

## Landslide Studies by the Geotechnical Engineering Office

**Key Message:** Systematic studies of landslides by the GEO improve the understanding of slope failures in Hong Kong, provide new ideas for reducing landslide risk and innovative design of slopes, and assist in the Government's Landslip Prevention and Mitigation Programme (LPMitP) by identifying areas for improved practice in slope design, construction and maintenance.

### Introduction

Since the early 1980s, the Geotechnical Engineering Office (GEO) has been collecting data and conducting annual reviews of rainfall and landslides in Hong Kong. Landslides were selected for detailed study, on the basis either of their serious nature or for purposes of advancing the understanding of landslides in Hong Kong.

Professor N R Morgenstern of the University of Alberta was engaged by the Government to carry out an independent review of the 23 July 1994 Kwun Lung Lau landslide. One of Professor Morgenstern's recommendations was for the Government to supplement its Landslip Preventive Measures (LPM) Programme by a process that involves a more integrated stability assessment through review of landslides. A new landslide investigation (LI) methodology was subsequently developed, which was tested in a three-year trial implementation from 1996 to 1999 and was found to be useful. Starting from 2000, landslide investigation work has become part of the LPM Programme to make the best use of the investigation results and supplement the conventional, catalogue-based slope stability assessment process. Systematic LI continues to form an integral part of the LPMitP, which was launched in 2010 to dovetail with the LPM Programme upon its completion in that year.

### Benefits and Arrangement of Landslide Investigations

The benefits of systematic landslide investigations include:

- (i) identification of slopes in need of early attention under the LPMitP and review of earlier studies,
- (ii) provision of forensic evidence in cases of landslides that may involve coroner's inquest, legal action or financial dispute,
- (iii) provision of data for reviewing the performance of Government's slope safety system and identifying areas for improvement, and
- (iv) improvement in knowledge on the causes and mechanisms of landslides in Hong Kong so as to formulate new ideas for reducing landslide risk and enhancing the reliability of landslide preventive/remedial works.

On average, about 300 landslides are reported to the GEO every year. All landslides reported

to the GEO are examined and screened in order to identify cases that warrant follow-up study. Worthy cases are studied in detail to document the failure and relevant background information, establish the probable causes, and identify the necessary follow-up actions, for example, arranging out-of-turn investigations and any necessary upgrading works at the landslide site and any adjoining areas with generic instability problems.

There are dedicated resources in the GEO (i.e. Landslip Preventive Measures Division 2) to coordinate the work on landslide investigations. The Landslip Preventive Measures Division 2 carries out an overall diagnosis of the landslide data and findings from landslide studies yearly to consolidate experience and make recommendations to enhance slope engineering practice in Hong Kong.

The GEO continues to undertake in-house investigations of selected landslides. For example, investigation of significant landslides may be carried out by the Landslip Preventive Measures Division 2, the Standards and Testing Division or the Planning Division. Input to landslide investigations is also provided by the Hong Kong Geological Survey through provision of specialist geological advice, by the Geotechnical Projects Division through provision of ground investigation services and by the Standards and Testing Division through provision of laboratory testing services. However, in-house resources are insufficient to study all the slope failures and assistance from consultants is needed. The use of consultants also provides a mechanism for external independent review.

Two consultants have been engaged to assist in landslide investigations, with one covering Hong Kong Island and outlying islands and another covering Kowloon and the New Territories. Both consultants can mobilise large teams of experienced and dedicated geotechnical engineers who are on standby round the clock. The investigation teams can also be backed up by overseas landslide experts where necessary. For cases involving conflict of interest by the LI consultants concerned, provisions have been made in the consultancy agreements for the other term LI consultants to carry out the investigation.

### **Output of Landslide Investigations**

Over the years, the GEO has undertaken detailed landslide studies and forensic investigations using in-house teams. Completed forensic investigations include the fatal landslides at Baguio Villa and Kennedy Road of 8 May 1992, the fatal landslide at Cheung Shan Estate of 16 June 1993, the fatal landslide at Kwun Lung Lau of 23 July 1994, the fatal landslide at Castle Peak Road of 7 August 1994, and the fatal landslides at Fei Tsui Road and Shum Wan Road of 13 August 1995. A few detailed landslide studies with public interest are the Shatin Heights landslide on 20 August 2005 and the Ting Kok Road landslide in June 2008 etc.

Notable examples of work completed under the LI consultancies to date include about 1 350 landslide inspections (out of more than 6 000 records examined), about 235 detailed landslide studies, and nine forensic investigations, namely the fatal landslides at Kau Wa Keng and Ten Thousand Buddhas' Monastery on 4 June 1997 and 2 July 1997 respectively, the Ching Cheung Road landslide on 3 August 1997, the fatal debris flow at Sham Tseng San Tsuen on 23 August 1999, the Shek Kip Mei landslide on 25 August 1999, the fatal landslides at Fu Yung Shan Tsuen and Cafeteria Old Beach on 20 August 2005 and 7 June 2008 respectively, and the two Sau Mau Ping landslides on 22 May 2013.

The GEO, with the assistance of the LI consultants, has carried out several major reviews of batches of old slopes of potential concern, detailed mapping of natural terrain landslides with long runout, assessment of residual risk for significant natural terrain landslides to facilitate review of the adequacy of the urgent mitigation measures, annual diagnostic reviews of landslides since 1997, compilation of landslide statistics, and updating of the landslide database within the GEO's Slope Information System and the Enhanced Natural Terrain Landslide Inventory.

Examples of technical and system improvements arising from landslide investigations in recent years include input to the drafting of the GEO Publication No. 1/2007 – Engineering Geological Practice in Hong Kong, improved guidelines for the GEO Emergency Manual on landslide inspections, and promulgation of lessons learnt to enhance the slope engineering practice through GEO Technical Guidance Notes. Areas of improved technical knowledge on landslide prevention and mitigation include slope deformation prior to landsliding, mobility of landslide debris, mechanisms of natural terrain landslides, potential impact of climate change and extreme rainfall on landsliding, and effective landslide mitigation measures.

Reports on all forensic investigations have been published and made available to the geotechnical profession. The detailed landslide investigations are documented in a series of Landslide Study Reports (LSR) and Special Project Reports (SPR). Up to the end of December 2021, 181 LSR and 36 SPR on landslide investigations have been issued. These are lodged in the Civil Engineering Library and are accessible by the general public. To further promulgate the study findings, selected study reports have been reprinted as GEO Reports, which are available on the CEDD website (<https://www.cedd.gov.hk>).

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