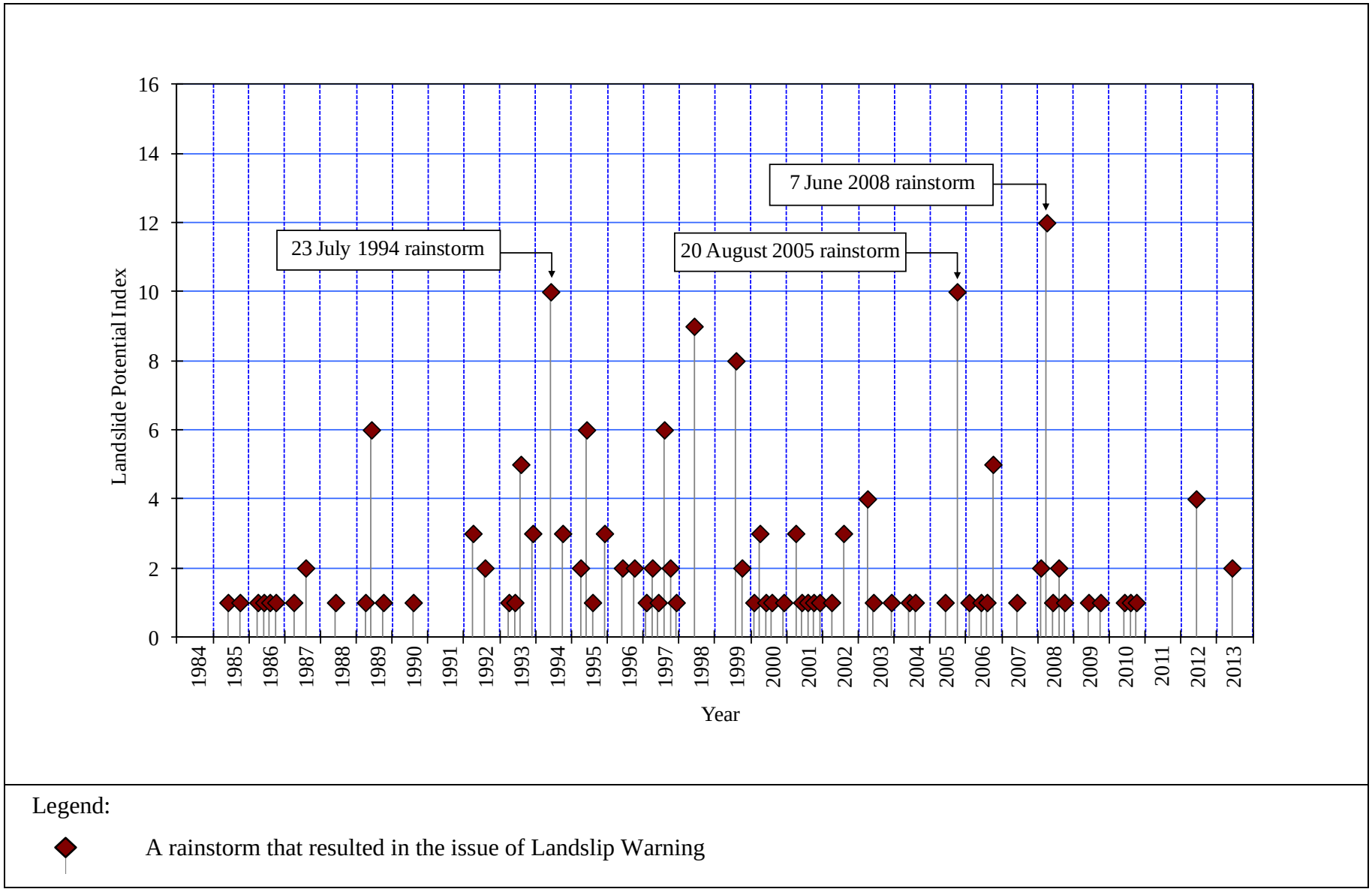


Figure 3.1 Landslide Potential Index for Rainstorms that Resulted in the Issue of Landslip Warnings from 1984 to 2013

4.2.2 Diagnosis

Of the 241 genuine landslides, 131 occurred on registered slope features (comprising 128 on registered man-made slopes and 3 on registered disturbed terrain features) and 110 occurred on slopes not registered in the Catalogue of Slopes (Table 2.5).

Among the above 110 landslides, 45 occurred on natural hillside, 51 occurred on small man-made slope features that do not meet the slope registration criteria (GEO, 2004) and two occurred on slopes being formed at the time of failures. The remaining 12 landslides, corresponding to 5.0% of the total number of genuine landslides in 2013, involved slope features that satisfy the slope registration criteria but was not registered in the Catalogue of Slopes at the time of failures. A breakdown of these 110 landslides is given in Figure 4.1.

Of the 14 landslides that involved registrable slopes, one occurred on a fill slope (failure volume of about 530 m^3) and one occurred on a reinforced fill retaining wall (soil loss of about 1,300 m^3 and distressed groundmass of approximately 5,500 m^3) within a construction site at Sau Mau Ping. Both were under construction and hence were not yet registered at the time of failures. These two incidents resulted in temporary closure of Lee On Road and Shun On Road for 13 hours and 18 days respectively. The remaining 12 incidents on registrable slopes were all minor failures with failure volume of 15 m^3 or less. Amongst these 12 minor failures, three resulted in temporary closure of minor footpaths/access whereas the other incidents did not cause any significant impact on the community (Appendix A). Following the landslides, arrangements have been made to register the man-made slope features concerned in the Catalogue of Slopes.

The 51 landslides involving unregistrable man-made slope features were all minor failures with failure volume of 20 m^3 or less. One incident resulted in temporary evacuation of six residents from a squatter dwelling at Tseng Tau Sheung Tsuen, Tuen Mun. Another incident resulted in temporary evacuation of three residents from two village houses at Shun Yee San Tsuen, Ma Tso Lung. In addition, one incident resulted in temporary closure of So Kwun Wat Road and one led to temporary closure of a minor footpath at Sham Tseng.

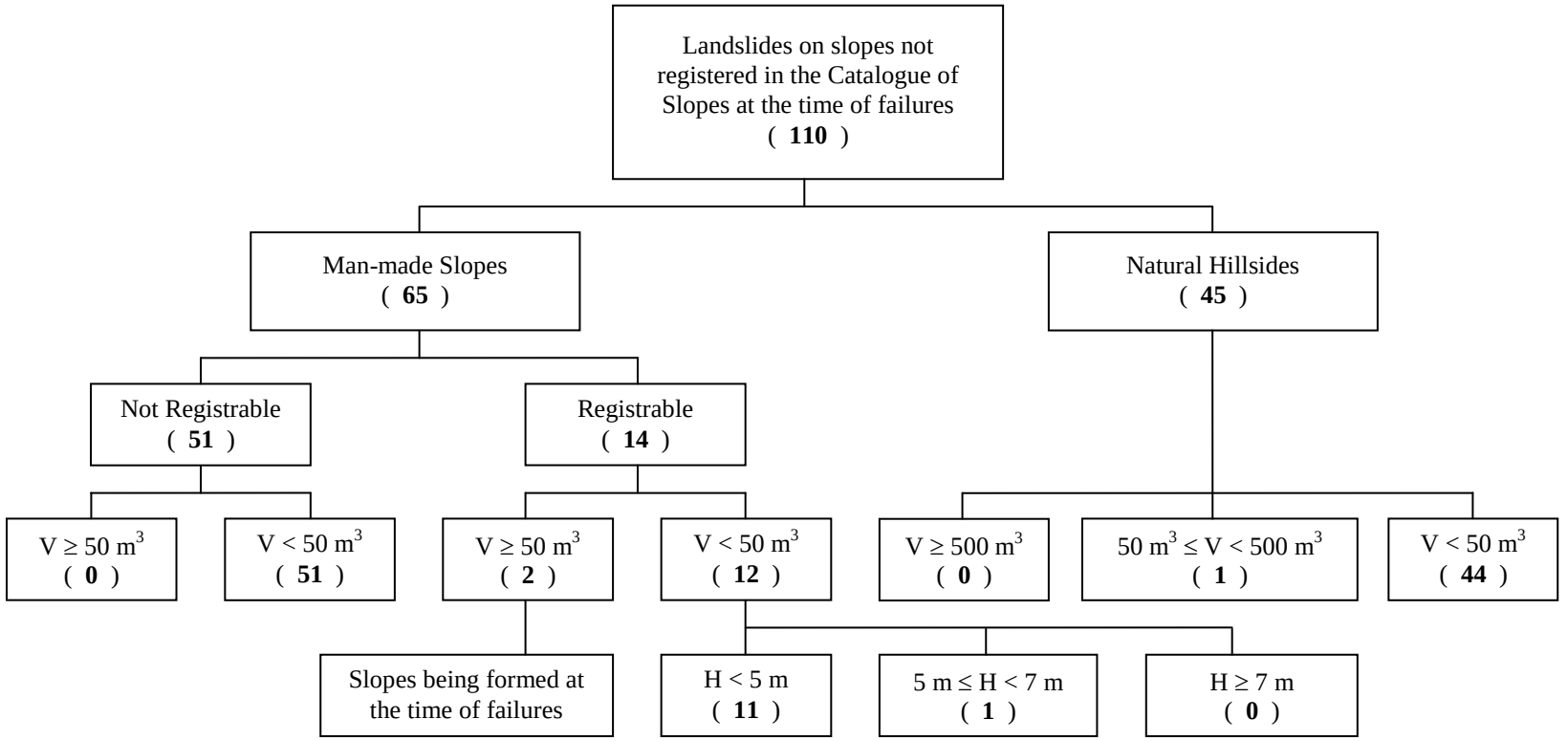
4.3 Performance of Registered Man-made Slopes

4.3.1 General

The man-made slopes registered in the Catalogue of Slopes can be broadly classified into engineered slopes and non-engineered slopes. The performance of the registered man-made slopes is reviewed in terms of their annual failure rates.

Engineered slopes include the following:

(a) slopes formed after 1977 (i.e. after the Geotechnical Control Office (renamed GEO in 1991) was established) that were designed, checked and accepted under the slope safety system as being up to the required geotechnical standards,



Legend:

V	Failure volume
H	Height of man-made feature before failure
(51)	Number of landslide incidents = 51

Notes:
(1) 'Not Registrable' refers to cases involving slopes that do not satisfy the feature height criteria for registration in the Catalogue of Slopes (GEO, 2004) at the time of failure.
(2) Following the landslides, arrangements have been made to register the registrable features in the Catalogue of Slopes.

Figure 4.1 Breakdown of Landslides on Unregistered Slopes in 2013

(b) slopes formed before 1977 that were subsequently assessed, checked and accepted under the slope safety system as being up to the required geotechnical standards,

(c) slopes formed before 1977 that were subsequently upgraded, checked and accepted under the slope safety system as being up to the required geotechnical standards, and

(d) slopes upgraded to the required geotechnical standards using Type 3 prescriptive measures (GEO, 2009) under an adequate quality system satisfying the requirements of Environment, Transport and Works Bureau (ETWB) Technical Circular (Works) No. 13/2005 (ETWB, 2005) whereby checking of the design by the GEO has been waived.

For the present diagnosis, slopes that were not accepted under the slope safety system (e.g. no geotechnical submissions made to the GEO for checking, or submissions with outstanding GEO comments) are considered as non-engineered slopes.

Of the 241 genuine landslides in 2013, a total of 128 landslides (about 53%) occurred on registered man-made slopes (Table 2.5). Six out of these 128 landslides (about 5%) were major failures, with failure volume ranging from 50 m^3 to 280 m^3, and the remaining 122 landslides were minor failures. Of the 128 landslides on registered man-made slopes, 14 landslides (about 11%) occurred on engineered slopes and the remaining 114 landslides occurred on non-engineered slopes. Except for an incident which occurred on an engineered slope with a failure volume of 280 m^3 (see Section 4.3.2), there was no major landslide occurring on consequence-to-life (CTL) Category 1 slope features in 2013. A breakdown of the CTL categories of the registered man-made slopes involved in the landslides is given in Table 4.1.

Table 4.1 Breakdown of Consequence-to-life Categories of Registered Man-made Slopes Involved in the Landslides

Types of Slopes	No. of Landslides			Total
	CTL Cat.1	CTL Cat.2	CTL Cat.3	
Engineered Slopes	7 (1)	7 (0)	0 (0)	14 (1)
Non-engineered Slopes	29 (0)	14 (2)	71 (3)	114 (5)

Legend:

7 (1) Seven landslides, one of which was a major failure

Further details of the landslides in 2013 involving engineered slopes are given in Appendix B. Detailed assessment of the engineered and non-engineered slopes is described in Sections 4.3.2 and 4.3.3 below.

4.3.2 Landslides on Engineered Slopes

Brief descriptions of the 14 landslides on engineered slopes in 2013 are given in Appendix B. A breakdown of these landslides in terms of feature type is given in Table 4.2. Among the 14 landslides, six involved slopes that have been previously upgraded under the LPMP (see Table 4.3). None of the landslides in 2013 involved slopes that have been previously upgraded under the LPMitP.

One landslide involved the failure of a fill slope (volume of 30 m^3) probably due to enhanced water ingress resulting from overspillage of surface water from the crest channel where an upstand was constructed following the landslide.

Four landslides involved minor rockfalls (volume ≤ 2 m^3). Post-landslide inspections revealed that all these four incidents occurred on bare rock faces, where no rock mesh was installed, with unplanned vegetations in the vicinity of the rockfall source areas. Extensive tree root growth and root wedging actions along the discontinuities over the failure surfaces were also evident in some of these cases. Again, these incidents illustrated that minor rockfalls from rock slopes are hard to assess and be prevented. The provision of surface protective measures such as rock mesh could be a pragmatic solution to deal with minor rockfalls.

Six landslides involved slopes installed with soil nails (volume ≤ 3 m^3). One occurred on a cut slope almost entirely installed with soil nails but it failed on the small steeply inclined (about 70°) unsupported portion at the return end of the slope probably associated with tree root action. No stability assessment or upgrading works proposal could be located for the return end of the slope. The remaining five cases all involved shallow failures within the soil-nailed zones of the cut slopes. Two incidents involved repeated failures on two adjoining soil-nailed slopes (gradient of 70° and 52°) at South Lantau Road. The 2013 failures (volume of 1.5 m^3 to 3 m^3) are respectively the 2nd and 3rd failures reported since the completion of LPM works with soil nails installed on the slopes in 2004/2005. In both cases, the 2013 failures are right next to the past landslide scars under the influence of similar geological settings and contributory factors to failures. The failures might be attributed to the build-up of local transient groundwater pressures above the soil/rock interface or less weathered materials at shallow depth. The presence of adversely orientated relict joints near the slope surface might have also contributed to the failures. In two of the soil-nailed slope failure cases, the landslide debris were either fully or mostly retained by the wire mesh installed on the slope surfaces, which limited the extent and hence minimized the consequences of the failures.

Table 4.2 Breakdown of Landslides on Engineered Slopes

Scale of Failure (m^3)	Fill Slopes	Cut Slopes			Retaining Walls	Total
		Soil	Soil/Rock	Rock		
> 500 m^3	0	0	0	0	0	0
50 m^3 to 500 m^3	0	1	0	0	0	1
> 5 m^3 to < 50 m^3	1	0	1 (1)	0	0	2
≤ 5 m^3	0	5 (4)	6	0	0	11
Total	1	6 (4)	7 (1)	0	0	14

Legend:

7 (1) Of the seven landslides, one occurred within the soil-nailed portion of the slope

Table 4.3 Breakdown of Landslides on Slopes Previously Treated under the LPMP

Scale of Failure (m^3)	Fill Slopes	Cut Slopes			Retaining Walls	Total
		Soil	Soil/Rock	Rock		
> 500 m^3	0	0	0	0	0	0
50 m^3 to 500 m^3	0	0	0	0	0	0
> 5 m^3 to < 50 m^3	0	0	0	0	0	0
≤ 5 m^3	0	3 (3)	3	0	0	6
Total	0	3 (3)	3	0	0	6

Legend:

6 (3) Of the six landslides, three occurred within the soil-nailed portion of the slopes

The remaining three landslides involved failures on unsupported soil or soil/rock cut slopes. One involved a major failure with a volume of 280 m^3 extending to the natural hillside above the slope. The failure was probably structural controlled with the presence of sub-vertical relict joints which provided a potential back-release surface along the backscarp. The old terrace on the hillside above the main scarp might have promoted surface infiltration and contributed to the failure. The other two incidents were of minor scale (volume ≤ 2 m^3) and primarily resulted in rupture/spalling of hard surface covers, probably attributed to tree root actions and bursting of buried watermain.

None of these 14 landslides on engineered slopes resulted in any significant consequence.

4.3.3 Landslides on Non-engineered Slopes

There were 114 failures on non-engineered slopes in 2013, among which five were major and 109 were minor.

The five major landslides, with failure volume ranging from 50 m^3 to 120 m^3, occurred on roadside slopes of CTL Category 2 or 3 and all of them resulted in temporary closure of roads. One of these major failures involved a soil/rock cut slope (Feature No. 6NE-D/C2) at Lam Kam Road, Yuen Long, with a failure volume of about 120 m^3. Details of this incident were documented in Lee & Ting (2014). Stage 3 Study was completed for the slope in 2005. However, the upgrading works were deferred and eventually suspended because of a roadwork project being contemplated by the Highways Department (HyD). In late 2011, HyD requested GEO to consider LPMit action on the slope in view that their project was unlikely to be implemented within the next 3 years. The feature was being scheduled for LPMit action at the time of failure.

Of the 109 minor landslides, 70 of them were relatively small in scale with a failure volume less than 5 m^3. Thirteen incidents resulted in temporary closure of roads, four resulted in temporary closure of pedestrian pavements or minor footpaths and one resulted in permanent evacuation of a squatter structure in Ma Tso Lung. The rest did not have any notable consequence.

There was a minor rockfall incident, where the fallen rock was retained by the rock mesh on the slope (Incident No. 2013/04/1006HY). This incident was not regarded as a failure in accordance with GEO Technical Guidance Note No. 10 (GEO, 2014b) and thereby it has been discarded from the compilation of the annual failure rates presented in Section 4.3.5.

4.3.4 Landslides Occurred in the Vicinity of Registered Squatter Structures

Thirteen landslides occurred on slopes located in the vicinity of registered squatter structures, of which five occurred on registered slopes, five on unregistrable man-made slopes, two on registrable man-made slopes not yet registered at the time of failure, and one on natural hillside. All these landslides were minor, with failure volume ranging from 0.2 m^3 to 15 m^3, and one case involved a distressed masonry wall with a distressed volume of about

20 m^3. Those man-made slopes involved in the landslides were all non-engineered.

The landslide debris reached the squatter structures in three of the 13 failures. Squatter structures were not affected by the debris in the other ten cases (either due to the small scale of failures or the squatter structures located aside the toes or beyond the crests of the landslide scars). In these three cases, one case involved Category 2 Non-development Clearance[1] (NDC) recommendation previously made on the affected squatter structure and one case involved the issuance of Category 1 NDC[2] recommendation on the affected squatter structure (with Category 2 NDC recommendation previously served) following the 2013 incident. No NDC recommendation was made for the remaining case as the affected squatter structure is on a license land.

For the 13 landslides on slopes located in the vicinity of registered squatter structures, NDC inspections were previously conducted by the GEO on the villages concerned, except two cases with the affected squatter structures lying within license land or private lot. Following the NDC inspections, Category 2 NDC recommendations were made on four of the cases.

4.3.5 Annual Failure Rates

The annual failure rates of registered man-made slopes under different categories are presented in Tables 4.4 and 4.5. The annual failure rates have been assessed in terms of:

(a) the number of landslides divided by the total number of slopes under a given category (e.g. slope type),

(b) the surface area of landslides divided by the total surface area of slopes under a given category, and

(c) the number of landslides divided by the total surface area of slopes under a given category.

By relating the failure rate to the surface area of slopes as in (b) above, it would have taken into account that a large slope is more susceptible to having 'defects' than a small slope. It is however noteworthy that the annual failure rates could be influenced by other factors, such as the rainfall characteristics, prevailing slope maintenance condition, etc.

The annual failure rates for all genuine landslides on registered man-made slopes in 2013 correspond to about 0.222% (number of landslides divided by number of registered man-made slopes), 0.0036% (total surface area of landslides divided by total surface area of registered man-made slopes), and about 2.266×10^{-6} (number of landslides divided by total

[1] Category 2 Non-development Clearance (NDC) recommendations are issued to squatter structures that are considered especially vulnerable to landslides due to their close proximity to potentially unstable slopes; the clearance is through advice and persuasion.

[2] Category 1 NDC recommendations are issued to squatter structures that are in 'immediate and obvious' danger; the clearance is compulsory and will be backed up by force if necessary.

Table 4.4 Annual Failure Rates of Registered Man-made Slopes in 2013

Annual Failure Rates		Non-engineered Slopes			Engineered Slopes		
		Fill/Retaining Wall	Soil/Rock Cut	Overall	Fill/Retaining Wall	Soil/Rock Cut	Overall
Slopes Involved in Landslides in 2013	Number of Slopes	13	100	113	1	13	14
	Surface Area of Landslides (m^2)	289	1,363	1,652	40	313	353
Slopes Involved in Major Landslides in 2013	Number of Slopes	1	4	5	0	1	1
	Surface Area of Landslides (m^2)	33	423	457	0	288	288
Slopes Involved in Minor Landslides in 2013	Number of Slopes	12	96	108	1	12	13
	Surface Area of Landslides (m^2)	256	940	1,195	40	25	65
Total Number of Registered Slopes		11,300	18,850	30,150	12,230	14,920	27,150
Total Surface Area of Registered Slopes (m^2)		6,387,400	10,074,700	16,462,100	13,571,970	26,021,430	39,593,400
Annual Failure Rates (All Landslides)	On Slope Number Basis	0.115%	0.531%	0.375%	0.008%	0.087%	0.052%
	On Slope Surface Area Basis	0.005%	0.014%	0.010%	0.0003%	0.0012%	0.0009%
	Number of Landslides Divided by Slope Surface Area (no./m^2)	2.035×10^{-6}	9.926×10^{-6}	6.864×10^{-6}	7.368×10^{-8}	4.996×10^{-7}	3.536×10^{-7}
Annual Failure Rates (Major Landslides)	On Slope Number Basis	0.009%	0.021%	0.017%	0%	0.007%	0.004%
	On Slope Surface Area Basis	0.001%	0.004%	0.003%	0%	0.0011%	0.0007%
	Number of Landslides Divided by Slope Surface Area (no./m^2)	1.566×10^{-7}	3.970×10^{-7}	3.037×10^{-7}	0	3.843×10^{-8}	2.526×10^{-8}

Note: Landslides on registered disturbed terrain features and the incident (see Section 4.3.3) involving fallen rock retained by rock mesh netting have been excluded from this calculation.

Table 4.5 Breakdown of Annual Failure Rates of Registered Man-made Slopes

Categories of Slopes		Failure Rates on Slope Number Basis (i.e. number of landslides divided by total number of slopes)	Failure Rates on Slope Surface Area Basis (i.e. surface area of landslides divided by total surface area of slopes)	Failure Rates in Terms of Number of Landslides Divided by Total Surface Area of Slopes (no./m^2)
Registered Man-made Slopes	All Landslides	0.222%	0.0036%	2.266×10^{-6}
	Major Landslides	0.010%	0.0013%	1.070×10^{-7}
	Minor Landslides	0.211%	0.0022%	2.159×10^{-6}
Engineered Slopes	All Landslides	0.052% (0.126%)	0.0009% (0.0002%)	3.536×10^{-7} (7.633×10^{-7})
	Major Landslides	0.004% (0)	0.0007% (0)	2.526×10^{-8} (0)
	Minor Landslides	0.048% (0.126%)	0.0002% (0.0002%)	3.283×10^{-7} (7.633×10^{-7})
Non-engineered Slopes	All Landslides	0. 375% [7.3/3.0]	0.0100% [11.3/52.7]	6.864×10^{-6} [19.4/9.0]
	Major Landslides	0.017%	0.0028%	3.037×10^{-7}
	Minor Landslides	0.358%	0.0073%	6.561×10^{-6}

Legend:

0.052% (0.126%)	Annual failure rate of engineered slopes (considering all landslides) is 0.052% and that for slopes previously treated under the LPMP or LPMitP is 0.126%
0.375% [7.3/3.0]	Annual failure rate of non-engineered slopes (considering all landslides) is 0.375%, which is about 7.3 times and 3.0 times higher than those of engineered slopes and slopes previously treated under the LPMP or LPMitP respectively

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surface area of registered man-made slopes in m^2) respectively. Further details are summarised in Table 4.5.

Based on the landslide data in 2013 (Table 4.5), the annual failure rates of engineered slopes are lower than that of non-engineered slopes by a factor of about 7 on a slope number basis, and about 11 on a slope surface area basis. In terms of the number of landslides per total slope surface area, the corresponding failure rate of engineered slopes is about 20 times lower than that of non-engineered slopes.

In 2013, six landslides involved slopes treated under the LPMP and none involved slopes upgraded under the LPMitP. The annual failure rates of slopes previously treated under the LPMP or LPMitP correspond to 0.126% (number of landslides divided by number of registered man-made slopes treated under the LPMP or LPMitP), 0.0002% (total surface area of landslides divided by total surface area of registered man-made slopes treated under the LPMP or LPMitP), and about 7.6×10^{-7} (number of landslides divided by total surface area of registered man-made slopes treated under the LPMP or LPMitP in m^2) respectively, as summarised in Table 4.5. The annual failure rate of slopes previously treated under the LPMP or LPMitP is lower than that of non-engineered slopes by a factor ranging from about 3 to 53, comparable to that of other engineered slopes.

GEO's target annual success rates (where success rate = 1 – failure rate) for engineered slopes are 99.8% and 99.5% against major and minor failures respectively, on the basis of the number of landslides per total number of slopes. In 2013, the corresponding annual success rates were 99.99% and 99.95% respectively. Hence, the targets were satisfactorily achieved. The trend of the annual success rates of engineered slopes against major and minor failures for the period from 1997 to 2013 is shown in Table 4.6 and Figure 4.2.

4.4 Landslides on Slopes within Active Construction Site

There were two incidents, both were major in scale, in 2013 occurring within a construction site. These two incidents involved a slope and a retaining wall which were both being formed within the construction site of the Development at Anderson Road (DAR) project at Sau Mau Ping. One involved a washout failure of a fill slope above Lee On Road with a failure volume of 530 m^3 and the other one involved an incident on a reinforced fill retaining wall above Shun On Road with a soil loss of about 1,300 m^3 and a distressed groundmass of approximately 5,500 m^3 (Lee & Ting, 2014). These two incidents resulted in temporary road closures, in particular the one above Shun On Road caused prolonged road closure for 18 days. They occurred in the early hours of the day and were 'near-miss' cases that could have resulted in much more serious consequence.

The two incidents were triggered by the severe rainstorm on 22 May 2013. The adequacy and effectiveness of the temporary site drainage provisions was found to be a major contributory factor to the two incidents. Detailed landslide study (FSWJV, 2013a & 2013b) was conducted on the two incidents. It is noted that overwhelming of drainage provisions during construction of major site formation works in severe rainstorm events can lead to landslides and serious consequences. Due attention should be given to the provision of effective drainage and precautionary measures to discharge the surface and subsurface water

Table 4.6 Annual Success Rates of Engineered Slopes from 1997 to 2013

Year	Annual Success Rates on Slope Number Basis (i.e. number of landslides divided by total number of slopes)	
	Engineered Slopes Processed by the Slope Safety System (Scale of Failure ≥ 50 m^3)	Engineered Slopes Processed by the Slope Safety System (Scale of Failure < 50 m^3)
1997	99.97%	99.89%
1998	99.98%	99.92%
1999	99.97%	99.92%
2000	99.98%	99.91%
2001	99.98%	99.93%
2002	100%	99.95%
2003	99.99%	99.95%
2004	100%	99.97%
2005	99.98%	99.89%
2006	100%	99.95%
2007	100%	99.97%
2008	99.99%	99.89%
2009	100%	99.95%
2010	100%	99.97%
2011	100%	99.97%
2012	100%	99.95%
2013	99.99%	99.95%
Note:	See Figure 4.2 for a plot of annual success rates of engineered slopes against the target annual success rates from 1997 to 2013.	

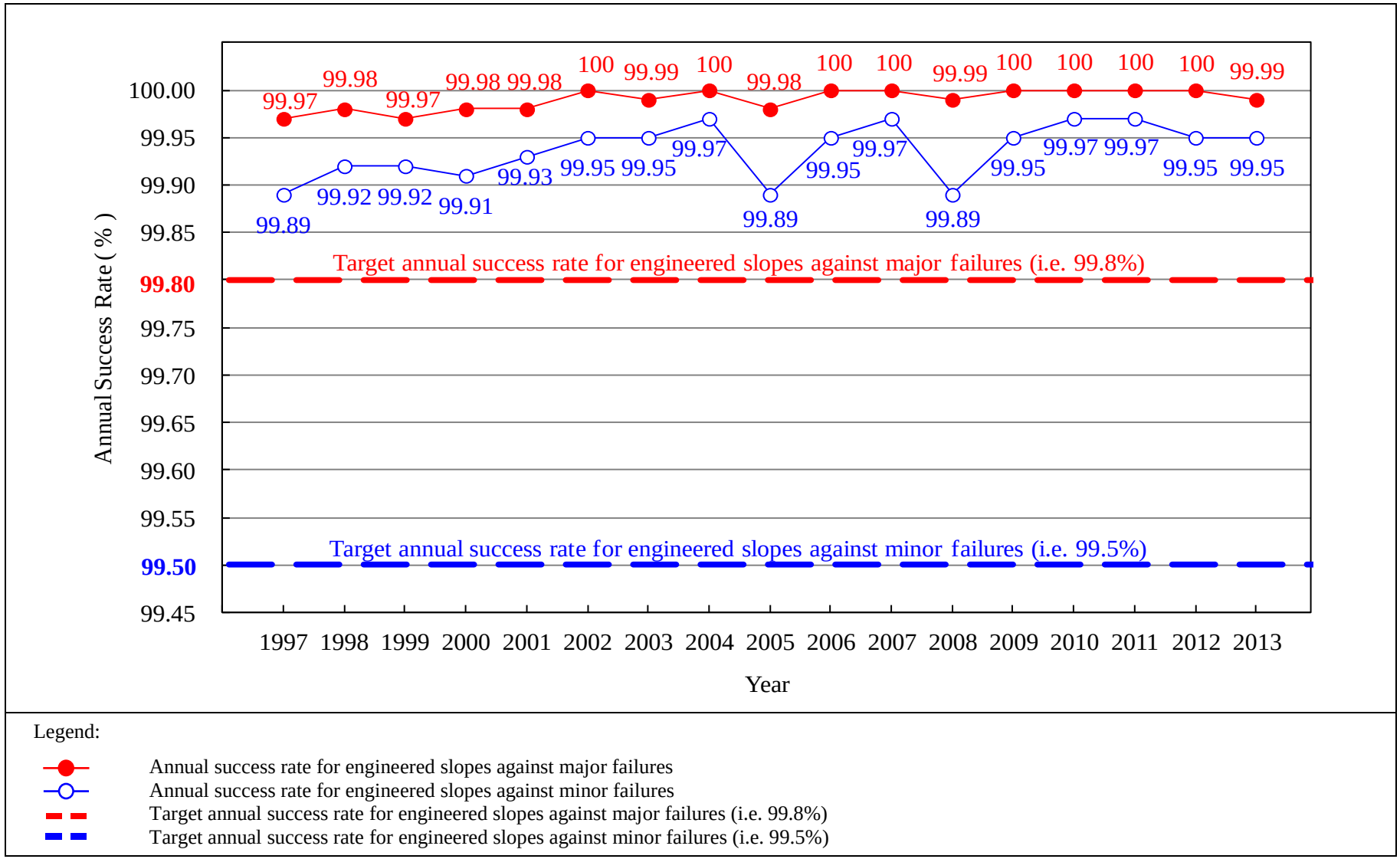

Figure 4.2 Annual Success Rates of Engineered Slopes from 1997 to 2013

properly during construction. Furthermore, the integrity and stability of reinforced fill walls are vulnerable to excessive ingress of water and such walls require special attention in design and construction control.

4.5 Natural Terrain Landslides

A total of 45 natural terrain landslides were reported in 2013, among which 44 failures were minor and one was major. The major incident (Incident No. 2013/05/1301) involved an open hillside failure on the natural hillside above Black Hill Wilson Trail Section 3 (section above Kwong Tin Estate) with a failure volume of about 80 m^3. Debris from the landslide was largely deposited on an open area approximately 10 m above the trail. No closure of the trail was resulted from the landslide.

The 44 minor incidents involved mainly boulder/rock falls (mostly less than 1 m^3 and up to 5 m^3) originating from natural hillside, open hillside failures (up to about 40 m^3) and washout failures (up to about 15 m^3). One of these incidents resulted in temporary closure of road and one resulted in minor damage of cars parked in an open area. In addition, four incidents resulted in temporary closure of minor access/footpaths/walking trails.

Among these 45 reported natural terrain landslides, four failures (comprising three landslides and one boulder fall incidents) were located within existing Historical Landslide Catchments (HLC). These incidents appear to be isolated cases which are not clustered around the previous natural terrain landslides recorded in the Enhanced Natural Terrain Landslide Inventory (ENTLI). Six other failures were located within 50 m from the existing HLC. These ten cases all involved minor failures and the landslide trails were not close to any important facilities, except in one case where the landslide debris was deposited close to village houses.

4.6 Landslides with Inadequate Slope Maintenance Diagnosed as a Key Contributory Factor to Failure

All the 128 landslides on registered man-made slopes were reviewed to assess whether inadequate slope maintenance was likely to have been a key contributory factor to the failures. Reference has been made to the records of emergency inspections by the GEO or other Government departments, inspections or follow-up studies by the LI consultants.

Inadequate slope maintenance such as blockage of surface drainage and inadequate hard surface protection was assessed to be a key contributory factor in 23 landslides, of which one was a major failure. These contributed to about 18% (i.e. 23 out of 128) of the landslides on registered man-made slopes. Amongst these 23 landslides, six occurred on engineered slopes.

Of these 23 landslides involving inadequate slope maintenance, 13 affected Government slopes and two affected private slopes. The remaining eight incidents affected slope features of mixed maintenance responsibility of Government/private, where five occurred on the Government portion and the other three occurred on the private portion of the slopes. All of the relevant maintenance parties have been informed of the incidents and

advised to take appropriate follow-up action. The above diagnosis re-affirms the importance of regular slope maintenance to the performance of slopes. It also serves as a reminder that even an engineered slope is liable to failure given inadequate maintenance.

Slopes are prone to 'washout' failures under short duration and high intensity rainfall if they are not properly maintained, in particular the surface drainage system and surface protection measures. The severe rainstorm on 22 - 23 May 2013 bore such rainfall characteristics where maximum 1-hr rolling rainfall over 150 mm was recorded in some of the raingauges. Of the 241 landslides in 2013, 58 were known to have occurred within the period of this rainstorm. Twenty-five of these 58 landslides affected registered man-made slopes being maintained by the government. Among these 25 landslides, four involved washout failures (all were minor with failure volume up to about 20 m^3). Washout failures accounted for about 16% (i.e. 4 out of 25) of the landslides on government registered man-made slopes under the intense rainstorm on 22 - 23 May 2013. This relatively low percentage of washout failures on government registered man-made slopes (c.f. as high as about 40% in some years) seems to suggest that the maintenance conditions of the majority of these slopes were generally satisfactory.

5 Proposed Improvement Initiative

Based on the present review, the following improvement initiatives are proposed:

(a) develop guidelines to remind practitioners of the need for adequate temporary drainage provisions and precautionary and mitigation measures against severe rainfall during site formation works and construction of reinforced fill structures (Section 4.4), and

(b) review the slope selection process to include monitoring of features that have been shelved from LPMit action and expedite LPMit action for these features should they be 'un-shelved' subsequently (Section 4.3.3).

Improvement initiative proposed by Lee et al (2015) following a review of landslides in 2012 and the associated progress of the follow-up actions are summarised in Appendix C.

6 Conclusions

Overall, 99.95% of the engineered man-made slopes performed satisfactorily without occurrence of landslides in 2013. There was one major landslide on engineered slope, which involved an unsupported cut slope, in 2013.

The annual failure rates of major and minor landslides on engineered slopes, on a slope number basis, are 0.004% and 0.048% respectively in 2013. This corresponds to annual success rates of 99.99% and 99.95% with respect to major and minor landslides, which are above the pledged annual success rates of 99.80% and 99.5% respectively.

Two improvement initiatives have been proposed, as detailed in Section 5 of this report, with a view to further enhancing the slope engineering practice and the slope safety system in Hong Kong.

7 References

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Appendix A

List of 2013 Landslide Incidents Involving Unregistered Man-made Slope Features but Registrable at the Time of Failure

Table A1 List of 2013 Landslide Incidents Involving Unregistered Man-made Slopes but Registrable at the Time of Failure (Sheet 1 of 4)

Incident No.	Location	Maximum Slope Height	Reported		Failure			Facility Affected	Consequence
			Date	By	Date (Time)	Feature Type	Scale (m^3)		
2013/01/1264	Behind House No. 7 Uk Tau, Sai Kung North (Lot 973 in DD289)	4 m	24/1	DLO	24/1 (09:00)	Soil cut	8	Village house	-
2013/04/1272	Fuk Lok Tsuen in Pak Tin near Lamp Post No. VE2028	3.2 m	5/4	Public	5/4	Retaining wall (Masonry)	3	Footpath	-
2013/05/1293	Lee On Road opposite On Yat House of Shun On Estate (within the construction site of the Development at Anderson Road Project)	15 m	22/5	FSD	22/5 (04:00)	Fill (Under construction)	530	Construction site and road	All two lanes of Lee On Road temporarily closed
2013/05/1317	About 400 m from Tso Kung Tam Outdoor Recreation Centre and 15 m from wall No. 6SE-B/R44	4.5 m	22/5	Public	22/5 (10:00)	Soil cut	15	Squatter structure	-

Table A1 List of 2013 Landslide Incidents Involving Unregistered Man-made Slopes but Registrable at the Time of Failure (Sheet 2 of 4)

Incident No.	Location	Maximum Slope Height	Reported		Failure			Facility Affected	Consequence
			Date	By	Date (Time)	Feature Type	Scale (m^3)		
2013/05/1337	No. 53 Leung Fai Tin, Clear Water Bay Road	3.9 m	23/5	Public	22/5	Soil cut	5	Open area	-
2013/05/1344	Near House No. 34, Yim Tin Tsai Village, Sai Kung	3.5 m	23/5	Public	Unknown	Retaining wall (Masonry)	5.5	Squatter structure and footpath	Damage to footpath leading to temporary closure
2013/06/1367	Shun On Road, opposite Tin Wan House of Shun Tin Estate (within the construction site of the Development at Anderson Road Project)	Up to about 30 m high at the time of failure	22/5	FSD	22/5	Reinforced fill wall (Under construction)	1,300 (Soil loss) 5,500 (Distressed ground)	Construction site and road	All two lanes of Shun On Road temporarily closed
2013/06/1372	14 m south of House No. 25 Chan Uk Village, Mang Kung Uk, Sai Kung	5 m	14/6	Public	22/5	Soil cut	4	Open area and footpath	-

Table A1 List of 2013 Landslide Incidents Involving Unregistered Man-made Slopes but Registrable at the Time of Failure (Sheet 3 of 4)

Incident No.	Location	Maximum Slope Height	Reported		Failure			Facility Affected	Consequence
			Date	By	Date (Time)	Feature Type	Scale (m^3)		
2013/06/1378	Peel Rise, Aberdeen (near Aberdeen Chinese Permanent Cemetery)	4 m	16/6	Police	Unknown	Soil cut	6	Access road	Minor access/ footpath partially blocked
2013/06/1386	Along a footpath above Feature No. 7SW-A/C186 in Wo Yi Hop Village, Tsuen Wan	4 m	24/6	Police	24/6	Soil cut	12	Footpath	Footpath temporarily closed
2013/07/1412	Slope to the east of Lamp Post No. V5540, Sai Kung	4.8 m	6/7	Public	18/6 (09:00)	Soil/rock cut	0.5 (Rockfall)	Village house	-
2013/08/1423	Unregistered Slope at 34B Lugard Road (near Lamp Post No. 16724)	3.5 m	2/8	HyD	2/8	Soil cut	1.5	Access road	-

Table A1 List of 2013 Landslide Incidents Involving Unregistered Man-made Slopes but Registrable at the Time of Failure (Sheet 4 of 4)

Incident No.	Location	Maximum Slope Height	Reported		Failure			Facility Affected	Consequence
			Date	By	Date (Time)	Feature Type	Scale (m^3)		
2013/09/1453	About 5 m southwest of Feature No. 6SE-C/C772, Tsing Lung Tau	4.2 m	19/9	GEO	Unknown	Soil cut	1.5	Access road	
2013/11/1465	10 m east of Feature No. 11SE-B/C107, access road to Tseung Kwan O Chinese Permanent Cemetery	4.3 m	6/11	LandsD	Unknown	Soil cut	7	Footpath	-

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Appendix B

Landslide Incidents Involving Slopes Processed under the Slope Safety System

Table B1 Landslide Incidents Involving Slopes Processed under the Slope Safety System (Sheet 1 of 8)

Incident No.	Slope No.	Location	Failure Volume (m^3)	Type of Slope	Remarks
1. Slopes Upgraded Under the LPMP ($\sum$ = 6 nos.)					
2013/03/1270	7SW-C/C353	Above Sam Tung Uk Road and Wo Yi Hop Interchange	0.02 (Rockfall)	Soil/rock cut	The slope was upgraded under the LPMP in 2004 with typical rock slope treatment works to the western rock portion where the rockfall occurred. The rockfall occurred on a local bare rock face with plenty of unplanned vegetation. Surface protection measures on the slope including shotcrete and rock mesh were noted immediately below and to the left of the rockfall location respectively.
2013/03/1005WS (WSD/2013/3/1/ NTW)	6SE-D/C54	Tsuen Wan West Lower Level Fresh Water Service Reservoir	0.3 (Rockfall)	Soil/rock cut	The slope was upgraded under the LPMP in 1993 with the provision of typical rock slope treatment works (viz. scaling, buttressing and rock dowels installation) to the rock portion. No rock mesh was provided on the entire rock surface. The minor rockfall was probably caused by tree root action and/or the build-up of cleft water pressure within the rock joints.

Table B1 Landslide Incidents Involving Slopes Processed under the Slope Safety System (Sheet 2 of 8)

Incident No.	Slope No.	Location	Failure Volume (m^3)	Type of Slope	Remarks
2013/04/1271	11SW-D/C398	Adjacent to No. 8 Shiu Fai Terrace, Wan Chai	0.5	Soil/rock cut	The slope was upgraded under the LPMP in 2008 with prescriptive soil nails installed on the main cut face. The failure occurred on the small steeply inclined (about 70°) un-nailed portion at the eastern end of the slope, probably associated with tree root action. The Stage 3 Study Report deduced that the small portion at which the failure occurred was less weathered. However, no stability assessment or upgrading works proposal could be located for this portion.
2013/05/1353	12NW-C/C264	Abacus Kindergarten, Mang Kung Uk Village, Clear Water Bay Road,Sai Kung	2	Soil cut	The slope was upgraded under the LPMP in 2003 by installation of prescriptive soil nails and provision of erosion control mat and local wire mesh. The incident involved a shallow failure on a steeply inclined slope portion (about 70°) where no wire mesh was installed. Two recessed soil nail heads were exposed on the failure scar.

Table B1 Landslide Incidents Involving Slopes Processed under the Slope Safety System (Sheet 3 of 8)

Incident No.	Slope No.	Location	Failure Volume (m^3)	Type of Slope	Remarks
2013/06/1384	13NE-A/C102	Along South Lantau Road near Shek Pik Reservoir, Lantau	1.5	Soil cut	The slope was upgraded under the LPMP in 2005 with soil nails installed and erosion control mat provided. The slope had experienced two minor failures in 2005 and 2010 since the completion of the upgrading works. The 2013 incident involved a shallow washout failure (on the slope standing at about 52°) next to the 2010 failure scar. The failure might be attributed to the presence of adversely orientated relict joints and the build-up of local transient groundwater pressure above the soil/rock interface or less weathered materials at shallow depth. A recessed soil nail head was exposed on the failure scar.
2013/09/1438	13NE-A/C100	South Lantau Road	3	Soil cut	The slope was upgraded under the LPMP in 2004 with soil nails installed and erosion control mat provided. The slope had experienced a minor failure in 2005 since the completion of the upgrading works. The 2005 failure scar was covered by shotcrete and wire mesh had been provided to the slope parts in its vicinity following the landslide. The 2013 incident involved a shallow washout failure on a steeply inclined slope portion (about 70°) adjacent to the 2005 failure scar. The failure might be attributed to the build-up of local transient groundwater pressure above the soil/rock interface or less weathered materials at shallow depth. The landslide debris was fully trapped by the wire mesh. Two recessed soil nail heads were exposed on the failure scar.

Table B1 Landslide Incidents Involving Slopes Processed under the Slope Safety System (Sheet 4 of 8)

Incident No.	Slope No.	Location	Failure Volume (m^3)	Type of Slope	Remarks
2. <u>Slopes Assessed under the LPMP with No Upgrading Works Required</u> (∑ = 0 no.) Nil.					
3. <u>Slopes Assessed by Studies in the late 1970</u>'s to mid-1980's with No Upgrading Works/Further Study Required (∑ = 1 no.)					
2013/05/1011AD (Arch SD/KT/2013/05/0005)	11NE-D/FR23	Sau Mau Ping Memorial Park	30	Fill	The feature was constructed in 1973 subsequent to the fatal landslide in 1972. Binnie & Partner (HK) Consulting Engineers Ltd. was commissioned by the Geotechnical Control Office to undertake a detailed stability study for the slope in 1979 which concluded that the stability of the existing fill slope and retaining wall was adequate. The failure occurred at the western portion of the slope, probably due to overspillage of surface water from the crest channel where an upstand was constructed following the landslide.
4. <u>Slopes Assessed by Government Departments and Checked by GEO with No Upgrading Works Required</u> (∑ = 0 no.) Nil.					
5. <u>Slopes Assessed by Private Owners and Checked by GEO with No Upgrading Works Required</u> (∑ = 0 no.) Nil.					

Table B1 Landslide Incidents Involving Slopes Processed under the Slope Safety System (Sheet 5 of 8)

Incident No.	Slope No.	Location	Failure Volume (m^3)	Type of Slope	Remarks
6. Slopes Formed or Upgraded by Government Departments and Checked by GEO ($\sum$ = 3 nos.)					
2013/03/1269	12NW-C/CR93	Opposite of Tak Chak House, Hau Tak Estate, Po Ning Road, Tseung Kwan O	0.05 (Rockfall)	Soil/rock cut	The slope was formed under the "Junk Bay Development - Contract No. JB17/84 Hang Hau Area" project and the geotechnical submission in relation to the design of the slope had been checked and accepted by the GEO in 1990. The rockfall involved detachment of a minor rock block from the bare rock cut portion at the lowest batter where no surface protection measures had been provided.
2013/04/1273	11NW-B/C126	Lung Cheung Road, near Lung Cheung Lookout	1	Soil cut	The slope was formed before 1978 and modified under the "Lung Cheung Road and Ching Cheung Road Improvement" project in the 1990s. The slope works design was carried out by the then Advisory Division and checked by the Mainland West Division of GEO in 1995. The slope works mainly comprised cutting back to an overall gradient of 45°. The failure was triggered by the bursting of a 300 mm diameter watermain buried in the slope causing rupture of the shotcrete cover and internal erosion of the soil beneath it.

Table B1 Landslide Incidents Involving Slopes Processed under the Slope Safety System (Sheet 6 of 8)

Incident No.	Slope No.	Location	Failure Volume (m^3)	Type of Slope	Remarks
2013/05/1024WS (WSD/2013/5/5/ HKI)	13NW-B/C173	CH. 0730-0860, Shek Pik Reservoir (Section C)	15 (2 m^3 only for the scar on slope No. 13NW-B/C173)	Soil/rock cut	The incident involved two failure scars. The smaller one occurred on slope No. 13NW-B/C173 which was upgraded by WSD under the Phase 1 Stage 1 "Reconstruction of Catchwater Channels and Upgrading of Adjoining Slopes on Hong Kong Island and Lantau Island" project in 2004. The upgrading works comprised the installation of soil nails and replacement of the existing hard surface by vegetation with erosion control mat and wire mesh. The landslide (failure volume of about 2 m^3) occurred on a slope inclining at about 55°. It severed the erosion control mat while the wire mesh remained intact and retained most of the landslide debris.
7. Slopes Formed or Upgraded by Private Owners and Checked by GEO ($\sum$ = 3 no.)					
2013/05/1290	12NW-C/C529	Behind Nos. 65-68 Hung Uk, Mang Kung Uk	280	Soil cut	The slope was formed by cutting back to an overall gradient of 35° between 1989 and 1993, and the design was checked and accepted by the GEO in 1988 and 1992. The failure extended to the natural hillside above the slope. The failure appeared to be structural controlled. The old terrace on the hillside above the main scarp might have promoted surface infiltration and contributed to the failure.

Table B1 Landslide Incidents Involving Slopes Processed under the Slope Safety System (Sheet 7 of 8)

Incident No.	Slope No.	Location	Failure Volume (m^3)	Type of Slope	Remarks
2013/05/1009AD (ArchSD/S/2013/ 05/0003)	11SE-C/C91	Wong Nai Chung Reservoir Park Fitness Trail	2 (Rockfall)	Soil/rock cut	The feature was modified by cutting back to 50° under the private project "RBL 1051, Tai Tam Reservoir Road - Proposed Residential Development" in 1983/84 as required under the lease conditions of sales and the design of the geotechnical works was subsequently checked by the GEO. The failure occurred on the eastern portion of the slope which was predominately a bare rock cut with no wire mesh protection.
2013/11/1464	11SW-B/C283	Opposite to No. 88 Caroline Hill Road (South China Athletic Association), Causeway Bay	2	Soil/rock cut	The slope was modified during the redevelopment of No. 6 Broadwood Road in 1988 and the works comprised cutting back the slope to an overall gradient of 45° and provision of a chunam cover. The relevant design submission was checked and accepted by the GEO between 1986 and 1988. The failure primarily involved spalling of the chunam cover with limited amount of detached soil. Extensive tree roots growth was noted over and above the failure scar.

Table B1 Landslide Incidents Involving Slopes Processed under the Slope Safety System (Sheet 8 of 8)

Incident No.	Slope No.	Location	Failure Volume (m^3)	Type of Slope	Remarks
8. Slopes Upgraded Following Service of DH Orders and Checked by GEO (∑ = 1 no.)					
2013/05/1324	11SE-C/C555	Mount Butler Road	0.1	Soil cut	The slope was upgraded in 2003 following the DH Order served by the BD in 2001. The upgrading works comprised installation of soil nails to the eastern portion of the slope where the 2014 landslide occurred. The incident involved a minor washout failure of the near-surface materials at the crest of the slope (inclined at about 50°) where no surface protection measures were provided. The failure scar was about 2 m above the top row of soil nails.
9. Slopes Assessed as Not Requiring Upgrading Works But with Outstanding GEO Comments (∑ = 0 no.)					
Nil.					
10. Slopes Assessed as Requiring Upgrading Works But with Outstanding GEO Comments (∑ = 0 no.)					
Nil.					

Legend:

Landslide occurred within the soil-nailed portion of a cut slope (∑ = 5 nos.)

Landslide involved unsupported cut (∑ = 4 nos.)

Notes:
(1) Slopes under Categories 1 to 8 are classified as engineered slopes.
(2) Slopes under Categories 9 and 10 are post-1977 features but are not regarded as engineered slopes for the purpose of this report.

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Appendix C

Progress of Follow-up Actions on the Improvement Measure Recommended in the Review of 2012 Landslides

Table C1 Progress of Follow-up Actions on the Improvement Measure Recommended in the Review of 2012 Landslides

Recommended Improvement Measure	Progress
1. Review of the fixing of rock mesh netting to rock face, in particular for rugged slope surface.	A review of the fixing details of rock mesh netting to rock face, in particular for rugged slope surface was carried out. GEO Technical Guidance Note No. 10 (GEO, 2014) and CEDD Standard Drawing No. C2205E had been updated to highlight the importance of providing adequate number of fixing pins to ensure that the rock mesh netting closely follows the rock slope profile as far as practical, particularly along the edge of the rock mesh netting on rugged rock surface to prevent any potential loose blocks from falling out from the opening between the netting and the rock surface.

GEO PUBLICATIONS AND ORDERING INFORMATION
土力工程處刊物及訂購資料

A selected list of major GEO publications is given in the next page. An up-to-date full list of GEO publications can be found at the CEDD Website http://www.cedd.gov.hk on the Internet under "Publications". Abstracts for the documents can also be found at the same website. Technical Guidance Notes are published on the CEDD Website from time to time to provide updates to GEO publications prior to their next revision.

部份土力工程處的主要刊物目錄刊載於下頁。而詳盡及最新的土力工程處刊物目錄，則登載於土木工程拓展署的互聯網網頁 http://www.cedd.gov.hk 的"刊物"版面之內。刊物的摘要及更新刊物內容的工程技術指引，亦可在這個網址找到。

Copies of GEO publications (except geological maps and other publications which are free of charge) can be purchased either by:

Writing to
Publications Sales Unit,
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Room 626, 6th Floor,
North Point Government Offices,
333 Java Road, North Point, Hong Kong.

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- 致電政府新聞處刊物銷售小組訂購 (電話：(852) 2537 1910)
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23th Floor, North Point Government Offices,
333 Java Road, North Point, Hong Kong.
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Civil Engineering and Development Building,
101 Princess Margaret Road,
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Tel: (852) 2762 5380
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MAJOR GEOTECHNICAL ENGINEERING OFFICE PUBLICATIONS
土力工程處之主要刊物

GEOTECHNICAL MANUALS

Geotechnical Manual for Slopes, 2nd Edition (1984), 302 p. (English Version), (Reprinted, 2011).

斜坡岩土工程手冊(1998)，308頁(1984年英文版的中文譯本)。

Highway Slope Manual (2000), 114 p.

GEOGUIDES

Geoguide 1	Guide to Retaining Wall Design, 2nd Edition (1993), 258 p. (Reprinted, 2007).
Geoguide 2	Guide to Site Investigation (1987), 359 p. (Reprinted, 2000).
Geoguide 3	Guide to Rock and Soil Descriptions (1988), 186 p. (Reprinted, 2000).
Geoguide 4	Guide to Cavern Engineering (1992), 148 p. (Reprinted, 1998).
Geoguide 5	Guide to Slope Maintenance, 3rd Edition (2003), 132 p. (English Version).
岩土指南第五冊	斜坡維修指南，第三版(2003)，120頁(中文版)。
Geoguide 6	Guide to Reinforced Fill Structure and Slope Design (2002), 236 p.
Geoguide 7	Guide to Soil Nail Design and Construction (2008), 97 p.

GEOSPECS

Geospec 1	Model Specification for Prestressed Ground Anchors, 2nd Edition (1989), 164 p. (Reprinted, 1997).
Geospec 3	Model Specification for Soil Testing (2001), 340 p.

GEO PUBLICATIONS

GCO Publication No. 1/90	Review of Design Methods for Excavations (1990), 187 p. (Reprinted, 2002).
GEO Publication No. 1/93	Review of Granular and Geotextile Filters (1993), 141 p.
GEO Publication No. 1/2006	Foundation Design and Construction (2006), 376 p.
GEO Publication No. 1/2007	Engineering Geological Practice in Hong Kong (2007), 278 p.
GEO Publication No. 1/2009	Prescriptive Measures for Man-Made Slopes and Retaining Walls (2009), 76 p.
GEO Publication No. 1/2011	Technical Guidelines on Landscape Treatment for Slopes (2011), 217 p.

GEOLOGICAL PUBLICATIONS

The Quaternary Geology of Hong Kong, by J.A. Fyfe, R. Shaw, S.D.G. Campbell, K.W. Lai & P.A. Kirk (2000), 210 p. plus 6 maps.

The Pre-Quaternary Geology of Hong Kong, by R.J. Sewell, S.D.G. Campbell, C.J.N. Fletcher, K.W. Lai & P.A. Kirk (2000), 181 p. plus 4 maps.

TECHNICAL GUIDANCE NOTES

TGN 1	Technical Guidance Documents