REVIEW OF LANDSLIDES IN 2002

GEO REPORT No. 172

T.H.H. Hui, T.T.M. Lam & H.W. Sun

GEOTECHNICAL ENGINEERING OFFICE

CIVIL ENGINEERING AND DEVELOPMENT DEPARTMENT

THE GOVERNMENT OF THE HONG KONG SPECIAL ADMINISTRATIVE REGION

REVIEW OF LANDSLIDES IN 2002

GEO REPORT No. 172

T.H.H. Hui, T.T.M. Lam & H.W. Sun

This report was originally produced in October 2003 as GEO Landslide Study Report No. LSR 8/2003

Table of Contents
Table of Contents
Table of Contents
Table of Contents

First published, September 2005

Prepared by:

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

Table of Contents
Table of Contents
Table of Contents

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. These include guidance documents and results of comprehensive reviews. These 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 last page of this report.

R.K.S. Chan
Head, Geotechnical Engineering Office
September 2005

Table of Contents
Table of Contents
Table of Contents
Table of Contents

FOREWORD

This report presents the findings of a detailed diagnosis of landslides that occurred in 2002 and were reported to the Geotechnical Engineering Office (GEO) of the Civil Engineering Department. It serves to review the performance of the Government's slope safety system and identify areas for improvement to enhance slope engineering practice in Hong Kong.

The review was carried out by Mr T.H.H. Hui, Mr T.T.M. Lam and Dr H.W. Sun of the Landslip Investigation Division under the supervision of Mr K.K.S. Ho. Assistance was provided by GEO's landslide investigation consultants, Halcrow China Limited and Maunsell Geotechnical Services Limited.

R.K.S. Chan
Head, Geotechnical Engineering Office

Table of Contents
Table of Contents
Table of Contents
Table of Contents

ABSTRACT

This report presents the findings of a detailed diagnostic review of landslides in 2002 that were reported to the Geotechnical Enineering Office (GEO) of the Civil Engineering Department. The diagnosis forms part of GEO's systematic landslide investigation programme which was introduced following the 23 July 1994 Kwun Lung Lau landslide. The aims of this report are to review the performance of the Government's slope safety system and identify areas for improvement to enhance slope engineering practice.

Altogether 138 genuine landslides were reported to Government in 2002. All the available landslide data were examined and 18 landslide incidents were selected for follow-up study under the landslide investigation programme. These studies provided information and insight into the types and mechanisms of landslides and facilitated the identification of areas deserving attention and improvement.

Based on the landslide data in 2002, there were no sizeable landslides (i.e. failure volume of $\geq 50\ m^3$) on engineered man-made slopes that had been accepted under the slope safety system. The annual failure rate of small-scale landslides (i.e. failure volume of $< 50\ m^3$) on engineered man-made slopes was 0.05% on a slope number basis (i.e. the number of landslides relative to the total number of slopes of this status).

Overall, about 99.95% of the engineered man-made slopes performed satisfactorily without occurrence of any reported landslides in 2002 and none of them had any sizeable landslides.

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

Table of Contents
Table of Contents
Table of Contents
Table of Contents

CONTENTS

Table of Contents
Table of Contents
Table of Contents

1. INTRODUCTION

This report presents the findings of a detailed diagnostic review of landslides in 2002 that were reported to the Geotechnical Engineering Office (GEO) of the Civil Engineering Department. The diagnostic review forms part of the GEO's systematic landslide investigation (LI) programme which was introduced following the 23 July 1994 Kwun Lung Lau landslide. The LI programme has two principal objectives, as follows:

(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 improvement to current slope engineering practice.

Individual landslides were selected for in-depth studies to identify lessons learnt and the necessary follow-up actions. The findings of the studies are presented in a series of Landslide Study Reports. The present diagnostic review examines all the available landslide data, together with the findings of the individual landslide studies, in order to assess the performance of the Government's slope safety system and identify areas deserving attention and improvement. The diagnostic review has been carried out by the Landslip Investigation Division of the GEO, with assistance provided by the GEO's LI consultants, Halcrow China Limited and Maunsell Geotechnical Services Limited.

Based on the review, improvement measures are proposed to further enhance the slope safety system and slope engineering practice in Hong Kong.

2. STUDIES OF INDIVIDUAL LANDSLIDES

The factual information and the relevant statistics on rainfall and reported landslides in 2002 were documented by Hui & Lam (2003). The annual rainfall recorded at the Hong Kong Observatory (HKO)'s principal raingauge at Tsim Sha Tsui was 2,490 mm, which is about 12% higher than the mean rainfall of 2,214 mm recorded between 1961 and 1990. Three Landslip Warnings were issued between 10 August 2002 and 17 September 2002.

Altogether 138 genuine landslides (discounting non-landslide incidents such as tree falls and very minor washouts) were identified to have occurred in 2002 out of a total of 167 reported incidents. The total number of sizeable failures (i.e. failure volume of $\geq 50\ m^3$) was nine, which amounts to about 6.5% of the number of genuine landslides.

The range of different facilities affected by the landslides is summarised in Table 1. The consequences of the landslides, which have been classified in accordance with the type of failure, are summarised in Table 2. Table 3 shows the distribution of the different facility groups that were affected by sizeable landslides. The distribution of landslides as classified by the type of failure is given in Table 4.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

The information on all the reported landslides has been uploaded to the computerised Slope Information System (SIS) of the GEO, which is accessible by the general public through computer terminals in the GEO. All the data on the reported landslides were examined and additional information was collated by the LI consultants to assist in the selection of incidents that warrant follow-up study. Altogether 18 landslide incidents in 2002 were selected for follow-up study.

The individual landslide studies provided valuable information and insight into the types and mechanisms of landslides, together with the necessary follow-up actions. The findings of the landslide studies have been documented and the reports are lodged in the Civil Engineering Library. The summary findings of the investigations of significant landslides are presented in the Hong Kong Slope Safety Website (http://hkss.cedd.gov.hk/hkss/eng/studies/lic/index.htm). Following each of the landslide studies, the key lessons learnt are identified and recommendations made on the necessary site-specific or more general follow-up actions.

Selected notable landslide incidents in 2002 are described in the factual report on rainfall and landslides by Hui & Lam (2003).

3. OVERALL DIAGNOSTIC REVIEW OF LANDSLIDES

3.1 Scope of the Review

The overall review of all the landslide data in 2002 provided a global picture of the performance of the different types of slopes in Hong Kong. This has greatly facilitated a diagnosis of the specific areas deserving attention.

The review has focused on the following aspects:

(a) coverage of the New Catalogue of Slopes,

(b) annual failure rates of different types of registered slopes, and

(c) diagnosis of landslides on slopes with geotechnical engineering input and submissions that have been accepted under the slope safety system (hereinafter referred to as engineered slopes).

Where appropriate, the review has also taken cognizance of selected categories of landslide problems whereby the collective information over the past few years has highlighted the need for attention.

3.2 Coverage of the New Catalogue of Slopes

3.2.1 General

Sizeable man-made slopes and retaining walls, including those compiled under the

Table of Contents
Table of Contents
Table of Contents
Table of Contents

project entitled 'Systematic Identification and Registration of Slopes in the Territory' (SIRST) which was completed in September 1998, together with features newly formed or identified after 1998, are registered in the New Catalogue of Slopes. The methodology of the identification of potentially registerable features under the SIRST project (which was done primarily using Aerial Photograph Interpretation (API) and existing topographic plans) and the criteria for registration of man-made slope features in the New Catalogue of Slopes are given in GEO Circular No. 15.

3.2.2 Diagnosis

A total of 56 out of the 138 genuine landslides occurred on slope features that were unregistered at the time of failure. A breakdown of these 56 incidents is given in Figure 1.

Of the 56 incidents, 21 landslide incidents (i.e. about 38%) involved small man-made slope features which do not satisfy the slope registration criteria and 29 landslide incidents (i.e. about 52 %) occurred on natural hillsides that are not registered in the New Catalogue of Slopes because they are not man-made slope features. One of the landslide incidents involved a cut slope where slope works were in progress at the time of failure and hence it was not yet ready for registration.

The remaining five landslide incidents (i.e. 56 - 21 - 29 - 1) involved slope features that satisfy the registration criteria but were not registered in the New Catalogue of Slopes at the time of slope failure. Of these five failures, three involved slopes which were being registered but the process was not yet completed when the failures occurred.

3.2.3 Discussion

The above diagnosis indicates that the number of registerable slopes that were yet to be included in the New Catalogue of Slopes at the time of landslide was about 1.5% of the number of genuine landslides in 2002. None of the two incidents involved a sizeable failure or any notable consequences, such as building evacuation or road closure.

All the two slope features of concern were marginally registerable (maximum slope height about 4 m) and were duly registered in the New Catalogue of Slopes following the landslides. Similar features are identified during the systematic follow-up inspections of reported landslide incidents by the GEO for registration.

3.3 Annual Failure Rates of Registered Slopes

3.3.1 General

Based on the landslide data and a review of slope status, the average failure rate of registered slopes can be assessed in terms of the different types of slopes of different ages, i.e. pre-1978 (viz. formed or substantially modified before 1978), or post-1978 (viz. formed or substantially modified after 1978).

The status of a slope can be distinguished in terms of whether or not it has been

Table of Contents
Table of Contents
Table of Contents
Table of Contents

engineered in the past. Engineered slopes include the following:

(a) slopes formed after 1978 that were designed, checked and accepted under the slope safety system as being up to the required geotechnical standards,

(b) slopes formed before 1978 that were subsequently assessed, checked and accepted under the slope safety system as being up to the required geotechnical standards,

(c) slopes formed before 1978 that were subsequently upgraded, checked and accepted under the slope safety system as being up to the required geotechnical standards, and

(d) slopes with Type 3 prescriptive measures under a quality assurance system that satisfies the requirements of WBTC No. 11/2000 (whereby checking of the design of Type 3 prescriptive measures by GEO is waived).

The types of slope features considered in the present diagnosis are soil cuts, rock cuts, fill slopes and retaining walls.

For the purpose of the present diagnostic review, the classification of the scale of failure is as follows:

(a) minor failure (i.e. failure volume of $< 50\ m^3$),

(b) major failure (i.e. failure volume between $50\ m^3$ and $500\ m^3$), and

(c) massive failure (i.e. failure volume of $> 500\ m^3$).

Failure volume refers to the total volume of detached material plus the volume of any deformed material that remains on the slope (which may or may not have displaced significantly).

The distribution of the failure volume of the genuine landslides is summarised in Table 5.

3.3.2 <u>Diagnosis</u>

Of the 138 genuine landslides reported in 2002, a total of 82 landslide incidents (about 59%) affected 79 registered slopes (i.e. three of the slopes had multiple landslide incidents). Of these 82 landslide incidents, eight (about 10%) were sizeable failures.

Approximate estimates of the number of engineered and non-engineered slope features have been made by reference to the classification assigned under the 'Systematic Identification of Features in the Territory' (SIFT) project. Thus, features with SIFT

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Classes A, B1 and C1 correspond to pre-1978 slopes, whereas features with SIFT Classes B2 and C2 correspond to post-1978 slopes. Notionally, pre-1978 slopes are assumed to be non-engineered slopes and post-1978 slopes are assumed to be engineered slopes for the present purposes, except for those pre-1978 slopes that are known to have been subsequently upgraded or checked to the required geotechnical standards, which are taken to correspond to engineered slopes.

The estimates of the number of engineered and non-engineered slopes based on reference to SIFT data are subject to some uncertainty as the SIFT class of a slope is assessed primarily using aerial photograph interpretation. Further information on the scope and limitations of the SIFT project is given by Wong & Ho (1999).

Ten of the 138 genuine landslides (about 7.3%) affected engineered slopes, none of which was sizeable failure.

Based on the 2002 landslide data and a detailed review of the status of the slopes involved in the landslides, the annual failure rates of the different types of registered slopes have been calculated (see Table 6). These calculated failure rates are not particularly sensitive to the assumptions made about the total numbers of different types of slopes given the likely order of uncertainty involved. It should be noted that the calculated failure rates do not necessarily correspond to long-term average values because of the limited observation period. Notwithstanding this, these annual failure rates derived from a systematic review of all the landslide data will provide useful insight into the performance of the slope safety system.

3.3.3 Discussion

The failure rates of engineered and non-engineered slopes may be calculated using three approaches. The first approach involves assessing the landslide rate on a slope number basis, i.e. the failure frequency is taken to correspond to the number of landslides divided by the total number of slopes of a certain status. This is relevant in relating the failure frequency of different categories of slopes and performance of the slope safety system to the slope population in the Slope Catalogue. The second approach involves assessing the landslide frequency on a unit slope surface area basis, i.e. the failure rate is taken to correspond to the area of landslides divided by the total surface area of slopes of a certain status. The third approach involves assessing the landslide frequency corresponding to the number of landslides divided by the slope surface area. The second and third approaches take into account the differing surface areas of different slopes in assessing the failure frequency which would be a more refined and rational way to assess the relative risks of the different categories of slopes.

In terms of number of registered slopes, the ratio of the number of non-engineered slopes to the number of engineered slopes is about 1.8. However, in terms of slope surface area (computed using the SIS data by means of Geographic Information System (GIS) tools) the total surface area of engineered slopes is about 1.6 times the total surface area of non-engineered slopes (Table 6).

As there is a marked difference in the surface areas of slopes of different status, it would be instructive to also relate the failure frequency to the slope surface area.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Based on the reported landslides on registered slopes in 2002 (excluding Disturbed Terrain features), the annual failure rates for all reported landslides correspond to 0.15%, 3.22 x 10^{-3} % and 1.41 x 10^{-6} (no./m²) using the three different approaches as described above. Comparisons of the annual failure rates of engineered slopes with non-engineered slopes are given in Section 3.4 below. It should be noted that the calculated failure rates for the different types of registered slopes could be affected by the actual rainfall characteristics, including the spatial distribution, intensity and duration of rainfall, together with the maintenance condition of slopes and the performance of any slope upgrading works.

3.4 Diagnosis of Landslides on Engineered Slopes

3.4.1 General

A review of the 2002 landslides indicates that some of the incidents involved failure of engineered slopes. A meaningful diagnosis of landslides on engineered slopes requires detailed information about the nature and probable causes of the failures, together with the status and development history of the slopes concerned. The present assessment is based on the detailed information obtained from the follow-up landslide studies.

Landslides occurred on ten engineered slopes in 2002 (two of which were upgraded in the 1980's, six in the 1990's and two since 2000, see Table 7). For the present purposes, slope features that did not get through the slope safety system (e.g. no geotechnical submissions made to the GEO for checking or submissions with outstanding GEO comments) are not considered to be engineered slopes. In 2002, none of the landslides involved slope features with outstanding GEO comments on the geotechnical submissions or slope features without evidence of a geotechnical submission being made to GEO for checking where this was required.

Engineered slopes with geotechnical submissions accepted under the slope safety system are classified in accordance with the following (see Table 8):

(a) whether the slope was formed after 1978 or whether it was an existing feature previously subjected to upgrading works or demonstrated by stability assessment as being up to the required geotechnical standards,

(b) the mechanism under which stability assessments or slope upgrading works were carried out (e.g. LPM Programme, private or Government development projects, works by private owners or default works by Government following the serving of DH Orders),

(c) whether detailed geotechnical design calculations were carried out,

(d) whether site-specific ground investigation and laboratory testing were carried out,

(e) whether the stability assessment or the design of slope upgrading works was accepted by the GEO or whether there

Table of Contents
Table of Contents
Table of Contents
Table of Contents

were any outstanding GEO comments on the submissions that were not satisfactorily resolved by the concerned party, and

(f) whether the slope was upgraded to meet current standards using prescriptive measures under an adequate quality system satisfying the requirements of WBTC No. 11/2000 with checking of the design of upgrading works by the GEO being waived.

A summary of the pertinent findings of the follow-up landslide studies is given in Table 9.

3.4.2 Diagnosis

The breakdown of the ten engineered slopes with respect to the type of slope and the scale of failure is shown in Table 10. It can be seen that all these cases involved minor failures.

The annual failure rates for the 2002 landslide data on a slope number basis, unit area basis and the number of landslides per slope surface area basis respectively are summarised in Table 11 for the different categories of slopes.

On a slope number basis, the likelihood of failure of engineered slopes is about four times less than that of non-engineered slopes while on a unit area basis, the likelihood of failure of engineered slopes is about 50 times less than that of non-engineered slopes. In terms of the number of landslides divided by the slope surface area, the likelihood of failure of engineered slopes is about ten times less than that of non-engineered slopes.

Caution needs to be exercised because the numbers being compared are fairly small and as a result they may not be statistically significant. The diagnosis should therefore be taken as indicative only.

The target annual success rates (where 'success rate' = 1 - 'failure rate') for engineered slopes pledged by the GEO are 99.8% and 99.5% for sizeable failures and minor failures respectively, as defined in terms of slope number. In 2002, the actual annual success rates were 100% and 99.95%. The pledged targets were therefore achieved.

Of the ten engineered slopes with failures in 2002, one was previously included in the LPM Programme (see Table 12). For 2002, the annual failure rates for slopes that were dealt with under the LPM Programme are summarised in Table 13.

One of the pledged targets under the GEO Strategic Plan for Slope Safety (1997-2002) was to "Reduce the defect rate for slopes upgraded under LPM Programme over the 5-year period 1998-2002 to 50% of the slopes upgraded under LPM Programme before 1998" (GEO, 1997). A review of records of landslides between 1984 and 2002 was carried out. Based on the review, the average annual failure rate (on a slope number basis) of LPM slopes upgraded before 1998 was 0.36% for all landslides whereas the corresponding figure for LPM

Table of Contents
Table of Contents
Table of Contents
Table of Contents

slopes upgraded between 1998 and 2002 was 0.18%. The average annual failure rate (on a slope number basis) for sizeable landslides on LPM slopes upgraded before 1998 was 0.05% whereas the corresponding figure for sizeable landslides on LPM slopes upgraded between 1998 and 2002 was zero. If the annual failure frequency is expressed in terms of number of landslides relative to the slope surface area, the reduction in annual 'defect rate' would be more than 50%.

The above assessment confirms that the target of 50% reduction in annual 'defect rate' for LPM slopes pledged under the GEO Strategic Plan for Slope Safety (1997-2002) has been achieved by 2002.

3.5 Technical Assessment

3.5.1 Severity of Rainstorms that Triggered Landslides

Of the ten failures that affected engineered slopes, six were triggered by rainfall where there was sufficiently reliable information to assess the timing and severity of the rainstorms preceding the landslides (Table 9). Five of the six incidents involved rainstorms which were less severe than those experienced in the past based on data from automatic raingauges installed in the mid-1980's.

The possibility of 'fatigue' of saprolitic soils that could potentially be caused by cycles of pore pressure changes has been examined. This possibility was examined during the investigation of the 1982 Ching Cheung Road landslide (Hencher, 1983) but the limited laboratory tests carried out at that time did not lend support to this postulation. An investigation into the possible effects of cyclic pore water pressure changes on the shear strength of granitic soils was carried out recently at the Hong Kong University of Science & Technology. It was found that the cumulative axial strain, volumetric strain and shear strain was very small (< 0.5%) upon application of cyclic pore water pressure changes and that there was no noticeable corresponding drop in shear strength.

For the above five 'surprise' failures with respect to the severity of rainstorms in 2002, progressive deterioration of the slope condition probably played a key role in those cases where contribution from inadequate slope maintenance was judged to be significant and where there were no obvious changes in environmental factors. Slope deterioration could take the form of intermittent slope deformation caused by previous successive severe rainstorms resulting in progressive opening up of the ground. It is conceivable that gradual deterioration of the slope condition could also take place without obvious deformation, e.g. changes in near-surface hydrogeology related to evolution of erosion pipes, washout or redistribution of joint infill, etc. As a result, subsequent failures could occur during or soon after rainstorms that are not particularly severe.

3.5.2 Landslides on Engineered Slopes

Minor landslides occurred on ten engineered slopes, which comprised two soil cuts, seven rock cuts and one recompacted fill slope. Maintenance responsibility for eight of these slopes belonged to the Government with the other two were of the responsibility of the private owners.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Two vegetated soil cut slopes of concern had soil nails installed over most of the slope surfaces. In one of the cases, the failed portion (2 m^3) was not nailed. In the other case, the failure (2 m^3) occurred between the nail heads where locally the as-constructed horizontal spacing of the soil nails was 3.8 m as opposed to the design spacing of 2.5 m. The design submissions for both of these cases were accepted under the slope safety system in the late 1990's. Neither of the two failures involved inadequate slope maintenance as a contributory factor to failure. The two incidents highlighted the importance of input by the designer (or Category 1 qualified supervision personnel where appropriate) to review the adequacy of the design during construction, and the importance of site control by the site supervisors (including Category 3 qualified supervision personnel where appropriate).

Of the seven rockfall incidents, two occurred on rock cuts that were accepted under the slope safety system in the early 1980's, one in the late 1980's and the other four in the 1990's. A combination of local adverse jointing and groundwater regimes, together with progressive deterioration since completion of slope upgrading works played a key role in most of the incidents. In some cases, inadequate attention to undesirable vegetation was also a key contributory factor. The rockfall in one of the cases occurred only about one and a half years after completion of extensive rock stabilisation works which comprised buttresses, rock dowels, rock bolts and shotcreting of local areas. In this instance, the source area of the rockfall was assessed by the Category 1 qualified supervision personnel (with support provided by an engineering geologist) as being adequately stable without the need for any support measures or protective meshing. Since the end of 2002, two GEO Technical Guidance Notes (GEO, 2002 & 2003) as well as a Special Project Report (Yu et al, 2003) have been published by the GEO to provide further guidance on investigation, design, construction and maintenance of and application of prescriptive measures to rock cut slopes.

The failure (30 m^3) on the recompacted fill slope (private maintenance responsibility) involved surface erosion due to concentrated surface water flow as a result of overflow from blocked surface drainage facilities (catchpit and U-channel) during heavy rainfall. The slope was accepted under the slope safety system in the early 1990's and there was no history of failure prior to the 2002 incident. Lack of maintenance was a primary contributory factor in this failure.

3.5.3 Landslides on Natural Hillsides and Disturbed Terrain

A total of 29 hillside failures was reported in 2002, none of which involved sizeable failures.

Of these 29 cases, 21 (i.e. 72%) were classified as natural hillside failures, i.e. the failure affected natural hillsides which had not been modified by man-made activities such as cutting, filling, cultivation, etc. The other eight failures involved hillsides locally modified or disturbed by man-made activities which did not play a significant contributory role in the failure.

None of the reported landslides in 2002 affected registered Disturbed Terrain (DT) features.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

3.5.4 Landslides with Poor Maintenance Diagnosed As a Key Contributory Factor to the Failure

All the 82 reported landslide incidents involving registered man-made slope features were reviewed to assess whether poor maintenance was likely to have been a major contributory factor in the failure. Reference has been made to the records of emergency inspections by the GEO or other Government departments, inspections of selected landslides by the LI consultants, together with findings of the follow-up landslide studies as appropriate. Poor slope maintenance was assessed as a major contributory factor in 17 of the 82 incidents (i.e. 21%).

Of these 17 incidents, ten affected Government slopes (three of which were engineered features) and seven affected private slopes (two of which were engineered features). The landslide frequency involving failures with poor maintenance as a key contributory factor is lower for Government slopes compared with that for private slopes (with a ratio of about 0.6). However, caution needs to be exercised because the numbers involved are relatively small and they may not be statistically significant. The above diagnosis should therefore be taken as indicative only.

3.5.5 Normalisation of Annual Failure Rate of Slopes to Account for Different Rainfall Characteristics

If the records of the principal raingauge in Tsim Sha Tsui are considered alone, the annual rainfall in 2002 represented a wetter-than-average year (Section 2). Given the hilly terrain of Hong Kong, there is a significant spatial variability of rainfall. The total number of landslides will be a function of, inter alia, the actual spatial rainfall characteristics, including spatial distribution, intensity and duration of rainfall, together with the geographical distribution of rainfall in relation to the disposition of slopes and retaining walls that are susceptible to landsliding. The total number of genuine landslides and the annual rainfall recorded by the principal raingauge at Tsim Sha Tsui for the period 1997 to 2002 are shown in Table 15. It can be seen from Table 15 that there is no direct correlation between these two parameters, as one would expect. Thus, the relatively small number of landslides (i.e. 138) that actually occurred in 2002, which was an apparently wetter-than-average year based on reference to the Tsim Sha Tsui raingauge alone, does not provide a good reflection of the scale of the landsliding problem in Hong Kong per se. In view of this, it is important to have a relevant index that represent the relative severity of rainfall in terms of the potential to cause landslides so that the actual number of landslides that occurred can be viewed in context.

GEO has been examining the possible use of a number of landslide potential indices (viz. 'Overall Index', 'Intensity Index' and 'Location Index') that could reflect the severity of rainstorms with respect to their potential to cause landslides. Details of the proposed indices are given in the report by Evans et al (2002). In principle, the 'Overall Index' may serve as a useful normalising parameter for the failure rates of slopes of different status as this would incorporate the effects of the variables associated with rainfall and better reflect the performance of the slopes on a more rational basis. The definition of 'Overall Index', which is related to the severity of a given rainstorm with respect to the potential to cause landslides, is as follows:

Table of Contents
Table of Contents
Table of Contents
Table of Contents

$$\text{Overall Index} = \frac{\text{Number of potential landslides in a rainstorm}}{\text{Number of potential landslides triggered by the Probable Maximum Precipitation (PMP)}}$$

Calculations showed that the 'Overall Index' for major rainstorms in 2002 is relatively low compared to that of the past few years. This indicates that the rainstorms in 2002 were not particularly severe in terms of their potential in triggering landslides. This is probably one of the principal reasons for the fairly small number of reported landslides compared with that of previous years (Table 15) despite a higher-than-average total rainfall recorded by the principal raingauge at Tsim Sha Tsui.

The Special Projects Division of the GEO has completed the evaluation of the various rainfall indices for the years starting from 1997 using the newly refined rainfall-landslide correlation model. Given this information, the normalised failure rates for different years may be worked out, which will cater for the variations in the severity of rainfalls in terms of their potential in triggering landslides.

There is merit in examining the feasibility of using the trend of annual failure rates normalised by a suitable rainfall index to serve as an indicator of the relative performance of the slope safety system.

3.5.6 Landslides Affecting Squatters

Five of the minor landslide incidents in 2002 affected registered squatter structures (i.e. included in the 1982 Housing Department (HD) Squatter Structure Survey with a squatter control survey number assigned by HD). Three of the cases involved the failure of 2 m to 2.5 m high cuts that do not satisfy the slope registration criteria (i.e. the height of the cut was less than 3 m). One of these three incidents resulted in GEO's recommendation for permanent evacuation of the squatter structure whilst another resulted in the recommendation for temporary evacuation of the affected squatter structure.

Of the remaining two of the five landslide incidents which affected registered squatter structures, one involved a natural hillside failure and one involved the failure of a registered cut slope feature (6.8 m high). The latter resulted in GEO's recommendation for temporary evacuation of the affected squatter structure.

Three of the cases involving squatter structures (which were all flimsy structures) affected by landslides in 2002 were inspected previously by the GEO under the Non-Development Clearance (NDC) Programme in the 1990's. None of the squatter structures was previously recommended for clearance under the NDC Programme.

Landslides in 2002 involved failures of a registered slope, natural hillside as well as non-registerable slopes affecting squatter structures but the consequences were not particularly serious for the year. In the past few years, there has been a number of significant landslides that affected squatter structures with serious consequences and 'near-miss' incidents with casualties narrowly avoided. It is noted that many of the squatters that were recommended for clearance under the NDC Programme opted to stay put, especially in the past several years. As a result, some squatters are subject to high landslide risk.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

There is merit in carrying out a review of the recent landslide incidents affecting squatter structures to gain some insight into the potential problems involved with the implementation of the present squatter policy in terms of landslide risk reduction so as to identify the possible way forward.

3.5.7 Guidance on Calculation of CNPCS Scores

One of the notable 2002 landslide incidents (viz. the 15 September 2002 landslide at Ngau Pei Sha New Village) highlighted, in practice, some possible problems in the proper calculation of CNPCS scores. This incident involved a registered retaining wall feature (R feature) above a separately registered cut/retaining wall feature (CR feature). The consultant under the SIRST project assessed a CNPCS score of 2.4 for the CR feature and 4.88 for the R feature. Depending on the assumptions made, however, the CNPCS score could be up to 12.99 assuming an equivalent combined feature comprising multiple walls. To facilitate the proper calculation of CNPCS scores for newly registered features or re-evaluation of CNPCS scores during Engineer Inspection for maintenance, it would be useful if suitable guidance is provided by the GEO to assist users to avoid adopting an inappropriate approach.

3.5.8 Further Enhancement of Standard of Engineer Inspections for Maintenance

The follow-up landslide studies have highlighted that there is room for further improvement in the conduct of Engineer Inspections (EI) as part of the long-term slope maintenance programme. EI, which should be carried out by a suitably qualified and experienced geotechnical professional, has a very important role in respect of taking the necessary follow-up actions to enhance slope stability in order to avoid the development of instability problems. However, some of the EIs have not been carried out in a sufficiently insightful and comprehensive manner and that some of the EI recommendations (e.g. scaling of loose blocks) have not been properly implemented, which was exacerbated by insufficiently specific recommendations and lack of follow-up inspection by the person who made the recommendations upon completion of works. Examples of areas that require attention include failure to locate past slope stability assessment/design reports for review, recommendations on follow-up actions in respect of undesirable vegetation and loose blocks on rock faces, possible tree fall hazards for trees on oversteep slopes and incomplete Maintenance Manuals which have missed out important slope work elements such as designed horizontal drains, cut-off drains, etc.

Landslide studies have highlighted that extensive distress of the hard surface cover to slopes may be a manifestation of the possible presence of adverse geological features concealed by the surface cover, or a result of inadequate detailing/construction of expansion joints. Where there is case for concern, a priority stability assessment should be recommended by the EI as a follow-up action as appropriate.

As noted in Section 3.3.2 above, the SIFT class of a slope based primarily on API under the SIFT project without reference to past slope works or slope assessments may not correctly reflect whether or not the slope is up to the required geotechnical standards. Where there is detailed information on the slope status based on a thorough file search under the EI

Table of Contents
Table of Contents
Table of Contents
Table of Contents

process, the EI should recommend the appropriate amendment of the SIFT class where necessary.

The review of the adequacy of past assessments under the EI should be carried out in a sufficiently rigorous manner to check whether the engineering approach used, the assumptions made and the conclusions reached are reasonable in the light of current practice and state of knowledge, with due cognizance taken of the slope performance history including records of landslides and slope maintenance. This is particularly relevant for those slope features dealt with in the early years of setting up the slope safety system, viz. in the late 1970's and early 1980's. Where there is justifiable cause of concern, the CNPCS score should be calculated (or re-assessed) under the EI to facilitate prioritisation of the necessary follow-up Stability Assessments or other appropriate actions.

The observations from LI studies as discussed above point to the need to provide further guidance on good practice for EI.

The methodology of the current maintenance audits by the GEO on the seven Government slope maintenance departments covers system adequacy audit and system compliance audit. Given the important role played by the EI in having timely actions taken before slope instability problems develop, there is merit in promulgating suitable guidance to assist the slope maintenance departments to undertake technical audits of EI. To promote the standard of EI, consideration should be given to recommending the maintenance departments to take due account of the seriousness of non-compliance identified by the audits in the consultant performance appraisal reports.

There is merit to review the practicality of GEO stepping up detailed independent technical audits of selected EI (including site visits, file searches and critical reviews of past study reports as appropriate) as a supporting service to the maintenance departments to identify common problems and promote good EI standards. The review could include pilot trials to examine resource~~s~~ requirements for this initiative if it were considered worthy of pursuing.

4. PROPOSED IMPROVEMENT MEASURES

Improvement measures were proposed by Lam et al (2002) following the review of the reported landslides in 2001. The progress of the follow-up actions taken is summarised in Table 16.

Based on the present review, the following initiatives are proposed with a view to further improving the slope engineering practice and slope safety system in Hong Kong:

(a) examine the feasibility of establishing a suitable annual index to serve as an indicator of the performance trend of the slope safety system with respect to rain-induced failures (see Section 3.5.5),

(b) carry out a review of landslides affecting squatter structures to gain some insight into the potential problems involved

Table of Contents
Table of Contents
Table of Contents
Table of Contents

with the present squatter policy and assist in identifying the possible way forward (see Section 3.5.6),

(c) provide guidelines for proper calculation of CNPCS scores for newly registered features or re-evaluation of CNPCS scores during Engineer Inspection for maintenance (see Section 3.5.7),

(d) review the need to provide further guidance on good practice for EI based on observations from landslide studies (see Section 3.5.8),

(e) promulgate guidance on technical audits of EI by the maintenance departments and recommend that the seriousness of non-compliance identified by the audits should be duly reflected in the consultant's performance appraisal reports (see Section 3.5.8), and

(f) review the practicality of stepping up independent detailed technical audits of selected EI by the GEO to provide a supporting service to the maintenance departments and the resource requirements (see Section 3.5.8).

5. CONCLUSIONS

Based on the detailed review presented in this report, the following observations are made with respect to the performance of the Government's slope safety system:

(a) No sizeable landslides on engineered slopes were reported in 2002.

(b) The annual failure rate, on a slope number basis, of minor landslides on engineered slopes was about 0.05% for the year 2002.

(c) The average annual failure rate (on a slope number basis) of slopes upgraded under the LPM Programme before 1998 is about 0.36%, whereas the corresponding figure for slopes upgraded under the LPM Programme between 1998 and 2002 was about 0.18%.

A number of initiatives is proposed with a view to improving the slope engineering practice and enhancing the slope safety system in Hong Kong, as detailed in Section 4 of this report.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

6. REFERENCES

Evans, N.C., Sun, H.W. & Pang, P.L.R. (2002). Landslide Potential (Rainstorm) Indices. Discussion Note No. DN 3/2002, Geotechnical Engineering Office, Hong Kong, 11 p.

Geotechnical Engineering Office (1997). Strategic Plan for Slope Safety 1997-2002. Administrative Report No. AR 9/97, Geotechnical Engineering Office, Hong Kong, 22 p.

Geotechnical Engineering Office (1998). Guide to Slope Maintenance (Geoguide 5) (Second edition). Geotechnical Engineering Office, Hong Kong, 91 p.

Geotechnical Engineering Office (2002). GEO Technical Guidance Note No. 10 - Enhancement of Rock Slope Engineering Practice Based on Findings of Landslide Studies. Geotechnical Engineering Office, Hong Kong, 8 p.

Geotechnical Engineering Office (2003). GEO Technical Guidance Note No. 13 - Guidelines on the Use of Prescriptive Measures for Rock Cut Slopes. Geotechnical Engineering Office, Hong Kong, 2 p.

Halcrow China Limited (2002). Detailed Study of the 22 May 2002 Rockfall Incident on Slope No. 11NE-A/C284 at Shatin Pass Road, Tsz Wan Shan. Landslide Study Report No. LSR 9/2002, Geotechnical Engineering Office, Hong Kong, 46 p.

Hencher, S.R. (1983). Landslide Studies 1982: Case Study No. 10 Ching Cheung Road. Special Project Report No. SPR 11/83. Geotechnical Engineering Office, Hong Kong, 38 p plus 7 drgs.

Ho, K.K.S., Chan, H.W. & Lam, T.M. (2000). Review of 1999 Landslides. Landslide Study Report No. LSR 8/2000, Geotechnical Engineering Office, Hong Kong, 68 p. (GEO Report No. 127).

Ho, K.K.S., Sun, H.W., Chan, H.W. & Lam, T.M. (2001). Review of Landslides in 2000. Landslide Study Report No. LSR 11/2001, Geotechnical Engineering Office, Hong Kong, 92 p.

Hui, T.H.H. & Lam, T.T.M. (2003). Factual Report on Hong Kong Rainfall and Landslides in 2002. Special Project Report No. SPR 2/2003, Geotechnical Engineering Office, Hong Kong, 77 p.

Lam, T.T.M., Sun, H.W. & Ho, K.K.S. (2002). Review of Landslides in 2001. Landslide Study Report No. LSR 6/2002, Geotechnical Engineering Office, Hong Kong, 43 p.

Maunsell Geotechnical Services Limited (2002). Detailed Study of the 23 March 2002 Rockfall Incident at Slope No. 11NW-A/C61 at Castle Peak Road, Kwai Chung. Landslide Study Report No. LSR 11/2002, Geotechnical Engineering Office, Hong Kong, 41 p.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Maunsell Geotechnical Services Limited (2003). Detailed Study of the 15 September 2002 Landslide on Slope No. 7SE-C/CR323 behind Nos. 11 to 16 Ngau Pei Sha New Village, Sha Tin. Landslide Study Report No. LSR 1/2003, Geotechnical Engineering Office, Hong Kong, 72 p.

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

Wong, H.N. & Ho, K.K.S. (1999). Review of 1997 and 1998 Landslides. Landslide Study Report No. LSR 15/99, Geotechnical Engineering Office, Hong Kong, 53 p. (GEO Report No. 107).

Yu, Y.F., Siu, C.K. & Pun. W.K. (2003). Guidelines on the Use of Prescriptive Measures for Rock Cut Slopes. Special Project Report No. SPR 3/2003, Geotechnical Engineering Office, Hong Kong, 29 p.

Table of Contents

Table of Contents

Table of Contents

Table of Contents

LIST OF TABLES

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 1 - Number of Landslides Affecting Different Facilities

Affected Facility	Hong Kong Island	Kowloon	New Territories and Outlying Islands	All
Squatters	0 (0)	0 (0)	5 (0)	5 (0)
Buildings	0 (0)	0 (0)	4 (1)	4 (1)
Roads	8 (0)	4 (0)	13 (2)	25 (2)
Transportation Facilities (railways, tramways, LRT, etc.)	0 (0)	0 (0)	0 (0)	0 (0)
Pedestrian Pavements/Footways	3 (1)	2 (0)	1 (0)	6 (1)
Minor Footpaths/Access	12 (0)	4 (0)	26 (1)	42 (1)
Construction Sites	3 (1)	2 (2)	0 (0)	5 (3)
Open Areas	7 (0)	6 (0)	15 (0)	28 (0)
Catchwaters	0 (0)	0 (0)	2 (0)	2 (0)
Others (e.g. carparks, parks, playgrounds, gardens, backyards, etc.)	5 (0)	1 (0)	16 (1)	22 (1)

Legend:

5 (1) Five landslides of which one was sizeable failures (i.e. failure volume of $\geq 50\ m^3$).

Notes:
(1) A given landslide may affect more than one key type of facility.
(2) The types of facility affected by landslide incidents are generally classified based on information given in GEO and other Government departments Incident Reports.

Table 2 - Landslide Consequence Related to Type of Slope Failure

Type of Failure		No. of Squatter Huts Evacuated		No. of Blocks, Houses or Flats Evacuated or Partially Closed	No. of Landslides Closure			Deaths	Injuries
		Permanent	Temporary		Roads	Pedestrian Pavements	Footpaths, Back Lanes, Private Access		
Fill Slope		0	1	0	0	0	0	0	0
Cut Slope	Soil	3	1	6	1	1	2	0	0
	Soil/Rock	0	0	0	8	3	1	0	0
	Rock	0	0	0	3	0	0	0	0
Retaining Wall		0	0	0	1	0	0	0	0
Natural Hillside		0	0	1	1	0	7	0	1[(2)]
Disturbed Terrain		0	0	0	0	0	0	0	0

Notes:
(1) A failure may give rise to more than one key type of consequence.
(2) Minor injury resulting from a rockfall from the natural hillside where rock blocks had been dumped (illegally) some time before the incident (Hui & Lam, 2003).
(3) The types of facility affected by landslide incidents are generally classified based on information given in GEO or other Government departments' Incident Reports.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 3 - Distribution of Facility Groups Affected by Sizeable Landslides

	Facility Group Affected by Sizeable Landslides (Group No.)						
	1a	1b	2a	2b	3	4	5
All Sizeable Landslides	1	0	0	4	1	2	1
Sizeable Landslides on Man-made Slope	1	0	0	4	1	2	1
Sizeable Landslides on Natural Hillside	0	0	0	0	0	0	0

Notes: (1) Facility groups are classified in accordance with that adopted for the New Priority Classification Systems (Wong, 1998).
(2) A given landslide may affect more than one key type of facility.

Table 4 - Number of Landslides As Classified by Type of Slope Failure

Type of Failure		No.	Percentage (%)
Fill Slope		5 (1)	3.6
Cut Slope	Soil	41 (5)	29.7
	Soil/Rock	44 (2)	31.9
	Rock	11 (0)	8.0
Retaining Wall		8 (1)	5.8
Natural Hillside		29 (0)	21.0
Disturbed Terrain		0 (0)	0
Total		138 (9)	100

Legend:

5 (1) Five landslides of which one was sizeable failure (i.e. failure volume of $\geq 50\ m^3$).

Note: Where a landslide involved more than one type of failure, the predominant type of failure has been assumed in the above classification.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 5 - Breakdown of Scale of Failures for Different Classes of Slopes

	Number of Minor Failures (< 50 m^3)	Number of Major Failures (50 to 500 m^3)	Number of Massive Failures (> 500 m^3)	
Registered Man-made Slopes	74	8	0	Σ = 82
Small Unregisterable Man-made Slopes	21	0	0	Σ = 21
Registerable Man-made Slopes Not Yet Registered at Time of Failure	5[(2)]	1[(1)]	0	Σ = 6
Natural Hillside	29	0	0	Σ = 29
	Σ = 129	Σ = 9	Σ = 0	Σ = 138

Notes:
(1) One major failure occurred on a man-made slope within an active construction, which was yet to be registered at the time of failure.
(2) Two minor landslides occurred on registerable slopes of which registration was in process at the time of failure.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 6 - Annual Failure Rates of Registered Slope Features Based on Landslides Reported in 2002

		Non-Engineered Slopes			Engineered Slopes		
		Fill/Retaining Wall	Soil/Rock Cut	Overall(1)	Fill/Retaining Wall	Soil/Rock Cut	Overall
Slopes Involved in Landslides in 2002	Number	4	67	71	1	9	10
	Surface Area of Landslides (m^2)	254	1,544	1,798	34	26	60
Slopes Involved in Sizeable Landslides in 2002	Number	2	6	8	0	0	0
	Surface Area of Landslides (m^2)	174	538	712	0	0	0
Slopes Involved in Minor Landslides in 2002	Number	2	61	63	1	9	10
	Surface Area of Landslides (m^2)	80	1,006	1,086	34	26	60
Total Number of Registered Slopes		11,900	22,850	34,750	9,580	10,670	20,250
Total Surface Area of Registered Slopes (m^2)		7,135,000	15,984,500	23,119,500	11,053,700	23,462,800	34,516,500
Annual Failure Rates (All Landslides Considered)	On a Slope Number Basis	0.03%	0.29%	0.20%	0.01%	0.08%	0.05%
	On a Unit Slope Surface Area Basis	3.56×10^{-3} %	9.66×10^{-3} %	7.78×10^{-3} %	0.31×10^{-3} %	0.11×10^{-3} %	0.17×10^{-3} %
	Number of Landslides Divided by Slope Surface Area (no./m^2)	0.56×10^{-6}	4.19×10^{-6}	3.07×10^{-6}	0.09×10^{-6}	0.38×10^{-6}	0.29×10^{-6}
Annual Failure Rates (Sizeable Landslides Only)	On a Slope Number Basis	0.02 %	0.03%	0.02%	0%	0%	0%
	On a Unit Slope Surface Area Basis	2.44×10^{-3} %	3.37×10^{-3} %	3.08×10^{-3} %	0%	0%	0%
	Number of Landslides Divided by Slope Surface Area (no./m^2)	0.28×10^{-6}	0.38×10^{-6}	0.31×10^{-6}	0	0	0

Note: (1) Disturbed Terrain features are excluded from this calculation of annual failure rates.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 7 - Landslide Incidents Involving Slopes Processed under the Slope Safety System (Sheet 1 of 4)

1. Slopes Upgraded Under the LPM Programme

Slope No.	Incident No.	Location	Volume (m^3)	Type of Slope	Remarks
11NW-A/C61	2002/03/0012	Castle Peak Road, Kwai Chung	0.1 (rockfall)	Soil/rock cut	LPM works completed in 2000.

2. Slopes Assessed under the LPM Programme with No Upgrading Works Required

Nil.

3. Slopes Assessed by Studies in the Late 1970's to mid-1980's with No Upgrading Works/Further Study Required

Nil.

4. Slopes Assessed by Government Departments and Checked by GEO with No Upgrading Works Required

Slope No.	Incident No.	Location	Volume (m^3)	Type of Slope	Remarks
6SE-D/C67	2002/05/0024	Tuen Mun Road, Tsing Lung Tau Section, Kowloon Bound, Tsuen Wan	0.3 (rockfall)	Soil/rock cut	The cut slope was assessed by HyD's consultant in 1983 as being up to the required standards. Geotechnical design was checked by GCO in 1983.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 7 - Landslide Incidents Involving Slopes Processed under the Slope Safety System (Sheet 2 of 4)

Slope No.	Incident No.	Location	Volume (m^3)	Type of Slope	Remarks
11NE-D/C890	2002/11/0157	Behind Sau Hong House and Sau Lok House, Sau Mau Ping Estate Phase III, Sau Mau Ping Road	0.1 (rockfall)	Rock cut	The cut slope was assessed by HD in 1997 as being up to the required standards. Geotechnical design was checked by GEO in 1995.

5. Slopes Assessed by Private Owners and Checked by GEO with No Upgrading Works Required

Nil.

6. Slopes Formed or Upgraded by Government Departments and Checked by GEO

Slope No.	Incident No.	Location	Volume (m^3)	Type of Slope	Remarks
11SE-B/C594	2002/09/0121	Behind Lift Tower of HK Museum of Coastal Defense, Shau Kei Wan	~2	Soil/rock cut	Geotechnical design on the subject slope prepared by Arch SD was checked by GEO in 1997.
10NE-A/C110	HyD/TMCA/2002/03/0001	Near Route 9 Kowloon Bound Chainage 13.4, North Lantau Expressway, Lantau	0.12 (rockfall)	Soil/rock cut	Geotechnical design on the subject slope prepared by HyD's consultant was checked by GEO in 1993.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 7 - Landslide Incidents Involving Slopes Processed under the Slope Safety System (Sheet 3 of 4)

Slope No.	Incident No.	Location	Volume (m^3)	Type of Slope	Remarks
11SE-C/CR29	2002/02/0006	East of Hong Kong Stadium, So Kon Po	< 0.5 (rockfall)	Soil/rock cut	Geotechnical design on the subject slope prepared by Arch SD's consultants was checked by GEO in 1993.
15NW-B/C114	2002/05/0031	Near lamp post No. 41848, Island Road, Repulse Bay	~0.5 (rockfall)	Soil/rock cut	Geotechnical design on the subject slope prepared by HyD's consultants was checked by GCO in 1983.
11SW-C/FR344	2002/09/0098	Hung Fuk Court, Tin Wan	~30	Fill slope	Geotechnical design on the subject fill slope prepared by Hong Kong Housing Authority's consultants was checked by GEO in 1992.

7. Slopes Formed or Upgraded by Private Owners and Checked by GEO

Slope No.	Incident No.	Location	Volume (m^3)	Type of Slope	Remarks
11SE-B/C590	2002/10/0144	Slope at the junction of O King Road and Pik Wan Road, Tseung Kwan O	2	Soil/rock cut	Geotechnical submission was checked by GEO in 1998.
12NW-C/C162	2002/12/0165	Behind No. 25, Villas Horizon, Silver Stream Path, Silverstrand, Sai Kung	0.2 (rockfall)	Soil/rock cut	Geotechnical submission was checked by GCO in 1989.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 7 - Landslide Incidents Involving Slopes Processed under the Slope Safety System (Sheet 4 of 4)

8. Slopes Upgraded Following Service of DH Orders and Checked by GEO

Nil.

9. Slopes Assessed as Not Requiring Upgrading Works But with Outstanding GEO Comments

Nil.

10. Slopes Assessed as Requiring Upgrading Works But with Outstanding GEO Comments

Nil.

Notes: (1) Slopes under Categories 1 to 8 are classified as engineered slopes.
(2) Slopes under Categories 9 and 10 are post-1978 features but are not taken as engineered slopes.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 8 - Classification of Engineered Slopes

Feature Type	Classification
Post-1978 Features (i.e. formed or upgraded after 1978)	1
Newly Formed	1N
Upgraded by LPM	1A
Upgraded by Other Government Departments	1B
Upgraded by Private Owners	1C
Upgraded following issue of DH Orders	1D
Pre-1978 Features (i.e. formed before 1978 and subsequently assessed under the slope safety system)	2
Assessed by LPM Stage 2 or Stage 3 Studies	2A
Assessed by Other Government Departments	2B
Assessed by Private Owners	2C
Assessed by Old Studies (e.g. Planning Division Stage 1 Study, Binnie & Partners Phase II Study, Existing Slopes Division Stage 1 Study)	2D

Note: The classification may be extended where possible by adding S, T, U, Y or N which are defined as follows:

S = detailed design calculations based on site-specific ground investigation and laboratory testing
T = detailed design calculations without site-specific ground investigation and laboratory testing
U = no detailed design calculations
Y = upgrading works/assessments were audited and accepted by the GEO
N = no evidence that the works/assessments were audited and accepted by the GEO

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 9 - Summary of Key Findings of Follow-up Landslide Studies (Sheet 1 of 7)

Landslide	Slope Status (classification)*	Worst Rain	Deterioration	Massive Relict Failure		Previous Failure/ Distress after Slope Assessed or Modified to Current Standards		Deficiency in Design/Assessment			Deficiency in Upgrading Works	Poor Condition of Maintenance	GEO Checking		Unauthorized Construction	Volume of Failure (m^3)		Remarks
				Recorded	More from API	Recorded	More from API	G/W	Material Strength	Others #			Submitted to GEO for Checking	Outstanding GEO comment not resolved		Detached	Deformed	
15.9.2002 Behind Lot No. 11-16, Ngau Pei Sha New Village, Sha Tin (7SE-C/CR323) (DS)	Not engineered	N	Y	N	N	N/A	N/A	N/A	N/A	N/A	N/A	Sig	N/A	N/A	N	50	0	The landslide occurred on an old 4.5 m high 70^o unsupported soil cut slope with a 2 m high toe retaining wall. The failure was probably triggered by water ingress resulting in reduction of soil suction. Blocked surface channels above the landslide scar and a cracked chunam slope cover probably contributed to the failure. Extensive slickensides, undulating, adversely orientated kaoline-infilled relict joints were found within CDG close to the rupture surface. These, together with some minor opening of relict joints, provide evidence of past movements and progressive deterioration of the slope.
23.3.2002 Castle Peak Road, Kwai Chung (11NW-A/C61) (DS)	Engineered (Slope upgraded under LPM in June 2000) (1ASY)	N	Y	N	Not done	N	Not done	N	N	Po	N	Sig	Y	N	N	0.15	0	The rockfall was probably triggered by rainfall and the development of cleft water pressure in rock joints behind the rock blocks after a period of moderate rainfall, which was exacerbated by the gradual opeing of rock joints. Poor detailing of surface drainage provisions led to discharge of water directly onto exposed rock portion of the slope and probably promoted progressive deterioration of the exposed rock portion and growth of unplanned vegetation.

Table 9 - Summary of Key Findings of Follow-up Landslide Studies (Sheet 2 of 7)

Landslide	Slope Status (classification)*	Worst Rain	Deterioration	Massive Relict Failure		Previous Failure/ Distress after Slope Assessed or Modified to Current Standards		Deficiency in Design/Assessment			Deficiency in Upgrading Works	Poor Condition of Maintenance	GEO Checking		Unauthorized Construction	Volume of Failure (m^3)		Remarks
				Recorded	More from API	Recorded	More from API	G/W	Material Strength	Others #			Submitted to GEO for Checking	Outstanding GEO comment not resolved		Detached	Deformed	
Time unknown Hillside above Yee King Road, North Point (DS)	Not engineered	N	Y	N	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	25	0	A 25 m^3 cavity was found on the hillside above Yee King Road. The cavity was probably formed primarily as a result of prolonged subsurface erosion and sudden collapse caused by a major underground stream system. The local geological conditions of the site are complex and unusual. Deeply weathered granite overlain by bouldery colluvium and displaced large slabs of granite was found on the downhill side of a 4 m to 8 m high cliff running parallel at about 55 m uphill of Yee King Road. The existing drainage line, which runs across the cliff, was likely to have migrated underground in pre-historic time. The area below the cliff may have been disrupted by general subsidence, which is probably largely due to significant internal erosion caused by the underground stream system. The outlet of the underground stream system was identified to be a spring at about 45 m below Yee King Road
28.11.2002 Hillside above Yip Hing Street, Wong Chuk Hang (DS)	Not engineered	N	N	N	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	0.3	0	The rockfall was probably related to the illegal tipping of rock blocks onto the natural hillside below a catchwater and about 10 m above the crest of slope No. 11SW-D/C639.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 9 - Summary of Key Findings of Follow-up Landslide Studies (Sheet 3 of 7)

Landslide	Slope Status (classification)*	Worst Rain	Deterioration	Massive Relict Failure		Previous Failure/ Distress after Slope Assessed or Modified to Current Standards		Deficiency in Design/Assessment			Deficiency in Upgrading Works	Poor Condition of Maintenance	GEO Checking		Unauthorized Construction	Volume of Failure (m^3)		Remarks
				Recorded	More from API	Recorded	More from API	G/W	Material Strength	Others #			Submitted to GEO for Checking	Outstanding GEO comment not resolved		Detached	Deformed	
10.8.2002 Victoria Road (within active construction site) (DS)	Not engineered (Slope formed in 2000, slope works partially completed at the time of failure)	N	N	N	N	N/A	N/A	Sig	Sig	Y	N/A	Sig	N/A	N/A	N	80	0	The landslide occurred on an over-steep unsupported cut portion of a partly soil-nailed cut slope. The failure was probably triggered by the development of transient water pressure within colluvium as a result of concentrated groundwater ingress and infiltration of surface runoff from probably overflowing along a blocked channel at the crest of the failed slope portion. Slope design by HyD's consultant prior to the landslide did not recognised the presence of adverse geological and hydrogeological conditions at the location of failure. A section of a stepped channel at location of landslide had yet been constructed at the time of failure. Some sections of the completed U-channels were blocked with soil debris and construction wastes.
22.5.2002 Shatin Pass Road, Tsz Wan Shan (11NE-A/C284) (DS)	Not engineered	N	Y	N	N	N/A	N/A	N/A	N/A	N/A	N/A	Little	N/A	N/A	N	7	0	The incident involved planar sliding of sizeable rock block (7 m^3) along an adversely orientated steeply dipping basal release surface at a height of about 7 m. The failure may have been the result of progressive deterioration of the rock slope, as indicated by the opening up of the rock joint. Root action associated with unplanned vegetation was a contributory factor to the rockfall.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 9 - Summary of Key Findings of Follow-up Landslide Studies (Sheet 4 of 7)

Landslide	Slope Status (classification)*	Worst Rain	Deterioration	Massive Relict Failure		Previous Failure/ Distress after Slope Assessed or Modified to Current Standards		Deficiency in Design/Assessment			Deficiency in Upgrading Works	Poor Condition of Maintenance	GEO Checking		Unauthorized Construction	Volume of Failure (m^3)		Remarks
				Recorded	More from API	Recorded	More from API	G/W	Material Strength	Others #			Submitted to GEO for Checking	Outstanding GEO comment not resolved		Detached	Deformed	
24.5.2002 Island Road, Shouson Hill (15NW-B/C114) (LR)	Engineered (Geotechnical submission checked by GCO in 1983) (1BSY)	N	Y	N	N	Y	N	N	N	N	N	Min	Y	N	N	0.5	0	The rockfall occurred on a 14 m high cut slope and the failure was probably caused by progressive erosion of soil matrix leading to loosening of round cobbles adjacent to a natural drainage line.
29.7.2002 123 Quarry Bay Street, Quarry Bay (11SE-A/C179) (LR)	Not engineered	N	Y	N	Not done	N/A	Not done	N/A	N/A	N/A	N/A	Sig	N/A	N/A	N	0.3	0	The rockfall occurred on an old cut slope with a history of local instabilities. The incident appeared to be result of a combination of toppling/planar failure due to continued deterioration along adversely orientated joints. The presence of tree roots adjacent to the location of failure might have given rise to root jacking of the rock joints causing the joints to progressively open as the roots grew and facilitating the ingress of water.
9.2.2002 East of Hong Kong Stadium, So Kon Po (11SE-C/CR29) (LR)	Engineered (Geotechnical submission checked by GEO in 1993) (1BSY)	N	Y	N	Not done	N	Not done	N	N	N	N	Mod	Y	N	N	0.5	0	The rockfall occurred in dry season with negligible rainfall recorded preceding the failure. The detachment may have been a result of progressive local deterioration or degradation of a dilated rock joint in slope. Rock scaling was recommended by the EI consultant but no specific locations of loose blocks to be scaled were given. The scaling works were completed in June 2000. The EI consultant did not undertake follow-up inspection after the completion of the works.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 9 - Summary of Key Findings of Follow-up Landslide Studies (Sheet 5 of 7)

Landslide	Slope Status (classification)*	Worst Rain	Deterioration	Massive Relict Failure		Previous Failure/ Distress after Slope Assessed or Modified to Current Standards		Deficiency in Design/Assessment			Deficiency in Upgrading Works	Poor Condition of Maintenance	GEO Checking		Unauthorized Construction	Volume of Failure (m^3)		Remarks
				Recorded	More from API	Recorded	More from API	G/W	Material Strength	Others #			Submitted to GEO for Checking	Outstanding GEO comment not resolved		Detached	Deformed	
16.9.2002 Cha Kwo Ling Tsuen, Fan Wa Street, Lam Tin, Kwun Tong (11NE-D/C18) (LR)	Not engineered	N	Y	Y	N	N/A	N/A	N/A	N/A	N/A	N/A	N	N/A	N/A	N	30	0	The landslide was probably triggered by infiltration and it is likely that transient water near-surface sheeting joints acted to reduce the shear strength of the sheeting joints and increase the pore water pressure within the joint infill.
9.8.2002 Yau Tam Mei Tsuen Road, Yuen Long (2SE-C/C199) (LR)	Not engineered	N	Y	N	N	N/A	N/A	N/A	N/A	N/A	N/A	Min	N/A	N/A	N	100	0	The landslide occurred on a 20 m high over-steep unsupported cut slope. The failure was probably triggered by ingress of surface water into the slope via opening in foliation planes and joints causing pore pressure to build-up along adversely orientated discontinuities.
23.3.2002 Tsing Ma Control Area, Lantau (10NE-A/C110) (LR)	Engineered (Geotechnical submission checked by GEO in 1993) (1NS)	N	N	N	Not done	N	Not done	N	N	N	N	N	Y	N	N	0.12	0	The rockfall was probably a result of slope ravelling due to continued slope deterioration along rock joints. It was possible that rock joints were opened up as a result of stress relief and blasting operation in the past. The maintenance and inspection records for the slope suggested that the slope is susceptible to small-scale instabilities.
15.09.2002 Hung Fuk Court, Tin Wan (11SW-C/FR344) (LR)	Engineered (Geotechnical submission checked by GEO in 1992) (1BSY)	Highest recorded 2-day rainfall since slope formation in 1996	N	N	N	N	N	N	N	N	N	Sig	Y	N	N	30	0	The landslide was probably triggered by rainfall. Possible over-toppling of runoff from a blocked drainage channel/catchpit located above the failure resulting in enhanced infiltration into the fill material may be a contributory factor to the failure.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 9 - Summary of Key Findings of Follow-up Landslide Studies (Sheet 6 of 7)

Landslide	Slope Status (classification)*	Worst Rain	Deterioration	Massive Relict Failure		Previous Failure/ Distress after Slope Assessed or Modified to Current Standards		Deficiency in Design/Assessment			Deficiency in Upgrading Works	Poor Condition of Maintenance	GEO Checking		Unauthorized Construction	Volume of Failure (m^3)		Remarks
				Recorded	More from API	Recorded	More from API	G/W	Material Strength	Others #			Submitted to GEO for Checking	Outstanding GEO comment not resolved		Detached	Deformed	
Time unknowm O King Road (11SE-B/C590) (LR)	Engineered (Geotechnical submission checked by GEO in 1998) (1NSY)	Not assessed	N	N	Not done	N	Not done	N	N	N	Sig	N	Y	N	N	2	0	The landslide was probably triggered rainfall and probable development of transient water pressure in colluvium near the surface. The horizontal spacing of soil nails at the failed location was wider than that stipulated in the drawing and this was a contributory factor to the failure.
16.9.2002 Behind the Entrance Block of Coastal Defense Museum, Shau Kei Wan (11SE-B/C594) (LR)	Engineered (Geotechnical submission checked by GEO in 1997) (1BSY)	N	N	N	Not done	N	Not done	N	N	Po	N	Min	Y	N	N	2	0	The minor landslide occurred on an unsupported soil portion of a soil/rock cut slope (maximum height of 30 m) which had been treated with rock dowels and soil nails in other parts of the slope. The landslide was probably triggered by rainfall and infiltration. It was likely that tree root action, resulting in progressive opening up of the soil/rock interface and allowing water ingress and local build-up of transient water pressure behind the soil/rock interface, was a contributory factor to the failure.
11.5.2002 Tuen Mun Road, Tsing Lung Tau Section, Kowloon Bound (6SE-D/C67) (LR)	Engineered (Geotechnical submission checked by GCO in 1983) (2BSY)	N	N	N	Not done	N	Not done	N	N	N	N	Min	Y	N	N	0.3	0	The rockfall occurred on a day with negligible rainfall recorded preceding the failure. The detachment may have been a result of progressive local deterioration of the rock slope.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 9 - Summary of Key Findings of Follow-up Landslide Studies (Sheet 7 of 7)

Landslide	Slope Status (classification)*	Worst Rain	Deterioration	Massive Relict Failure		Previous Failure/ Distress after Slope Assessed or Modified to Current Standards		Deficiency in Design/Assessment			Deficiency in Upgrading Works	Poor Condition of Maintenance	GEO Checking		Unauthorized Construction	Volume of Failure (m^3)		Remarks
				Recorded	More from API	Recorded	More from API	G/W	Material Strength	Others #			Submitted to GEO for Checking	Outstanding GEO comment not resolved		Detached	Deformed	
12.9.2002 Behind Sau Hong House and Sau Lok House, Sau Mau Ping Estate, Kwun Tong (11NE-D/C890) (LR)	Engineered (Geotechnical submission checked by GEO in 1995) (2BSY)	N	Y	N	Not done	N	Not done	N	N	N	N	Sig	Y	N	N	0.1	0	The rockfall was probably triggered by rainfall. It was likely that tree root action (resulting in progressive opening up of the rock joints and allowing water ingress and local build-up of transient water pressure behind the jointed rock face), together with inadequate maintenance, were contributory factors to the rockfall.
Time unknown Behind House No. 25 Villas Horizon Silver Stream Path, Silverstrand, Sai Kung (LR)	Engineered (Geotechnical submission checked by GCO in 1989) (1SY)	N	Y	N	Not done	N	Not done	N	N	N	N	Sig	Y	N	N	0.2	0	The rockfall was likely be the result of progressive local deterioration and degradation of the rock slope. Inadequate maintenance to clear loosen rock blocks on the exposed rock face was probably a contributory factor to the failure.

Legend:

Y = Yes N = No Po = Possible
Sig = Significant contribution Mod = Moderate contribution Min = Minor contribution Little = Little contribution
(DS) = Detailed Study (LR) = Landslide Review

Notes:
(1) Massive failure denotes incident with failure volume (detached + deformed volume) > 500 m^3.
Major failure denotes incident with failure volume between 50 m^3 and 500 m^3.
Minor failure denotes incident with failure volume < 50 m^3.
(2) * denotes classification of slope status in accordance with Table 8 of this report.
(3) # denotes other deficiency in design/assessment, including poor detailing, inappropriate geological model, incorrect slope stability analysis, inadequate drainage provisions, etc.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 10 - Breakdown of Landslides on Engineered Slopes

	Soil Cut Slope	Rock Cut Slope	Fill Slope	Retaining Wall	
All Landslides	2	7	1	0	$\Sigma = 10$
Massive Failure (> 500 m^3)	0	0	0	0	$\Sigma = 0$ (0%)
Major Failure (50 to 500 m^3)	0	0	0	0	$\Sigma = 0$ (0%)
Minor Failure (< 50 m^3)	2	7	1	0	$\Sigma = 10$ (100%)

Table 11 - Breakdown of Annual Failure Rates on Engineered and Non-Engineered Slopes

	Failure Rate on a Slope Number Basis (Number of Landslides Divided by Number of Slopes)	Failure Rate on a Unit Area Basis (Surface Area of Landslides Divided by Surface Area of Slopes)	Failure Rate in Terms of Number of Landslides Divided by the Slope Surface Area (no./m^2)
Registered Slopes with No Geotechnical Input (All Landslides Considered)	0.20%	7.78×10^{-3} %	3.07×10^{-6}
Engineered Slopes Processed by the Slope Safety System (All Landslides Considered)	0.05%	0.17×10^{-3} %	0.29×10^{-6}
Registered Slopes with No Geotechnical Input (Sizeable Landslides Only)	0.02%	3.08×10^{-3} %	0.31×10^{-6}
Engineered Slopes Processed by the Slope Safety System (Sizeable Landslides Only)	0%	0%	0
Registered Slopes with No Geotechnical Input (Minor Landslides Only)	0.18%	4.70×10^{-3} %	2.72×10^{-6}
Engineered Slopes Processed by The Slope Safety System (Minor Landslides Only)	0.05%	0.17×10^{-3} %	0.29×10^{-6}

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 12 - Breakdown of Landslides on Slopes Previously Treated under the LPM Programme

	Soil Cut Slope	Rock Cut Slope	Fill Slope	Retaining Wall	
All Landslides	0	1	0	0	$\Sigma = 1$
Massive Failure (> 500 m^3)	0	0	0	0	
Major Failure (50 to 500 m^3)	0	0	0	0	
Minor Failure (< 50 m^3)	0	1	0	0	$\Sigma = 1$

Table 13 - Breakdown of Annual Failure Rates on Slopes Previously Treated under the LPM Programme

	Failure Rate on a Slope Number Basis (Number of Landslides Divided by Number of Slopes)	Failure Rate on a Unit Area Basis (Surface Area of Landslides Divided by Surface Area of Slopes)	Failure Rate in Terms of Number of Landslides Divided by the Slope Surface Area (no./m^2)
Slopes Treated under LPM Programme (All Landslides Considered)	0.04 %	6.57×10^{-6} %	0.25×10^{-6}
Slopes Treated under LPM Programme (Sizeable Landslides Only)	0 %	0 %	0
Slopes Treated under LPM Programme (Minor Landslide Only)	0.04 %	6.57×10^{-6} %	0.25×10^{-6}

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 14 - Breakdown of Key Contributory Factors in Landslides on Engineered Unsupported Soil Cut Slopes

	All Landslides (Σ = 1 No.)	Local Minor Failures (Σ = 1 No.)	Sizeable Failures (Σ = 0 No.)
Adverse Groundwater	0 (0%)	0 (0%)	0 (0%)
Adverse Geological Material	1 (100%)	1 (100%)	0 (0%)
Inadequate Slope Maintenance	0 (0%)	0 (0%)	0 (0%)
Note: A given landslide may be associated with more than one key contributory factors to the failure.			

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 15 - Summary of Annual Rainfall Recorded by the HKO at Tsim Sha Tsui and Number of Genuine Landslides between 1997 and 2002

Year	Annual Rainfall at Tsim Sha Tsui (mm)	Number of Genuine Landslides
1997	3,343	559
1998	2,567	228
1999	2,129	402
2000	2,752	322
2001	3,092	214
2002	2,490	138

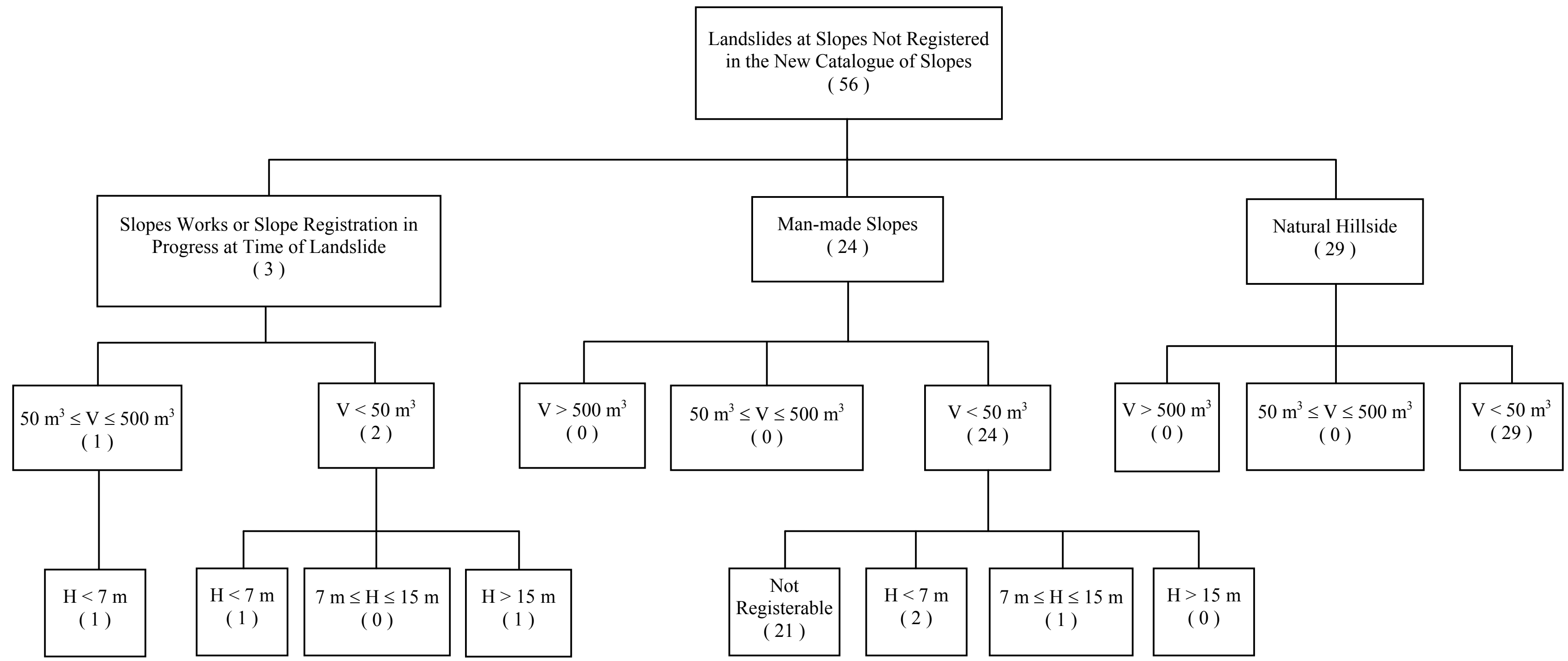
Table of Contents
Table of Contents
Table of Contents
Table of Contents

Table 16 - Progress of Follow-up Actions on the Improvement Measures Recommended in the Review of 2001 Landslides

Recommended Improvement Measures	Progress
Technical Improvement Measures	
1. It is proposed that a review be carried out to document the problematic cases in connection with soil nail construction and instability of temporary soil nailed slopes. This will assist in highlighting areas that warrant attention in the design and construction of soil nails.	Review completed. A Technical Note documenting the findings and areas that warrant attention is being circulated for comments.
Administrative Improvement Measures	
1. Review data on landslides that occurred prior to the engagement of an Authorised Person or default works following the service of a Dangerous Hillside Order and examine if there are any areas that warrant improvement.	Review completed. Landslide Study Report (LSR No. 7/2003) summarising the findings of the review and areas requiring attention is being issued.
2. Formalise a procedure to promptly re-calculate and update the CNPCS scores of slopes to take account of landslide occurrence to facilitate future selection of slopes for priority action under the LPM Programme	A suitable procedure for updating of CNPCS score components relating to past instability to take account of landslide occurrence has been established which has been implemented since 2002. Review of the CNPCS score component relating to past instability of features for landslides between 1998 and 2002 has been completed by the LI Division. Re-calculation of the CNPCS scores by SS Division has been completed and the SIS has been updated accordingly.

Table of Contents Table of Contents Table of Contents Table of Contents

LIST OF FIGURES



Legend:

V	Failure volume in m^3	H	Slope height in m	(2)	Number of cases = 2

Note: 'Not Registerable' refers to cases involving slopes that do not satisfy the feature height criteria for registration in the New Catalogue of Slopes

Figure 1 - Breakdown of Landslides on Unregistered Slopes in 2002

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 maps and other publications which are free of charge) can be purchased either by:

<u>writing to</u>
Publications Sales Section,
Information Services Department,
Room 402, 4th Floor, Murray Building,
Garden Road, Central, Hong Kong.
Fax: (852) 2598 7482

<u>or</u>

- Calling the Publications Sales Section of Information Services Department (ISD) at (852) 2537 1910
- Visiting the online Government Bookstore at http://bookstore.esdlife.com
- Downloading the order form from the ISD website at http://www.isd.gov.hk and submit 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):

<u>書面訂購</u>
香港中環花園道
美利大廈4樓402室
政府新聞處
刊物銷售組
傳真: (852) 2598 7482

<u>或</u>

- 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，網址爲 http://bookstore.esdlife.com
- 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 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: 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: 2231 3187
傳真: (852) 2116 0774

Requests for copies of Geological Survey Sheet Reports, publications and maps which are free of charge should be sent to:

<u>For Geological Survey Sheet Reports and maps which are free of charge:</u>
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

<u>For other publications which are free of charge</u>:
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 5345
Fax: (852) 2714 0275
E-mail: ykhui@cedd.gov.hk

如欲索取地質調查報告、其他免費刊物及地質圖，請致函：

<u>地質調查報告及地質圖</u>:
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

<u>其他免費刊物</u>:
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 5345
傳真: (852) 2714 0275
電子郵件: ykhui@cedd.gov.hk

Table of Contents
Table of Contents
Table of Contents
Table of Contents

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

GEOTECHNICAL MANUALS

Geotechnical Manual for Slopes, 2nd Edition (1984), 300 p. (English Version), (Reprinted, 2000).

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, 2000).
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.

GEOSPECS

Geospec 1	Model Specification for Prestressed Ground Anchors, 2nd Edition (1989), 164 p. (Reprinted, 1997).
Geospec 2	Model Specification for Reinforced Fill Structures (1989), 135 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. 1/96	Pile Design and Construction (1996), 348 p. (Reprinted, 2003).
GEO Publication No. 1/2000	Technical Guidelines on Landscape Treatment and Bio-engineering for Man-made Slopes and Retaining Walls (2000), 146 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

Table of Contents
Table of Contents
Table of Contents
Table of Contents