REVIEW OF 1999 LANDSLIDES

GEO REPORT No. 127

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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. A charge is made to cover the cost of printing.

The Geotechnical Engineering Office also publishes guidance documents as GEO Publications. These publications and the 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.

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October 2002

FOREWORD

This report presents the findings of a detailed review of landslides that occurred in 1999. It serves to review the performance of Government's slope safety system and identify improvement to current slope engineering practice in Hong Kong.

The review was carried out by the Landslip Investigation Division of the Geotechnical Engineering Office, with assistance provided by the 1999 landslide investigation consultant, Fugro Maunsell Scott Wilson Joint Venture. Appendix A of the report was prepared by the Special Projects Division.

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ABSTRACT

This report aimed to review the performance of Government's slope safety system and identify improvement to current slope engineering practice. It was carried out by the Geotechnical Engineering Office of the Civil Engineering Department, as part of the landslide investigation initiative introduced following the 23 July 1994 Kwun Lung Lau landslide.

About 400 genuine landslides occurred in 1999, all of which had been reviewed. A total of 27 landslide incidents were selected for follow-up study by the 1999 landslide investigation consultant, Fugro Maunsell Scott Wilson Joint Venture. These studies provided information and insight on the types and mechanisms of landslides in Hong Kong and enabled diagnosis of areas requiring attention.

Based on the landslide data in 1999, the annual failure rate in terms of sizeable landslides (i.e. failure volume of 50 m^3 or above) on catalogued slopes processed by the slope safety system as being up to the required geotechnical standards is about 0.03%. These include slopes that were previously assessed, designed or upgraded to meet the required geotechnical standards. For slopes dealt with under the Landslip Preventive Measures (LPM) Programme, the annual failure rate in terms of sizeable landslides is about 0.04%.

More than 99.9% of the slopes processed by the slope safety system as being up to the required geotechnical standards performed satisfactorily without the occurrence of any sizeable landslides in 1999.

Recommendations for enhancement of current slope engineering practice are given in this report. These include promulgation of improved guidance to practitioners in respect of design and construction control of soil cut slopes and fill slopes, further enhancement of the slope selection process to ensure early action on deserving slopes under the LPM Programme, giving attention to potential natural terrain instability problems brought about by human influence and tightening up selected administrative aspects of the slope safety system.

CONTENTS

1. INTRODUCTION

This report presents the findings of a detailed review of landslides that occurred in 1999. The review forms part of the Geotechnical Engineering Office (GEO)'s systematic landslide investigation (LI) initiative which was introduced following the 23 July 1994 Kwun Lung Lau landslide. This new initiative, which commenced in 1997, has two principal objectives:

(a) to identify, through studies of landslides, slopes that are affected by inherent stability 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 study to identify lessons learnt and the necessary follow-up actions. This review examines all the landslide data and information from individual landslide studies to assess the overall performance of the slope safety system and identify areas requiring attention. The review has been carried out by the Landslip Investigation Division of the GEO, with assistance provided by the 1999 LI consultants, Fugro Maunsell Scott Wilson Joint Venture.

Recommendations on improvement to slope engineering practice in Hong Kong are made arising from this review.

2. STUDIES OF INDIVIDUAL LANDSLIDES

Information relating to rainfall and issuance of Landslip Warning in 1999 is given in Appendix A.

A total of 402 genuine landslides (i.e. discounting non-landslide incidents, such as tree falls, flooding, very minor washout, etc.) were identified to have occurred in 1999 out of a total of 483 incidents reported to the GEO. The number of sizeable failures (i.e. with volume equal to or exceeding 50 m^3) that occurred in 1999 is 64, including 25 incidents that involved natural terrain or disturbed natural terrain.

All the landslides were reviewed and additional data were collated to assess incidents which might warrant further study. Altogether 27 landslide incidents in 1999 were selected for follow-up study. There are three types of landslide studies, namely:

(a) forensic study of fatal or serious landslides (i.e. a study with the highest rigour of proof which can be presented as evidence in legal proceedings),

(b) detailed study of significant landslides (i.e. an in-depth study of the history of the slope and probable causes of the failure), and

(c) review of selected landslides (i.e. a study that focuses on certain aspects of the incident without the need for comprehensive documentation of all the details pertaining to the site and technical causes of the failure).

These individual landslide studies provided insight and valuable information on the types and mechanisms of landslides in Hong Kong, together with the necessary follow-up actions in respect of each incident. The findings of the studies are documented in a series of Landslide Study Reports. Following each study, the key lessons learnt are identified and recommendations on site-specific and/or general follow-up actions are made, and action parties are agreed with GEO's senior management to implement the recommendations.

Selected notable landslides are shown in Plates 1 to 9.

3. OVERALL LANDSLIDE REVIEW

3.1 Scope of the Review

The review of the overall landslide data in 1999 provided a global picture of the performance of different types of slopes in Hong Kong and allowed a diagnosis of specific areas requiring attention.

The overall review has focused on the following key aspects:

(a) coverage of the New Catalogue of Slopes,

(b) failure rates of different types of catalogued slopes, and

(c) diagnosis of landslides on catalogued slopes which were previously processed by the slope safety system as being up to the required geotechnical standards.

3.2 Coverage of the New Catalogue of Slopes

3.2.1 General

All sizeable man-made slopes and retaining walls should be registered in the New Catalogue of Slopes, compiled under the 'Systematic Identification and Registration of Slopes in the Territory' (SIRST) project, which was completed in September 1998. The criteria for registration of man-made slope features in the New Slope Catalogue are detailed in Wong & Ho (2000).

3.2.2 Diagnosis

In terms of the overall landslide data, about 31% (i.e. 125 out of 402, excluding the one incident that involved an active construction site) of the landslide incidents occurred on unregistered slope features at the time of their failure. A breakdown of these incidents is given in Figure 1.

Of these incidents, 30 cases involved small man-made slope features that do not satisfy the slope registration criteria, and 76 cases involved natural hillsides which will not be registered.

A total of 19 incidents involved registerable man-made slope features which were yet to be registered at the time of their failure. Of the 19 incidents, 2 cases involved major failures. These affected a squatter and a village house.

3.2.3 Discussion

The coverage of the New Catalogue of Slopes has been assessed by reference to actual landslides. The diagnosis shows that the number of registerable slopes that were not included in the New Catalogue of Slopes at the time of their failure corresponds to a rate of about 4.7% for landslides in 1999. The majority of these cases (>70%) involved slope features of less than 7 m high and there is a mechanism in place for subsequent registration of the concerned slope features as identified following landslide incidents. None of the failures at such unregistered slope features in 1999 resulted in serious consequences.

3.3 Failure Rates of Catalogued Slopes

3.3.1 General

The rates of failure of catalogued slopes have been diagnosed in terms of the different types of slopes of different ages, viz. pre-1977 (i.e. formed or substantially modified before 1977), or post-1977 (i.e. formed or substantially modified after 1977).

The status of a slope has been distinguished as whether or not it has been processed by Government's slope safety system as being up to the required geotechnical standards. Slopes that were processed by the slope safety system as being up to the required geotechnical standards include the following:

(a) slopes formed after 1977 that are designed, and checked by the GEO as necessary, to the required geotechnical standards,

(b) slopes formed before 1977 that are subsequently assessed, and checked by the GEO as necessary, as being up to the required geotechnical standards, and

(c) slopes formed before 1977 that are subsequently upgraded, and checked by the GEO as necessary, to the required geotechnical standards.

The types of slope failures considered in the diagnosis are soil cut, rock cut and fill slope/retaining wall.

The classification of the scale of failure is as follows:

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

(b) major (i.e. failure volume of 50 m^3 to 500 m^3), and

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

In the context of this review, failure volume refers to the sum total of volume of detached material and volume of any deformed material (which remains on the slope and has not displaced significantly).

The distribution of the volumes of failures is summarised in Table 1.

3.3.2 <u>Diagnosis</u>

Of the 402 landslides in 1999, 276 occurred on catalogued slopes. Of these 276 landslides, 37 were sizeable (i.e. major or massive) failures.

Of the 276 landslides on catalogued slopes, a total of 20 slopes involved slope features that were previously processed by the slope safety system as being up to the required geotechnical standards (see Section 3.4). The estimate of the number of pre-1977 and post-1977 slopes in the New Catalogue of Slopes has been made approximately by reference to the 'Systematic Identification of Features in the Territory' (SIFT) project (i.e. SIFT Classes A, B1 and C1 correspond to pre-1978 slopes, and SIFT Classes B2 and C2 correspond to post-1978 slopes), together with slopes whose status has been changed following actions under the LPM Programme or re-development projects. Further information about the SIFT project, including its scope and limitations, is given by Wong & Ho (2000).

For the present review of the 1999 landslides, the numbers of slopes that have been processed and have not been processed by the slope safety system have been taken to be 18,000 and 36,000 respectively.

Based on the above assumptions and the landslide data in 1999, the assessed annual failure rates for different types of catalogued slopes are summarised in Table 2. The calculated failure rates are not particularly sensitive to the assumptions made about the number of different types of slopes given the likely order of uncertainty involved.

3.3.3 <u>Discussion</u>

Overall, the total number of landslides in 1999 on catalogued slopes corresponds to an annual failure rate of about 0.51% of features registered in the New Catalogue of Slopes. Given the relatively short period of observation, there is some uncertainty regarding the representativeness of the calculated failure rates compared to the long-term average values.

The failure rates of the different types of catalogued slopes could be affected by the rainfall characteristics, including the spatial distribution of rainfall. As noted in Appendix A, 1999 was an average year in terms of annual rainfall (i.e. 2129 mm) at the Hong Kong Observatory where records began in 1884. R&D work is being carried out by the GEO to see whether a methodology can be developed to correlate slope failure rate with rainfall.

3.4 Diagnosis of Landslides on Catalogued Slopes with Past Geotechnical Engineering Input

3.4.1 General

A review of the 1999 landslides indicates that some of the incidents involved failure of slopes which had received input from geotechnical engineers and had been through the slope safety system. A meaningful diagnosis of this calls for detailed information on the nature and probable causes of the landslides, together with the status and development history of the slopes concerned. The present assessment has been based on information from follow-up landslide studies.

Slopes involving input from geotechnical engineers are listed in Table 3. A total of 20 incidents in 1999 involved catalogued slopes which were processed by the slope safety system as being up to the required geotechnical standards. In addition, there are 24 incidents which involved post-1977 slopes according to the SIFT classification or documentary evidence. However, these slope features could not be taken as having been processed to be up to the required geotechnical standards based on a detailed file search. Three of these 24 incidents involved features constructed as part of New Territories Exempted Houses (NTEH). Pertinent information on selected landslide studies is summarised in Table 4.

Slopes that were previously processed by the slope safety system as being up to the required geotechnical standards had sufficient information to permit a diagnosis of failures on this class of slopes. The status of these slopes has been assigned in accordance with the classification system in Table 5 which considers the following aspects:

(a) whether the slope was a newly-formed feature, or an existing feature which was previously subjected to upgrading works or Stability Assessments as being up to the required geotechnical standards,

(b) the mechanism under which Stability Assessments or slope upgrading works were carried out (e.g. via the LPM Programme, private owners, Government Departments or defaulted Dangerous Hillside Orders),

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

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

(e) whether the Stability Assessment or design of slope upgrading works was checked and accepted by the slope safety system, and whether there are outstanding GEO's comments on the submissions that were not satisfactorily addressed by the designers.

3.4.2 Diagnosis

The breakdown of the 20 slopes processed as being up to the required geotechnical standards with respect to the types of slopes (e.g. soil cut, rock cut or fill) and the scale of failure is given in Table 6. It can be seen from Table 6 that 70% of these cases (i.e. 14 cases) involved minor failures, whereas 20% involved major failures and 10% involved massive failures.

Based on the 1999 landslide data, the annual failure rates for different classes of slopes can be deduced, as summarised below (Table 2):

(a) catalogued slopes not processed by the slope safety system as being up to the required geotechnical standards (all landslides) = 0.71%,

(b) catalogued slopes processed by the slope safety system as being up to the required geotechnical standards (all landslides) = 0.11%,

(c) catalogued slopes not processed by the slope safety system as being up to the required geotechnical standards (major and massive landslides) = 0.09%, and

(d) catalogued slopes processed by the slope safety system as being up to the required geotechnical standards (major and massive landslides) = 0.03%.

Thus, the likelihood of failure of slopes processed by the slope safety system as being up to the required geotechnical standards is about six times less compared to slopes that had not been processed by the slope safety system as being up to the required geotechnical standards. In terms of sizeable landslides (i.e. major and massive failures), the likelihood of failure of slopes processed by the slope safety system as being up to the required geotechnical standards is about one third of that for slopes that had not been processed by the slope safety system as being up to the required geotechnical standards.

It should be noted that the figure of 0.09%, i.e. item (c) is the failure rate for major and massive failures on the 36,000 slopes not processed by the slope safety system as being up to the required geotechnical standards. However, many of these slopes are of relatively small size and the chance of a sizeable failure on these slopes is very small. Hence, the actual rate of sizeable failure on the more vulnerable population of slopes (i.e. slopes of relatively large size) will be much greater than 0.09%.

Of the 20 slopes processed by the slope safety system as being up to the required geotechnical standards, five were previously dealt with under the LPM Programme, one of which subsequently involved a sizeable failure. The breakdown of landslides involving LPM slopes is shown in Table 7.

Given that about 2,300 slopes had been dealt with under the LPM Programme by mid-1999, the annual failure rates, based on the 1999 landslide data, are as follows:

(a) LPM slopes (all landslides) = 0.22%, and

(b) LPM slopes (major & massive landslides) = 0.04%.

It may be noted from the above diagnosis that in 1999, the annual failure rates of LPM slopes are higher than the annual failure rate of slopes processed by the slope safety system as being up to the required geotechnical standards. However, it should be noted that in the case of the sizeable failure of LPM slope in 1999, the cause of failure was related to inadequacy in surface water drainage provisions upslope of the LPM feature, together with inadequate construction control and inadequate maintenance. In general, caution needs to be exercised because small numbers are being compared, particularly in the case of sizeable failures, and the above diagnosis should be taken as indicative only.

The above diagnosis highlights the need to improve current slope engineering practice in order to further reduce the failure rate of slopes processed by the slope safety system as being up to the required geotechnical standards.

Analysis of the 1999 landslide data has identified a total of 24 incidents involving 'post-1977' slopes which cannot be regarded as having been processed by the slope safety system as being up to the required geotechnical standards (Table 3). These primarily comprise cases with no evidence of design submissions having been made to the GEO for checking. Of the 24 incidents above, five involved major failures and one involved a massive failure.

The post-1977 status of 16 out of the 24 cases was deduced from aerial photographs. As such, some of them could have involved slope modification works comprising urgent repairs to landslides, which should not be regarded as being up to the required geotechnical standards in terms of long-term slope stability. It is important to identify such cases for follow-up actions during the review of past stability assessment as part of the Engineer Inspection (EI) for maintenance.

3.5 Technical Assessment

3.5.1 Slope Deformation Without Full Detachment of Debris

The majority of landslides in Hong Kong are shallow failures and reportedly occur with little or no prior warning at or around peak rainfall intensity. However, the 1999 landslide data have shown that some of the instabilities involved slope deformation, as evidenced by signs of distress (such as extensive tension cracking) without complete detachment of the displaced mass from the slip surface. The localised detachment that occurred from part of the unstable mass could involve a volume of detached material ranging from a small to significant scale. A proportion of these cases is characterised by deep-seated movement of a large volume of material in a deeply-weathered profile, although the same phenomenon has also been observed on fill slopes. Some of these cases have also exhibited signs of prolonged slope movement.

Altogether there are a total of seven known cases (i.e. 1.7% of the total number of landslides of 402) involving significant slope deformation without complete detachment of the unstable mass. Six of the seven cases had major local detachment (i.e. about 9% of all the major and massive failures in 1999) and the remaining one involved minor detachment (i.e. about 0.3% of all the minor failures).

Of the seven cases, at least five had observable evidence of slope deformation occurring for some time (i.e. several months or years), with deterioration of the unstable ground mass being a key contributory factor to the failure.

Four of the seven cases involved slopes processed by the slope safety system as being up to the required geotechnical standards (i.e. 20% of the total number of failures involving slopes previously processed as being up to the required geotechnical standards), whereas the other three cases involved slopes not previously processed by the slope safety system as being up to the required geotechnical standards. One of the seven cases involved a fill slope, five involved soil cut slopes and one involved natural terrain. There were no data for rock cut slopes.

There is great practical significance of the above observations, as pointed out by Wong & Ho (2000):

(a) care must be taken in confirming the absence of signs of distress or slope deformation during maintenance and landslide inspections, and

(b) slopes with past significant movements are liable to deteriorate as any unstable ground continues to open up without significant detachment (e.g. during a severe rainstorm) and could fail in subsequent less severe rainstorms, giving rise to landslides that are a ‘surprise’ in that the slopes apparently survived more severe rainstorms. Given continued deterioration, slope instability may change from a ‘ductile’ mode to a ‘brittle’ mode, particularly where there is water ingress into ground which has opened up significantly, e.g. the 24 August 1999 Tsing Yi Road landslide.

It should be qualified that the above sample of seven cases was probably biased in that incidents with deformed volumes being significantly greater than the detached volumes tend to get selected for study. As a result, the estimated proportion of cases involving incomplete detachment is likely to be on the low side since cases involving deformed volumes that are comparable to the detached volumes were probably not selected for study.

3.5.2 Severity of Rainstorms that Triggered Landslides

Of the 20 failures in 1999 involving catalogued slopes processed by the slope safety system as being up to the required geotechnical standards, 10 incidents had sufficient information on the severity of the rainstorm that triggered the landslide (Table 4). Three of the 10 incidents occurred during unprecedented rainstorms, whilst the remaining seven cases failed during rainstorms which were less severe than those experienced in the past by the site according to automatic raingauges installed since about the mid-1980's.

For the above seven 'surprise' failures with respect to the severity of the rainstorms, deterioration of the slope condition may have played a role in those cases where there were no obvious changes in environmental factors and where contribution from inadequate slope maintenance was judged to be probably insignificant. Another possible reason could be slope deformation caused by previous severe rainstorms which could have resulted in cracking and opening up of the ground, with subsequent failures occurring in less severe rainstorms.

The above diagnosis suggests that the proposition that the continued stability of an existing slope may be proven by past rainstorms should be treated with extreme caution. As noted by Wong & Ho (2000), before one could confidently count on past performance regarding the margin of safety for long-term stability, there is a need to consider other factors such as slope deterioration, deformation, possible changes in environmental factors, etc.

3.5.3 Landslides on Slopes with Past Instability

Of the two massive landslides on soil cut slopes previously processed as being up to the required geotechnical standards, one (i.e. Shek Kip Mei) had a relict massive failure. Of the five massive landslides at 'pre-GEO' catalogued soil cut slopes, at least two (i.e. Lai Chi Yuen and Shum Wat Road) had relict sizeable failures. Thus, there is a significant percentage of massive landslides on soil cut slopes with relict sizeable failures.

Of the 20 slopes processed by the slope safety system as being up to the required geotechnical standards, 17 incidents contained information on whether the slope had subsequently suffered instability. Altogether seven of these 17 cases suffered failure after being processed as being up to the required geotechnical standards, two of which were major failure and five were minor. Of these seven cases, information on the previous failures for two of them was obtained from aerial photographs only with no other documentary records of such instabilities.

As highlighted by Wong & Ho (2000), the above diagnosis has reinforced the following key messages:

(a) consideration of past instability, particularly relict massive landslides, is important in slope assessment and design,

(b) a detailed API can provide useful information about past slope performance that cannot otherwise be obtained from documentary records, and

(c) consideration of past slope performance is important in EI because this will assist in picking up cases with inherent design or construction defects and facilitate review of the adequacy of past stability assessment.

3.5.4 Landslides on Fill Slopes Previously Processed as Being up to the Required Geotechnical Standards

A total of three fill slopes previously processed as being up to the required geotechnical standards (Table 4) has been studied in sufficient detail to provide some insight on the principal causes of failure. Of the three cases, two involved major landslides (i.e. ≥50 m^3 and ≤500 m^3) and other one was minor (i.e. <50 m^3).

Two of the three fill slopes were recently upgraded under the LPM Programme and both failed in their first wet season under a modest rainstorm after slope upgrading. Subsequent investigations revealed shortcomings in the design (e.g. inadequate consideration of the drainage condition of areas above slope crest, poor detailing of surface drainage provisions, etc.) and inadequate construction control. The other fill slope involved poor detailing of subsurface drainage provisions and inadequate construction control.

To further reduce the rate of failure on fill slopes processed by the slope safety system as being up to the required geotechnical standards would call for improvement in, inter alia, construction control and attention to detailing of surface and subsurface drainage provisions.

3.5.5 Landslides on Rock Cut Slopes Previously Processed as Being up to the Required Geotechnical Standards

Of the five failures at rock cut slopes processed as being up to the required geotechnical standards, two involved a failure volume of less than 1 m^3, one involved a failure of 1 m^3, one involved a failure of 3.5 m^3 and the other one involved a failure volume of 25 m^3 (where active construction works above the slope crest probably played a key role in triggering the failure). The instabilities were generally caused by local groundwater and local adverse or open jointing in the rock mass which may not have been adequately considered in the design. Also, rock slopes can be vulnerable to local deterioration, bearing in mind most rock slopes are not provided with a surface cover.

The occurrence of minor failures arising from local adverse groundwater regimes and defects in the rock mass, possibly exacerbated by deterioration, is very difficult to confidently guard against in design assessment. This points to the need for improved detailing and protective measures in the design, such as rock debris traps, meshing, toe barriers, buffer zones, etc. to cater for such localised detachments (Wong & Ho, 2000).

3.5.6 Landslides on Soil Cut Slopes Previously Processed as Being up to the Required Geotechnical Standards

Of the 12 landslides on soil cut slopes previously processed as being up to the required geotechnical standards, nine were studied in sufficient detail to enable a diagnosis of the problems involved.

Of the nine cases, the breakdown of key contributory factors to the failures is as follows:

(a) eight cases involved more adverse groundwater conditions than that allowed for in the design,

(b) seven cases involved more adverse geological material than that allowed for in the design, and

(c) eight cases involved inadequate slope maintenance.

A detailed breakdown of the key contributory factors, together with the mode and scale of failure, is shown in Table 8. It can be seen from Table 8 that inadequate slope maintenance was a key factor primarily for small failures but this could also be significant given the adverse setting involving the presence of pre-existing tension cracks below a hard cover (e.g. the 25 August 1999 Shek Kip Mei landslide). In one of the incidents involving an engineered slope, the designed horizontal drains were not being monitored and maintained properly. The 1997 Ching Cheung Road landslide also revealed similar problems of lack of monitoring and maintenance of such special measures.

Of the eight cases with groundwater problems, six (i.e. 75%) involved subsurface seepage and possible perching within the near-surface materials resulting from direct infiltration through the slope face or slope crest area. Transient elevated groundwater pressure may build up at the interface of colluvium and insitu material, at the soil/rock interface, or within a relict-jointed weathering profile where groundwater flow is significantly affected by infilled discontinuities. Two of the cases involved groundwater problems associated with development of cleft water pressures in open joints, or the build-up of groundwater levels at depth within the body of the slope as a result of subsurface drainage concentration, such as streamcourse, drop in rockhead profile, etc.

Five out of nine failures (i.e. about 56%) on soil cut slopes previously processed as being up to the required geotechnical standards involved localised minor failures controlled mainly by local geological and/or groundwater conditions. This provides an indication of the failure rate (about 0.08%) associated with such localised failures in soil cut slopes given the current state-of-practice in Hong Kong. The data emphasize the need for improved detailing and protective measures in order to further reduce the failure rate.

The other 44% of the landslides at soil cut slopes previously processed as being up to the required geotechnical standards involving major or massive failures occurred at difficult sites with complex geology and/or groundwater conditions. Possible indicators of potentially difficult sites are summarised by Wong & Ho (2000).

None of the failures of slopes in 1999 previously processed as being up to the required geotechnical standards involved soil nailed slopes. This probably reflects the merit of adopting more robust solutions (e.g. use of soil nails as opposed to cutting back) which are less sensitive to local variations in ground conditions and better able to cope with unforeseen, adverse ground conditions.

The above diagnosis indicates that the majority of soil cut slopes previously processed as being up to the required geotechnical standards performed satisfactorily in 1999. To further reduce the rate of sizeable failures would call for enhanced geological input, use of more robust slope design solutions and improved slope engineering practice, particularly for difficult sites (Wong & Ho, 2000).

3.5.7 Landslides on Natural Terrain Previously Processed as Being up to the Required Geotechnical Standards

There are three cases involving the failure of natural terrain below developments which were previously processed as being up to the required geotechnical standards. One of these cases involved a massive failure whereas the other two involved minor local detachments. The massive failure occurred in terrain with a break in slope (possible location of a relict failure), which was not accounted for in the stability assessment.

3.5.8 Large-scale Landslides on Man-made Slopes

Of the 37 sizeable landslides on catalogued man-made slopes, 11 were subjected to follow-up landslide studies or review (Table 4). The majority (>70%) of the sizeable failures involved cut slopes.

Of the eight soil cut slopes that had sizeable failures, four of them were assessed by geotechnical consultants and checked by the GEO as being up to the required standards (one in the late 1970's, one in the mid-1980's and two in the 1990's). In these cases, safety-critical features including significant build-up in groundwater pressure and/or adversely orientated weakness were not detected during the investigation and construction stages. Factors that are common to large-scale failures at cut slopes (with or without past geotechnical engineering input) include influence of past instability, adverse hydrogeological regime and structural control by geological defects.

Of the three fill slopes that had sizeable failures, two of them were previously processed as being up to the required geotechnical standards. These two incidents on engineered fill slopes involved inadequate surface drainage provisions and poor construction control. The remaining fill slope (i.e. Castle Peak Road near Lido Beach) with no past engineering input probably involved liquefaction of loose fill resulting in mobile debris.

3.5.9 Slopes Treated in the Late 1970's/Early 1980's

Slopes that were assessed or improved during the early years of setting up Government's slope safety system form a target group that deserves attention. This is because of the possibility of slope deterioration, reliance on practice or assumptions that are no longer considered appropriate (e.g. soil suction), and possible adoption of slope improvement schemes that are comparatively less reliable and robust than schemes developed more recently. The design process and practice in the early years of setting up the slope safety system may not have been sufficiently robust and could have resulted in premature 'sign-off' of slopes as being up to the required geotechnical standards. Given this and the possibility of deterioration of the overall slope condition, slopes processed in the early years, particularly those formed in the period of 1977 to 1979, constitute a target group of slopes that deserves attention. The 25 August 1999 Shek Kip Mei landslide incident highlighted the residual risk of slopes that were previously signed off by an 'old study' in the early years of setting up the slope safety system. This reflects that some of these slopes may be approaching the end of their service lives and that they deserve a re-assessment of the need for follow-up actions. Lessons learnt and recommendations for improvement in the slope safety system arising from the 1999 Shek Kip Mei landslide are summarised by Burland (2000).

A review of all the 2,525 slopes considered under old studies (e.g. B&P Phase IIC Study, B&P Phase IID Study, B&P Fill Slopes Study, GCB Investigation, North Point Rock Slopes Study, Existing Slopes Division Stage 1 Study, Planning Division Stage 1 Study, Planning Division Stage 1 Summary Report and GCO Mid-levels Area Study) has been carried out. Of these, 971 slopes were subsequently subjected to more detailed assessments, some resulting in upgrading works or issue of statutory orders. Discounting these cases as well as those slopes which were subsequently removed or modified as part of development, a total of 1284 slope features had to be re-examined. Arrangement was made in late 1999 for the concerned features to have New Priority Classification System (NPCS) scores assigned to them so that they can be ranked for action under the 10-year Extended LPM Project. About 50% of these features turn out to have a combined NPCS score of greater than 6, which is the current cut-off level for action on government slopes under the 10-year Extended LPM Project.

The rate of sizeable failure of slopes subjected to old studies has been assessed by reference to the available landslide records. Between 1984 and 1999, a total of 11 slopes that were 'signed off' by old studies subsequently had a sizeable failure. This corresponds to an average annual failure rate of about 0.05% for this category of slopes.

3.5.10 Failures in Construction Sites

There were four failures in 1999 (and three failures in 1998) involving construction sites. All these cases affected public or quasi-government projects.

Of the seven landslides, three involved inadequate geological and/or hydrogeological models, three involved inadequate temporary drainage provisions, three involved poor detailing, two involved inappropriate construction sequence (e.g. excavation in advance of constructing proper support) and two involved inadequate construction control. One of the seven cases involved a slope with trench excavation works near the slope crest.

The relatively high incidence of significant landslides involving construction sites emphasises the need for increased geotechnical input during construction. Apart from these failures during construction, three landslides in 1999 involved failure of processed slopes in their first wet season after completion of upgrading works. This again suggests that inherent design and/or construction defects were not being identified during the construction stage by the designers.

Apart from the one landslide in 1999 where trench excavation works probably played a role in the failure, one other landslide occurred in 1999 when trench excavation works were in progress, although a landslide study was not subsequently carried out as no serious consequence was caused in the event. A number of the landslide incidents in 2000 also involved slopes below trench excavations. Overall, the above incidents suggest the need to review the current practice of trench excavation works for services in the vicinity of slopes.

At least two of the above seven incidents in 1998 and 1999 were not reported promptly to the GEO by the parties concerned. Occurrence of genuine landslides during construction could have implications on the adequacy of the design assumptions which need to be reviewed in the light of the failures. Also, prompt reporting of significant failures would facilitate the GEO (as well as other concerned Government departments) to prepare considered responses to enquiries.

3.5.11 Natural Terrain Landslides Involving Influence of Human Actions

The 1994 Shum Wan Road landslide involved the failure of natural terrain with human influence contributing to triggering the collapse in that surface water was being channelled by the road at the crest acting as a catchment and directed onto the marginally stable hillside below. Two of the major failures in 1999 (i.e. Mount Davis Road and Pokfulam Road) affected terrain above catalogued cut slopes with human influences involved in triggering the failure. Overspilling of surface water from a minor access road to waterworks facilities was involved in one of the cases, whilst active trench excavation works for the construction of a new culvert which affected the surface water flow characteristics resulting in increased water ingress were involved in the other case. Both cases were ‘near-miss’ incidents in that casualties were only narrowly avoided.

Other landslide incidents in recent years are also known to have involved failure of natural terrain where human actions were probably contributory causes of the instability. For example, the 1997 Shatin Heights Road incidents involved some six failures on terrain below an old hilltop development and debris from some of the more mobile failures affected the downhill developments.

Such scenarios involving natural terrain within developed areas deserve attention as the affected terrain is not registered in the New Slope Catalogue and hence will not be systematically screened for action under the LPM Programme. Also, the terrain may be marginally stable with a potential for large-scale instability. For vulnerable terrain overlooking downhill developments, failures could be triggered by human activities in the upslope area, e.g. overspilling of surface runoff from roads or platforms, discharge from cross-road drains, leakage from water-carrying services, etc.

It would be useful to examine natural terrain landslides involving influence of human actions and identify the specific setting and scenarios deserving attention by reviewing the available landslide records.

4. PROPOSED IMPROVEMENT MEASURES

4.1 General

Technical and administrative improvement measures were proposed by Wong & Ho (2000) arising from a review of the 1997 and 1998 landslides in Hong Kong. The progress of the follow-up actions is summarised in Table 9.

4.2 Technical Improvement Measures

The following technical improvement measures are proposed:

(a) Improve the identification of slopes susceptible to sizeable failures (≥50 m^3) to facilitate early action under the LPM Programme.

(b) Promulgate improved standard of good practice in respect of assessment of groundwater, engineering properties and geological defects for soil cut slopes.

(c) Promulgate improved standard of good practice in respect of design and construction control for upgrading of old fill slopes and construction of new fill slopes.

(d) Review available landslide records to improve understanding of natural terrain landslides involving influence of human actions and assess the potential scale of the problem.

4.3 Administrative Improvement Measures

The following administrative improvement measures are proposed:

(a) Introduce qualified geotechnical supervision for the 10-year Extended LPM Project, modelled on the requirements for private and public sites.

(b) Review the current practice of trench excavations for services in the vicinity of slopes and identify the necessary measures to reduce the potential hazard of slope failure associated with such excavations.

(c) Examine the viability of reminding, at the approval stage, project offices or AP/RSE of the need to promptly report all significant signs of distress and/or notable landslides at active construction sites to the GEO.

(d) Examine the need to compile an inventory of slopes with designed horizontal drains to facilitate audit of such special measures.

5. CONCLUSIONS

Based on a detailed review of the landslides in 1999, the following conclusions are made in respect of the performance of Government's slope safety system:

(a) The annual failure rate of sizeable landslides on catalogued slopes processed by the slope safety system as being up to the required geotechnical standards is about 0.03% for the landslides in 1999. For slopes dealt with under the LPM Programme, the annual failure rate in terms of sizeable landslides is about 0.04%.

(b) More than 99.9% of the slopes processed by the slope safety system as being up to the required geotechnical standards performed satisfactorily without the occurrence of any sizeable landslides in 1999.

Areas requiring attention and recommendations for further improving the performance of the slope safety system are summarised in Table 10.

6. REFERENCES

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Wong, H.N. & Ho, K.K.S. (2000). Review of 1997 and 1998 landslides. Geotechnical Engineering Office, Hong Kong, 53 p. (GEO Report No. 107).

LIST OF TABLES

Table 1 - Breakdown of Scale of Failures on Different Classes of Slopes

	No. of minor failure (< 50 m^3)	No. of major failure (50 to 500 m^3)	No. of massive failure (> 500 m^3)	
Registered man-made slopes	239	30	7	Σ = 276
Small unregisterable man-made slopes	29	1	0	Σ = 30
Registerable man-made slopes not yet registered at time of landslide	18[(1)]	2	0	Σ = 20
Natural hillside	52	21	3	Σ = 76
	Σ = 338	Σ = 54	Σ = 10	Σ = 402

Note: Of the 18 minor landslides that occurred on registerable man-made slopes that were yet to be registered at the time of landslide, one involved an active construction site.

Table 2 - Annual Failure Rates of Catalogued Slopes Based on Landslides in 1999

	Slopes Not Processed by the Slope Safety System as Being up to the Required Geotechnical Standards			Slopes Processed by the Slope Safety System as Being up to the Required Geotechnical Standards		
	Fill/Retaining Wall	Soil/Rock Cut	Overall [Note]	Fill/Retaining Wall	Soil/Rock Cut	Overall
Number of landslides in 1999	23	226	256	3	17	20
Number of major & massive landslides in 1999	7	22	31	2	4	6
Number of minor landslides in 1999	16	204	225	1	13	14
Number of slopes	11,450	22,250	36,000	8,550	9,450	18,000
Annual Failure Rates (all landslides)	0.20%	1.03%	0.71%	0.04%	0.18%	0.11%
Annual Failure Rates (major & massive)	0.06%	0.10%	0.09%	0.02%	0.04%	0.03%

Note: The number of slopes and landslides involving Disturbed Terrain has not been shown for clarity.

Table 3 - Landslide Incidents Involving Pre-1977 Slopes Processed by the Slope Safety System as Being up to the Required Geotechnical Standards and Post-1977 Slopes (Sheet 1 of 9)

1. Slopes Upgraded Under the LPM Programme

Slope No.	Incident No.	Location	Volume (m^3)	Type of Slope	Remarks
11SE-B/C36	K1999/08/01	Cha Kwo Ling Road. MTRC site, Contract 612.	25	Rock Cut Slope	86/87 LPM Programme - works completed 8/8/89.
12SW-A/F31	ME1999/08/18	Tai Au Mun Bus Terminus	25	Fill Slope	LPM works completed 25/3/99.
11SW-C/F24	HK1999/08/30	Waterfall Bay Park, Wah Fu Estate	65	Fill Slope	LPM works completed 25/3/98.

2. Slopes Assessed by the LPM Programme as Being up to Standards (i.e. No Upgrading Works Required)

Slope No.	Incident No.	Location	Volume (m^3)	Type of Slope	Remarks
11NW-D/CR10	K1999/08/02	Behind Caritas Bianchi College of Careers, 4 Cliff Road	1	Soil Cut Slope	Slope assessed under LPM Programme.
6SE-C/C11	MW2000/02/05	Rear of Vista Del Mar, Below Ting Kau Bridge Ramp G	10	Soil Cut Slope	Design Division Stage 2 Study S2R 31/88 recommended no further action.

Table 3 - Landslide Incidents Involving Pre-1977 Slopes Processed by the Slope Safety System as Being up to the Required Geotechnical Standards and Post-1977 Slopes (Sheet 2 of 9)

3. Slopes Assessed by Old Studies[Note] and No Upgrading Works or Further Study Required

Slope No.	Incident No.	Location	Volume (m^3)	Type of Slope	Remarks
7NE-C/C23	No Incident Report	Chinese University	30	Soil Cut Slope	Planning Division Stage 1 Study S1R 71/88 recommended maintenance but no further study. Advisory letter issued on 31/5/89 and complied with on 4/12/89.
11NW-D/C81	K1999/06/01	Chatham Road North	<1	Rock Cut Slope	Planning Division Stage 1 Study S1R 34/90 recommended maintenance but no further study. Maintenance works completed in 1991 by HyD.
11SE-C/CR49	HK1999/08/23	Upper Blue Pool Road	17	Soil Cut Slope with Retaining Wall	Planning Division Stage 1 Study S1R 17/85 recommended no further study.
11SW-C/CR187	HK1999/08/15	The Duchess of Kent Children's Hospital.	20	Soil/Rock Cut Slope	Planning Division Stage 1 Study S1R 10/90 recommended no further study.
11NW-B/C90	MW1999/08/42	Shek Kip Mei	6,000	Soil/Rock Cut Slope	Studied in 1978 by Binnie and Partners-Phase IIC Landslide Study, Shek Kip Mei. Slope works completed in 1980 under a Highways Office Contract.

Table 3 - Landslide Incidents Involving Pre-1977 Slopes Processed by the Slope Safety System as Being up to the Required Geotechnical Standards and Post-1977 Slopes (Sheet 3 of 9)

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

Slope No.	Incident No.	Location	Volume (m^3)	Type of Slope	Remarks
Natural Hillside	MW1999/08/222	Mui Wo Ferry Pier road	30	Natural Hillside	Consultants for private developer produced Geotechnical Report for natural hillside in 3/81. Analysis of section nearest to failure gave FOS = 1.21.

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

Slope No.	Incident No.	Location	Volume (m^3)	Type of Slope	Remarks
Natural Hillside	MW1999/08/226	Kap Lung	2,000	Natural Hillside	Studied by consultant during design of adjacent electricity pylon. Geotechnical study dated 6/95 gave FOS = 1.3 for upper part of failure area (lower portion not studied).
Natural Hillside (Failure scar now registered as 10SW-B/DT43)	MW1999/08/224	Sea Bee Lane, Discovery Bay	25	Natural Hillside	Natural hillside checked prior to construction of housing above - approved by GEO.

6. Post-1977 Slopes Formed or Upgraded by Other Government Departments and Checked by GEO

Slope No.	Incident No.	Location	Volume (m^3)	Type of Slope	Remarks
10NE-B/C254	MW1999/08/36	Tsing Yi Road	1,000	Soil Cut Slope	Cut slope formed above new section of road between 1978 and 1980. Consultants geotechnical design report submitted 1980 (min. FOS = 1.2). Approved by GEO in 1988.

Table 3 - Landslide Incidents Involving Pre-1977 Slopes Processed by the Slope Safety System as Being up to the Required Geotechnical Standards and Post-1977 Slopes (Sheet 4 of 9)

6. Post-1977 Slopes Formed or Upgraded by Other Government Departments and Checked by GEO

Slope No.	Incident No.	Location	Volume (m^3)	Type of Slope	Remarks
7NW-B/F53	ME1999/08/39	Garden Dynasty View, Tolo Highway	240	Fill Slope	Highway embankment designed by Highways Office (min. FOS = 1.3). Works completed in 1985. Advice tendered by GEO Advisory Division prior to completion of works.
7SW-D/C235	MW1999/08/216	King Tin Court, Shatin	3	Soil Cut Slope	Design submission approved by GEO in early 1980's. Repeated small-scale failures after being processed by the slope safety system.
6SE-C/C188	MW1999/08/20 & MW1999/08/209	Trail from Sham Tseng Kau Tsuen to Tai Lam Country Park	60	Soil Cut Slope	Slope formed during mainlaying works by WSD in 1994. Affected by further mainlaying circa 1996/7 - design approved by GEO.
12SW-C/C16	ME1999/08/20	Tai Au Mun Road, Entrance to Clearwater Bay Golf & Country Club	3.5	Rock Cut Slope	Cut slope formed between 1978 and 1982 as part of a private development. Design approved by GCO in early 1980's.
New cut slope	MW1999/08/202	Near Ting Kau Bridge/Tuen Mun Road intersection	5	Soil Cut Slope	Slope work completed in 1996. In-principle check carried out by GEO and detailed checking by Independent Checking Engineer.
11NW-A/C83	MW1999/04/01	Kwai Chung Road, below Princess Margaret Hospital Nurses Training Quarters	<1	Rock Cut Slope	Rock slope studied under B&P Phase IID, remedial works recommended for whole slope. Remedial works on central portion, where the 1999 failure occurred, were approved by GEO and completed in December 1984. (No remedial works or further studies carried out for the eastern or western portions).

Table 3 - Landslide Incidents Involving Pre-1977 Slopes Processed by the Slope Safety System as Being up to the Required Geotechnical Standards and Post-1977 Slopes (Sheet 5 of 9)

7. Post-1977 Slopes Formed or Upgraded by Private Owners and Checked by GEO

Slope No.	Incident No.	Location	Volume (m^3)	Type of Slope	Remarks
11SW-A/C327	HK1999/08/35	94B Pok Fu Lam Road	2	Soil Cut Slope	The failed portion was upgraded in 1982 when the area at the toe was redeveloped.
6SE-C/C433	MW1999/08/144	Slope beneath elevated road, Sea Crest Villa, Tsuen Wan	1	Rock Cut Slope	Cut slope formed between 1991 and 1993 as part of a private development. Design approved by GEO in early 1990's.
10SW-B/C141	MW1999/08/157	Next to Blossom Court, Discovery Bay	10	Soil Cut Slope	Cut slope formed between 1988 and 1990 as part of a private development. Design approved by GCO in late 1980's.

8. Pre-1977 Slopes Upgraded under Default Works and Checked by GEO

Slope No.	Incident No.	Location	Volume (m^3)	Type of Slope	Remarks
9SW-D/C66	MW1999/08/187	Yin Hing Temple	200	Soil Cut Slope	DH Order: DH/1455/93/NT. Default works completed in early 1999. Design approved by GEO subject to groundwater report [Note : failure was not related to significant groundwater rise].

9. Pre-1977 Slopes Assessed and No Upgrading Works Required with Outstanding GEO Comments

Nil.

Table 3 - Landslide Incidents Involving Pre-1977 Slopes Processed by the Slope Safety System as Being up to the Required Geotechnical Standards and Post-1977 Slopes (Sheet 6 of 9)

10. Post-1977 Slopes with Outstanding GEO Comments on Geotechnical Submissions

Nil.

11. Post-1977 Slopes with No Evidence of Proper Design Submissions and GEO Checking

Slope No.	Incident No.	Location	Volume (m^3)	Type of Slope	Remarks
7NE-C/C184	ME1999/08/10	Lot 54 Tai Po Road, Shatin	15	Soil Cut Slope	SIFT Class C2. SIS notes construction pre-1980. No relevant files located in GEO. DH Order recommended on 30/8/99.
10SW-B/C68	MW1999/08/28	G/F 27A Tung Wan, Peng Chau	100	Soil Cut Slope	SIFT Class C2. SIS notes construction in 1981 - 82, but no relevant files located in GEO (NTEH feature).
10SW-B/C26	MW1999/08/71	Sea Crest Villa, Peng Chau	<10	Soil Cut Slope	SIFT Class C2. No relevant files located in GEO.
13NE-A/C253	MW1999/08/121	South Lantau Road	10	Soil Cut Slope	SIFT Class C2. No information regarding any submission or confirmation of GEO approval for this slope.
7SE-A/C367	ME1999/08/23	Sui Wo Court, Block C, Ha Wo Tsuen	9	Soil Cut Slope	SIFT Class C2. SIS notes construction in 1978 - 79. No relevant files located in GEO.
9SW-D/C114 & 9SW-D/CR115	MW1999/08/107	Sham Wat Road	1700	Soil Cut Slope with Gabion Toe Wall	SIFT Class C2. Constructed since 1978. GEO agreed road did not have to be constructed to "new works standard currently adopted for main roads". No clear evidence of sign-off by GEO.
9SW-D/C111	MW1999/08/230	Sham Wat Road	30	Soil Cut Slope	

Table 3 - Landslide Incidents Involving Pre-1977 Slopes Processed by the Slope Safety System as Being up to the Required Geotechnical Standards and Post-1977 Slopes (Sheet 7 of 9)

11. Post-1977 Slopes with No Evidence of Proper Design Submissions and GEO Checking

Slope No.	Incident No.	Location	Volume (m^3)	Type of Slope	Remarks
13NE-A/C76	MW1999/08/105	South Lantau Road	70	Soil/Rock Cut Slope	SIFT Class C1, but South Lantau Road (Stage III) reconstructed in late 1970's (SIS notes construction in 1976 - 79) - No formal design check. Failure in 1987 (100 m^3).
10SW-D/C44	MW1999/08/74	Hei Ling Chau Road, Hei Ling Chau	10	Soil Cut Slope	SIFT Class C2, but SIS notes construction in 1976 - 78. No relevant files located in GEO.
9SW-D/C42	MW1999/08/179	Sham Wat Road	8	Soil Cut Slope	SIFT Class C1, but the GEO District files note that the slopes have been upgraded between 1988 and 1990. GEO agreed the roadside slopes did not have to be upgraded to "present new works standard" and that a geotechnical submission was "not necessary". No clear evidence of sign-off by GEO.
9SW-D/C47	MW1999/08/180	Sham Wat Road	8	Soil Cut Slope	
9SW-D/C49	MW1999/08/181	Sham Wat Road	40	Soil Cut Slope	
9SW-D/C50	MW1999/08/182	Sham Wat Road	15	Soil Cut Slope	
10SW-D/C82	MW1999/08/82	Addiction Treatment Centre, Hei Ling Chau	15	Soil Cut Slope	SIFT Class C2. SIS notes construction in 1993 - 95. No relevant files located in GEO.
10SW-D/C75	MW1999/08/175	Hei Ling Chau Road, Hei Ling Chau	50	Soil Cut Slope	SIFT Class C2. SIS notes construction in 1979 - 82. No relevant files located in GEO.
3SW-A/C62	ME1999/09/5	Tsin Ping Shan, Fanling	20	Soil Cut Slope	SIFT Class C2. SIS notes construction in 1987 - 92. No relevant files located in GEO.

Table 3 - Landslide Incidents Involving Pre-1977 Slopes Processed by the Slope Safety System as Being up to the Required Geotechnical Standards and Post-1977 Slopes (Sheet 8 of 9)

11. Post-1977 Slopes with No Evidence of Proper Design Submissions and GEO Checking

Slope No.	Incident No.	Location	Volume (m^3)	Type of Slope	Remarks
3SW-C/C135	MW1999/08/214	1983 Urn burial ground, Wo Hop Shek Cemetery, Lo Wu	40	Soil Cut Slope	SIFT Class C2. SIS notes construction in 1981 - 82. File refers to GEO checking of this part of cemetery, but no specific details located. No other relevant information located in GEO.
6NE-A/C30	MW1999/08/201	Au Tau Roundabout	30	Soil Cut Slope	SIFT Class C2. SIS notes construction in 1978 - 84. No relevant files located in GEO.
14NE-B/C48	MW1999/08/229	53 Pak Kok Kau Tsuen, Lamma	5	Soil Cut Slope	SIFT Class C2. No relevant files located in GEO (NTEH feature).
3SW-C/C170	MW1999/09/31	Behind Pentecostal Yu Lung Fat Primary School	8	Soil Cut Slope	SIFT Class C2. SIS notes construction in 1978 - 84. Site formation plan by consultants, but no submissions located. No other relevant files located in GEO.
6SE-C/C350	MW2000/01/02	Slope behind house no. 14A, Sham Tseng Tung Tsuen	2	Soil Cut Slope	SIFT Class C2. No relevant files located in GEO. SIS notes construction in 1979 - 81 (NTEH feature).
13NE-A/C133	MW1999/08/122	South Lantau Road	50	Rock Cut Slope	SIFT Class C1, but South Lantau Road (Stage IV) reconstructed late 1970's/early 1980's. No information regarding any submissions or confirmation of GEO approval for this slope. Failure during construction. Permanent remedial works advised by GCO (Report No. 3/82) - do not appear to have been undertaken.

Table 3 - Landslide Incidents Involving Pre-1977 Slopes Processed by the Slope Safety System as Being up to the Required Geotechnical Standards and Post-1977 Slopes (Sheet 9 of 9)

11. Post-1977 Slopes with No Evidence of Proper Design Submissions and GEO Checking

Slope No.	Incident No.	Location	Volume (m^3)	Type of Slope	Remarks
13NE-A/C98	MW1999/08/119	South Lantau Road	20	Soil Cut Slope	SIFT Class C1, but South Lantau Road (Stage IV) reconstructed late 1970's/early 1980's. No information regarding any submissions or confirmation of GEO approval for this slope. Failures during construction. Submission for permanent remedial works requested by GEO. Site visit notes indicate HyD had "no plan to carry out permanent remedial works".
13NE-A/F59	MW1999/08/118	South Lantau Road	50	Fill Slope	SIFT Class B1, but South Lantau Road (Stage III) reconstructed in late 1970's (SIS notes construction in 1976 - 79) - empirical design. Tension cracks observed on slope in 9/78. Reconstruction completed in 4/79, but signs of distress noted - tension cracks and cracked drains. Consultants for GCO recommended remedial works in 12/80 - no further information available.

Note : The range of studies that are defined as 'Old Studies' is given in GEO Circular No. 19.

Table 4 - Summary of Key Findings of Individual Landslide Studies (Sheet 1 of 6)

Landslide	Slope Status (classification)*	Worst Rain	Deterioration	Massive Relic Failure		Previous Failure/ Distress after Slope Assessed or Modified to Current Standards		Deficiency in Design/Assessment			Deficiency in Upgrading Works	Inadequate Maintenance	GEO Checking		Unauthorized construction	Failed Volume (m^3)		Remarks
				Recorded	More from API	Recorded	More from API	GW	Mat. Strength	Others			Submitted to GEO for Checking	Outstanding GEO comment not resolved		Detached	Deformed	
25.8.99 Shek Kip Mei (11NW-B/C90) (FS)	Processed as being up to required standards (Old Area Study recommended relatively minor works and feature upgraded by other government department for 19 years) (1BUY)	Y (31 years)	Y	N	Y	Y (Boulder fall)	N	Sig	Sig	Little	Little	Sig	Y	N	*Y	200	5800	* Unauthorised cultivation above slope crest.
23.8.99 Sham Tseng San Tsuen (FS)	Not processed as being up to required standards	Y (49 years)	Y	N	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N	600	0	Failure of surface colluvium on natural hillside.
12.8.99 Cha Kwo Ling Road. MTRC site, Contract 612 (11SE-B/C36) (DS)	Processed as being up to required standards (upgraded under LPM for 10 years) (1ASY)	N	Po	N	N	N	N	Little	Mod	Mod	Sig	Min	Y	N	N	25	0	Zones of weaker Grade IV/V material remained untreated on a steep, engineered rock cut slope. Temporary drainage provisions during construction were inadequate leading to ponding of water above the slope crest.
23. 8.99 Tai Au Mun Bus Terminus (12SW-A/F31) (DS)	Processed as being up to required standards (Upgraded under LPM for <1 year) (1ASY)	N	N	N	N	N	N	Little	Little	Sig	Sig	Little	Y	N	N	25	0	Deviation from the standard practice of providing a 3m thick recompacted cap over the entire slope (a number of zones were not recompacted). Inadequate attention to surface water drainage. Inadequate construction control.
24.8.99 Waterfall Bay Park, Wah Fu Estate (11SW-C/F24) (DS)	Processed as being up to required standards (upgraded under LPM for 1 year) (1ASY)	N	N	N	N	Y (Minor washout)	N	Little	Little	Sig	Sig	Mod	Y	N	N	65	0	Inadequate attention to and poor detailing of surface water drainage. Inadequate construction control.

Table 4 - Summary of Key Findings of Individual Landslide Studies (Sheet 2 of 6)

Landslide	Slope Status (classification)*	Worst Rain	Deterioration	Massive Relic Failure		Previous Failure/ Distress after Slope Assessed or Modified to Current Standards		Deficiency in Design/Assessment			Deficiency in Upgrading Works	Inadequate Maintenance	GEO Checking		Unauthorized construction	Failed Volume (m^3)		Remarks
				Recorded	More from API	Recorded	More from API	GW	Mat. Strength	Others			Submitted to GEO for Checking	Outstanding GEO comment not resolved		Detached	Deformed	
7.6.99 Chinese University (7NE-C/C23) (DS)	Processed as being up to required standards (Planning Division Stage 1 study for 11 years) (2DTY)	N	Po	N	N	N	Po (Minor)	Little	Mod	Little	N/A	Mod	Y	N	N	30	0	Failure triggered by leaking services and rain infiltration.
Natural hillside above Kap Lung (DS)	Processed as being up to required standards (upper part of slope checked by consultant for 4 years) (2CSY)	Y	N	N	N	N	N	Mod	Little	Sig	N/A	N/A	Y	N	N	2000	0	Over-steep portion of terrain below CLP pylon not accounted for in slope stability analysis.
24.8.99 Tsing Yi Road (10NE-B/C254) (DS)	Processed as being up to required standards (Designed and checked by consultant for 14 years) (1BSY)	Y (50 years)	Y	N	N	Y (Major)	Y (Tension cracks)	Mod	Po	Min	Little	Sig	Y	N	N	300	700	Horizontal drains installed in the lower northern portion of the slope not maintained.
23.8.99 Route Twisk near Shek Kong (6NE-D/C57) (DS)	Not processed as being up to required standards	Y (85 years)	Y	N	N	N/A	N/A	N/A	N/A	N/A	N/A	Mod	N/A	N/A	N	1000	300	Major failure to cut slope formed between 1945 and 1963 and hillside above.
24.8.99 Victoria Road below VTC (DS)	Not processed as being up to required standards	N	Y	N	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	Y	300	0	One failure in natural hillside and one in fill slope within same catchment. Unauthorised dumping of fill.
24.8.99 South Lantau Road near Lai Chi Yuen (10SW-C/C116 & 10SW-C/C117) (DS)	Not processed as being up to required standards	Y (150 years)	Y	N	Y	N/A	N/A	N/A	N/A	N/A	N/A	Mod	N	N/A	N	1000	0	

Table 4 - Summary of Key Findings of Individual Landslide Studies (Sheet 3 of 6)

Landslide	Slope Status (classification)*	Worst Rain	Deterioration	Massive Relic Failure		Previous Failure/ Distress after Slope Assessed or Modified to Current Standards		Deficiency in Design/Assessment			Deficiency in Upgrading Works	Inadequate Maintenance	GEO Checking		Unauthorized construction	Failed Volume (m^3)		Remarks
				Recorded	More from API	Recorded	More from API	GW	Mat. Strength	Others			Submitted to GEO for Checking	Outstanding GEO comment not resolved		Detached	Deformed	
16.9.99 Rear of Vista Del Mar, Below Ting Kau Bridge Ramp G (6SE-C/C11) (IR)	Processed as being up to required standards (Design Division Stage 2 Study for 11 years) (2ASY)	N	N	N	N	N	Y (Minor)	Mod	Little	Little	N/A	Sig	Y	N	N	10	0	
18.6.99 Chatham Rd North (11NW-D/C81) (IR)	Processed as being up to required standards (Planning Division Stage 1 Study for 9 years) (2DTY)	N	Y	N	N	N	N	Little	Little	Min	N/A	Sig	Y	N	N	0.05	0	Minor rock fall probably triggered by tree root action from unplanned vegetation.
24.8.99 Garden Dynasty View, Tolo Highway (7NW-B/F53) (IR)	Processed as being up to required standards (Designed and checked by government departments for 14 years) (1BTY)	Y (40 years)	N	N	N	Y (Major)	N	Little	Little	Mod	Sig	Mod	Y	N	N	40	200	A local area of loose fill led to settlement and instability. Grouting works employed to stabilise settlement within the embankment formed thin seams within the near surface materials, as observed in the 1999 landslide main scarp, which may have obstructed downslope water flow. The non-provision of subsurface drainage blanket was unfavourable to slope stability.
24.8.99 Sham Wat Road (9SW-D/C114 & 9SW-D/C115) (IR)	No evidence of being processed as being up to required standards	N	Y	N	Y	N/A	N/A	N/A	N/A	N/A	Little	Mod	N	N/A	N	200	1500	
24.8.99 Victoria Road & Mt. Davis Road (IR)	Not processed as being up to required standards	N	N	N	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N	200	0	Failure probably caused by concentrated surface flow arising from poor surface water drainage provisions along the crest access road and inadequate maintenance of catchpit to slope uphill of the landslide.

Table 4 - Summary of Key Findings of Individual Landslide Studies (Sheet 4 of 6)

Landslide	Slope Status (classification)*	Worst Rain	Deterioration	Massive Relic Failure		Previous Failure/ Distress after Slope Assessed or Modified to Current Standards		Deficiency in Design/Assessment			Deficiency in Upgrading Works	Inadequate Maintenance	GEO Checking		Unauthorized construction	Failed Volume (m^3)		Remarks
				Recorded	More from API	Recorded	More from API	GW	Mat. Strength	Others			Submitted to GEO for Checking	Outstanding GEO comment not resolved		Detached	Deformed	
24.8.99 Pokfulam Road Opp Chinese Christian Cemetery (11SW-A/C332) (IR)	Not processed as being up to required standards	N	Po	N	Not Done	N/A	N/A	N/A	N/A	N/A	Sig	Mod	N	N/A	N	100	0	Failure probably influenced by construction work above the slope crest (inadequate control of surface water).
24.8.99 Victoria Road Opp Access Road to Pokfulam Kennels (11SW-C/C133) (IR)	Design Approved by GEO (Failure during construction)	N	N	N	N	N/A	N/A	Little	Little	Little	Sig	Mod	Y	N	N	40	0	Progressive failure (in 3 stages) of part of soil nailed cut slope and hillside above. Soil nail head arrangement had not been installed at the time of failure. Inadequate control of surface water during construction led to water cascading down the slope face.
24.8.99 Blue Pool Road, Behind 335 to 339 Tai Hang Road (11SE-C/CR49) (FN)	Processed as being up to required standards (Planning Division Stage 1 Study for 14 years) (2DTY)	Not Assessed	N	N	Not Done	N	Not Done	Little	Mod	Sig	N/A	Mod	Y	N	N	17	0	Over steep portion of slope and relic joints not considered in slope stability analysis.
24.8.99 Behind the Duchess of Kent Children's Hospital (11SW-C/CR187) (FN)	Processed as being up to required standards (Planning Division Stage 1 Study for 9 years) (2DTY)	Not Assessed	Po	N	Not Done	Y (Minor)	Not Done	Min	Little	Sig.	N/A	Mod	Y	N	N	20	0	Over steep portion of slope not considered in slope stability analysis.
23.8.99 Footpath from Sham Tseng Kau Tsuen to Tai Lam Country Park (6SE-C/C188) (FN)	Processed as being up to required standards (Designed and checked by government departments for 6 years) (1BTY)	Not Assessed	N	N	Not Done	N	Not Done	Mod.	Little	Sig	Min	Sig	Y	N	N	60	0	Over steep portions of slope and ground water not considered in slope stability analysis. Lack of surface drainage provisions and failure of recently placed fill at toe possibly contributed to failure.

Table 4 - Summary of Key Findings of Individual Landslide Studies (Sheet 5 of 6)

Landslide	Slope Status (classification)*	Worst Rain	Deterioration	Massive Relic Failure		Previous Failure/ Distress after Slope Assessed or Modified to Current Standards		Deficiency in Design/Assessment			Deficiency in Upgrading Works	Inadequate Maintenance	GEO Checking		Unauthorized construction	Failed Volume (m^3)		Remarks
				Recorded	More from API	Recorded	More from API	GW	Mat. Strength	Others			Submitted to GEO for Checking	Outstanding GEO comment not resolved		Detached	Deformed	
24.8.99 Behind 94B Pok Fu Lam Road (11SW-A/C327) (FN)	Processed as being up to required standards (Designed by private owner and checked by government department for 19 years) (1CTY)	Not Assessed	Po	N	Not Done	N	Not Done	Little	Mod	Little	N/A	Sig	Y	N	N	2	0	Design and works checked and approved by CGE/Pr. (Private Development Checking Unit of GCB). Failure probably caused by concentrated surface flow arising from blocked and damaged surface water drainage provisions.
22.8.99 Yin Hing Temple (9SW-D/CR66) (FN)	Processed as being up to required standards (Default works completed for <1 year) (1DSY)	N	N	N	N	N	N	Min	Mod	Mod	Minor	Little	Y	N	N	75	125	Approved by GEO subject to confirmation of groundwater regime assumed in design submission. Groundwater regime not considered to be a major contributory factor in the failure, but surface water was significant. Failure was partly controlled by a relic discontinuity with weak infill.
23.8.99 Natural Hillside Adjacent to Mui Wo Ferry Pier Road (FN)	Processed as being up to required standards (Assessed by private owner and checked by government department for 19 years) (2CTY)	Not Assessed	N	N	Not Done	N	Not Done	Mod	Little	Sig	N/A	N/A	Y**	Y	N	30	0	**Design and works checked and approved by CGE/Pr. (Private Development Checking Unit of GCB). Probability of shallow failure during heavy rainfall identified in assessment and regarded as acceptable due to low consequence of road at toe. Assessment of rock outcrops and boulders not completed.
24.8.99 Natural Hillside Below No. 73 Sea Bee Lane, Discovery Bay (FN)	Processed as being up to required standards (Assessed by private owner and checked by government department for 12 years) (2CSY)	Not Assessed	N	N	Not Done	N	Not Done	Little	Sig	Sig	N/A	N/A	Y	N	N	25	0	Over steep portion of soil slope not considered in assessment.

Table 4 - Summary of Key Findings of Individual Landslide Studies (Sheet 6 of 6)

Landslide	Slope Status (classification)*	Worst Rain	Deterioration	Massive Relic Failure		Previous Failure/ Distress after Slope Assessed or Modified to Current Standards		Deficiency in Design/Assessment			Deficiency in Upgrading Works	Inadequate Maintenance	GEO Checking		Unauthorized construction	Failed Volume (m^3)		Remarks
				Recorded	More from API	Recorded	More from API	GW	Mat. Strength	Others			Submitted to GEO for Checking	Outstanding GEO comment not resolved		Detached	Deformed	
Natural Hillside at Pat Heung	Not processed as being up to required standards	Y (25 Years)	N/A	N	N	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N	200	60	Failure in natural hillside along a pre-existing tension crack. Debris became channelised & deposited onto a platform adjacent to a resident building at the toe of the hillside.
23.8.1999 Casam Beach Castle Peak Road (6SE-C/F146 & 6SE-C/CR84) (FN)	Not processed as being up to required standards	Not Assessed	Po	N	Not Done	N/A	N/A	N/A	N/A	N/A	N/A	Sig	N/A	N/A	N	200	0	Landslide debris engulfed a bus stop at the toe and travelled across Castle Peak Road. The travel angle is estimated to be 20°.

Legend:

Y = Yes	N = No	Po = Possible	? = Not known
Sig = Significant contribution	Mod = Moderate contribution	Min = Minor contribution	Little = Little contribution
(FS) = Forensic Study	(DS) = Detailed Study	(IR) = Initial Review	(FN) = File Note

Massive failure = failure volume (detached + deformed) above 500 m^3

Major failure = failure volume between 50 m^3 and 500 m^3

Minor failure = failure volume less than 50 m^3

* denotes classification of slope status in accordance with Table 5

Table 5 - Classification of Slope Features

Feature Type	Classification
Post-1977 Features (Formed or upgraded after 1977)	1
Newly Formed	1N
Upgraded by LPM	1A
Upgraded by Other Government Departments	1B
Upgraded by Private Owners	1C
Upgraded by default of DH Orders.	1D
Pre-1977 Features (Formed before 1977 and subsequently assessed as being up to the required geotechnical standards)	2
Assessed by LPM Stages 2 or 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

Notes: The classification may be extended where possible by adding S, T, U, Y or N 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 checked and accepted by the GEO

N = no evidence that works/assessments were checked and accepted by the GEO

Table 6 - Breakdown of 1999 Landslides on Catalogued Slopes Processed as Being up to the Required Geotechnical Standards

	Soil Cut Slope	Rock Cut Slope	Fill Slope	Retaining Wall	
All landslides	12	5	3	0	$\Sigma = 20$
Massive failure (> 500 m^3)	2	0	0	0	$\Sigma = 2$ (10%)
Major failure (50 to 500 m^3)	2	0	2	0	$\Sigma = 4$ (20%)
Minor failure (< 50 m^3)	8	6	1	0	$\Sigma = 14$ (70%)

Notes:

(1) Of the 6 rock cut slope failures, two involved a failure volume of less than 1 m^3.

(2) Two failures which involved the soil portion of combined features (a soil/rock cut slope and a CR feature), were classified as having occurred on soil cut slopes.

Table 7 - Breakdown of 1999 Landslides on Slopes Treated under the LPM Programme

	Soil Cut Slope	Rock Cut Slope	Fill Slope	Retaining Wall
All landslides	2	1	2	0
Massive failure (> 500 m^3)	0	0	0	0
Major failure (50 to 500 m^3)	0	0	1	0
Minor failure (< 50 m^3)	2	1	1	0

Table 8 - Breakdown of Key Contributory Factors in Failures of Catalogued Soil Cut Slopes Processed as Being up to the Required Geotechnical Standards

	All landslides (Σ = 9 no.)	Local Minor Failures (Σ = 5 no.)	Massive or Major Failures (Σ = 4 no.)
Adverse Groundwater	8 (89%)	5 (100%)	3 (75%)
Adverse Material	7 (78%)	3 (60%)	4 (100%)
Inadequate Slope Maintenance	8 (89%)	5 (100%)	3 (75%)

Table 9 - Progress of Follow-up Actions for the Recommended Improvement Measures Made in the Review of 1997 and 1998 Landslides (Sheet 1 of 2)

Recommended Improvement Measures	Progress
1. Develop and promote improved detailing and protective measures in slope improvement works to reduce the risk of localised failures.	Suitable guidance was included in the Highway Slope Manual and the Technical Guidelines on Landscape Treatment and Bio-engineering for Man-made Slopes and Retaining Walls (GEO Publication No. 1/2000). **Action Completed.** The need to do more research and development will be examined as part of the GEO Goal 2 Strategy 2.
2. Enhance reliability of slope assessment and improvement works by attending to the following : (a) carry out a comprehensive API and take due account of past instability in slope assessment, (b) consider reliability of the design scheme in option assessments for slope improvement works, (c) incorporate the findings of verification of design geological model during slope works as part of the as-built records for inclusion in slope maintenance manuals, and (d) require designer to review slope performance and adequacy of design assumptions during the Contract Maintenance Period.	Guidance incorporated in TGN 2 which was issued in August 2000. **Action Completed.**
3. Review the need for, and practicality of, a slope certification system in the public works checking process.	A slope checking certification system has been introduced for public works. The system was promulgated in August 2001 via WBTC No. 16/2001. **Action Completed.**

Table 9 - Progress of Follow-up Actions for the Recommended Improvement Measures Made in the Review of 1997 and 1998 Landslides (Sheet 2 of 2)

Recommended Improvement Measures	Progress
4. Upgrade the practice and quality of Engineer Inspection for Maintenance (EI) carried out by Government Departments by:	
(a) expanding the model EI brief to require the completion of a checklist on background information in order to establish the history and status of the slope, prompt updating key slope data (including identification of unauthorized constructions and registerable slopes not yet registered), and assessment of compliance of past slope works with the design as far as possible, as part of the review of past Stability Assessments,	(a) Revised model EI brief issued by GEO in May 2000. **Action Completed.**
(b) requiring an out-of-turn EI following landslides or report of significant signs of distress or new or increased seepage, and	(b) Guidance Note covering this point among others issued by GEO in May 2000. **Action Completed.**
(c) introducing a procedure to facilitate timely feedback of relevant EI findings to update the Slope Information System.	(c) This is covered in WBTC No. 9/2000 which was issued in April 2000. **Action Completed.**
5. Examine the practicality or extending the scope of GEO's Maintenance Audit to include technical audit of the quality of EI procured by Government Departments.	Revised Model Brief for EI issued in May 2000 now requires Maintenance Departments to arrange for technical audit of the quality of EI. **Action Completed.**

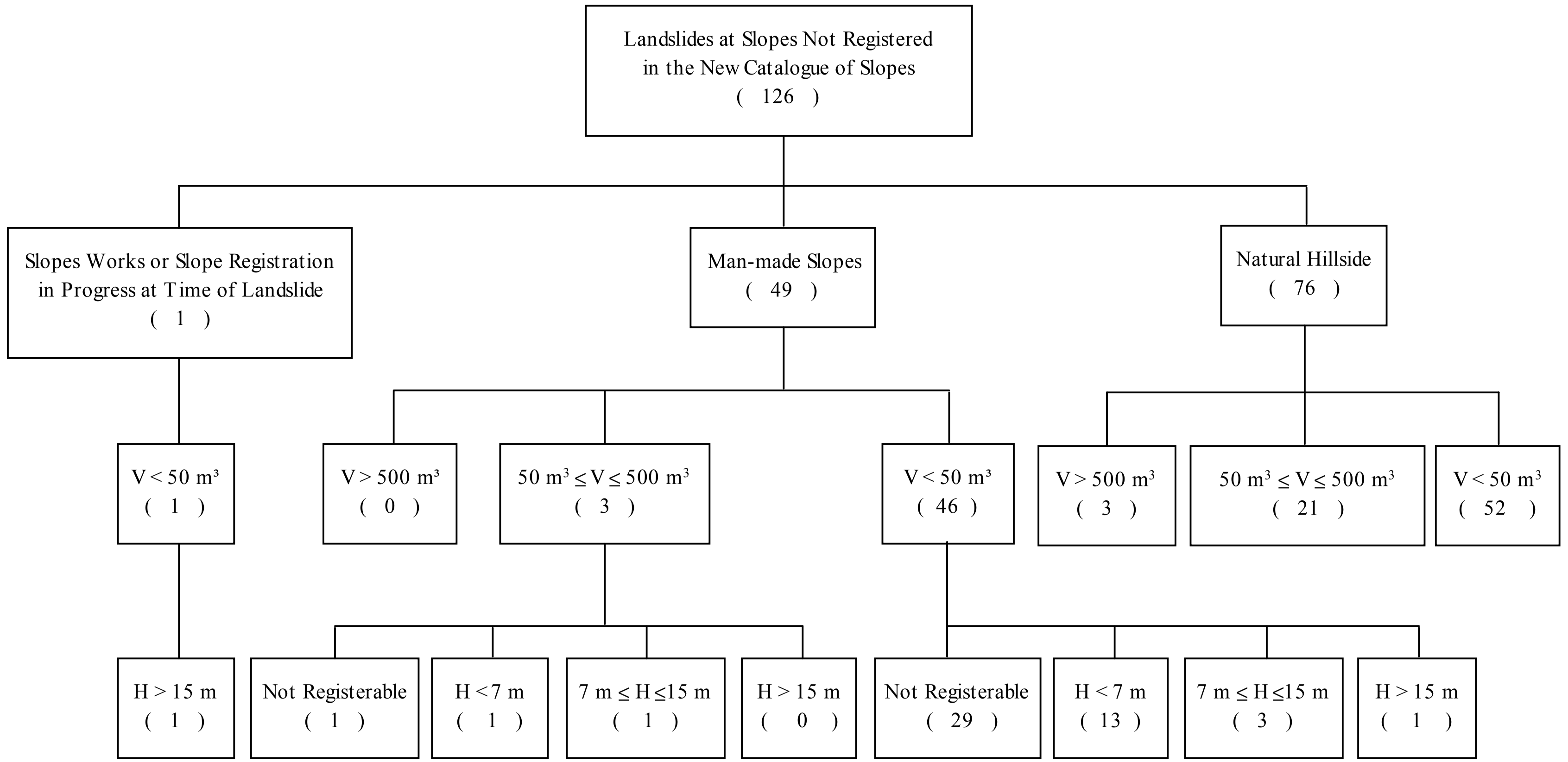
Table 10 - Summary of Areas Requiring Attention and Recommended Improvement Measures (Sheet 1 of 2)

Areas Requiring Attention	Recommended Improvement Measures
	<u>Technical Improvement Measures</u>
● Many of the sizeable landslides at old soil cut slopes involve a strong element of structural control and adverse hydrogeological conditions dictated by the overall site setting. There is scope to improve the current NPCS system to account for regional structural geological and hydrogeological features to better identify slopes that are predisposed to large-scale failures.	1. Improve the identification of slopes susceptible to sizeable failures ($\geq 50\ m^3$) to facilitate early action under the LPM Programme.
● In many of the sizeable failures involving engineered soil cut slopes, safety-critical features such as adversely orientated geological defects and significant build-up of groundwater pressure were not detected during the investigation and construction stages.	2. Promulgate improved standard of good practice in respect of the assessment of groundwater, engineering properties and geological defects for soil cut slopes.
● Problems have been observed at fill slopes that were processed by the slope safety system as being up to the required geotechnical standards.	3. Promulgate improved standard of good practice in respect of design and construction control for upgrading of old fill slopes and construction of new fill slopes.
● Significant landslides have occurred on natural terrain where changes in environmental conditions arising from human influences probably play a significant role in causing the failure. Such vulnerable natural terrain will not be systematically screened for action under the LPM Programme.	4. Review available landslide records to improve understanding of natural terrain landslides involving influence of human actions and assess the potential scale of the problem.

Table 10 - Summary of Areas Requiring Attention and Recommended Improvement Measures (Sheet 2 of 2)

Areas Requiring Attention	Recommended Improvement Measures
	<u>Administrative Improvement Measures</u>
● Notable landslides have occurred at active construction sites and where trench excavation activities are in progress in close proximity to slopes. Some of these significant failures, which could have major implications on the validity of design assumptions and Government's response to media queries, were not promptly reported to the GEO.	1. Introduce qualified geotechnical supervision for the 10-year Extended LPM Project, modelled on the requirements for private and public sites. 2. Review the current practice of trench excavations for services in the vicinity of slopes and identify the necessary measures to reduce the potential hazard of slope failure associated with such excavations. 3. Examine the viability of reminding, at approval stage, project offices or AP/RSE of the need to promptly report all significant signs of distress and/or notable landslides at active construction sites to the GEO.
● Significant failures have occurred on slopes with designed horizontal drains where the continued effectiveness of such special measures was not being monitored and maintained properly.	4. Examine the need to compile an inventory of slopes with designed horizontal drains to facilitate audit of such special measures.

LIST OF FIGURES

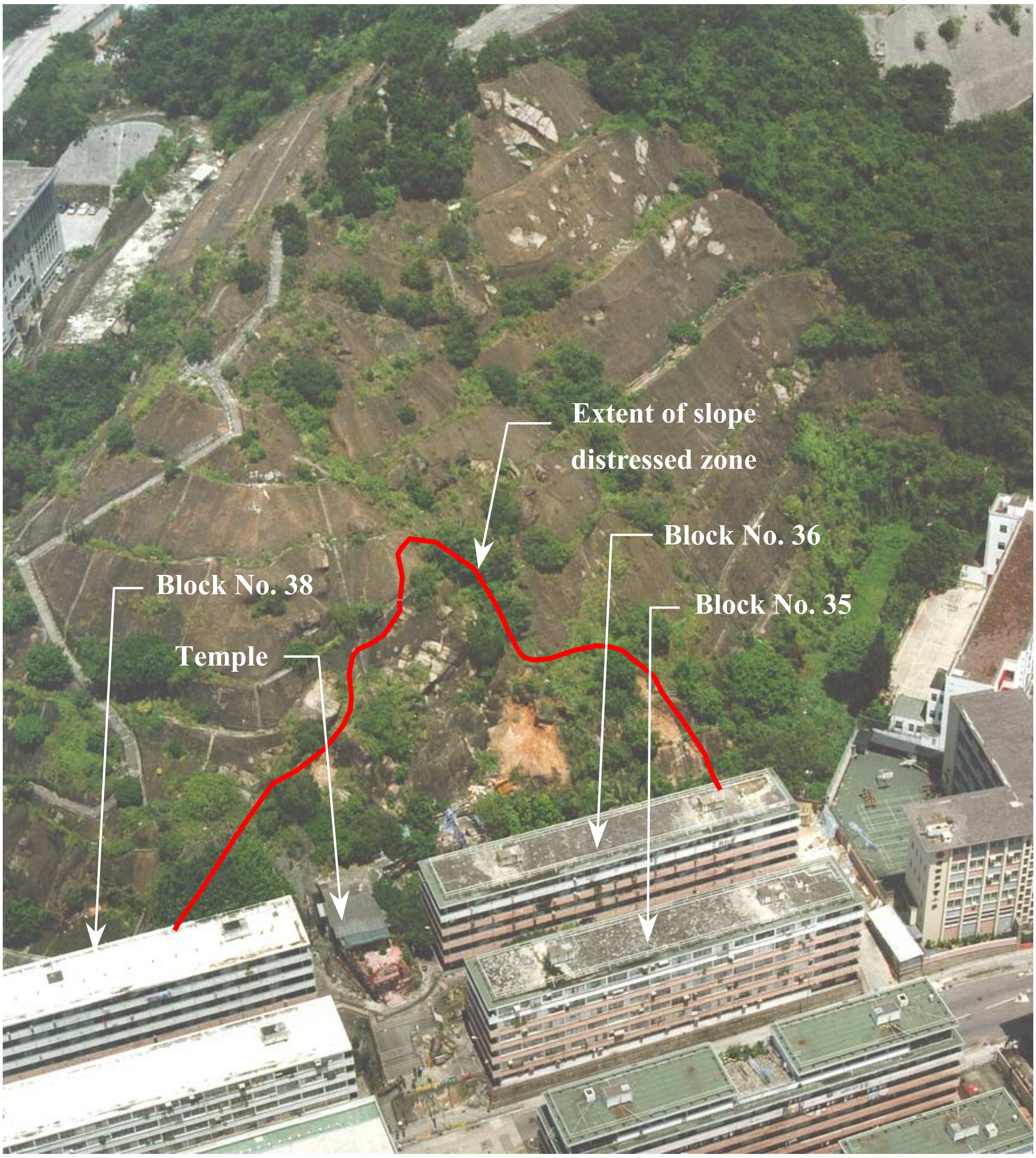


Legend: V Failure volume in m^3
H Slope height in m
(3) Number of cases = 3

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

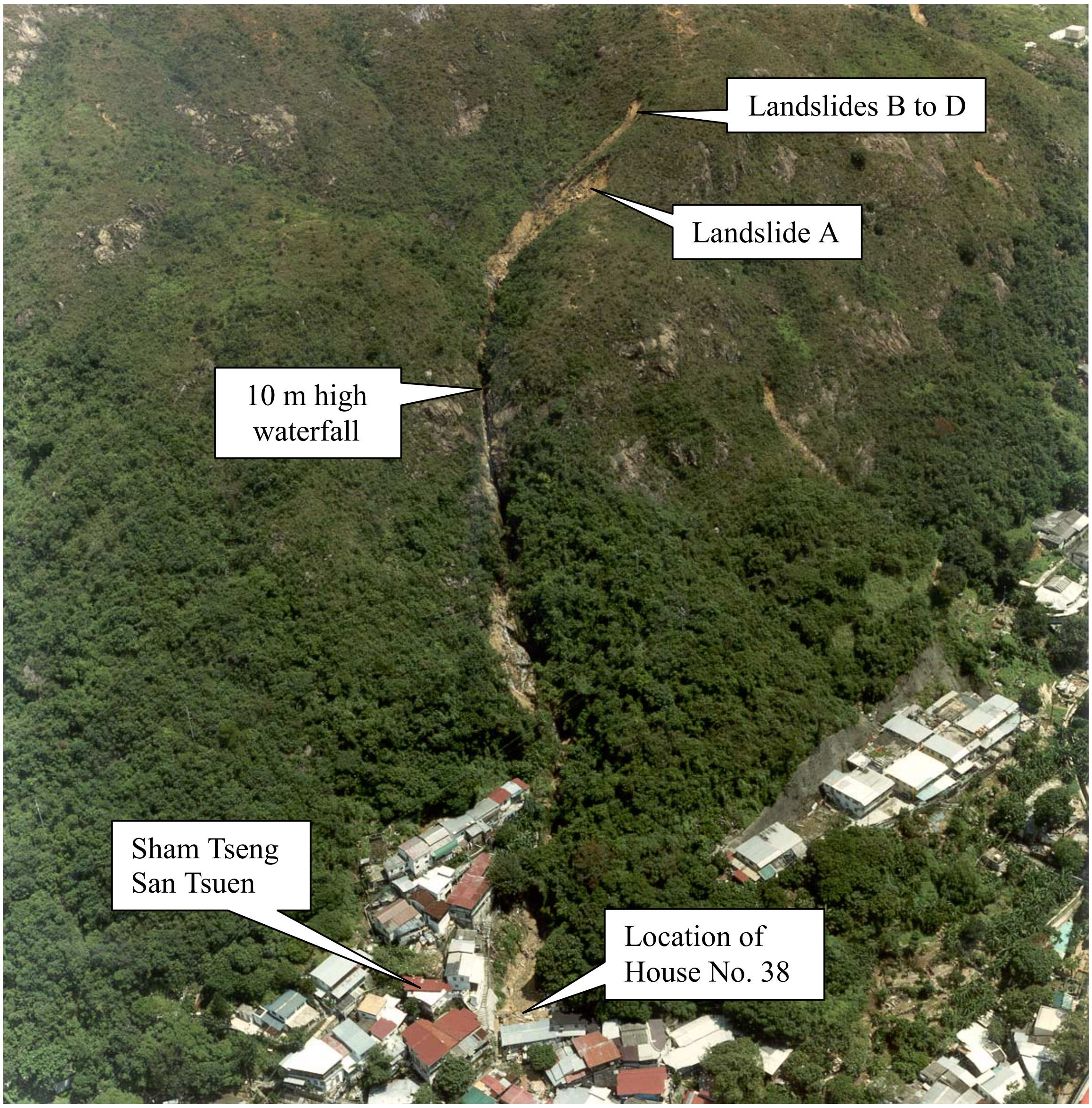
Figure 1 - Breakdown of Landslides at Unregistered Slopes in 1999

LIST OF PLATES



Description : A massive landslide occurred on a sizeable old cut slope. The incident resulted in the permanent evacuation of three public housing blocks.

Plate 1 - Shek Kip Mei Landslide (FMSW, 2000a)



Description : Landslides occurred on natural hillside giving rise to a debris flow down a stream course. The debris flow demolished a number of squatter dwellings and resulted in one fatality and 13 injuries.

Plate 2 - Sham Tseng San Tsuen Debris Flow (FMSW, 2000b)

Description : The landslide involved a slope which was previously upgraded. At the time of failure, the slope was within an active construction site with excavation works in progress above the crest of the slope. The failure resulted in the temporary closure of Cha Kwo Ling Road.

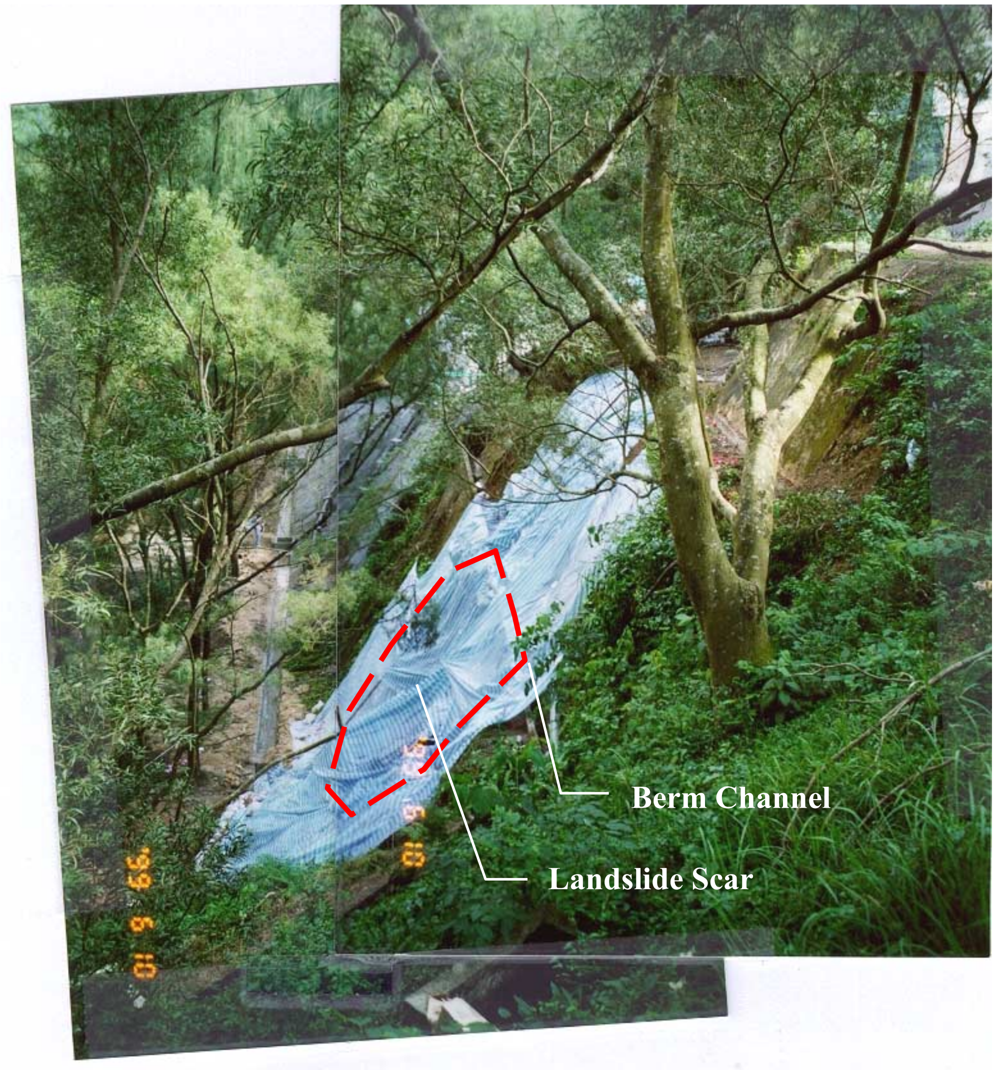
Plate 3 - Cha Kwo Ling Road, Yau Tong (FMSW, 2000c)

Description : A massive landslide occurred on old cut slopes and the ground above which had a history of instability. A van was damaged by the landslide debris and the failure resulted in the complete closure of South Lantau Road for two weeks.

Plate 4 - South Lantau Road, near Lai Chi Yuen, Lantau Island (FMSW, 2001a)

Description : A massive landslide occurred on a hillside that was assessed as being up to the required geotechnical standards. The landslide debris became channelised and travelled for about 600 m.

Plate 5 - Kap Lung, near Shek Kong (FMSW, 2001b)

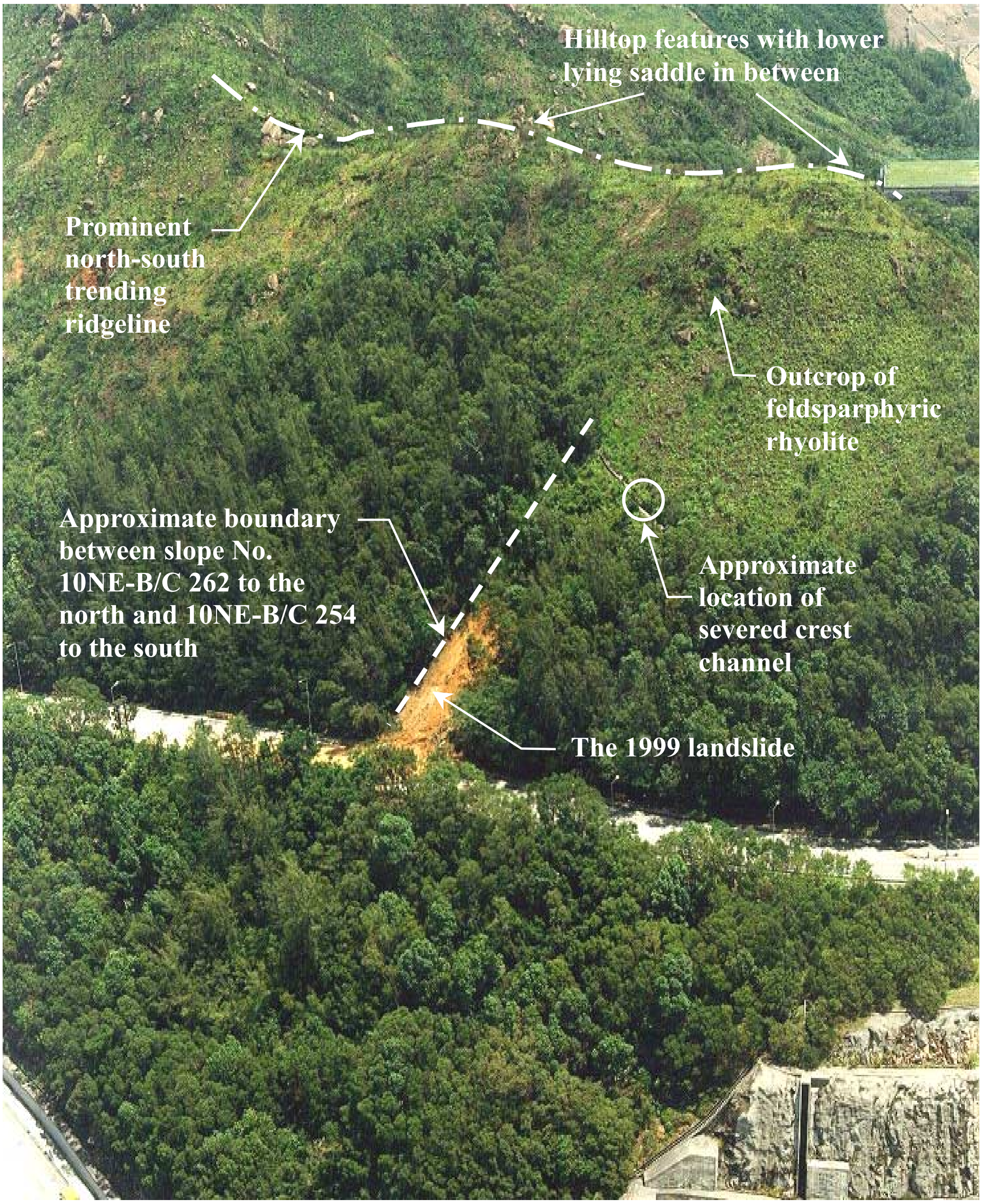


Description : The landslide occurred on an old cut slope which was previously assessed as being up to the required geotechnical standards. Leakage of services was a major contributory factor in the failure.

Plate 6 - Benjamin Franklin Centre, The Chinese University of Hong Kong (FMSW, 2001d)

Description : A massive landslide occurred on an old cut slope which had a history of instability. The failure resulted in the complete closure of Route Twisk for several weeks.

Plate 7 - Route Twisk Opposite the Lookout Point, near Shek Kong (FMSW, 2001a)



Description : A massive landslide occurred on a cut slope which was previously designed to the required geotechnical standards. Significant signs of distress and slope movement were observed several months prior to the landslide. The failure resulted in the complete closure of Tsing Yi Road for 6 weeks and the landslide debris affected a taxi and a lorry.

Plate 8 - Tsing Yi Road, Tsing Yi Island (FMSW, 2001c)

Description : Two major landslides occurred within the same local catchment of the hillside. One of the failures involved unregistered end-tipped fill while the other involved natural terrain. Debris from both landslides became channelised in an ephemeral stream course and was transported to Victoria Road.

Plate 9 - Vocational Training Centre Pokfulam Skills Centre, Pokfulam Road (FMSW, 2001b)

APPENDIX A

RAINFALL IN 1999

A.1 RAINGAUGE SYSTEM

The GEO, in cooperation with the HKO, operates a network of automatic raingauges. The raingauges transmit real-time rainfall data via telephone lines to HKO and GEO at five-minute intervals. The system was upgraded substantially during 1999 and, at the end of the year, comprised 86 GEO rainguages and 24 HKO rainguages. The locations of the rainguages are shown in Figure A1.

A.2 RAINFALL IN 1999

The annual rainfall recorded at the HKO in 1999 was 2,129 mm, which is close to the average figure of 2,214 mm. The cumulative annual rainfall during the year at the HKO is shown in Figure A2.

A.3 RAINSTORMS

There were 20 significant rainstorms (defined as those in which the rolling 24-hour rainfall exceeded 50 mm anywhere in Hong Kong) during 1999. Of these, two caused the Landslip Warning to be issued. Table A1 provides details of these events. Figures A3 and A4 show isohyets of the maximum rolling 24-hour rainfall during these two storms, with the locations of associated landslides.

LIST OF TABLES

Table A1 - Rainstorms Causing the Landslip Warning to be Issued in 1999

Date	Landslip Warning in Force	Max. Rolling 24-hour Rainfall Anywhere in Hong Kong	Max. Rolling 24-hour Rainfall at HKO	No. of Major Landslides	No. of Minor Landslides	Total No. of Landslides
22-26 Aug 1999	1999/8/22 21:45 to 1999/8/24 13:45 1999/8/25 03:50 to 1999/8/26 05:50	565	303	51	224	275
16-17 Sep 1999	1999/9/16 06:10 to 1999/9/17 09:50	384	274	2	25	27

Note: Only genuine landslides are included. The number of landslides attributed to each storm includes those reported to have occurred during Landslip Warning and the following two days.

LIST OF FIGURES

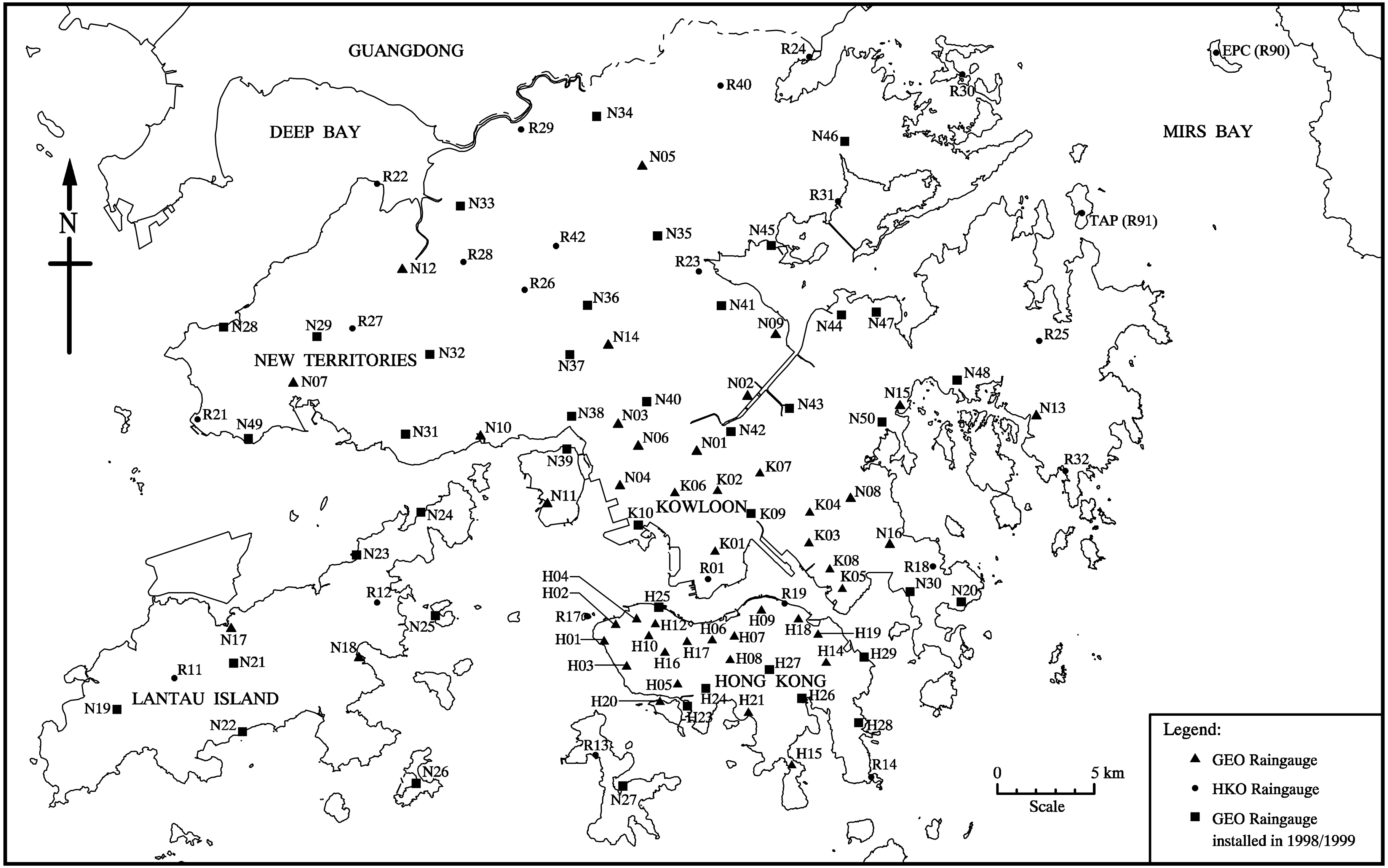
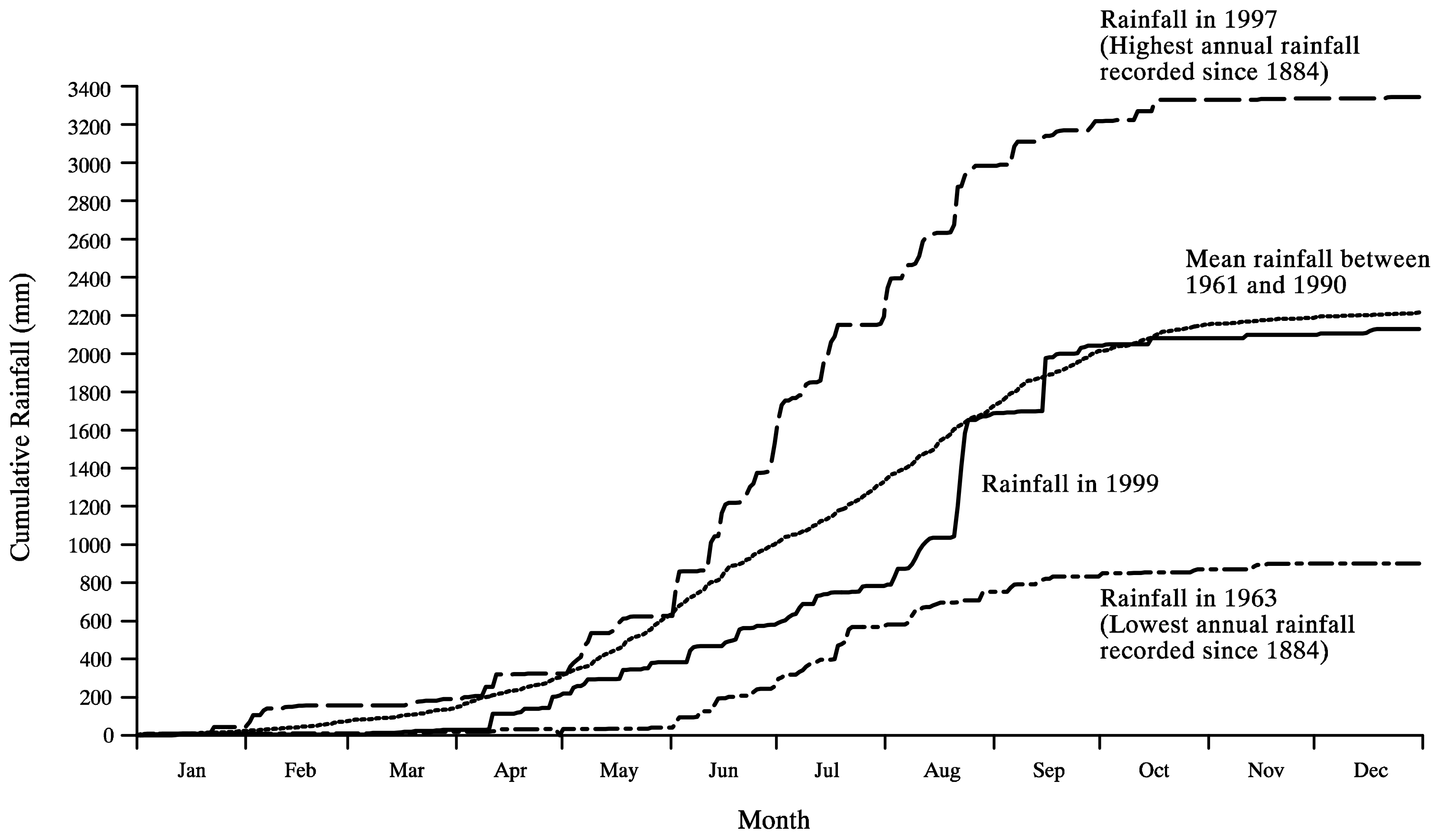
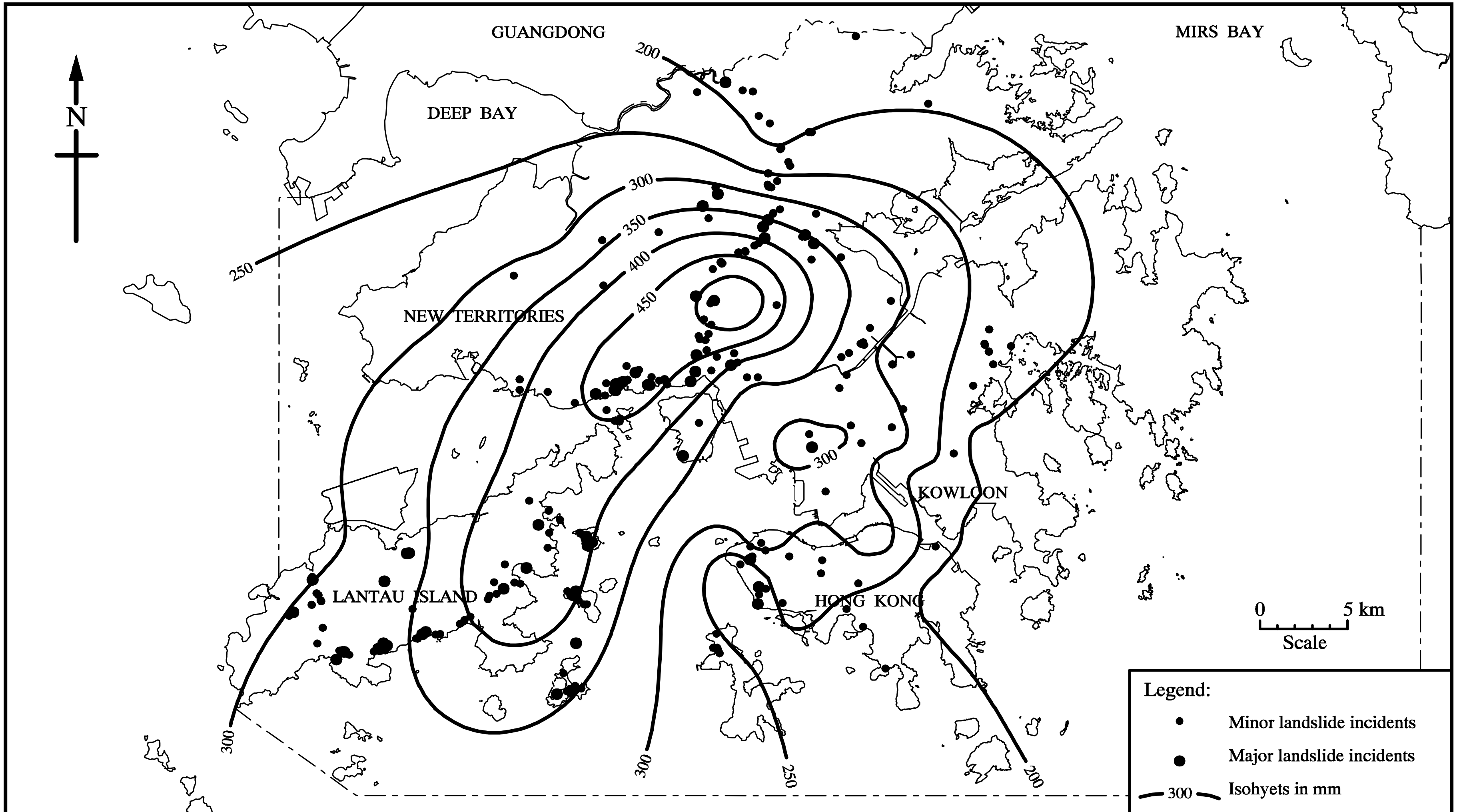


Figure A1 - GEO and HKO Automatic Raingauges (Since October 1999)



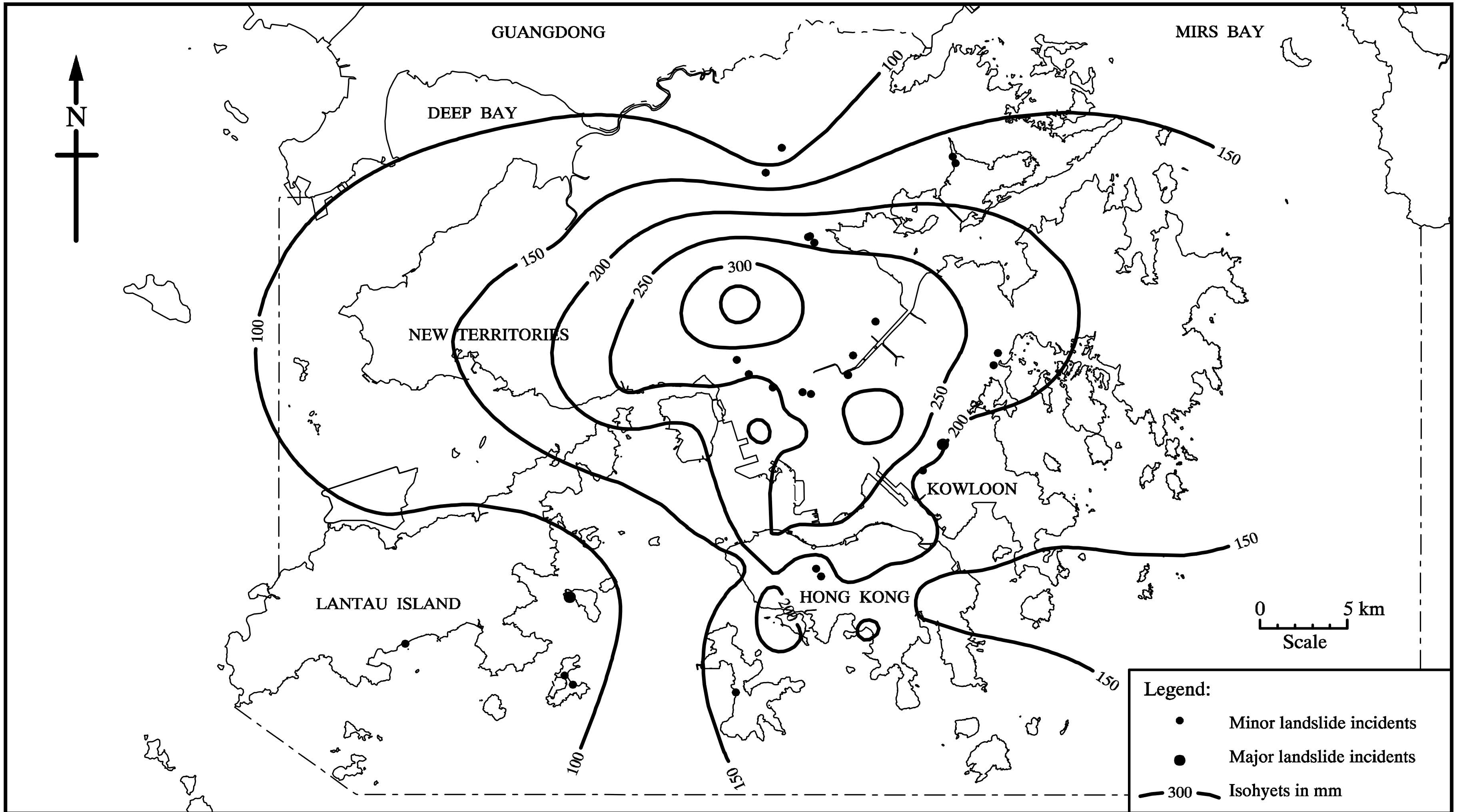
Note: Rainfall recorded at the Hong Kong Observatory, Tsim Sha Tsui.

Figure A2 - Cumulative Rainfall for 1999 and Recorded Highest, Mean and Lowest Cumulative Rainfalls



Notes:
(1) Isohyets are prepared based on all the GEO raingauges and the raingauge at Hong Kong Observatory.
(2) Genuine landslides reported to have occurred within the period between 22 August 1999 and 28 August 1999 (275 nos.) are shown.

Figure A3 - Maximum Rolling 24-hour Rainfall Distribution for the Period between 00:00 22 August 1999 and 23:55 26 August 1999 and Locations of Landslides



Notes: (1) Isohyets are prepared based on all the GEO rainguages and the raingauge at Hong Kong Observatory.
(2) Genuine landslides reported to have occurred within the period between 16 September 1999 and 19 September 1999 (27 nos.) are shown.

Figure A4 - Maximum Rolling 24-hour Rainfall Distribution for the Period between 00:00 16 September 1999 and 23:55 17 September 1999 and Locations of Landslides