Assessment of Landslide Risk Posed by Man-Made Slopes as of 2010

GEO Report No. 297

P.F.K. Cheng

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

Assessment of Landslide Risk Posed by Man-Made Slopes as of 2010

GEO Report No. 297

P.F.K. Cheng

This report is largely based on GEO Special Project Report No. SPR 1/2011 produced in June 2011

First published, June 2014

Prepared by:

Geotechnical Engineering Office,
Civil Engineering and Development Department,
Civil Engineering and Development Building,
101 Princess Margaret Road,
Homantin, Kowloon,
Hong Kong.

Preface

In keeping with our policy of releasing information which may be of general interest to the geotechnical profession and the public, we make available selected internal reports in a series of publications termed the GEO Report series. The GEO Reports can be downloaded from the website of the Civil Engineering and Development Department (http://www.cedd.gov.hk) on the Internet. Printed copies are also available for some GEO Reports. For printed copies, a charge is made to cover the cost of printing.

The Geotechnical Engineering Office also produces documents specifically for publication in print. These include guidance documents and results of comprehensive reviews. They can also be downloaded from the above website.

The publications and the printed GEO Reports may be obtained from the Government's Information Services Department. Information on how to purchase these documents is given on the second last page of this report.

H.N. Wong
Head, Geotechnical Engineering Office
June 2014

Foreword

This report presents the findings of an updated assessment of the landslide risks posed by man-made slopes registered in the Catalogue of Slopes as of 2010.

The QRA framework adopted in this report follows that given in GEO Report No. 252, with some refinements made on the assumptions. The assessment was carried out by Ms P.F.K. Cheng, with assistance by technical staff, Mr T.H. Lo and Mr A.C.F. Chow of the Standards and Testing Division and Mr K.Y. Wong of the Mainland West Division.

The database controllers of the Landslip Preventive Measures Division 1, Slope Safety Division, Island Division, Mainland East Division and Mainland West Division provided valuable assistance to the collection of the slope data. All contributions are gratefully acknowledged.

K.K.S. Ho
Chief Geotechnical Engineer/Standards & Testing

Abstract

The objective of this Quantitative Risk Assessment (QRA) is to evaluate the risk-to-life of man-made slopes registered in the New Catalogue of Slopes as of 2010. The risks posed by natural hillsides and Disturbed Terrain are excluded from this study.

This study follows the same QRA framework and failure frequency and consequence models used in the previous study as detailed in GEO Report No. 252 (Cheng & Ko, 2010). Some refinements of the assumptions made in the present assessment are highlighted in this report.

The QRA results indicate that by 2010, the landslide risk posed by old man-made slopes has been reduced to below 25% of that which existed in 1977.

Contents

List of Tables

List of Figures

1 Introduction

The Geotechnical Engineering Office (GEO) carried out a Quantitative Risk Assessment (QRA) in 2007 to project the landslide risk level and risk profile of the registered man-made slopes in 2010. The details of the study are documented in GEO Report No. 252 (Cheng & Ko, 2010). The present study comprises an updated evaluation of the landslide risk posed by man-made slopes as of 2010 based on the latest information.

The present study follows the same QRA framework and failure frequency and consequence models used in GEO Report No. 252, with some refinements made on the assumptions (see Section 3).

This QRA study focuses on risk-to-life as expressed in terms of annual Potential Loss of Life (PLL). The landslide risks posed by natural hillsides and Disturbed Terrain are excluded from this study.

2 Sources of Information

The latest updated slope data have been extracted from the following sources:

(a) Slope Information System (SIS);

(b) Landslip Preventive Measures Information System (LPMIS);

(c) Database of the Enhanced Maintenance Programme (EMP);

(d) Dangerous Hillside Orders and Advisory Letters Database System (DADS);

(e) District Works Information System (DWIS);

(f) Database of Feature Status Review (FSR);

(g) Slope Checking Status Information System (SCSIS);

(h) Database of GEO Checking Certificates;

(i) Systematic Identification and Registration of Slopes in the Territory (SIRST) database, which was compiled in the early 1990's; and

(j) List of slopes affecting registered squatter structures[1].

[1] Structures covered by the Housing Department's Squatter Control Survey conducted in 1982.

3 Assumptions

The refinements made to the assumptions of this study, as compared to the previous QRA study in 2007, are highlighted below:

(a) The number of registered man-made slopes under different categories has been updated based on the latest information (i.e. a total of 57,500[2] slopes in 2010 as compared to 56,400 slopes projected in 2007).

(b) Old private slopes formed before 1977 that were subsequently signed-off by LPM safety-screening studies (i.e. Stage 2 studies) are assumed to have the failure frequency of old technology slopes instead of that of robust slopes as previously assumed.

Other assumptions made in the present QRA are as follows:

(a) Slopes assigned with SIFT (Systematic Identification of Features in the Territory) Classes A, B1 or C1 correspond to old slopes[3], except for those that were treated after 1977, which are correspondingly classified either as robust slopes or old technology slopes, depending on the type of works implemented.

(b) The number of old slopes affecting registered squatter structures is based on the estimate given in GEO Report No. 252 and the latest updated slope data.

(c) Those newly formed slopes of SIFT Class B2 or C2 using robust technology, as well as those old slopes treated by robust technology under LPM or development projects, are taken as robust slopes.

(d) The number of old technology slopes is based on the estimate given in GEO Report No. 252 (which is based on the findings of FSR) and the latest updated slope data. The estimated number also includes old private slopes signed-off by safety-screening studies (see above).

(e) Based on the SIS, there are about 57,500 registered man-made slopes in 2010. These slopes are classified into four categories according to (a) to (d) above, as shown in Figure 3.1. Each category is further sub-divided with

[2] Disturbed Terrain (i.e. DT features) and mitigation measures on natural hillsides (i.e. NS and ND features) registered in the Slope Catalogue are excluded.

[3] Pre-1977 slopes without subsequent treatment after the establishment of the GEO are referred to as "old slopes".

respect to their feature type, i.e. soil cut slopes, rock cut slopes, retaining walls and fill slopes, for computation of the respective landslide risk.

(f) The number of government slopes upgraded under the LPM Programme and the number of private slopes subjected to safety-screening studies are obtained from LPMIS.

(g) The number of government and private slopes upgraded under development projects is obtained from GEO Checking Certificate database, DWIS and SCSIS.

(h) The same failure frequency models as adopted in GEO Report No. 252 are assumed.

(i) The failure frequency of an old slope is assumed to be halved after the implementation of Type 1 and/or Type 2 prescriptive measures.

(j) The same consequence models as adopted in GEO Report No. 252 are assumed.

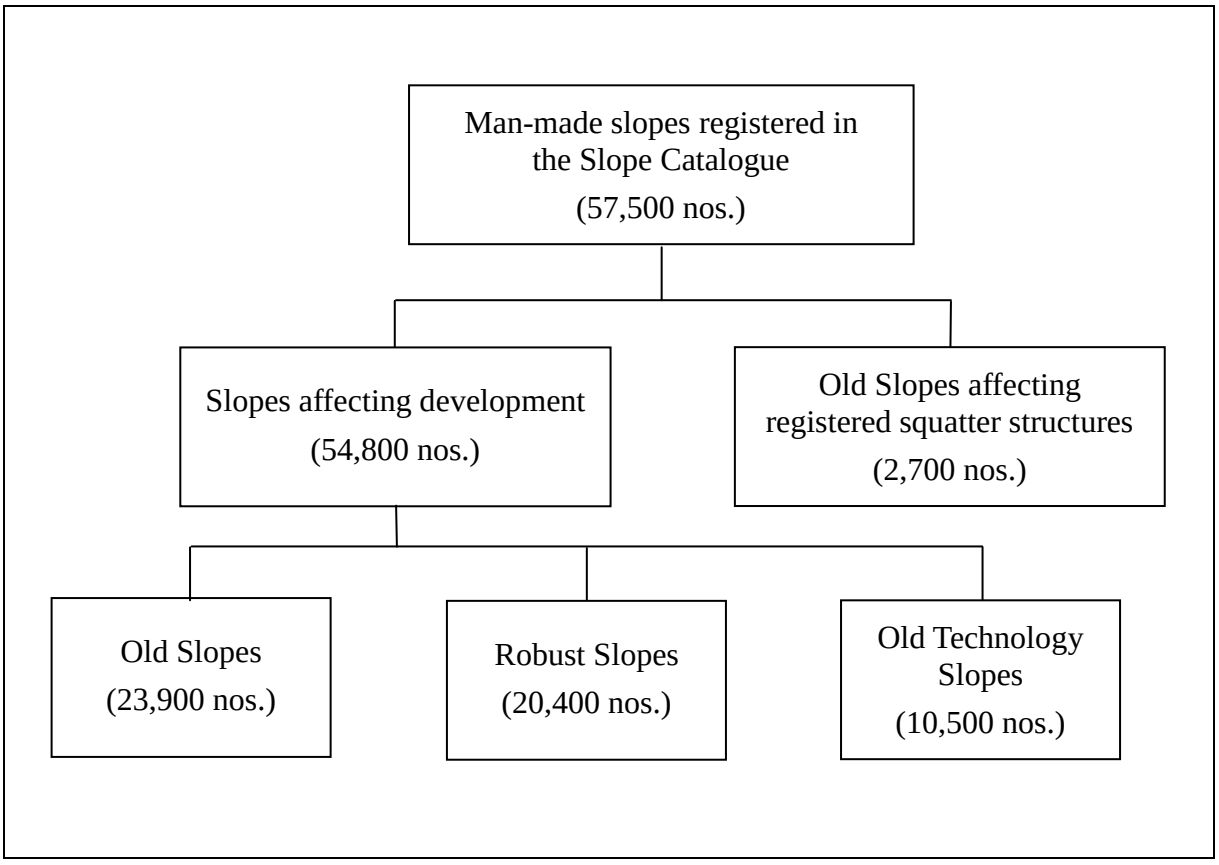

Figure 3.1 Distribution of Registered Man-made Slopes as of 2010

4 Methodology

Details of the QRA methodology are described in Section A4 in GEO Report No. 252.

5 Results

5.1 Landslide Risk in 2010

A breakdown of the registered man-made slopes with respect to the different slope categories as of 2010 is shown in Figure 3.1. The findings of the QRA are summarised below:

(a) The landslide risk attributed to old slopes affecting development is 2.7 PLL/year.

(b) The landslide risk attributed to old slopes affecting registered squatter structures is 0.9 PLL/year.

(c) The landslide risk attributed to robust slopes affecting development is 0.3 PLL/year (0.17 PLL/year of which is associated with newly formed slopes after 1977).

(d) The landslide risk attributed to old technology slopes affecting development is 1.8 PLL/year (0.92 PLL/year of which is associated with newly formed slopes after 1977).

The overall landslide risk attributed to man-made slopes, i.e. summation of (a) to (d) above, is 5.7 PLL/year. The corresponding risk profile risk is shown in Table 5.1.

Table 5.1 Risk Profile of Registered Man-made Slopes as of 2010

Slope Category		Proportion of Total Landslide Risk of Registered Man-made Slopes (%)
Old slopes affecting development	CTL Category 1 and 2	45
	CTL Category 3	2
Old slopes affecting registered squatter structures		16
Robust slopes affecting development[4]		5
Old technology slopes affecting development[4]		32

[4] These figures include the landslide risks attributed by newly formed slopes after 1977 and the residual risks of the treated existing old slopes.

5.2 Landslide Reduction of Old Man-made Slopes Affecting Development

The present risk assessment indicates that by 2010 (i.e. upon completion of the 10-year Extended LPM Project and EMP), the landslide risk arising from old man-made slopes affecting development has been reduced to 2.7 PLL/year. Cheung & Shiu (2002) estimated that the landslide risk posed by old slopes was 15.9 PLL/year in 1977 and Lo & Cheung (2005) estimated that the landslide risk posed by old man-made slopes affecting development was 7.9 PLL/year in 2000. On this basis, the corresponding risk reductions are 50% in 2000 and 83% in 2010 respectively.

5.3 Discussion

The landslide risk level in 1977 as estimated by Cheung & Shiu (2002) was based on the assumption of 34,000 old slopes by reference to all the pre-1977 slopes in the SIFT database (i.e. SIFT Class A, B1 or C1), which was compiled in the early 1990's. This has under-estimated the actual number of old slopes that existed in 1977 due to the following reasons:

(a) The 1977/78 Slope Catalogue only registered those sizeable man-made slopes in the urban areas at that time, i.e. some of the pre-1977 slopes that were subsequently registered have not been accounted for.

(b) Some of the previously registered pre-1977 slopes were subsequently deleted from the Slope Catalogue.

(c) Some of the SIFT Classes B2 and C2 slopes are in fact pre-1977 slopes as of 1977 (i.e. slopes formed prior to 1977 with works carried out between 1977 and around 1992/93 when the SIFT exercise commenced).

The revised estimated number of pre-1977 slopes taking into account (a) to (c) above is 42,200. Adopting similar assumptions with respect to the failure frequency and consequence models taken in 2000, the updated estimate of the landslide risk associated with the 42,200 old slopes that existed in 1977 is 23.1 PLL/year.

When an old, substandard slope is treated after 1977, the corresponding failure frequency would have been reduced (the value of which will depend on whether works corresponding to old technology or robust technology have been implemented), albeit with a residual risk. Taking the residual risks of engineered slopes into account and considering also the risk posed by old man-made slopes to registered squatters, the overall landslide risks in 1977, 2000 and 2010 were 23.1 PLL/year, 11.5 PLL/year (based on Lo & Cheung, 2005) and 5.7 PLL/year respectively. Thus, the corresponding risk reductions from the 1977 baseline are 50% in 2000 and 75% in 2010 respectively.

It should be noted that both the estimated overall risk figures in 2000 and 2010 are on the high side as far as old slopes are concerned, because they have included the landslide risk associated with newly formed slopes. If only the old slopes and the residual risks of treated

old slopes are considered, the overall risk reduction would have exceeded 50% in 2000 and 75% in 2010 respectively. For example, if the risk of newly formed slopes (a total of 1.1 PLL/year for both old technology and robust slopes) is excluded, the overall landslide risk in 2010 becomes 4.6 PLL/year. Hence, the corresponding risk reduction, using the 1977 risk level as the base, is 80%.

6 Conclusions

An updated assessment has been carried out using the latest slope data and assuming the same QRA framework as that adopted in the 2007 study. The results of the updated assessment indicate that the overall landslide risk of man-made slopes in 2010 corresponds to 5.7 PLL/year.

The QRA results indicate that by 2010, the landslide risk posed by old man-made slopes has been reduced to below 25% of that which existed in 1977.

7 References

Cheng, P.F.K. & Ko, F.W.Y. (2010). *An Updated Assessment of Landslide Risk Posed by Man-made Slopes and Natural Hillsides in Hong Kong (GEO Report No. 252)*. Geotechnical Engineering Office, Hong Kong, 46 p.

Cheung, W.M. & Shiu, Y.K. (2002). *Assessment of Global Landslide Risk Posed by Pre-1978 Man-made Slope Features: Risk Reduction from 1977 to 2000 Achieved by the LPM Programme (GEO Report No. 125*). Geotechnical Engineering Office, Hong Kong, 63 p.

Lo, D.O.K. & Cheung, W.M. (2005). *Assessment of Landslide Risk of Man-made Slopes in Hong Kong (GEO Report No. 177)*. Geotechnical Engineering Office, Hong Kong, 84 p.

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,
Information Services Department,
Room 626, 6th Floor,
North Point Government Offices,
333 Java Road, North Point, Hong Kong.

or

- Calling the Publications Sales Section of Information Services Department (ISD) at (852) 2537 1910
- Visiting the online Government Bookstore at http:// www.bookstore.gov.hk
- Downloading the order form from the ISD website at http://www.isd.gov.hk and submitting the order online or by fax to (852) 2523 7195
- Placing order with ISD by e-mail at puborder@isd.gov.hk

讀者可採用以下方法購買土力工程處刊物(地質圖及免費刊物除外):

書面訂購
香港北角渣華道333號
北角政府合署6樓626室
政府新聞處
刊物銷售組

或

- 致電政府新聞處刊物銷售小組訂購 (電話：(852) 2537 1910)
- 進入網上「政府書店」選購，網址為 http://www.bookstore.gov.hk
- 透過政府新聞處的網站 (http://www.isd.gov.hk) 於網上遞交訂購表格，或將表格傳真至刊物銷售小組 (傳真：(852) 2523 7195)
- 以電郵方式訂購 (電郵地址：puborder@isd.gov.hk)

1:100 000, 1:20 000 and 1:5 000 geological maps can be purchased from:

Map Publications Centre/HK,
Survey & Mapping Office, Lands Department,
23th Floor, North Point Government Offices,
333 Java Road, North Point, Hong Kong.
Tel: (852) 2231 3187
Fax: (852) 2116 0774

讀者可於下列地點購買1:100 000、1:20 000及1:5 000地質圖：

香港北角渣華道333號
北角政府合署23樓
地政總署測繪處
電話: (852) 2231 3187
傳真: (852) 2116 0774

Requests for copies of Geological Survey Sheet Reports and other publications which are free of charge should be directed to:

For Geological Survey Sheet Reports which are free of charge:
Chief Geotechnical Engineer/Planning,
(Attn: Hong Kong Geological Survey Section)
Geotechnical Engineering Office,
Civil Engineering and Development Department,
Civil Engineering and Development Building,
101 Princess Margaret Road,
Homantin, Kowloon, Hong Kong.
Tel: (852) 2762 5380
Fax: (852) 2714 0247
E-mail: jsewell@cedd.gov.hk

For other publications which are free of charge:
Chief Geotechnical Engineer/Standards and Testing,
Geotechnical Engineering Office,
Civil Engineering and Development Department,
Civil Engineering and Development Building,
101 Princess Margaret Road,
Homantin, Kowloon, Hong Kong.
Tel: (852) 2762 5346
Fax: (852) 2714 0275
E-mail: florenceko @cedd.gov.hk

如欲索取地質調查報告及其他免費刊物，請致函：

免費地質調查報告:
香港九龍何文田公主道101號
土木工程拓展署大樓
土木工程拓展署
土力工程處
規劃部總土力工程師
(請交:香港地質調查組)
電話: (852) 2762 5380
傳真: (852) 2714 0247
電子郵件: jsewell@cedd.gov.hk

其他免費刊物:
香港九龍何文田公主道101號
土木工程拓展署大樓
土木工程拓展署
土力工程處
標準及測試部總土力工程師
電話: (852) 2762 5346
傳真: (852) 2714 0275
電子郵件: florenceko@cedd.gov.hk

MAJOR GEOTECHNICAL ENGINEERING OFFICE PUBLICATIONS
土力工程處之主要刊物

Table of Contents

GEOTECHNICAL MANUALS

Geotechnical Manual for Slopes, 2nd Edition (1984), 300 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.

Table of Contents

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.

Table of Contents

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

Table of Contents