# DETAILED STUDY OF THE 28 NOVEMBER 2002 ROCKFALL ABOVE YIP HING STREET, WONG CHUK HANG

**GEO REPORT No. 164**

**Halcrow China Limited**

**GEOTECHNICAL ENGINEERING OFFICE**
**CIVIL ENGINEERING AND DEVELOPMENT DEPARTMENT**
**THE GOVERNMENT OF THE HONG KONG**
**SPECIAL ADMINISTRATIVE REGION**

# DETAILED STUDY OF THE 28 NOVEMBER 2002 ROCKFALL ABOVE YIP HING STREET, WONG CHUK HANG

**GEO REPORT No. 164**

**Halcrow China Limited**

**This report was originally produced in October 2003 as GEO Landslide Study Report No. LSR 9/2003**

First published, May 2005

Prepared by:

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

Table of Contents

Table of Contents

Table of Contents

# PREFACE

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

The Geotechnical Engineering Office also produces documents specifically for publication. These include guidance documents and results of comprehensive reviews. These publications and the printed GEO Reports may be obtained from the Government's Information Services Department. Information on how to purchase these documents is given on the last page of this report.

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

# FOREWORD

This report presents the findings of a detailed study of a rockfall incident (GEO Incident No. 2002/11/0164) which occurred in the afternoon of 28 November 2002, from the hillside above a 36 m high cut slope at Yip Hing Street, Wong Chuk Hang, Hong Kong. The rock block involved in the incident was about 0.2 $m^3$ in volume. The rockfall resulted in minor injury to the driver in a vehicle parked at the slope toe. The incident also resulted in damage to two vehicles and the temporary closure of part of Yip Hing Street.

The key objectives of the detailed study were to document the facts about the incident, present relevant background information and establish the probable causes of the failure. Recommendations for follow-up actions are reported separately.

The report was prepared as part of the 2002 Landslide Investigation Consultancy for the Geotechnical Engineering Office, Civil Engineering Department, under Agreement No. CE 86/2001 (GE). This is one of a series of reports produced during the consultancy by Halcrow China Limited.

Dr X D Pan
Project Director
Halcrow China Limited

Agreement No. CE 86/2001 (GE)
Study of Landslides Occurring in Hong Kong Island and Outlying Islands in 2002 – Feasibility Study

CONTENTS

## 1. INTRODUCTION

At about 2:30 p.m. on 28 November 2002, a rockfall (GEO Incident No. 2002/11/0164) occurred from the hillside located below the Bennet's Hill Lower Catchwater (BHLC) and above the crest of cut slope No. 11SW-D/C639 at Yip Hing Street, Wong Chuk Hang (see Figure 1 and Plates 1 and 2). The rock block involved in the incident (Plate 3) measured 0.7 m by 0.8 m by 0.4 m (about 0.2 $m^3$) and landed on Yip Hing Street. The impact of the detached rock block on the ground caused it to break up into several smaller fragments of flyrocks. Two vehicles that were parked along Yip Hing Street were hit by the flyrocks and the driver in one of the vehicles was slightly injured by shattered glass of the vehicle (Plate 4). A portion of the western end of Yip Hing Street was temporarily closed following the incident.

The rockfall involved a single rock block that fell from the hillside at an elevation of about 85 mPD. The rock block travelled (bounced and rolled) over the hillside along an approximately linear path towards the crest of slope No. 11SW-D/C639. The rock block bounced down the slope, impacting the hard surface cover of the slope and the berms as it descended, before coming to rest on Yip Hing Street at the slope toe at an elevation of 35.3 mPD (see Figure 2 and Plate 2).

Following the incident, Halcrow China Limited (HCL), the 2002 Landslide Investigation Consultants, carried out a detailed study of the landslide for the Geotechnical Engineering Office (GEO) of the Civil Engineering Department (CED), under Agreement No. CE 86/2001 (GE).

The key objectives of the detailed study were to document the facts about the incident, present relevant background information and establish the probable causes of the rockfall. Recommendations for follow-up actions are reported separately.

This report presents the findings of the detailed study, which comprised the following key tasks:

(a) a review of relevant documentary records relating to the history of the site,

(b) detailed observations and measurements at the landslide site,

(c) aerial photograph interpretation (API),

(d) interviews of eye-witnesses,

(e) review of rainfall data, and

(f) diagnosis of the probable causes of the incident.

## 2. THE SITE

### 2.1 Site Description

A site location plan is shown in Figure 1. The site is a south-facing hillslope on the

southern flank of Bennet's Hill (summit elevation of 214 mPD). The BHLC cuts across the site at about the mid-height of the hillslope, and is situated at an elevation of about 90 mPD. The natural hillside above and below the BHLC is predominantly densely vegetated and is inclined at about 30°. The footpath along the BHLC had recently been paved with concrete between September and November 2002 (see Section 4). The footpath has an access close to its western end via an old granite/concrete paved footpath of about 400 m long from the service road of the Aberdeen Lower Reservoir (Figure 1). At the eastern end of the BHLC, the existing minor unpaved footpath continues about 400 m before reaching a road.

The probable source area for the rock block involved in the incident based on field inspection (see Section 5.2) is identified to be an area with a small accumulation of rock blocks that lie on the hillside located below the southern side of the BHLC (Figure 2). The hillside below the BHLC is densely vegetated and at an overall angle of about 30°, extends about 12 m (vertical) to the crest of slope No. 11SW-D/C639.

Slope No. 11SW-D/C639 is a soil/rock cut slope of about 40 m in height and about 50 m in length with the slope toe extending to Yip Hing Street at an elevation of 35.3 mPD. A plan of slope No. 11SW-D/C639 and the natural hillside above is shown in Figure 2 with general view photographs shown in Plates 1, 2 and A1. The cut slope comprises four berms and five slope batters. Berms vary in width between 1.5 m and 3 m and slope batters vary in height between 5 m and 7 m. Slope angles vary between about 60° and sub-vertical at the lower two batters which comprise rock cut with shotcrete cover in places. The upper three slope batters are inclined at about 40°, have a shotcrete cover and are predominantly soil cut.

Cut slope No. 11SW-D/C1019 is located at the northern side of the catchwater, above and opposite the probable source area of the rockfall (Figure 2). Slope No. 11SW-D/C1019 is a predominantly rock cut comprising a single slope batter of about 4.5 m in height and about 100 m in length with a slope angle of about 75°.

The southern (downhill) side of the BHLC, in the vicinity of the rockfall incident, comprises a small fill slope of about 2 m to 3 m in height that forms part of an embankment for the catchwater.

## 2.2 Geology

Sheet 11 of the Hong Kong Geological Survey 1:20 000 scale map series HGM20 (GCO, 1986) indicates that the solid geology in the vicinity of the study area is fine ash vitric tuff and in the surrounding area comprises eutaxite (tuff) to the east and west of slope No. 11SW-D/C639 and medium grained quartz syenite to the south.

## 2.3 Water-carrying Services

Records from the Water Supplies Department (WSD) indicate that no water-carrying services are present on the hillside above the crest of slope No. 11SW-D/C639 other than the catchwater channel.

### 2.4 Maintenance Responsibility

According to the Lands Department, the natural hillside between the BHLC and slope No. 11SW-D/C639 is unallocated government land (Green Belt) and is under the maintenance responsibility of the Lands Department.

Based on records obtained from the WSD, the BHLC and its accesses are maintained by the WSD.

According to the Slope Maintenance Responsibility Information System (SMRIS) of the Lands Department, slope No. 11SW-D/C1019 is under the maintenance responsibility of the WSD and slope No. 11SW-D/C639 is under the maintenance responsibility of the Highways Department (HyD).

## 3. SITE HISTORY AND PREVIOUS STUDIES

### 3.1 General

The site history has been established from a review of aerial photographs and inspection of the available documentary records. A detailed account of the aerial photograph interpretation (API) is presented in Appendix A.

### 3.2 Site History

Records in the GEO and in the Buildings Department (BD) indicate that the BHLC was constructed by the Public Works Department in the 1930's under Public Works Department (PWD) contract No. 23/1932.

As seen in the high altitude 1949 aerial photographs (Plate A2), the natural hillside above the catchwater was densely vegetated. The vegetation is possibly planted trees, as a probable fire break is observed on the hillside above the catchwater. Below the catchwater the south-facing natural hillside was crossed by an east-west trending footpath and a north-south trending footpath. The 1949 aerial photographs also show that the BHLC, in the vicinity of the probable source area of the rockfall, is supported by a small (2 m to 3 m high) fill embankment, which on its southern (downhill) side appears to comprise a bouldery material. Two north-south trending boulder accumulations are visible, which are probably related to the construction of the rock cut slopes along the catchwater (Figure 2). One of the boulder accumulations lies approximately at the future location of the crest of slope No. 11SW-D/C639 and the other about 80 m east of this location. Individual boulders (typically less than 1 m across, and possibly of natural origin) also appear to be strewn across the hillside.

The hillside below the BHLC was developed in stages from the early 1960's to the 1990's to form Yip Kan Street and Yip Hing Street and associated buildings. In the 1967 aerial photographs, a probable landslide scar (observed as a light patch with a teardrop shape in plan) was observed on the hillside above the catchwater, with associated landslide debris deposited on the hillside below the catchwater (Plate A5).

In the early 1980's, slope No. 11SW-D/C639 was formed by the private developer as part of the site formation for Lot No. AIL 399 and construction of Yip Hing Street (Plate A3). Between 1980 and 1983 the lower three batters of slope No. 11SW-D/C639 were formed and a strip of vegetation, approximately 4 m in width, was cleared from the hillside surrounding the slope boundary (Plate A4). The vegetation clearance exposed several boulders and bare soil, notably on the hillside in the area above the northeastern end of the slope. In 1983, slope No. 11SW-D/C639 was cut further to form the current profile. The probable source area of the November 2002 rockfall above slope No. 11SW-D/C639 remained largely undeveloped.

A possible landslide scar was observed in the 1984 aerial photographs (Plate A5) near cut slope No. 11SW-D/C1019 along the northern side of the catchwater. The south-facing 58 m high (about 23 m above and 35 m below the level of Yip Hing Street) cut slope No. 11SW-D/C2087 (Figure 2), adjacent to the western lower end of cut slope No. 11SW-D/C639, was formed between 1998 and 1999. Between 1999 and 2002 the site remained essentially unchanged.

Prior to the recent improvement works for the catchwater in 2002 by WSD, an unpaved footpath ran along the southern side of BHLC. Between September and November of 2002, vegetation was cleared from the southern side of the catchwater, over a length of about 700 m, to form a 1 m wide footpath which was subsequently paved with concrete.

### 3.3 Previous Slope Assessments and Upgrading Works

No records of the original formation of the slopes along the 70 years old BHLC were found. Slopes Nos. 11SW-D/C1019, 11SW-D/C1022 and 11SW-D/C1030 were identified and registered under the GEO's "Systematic Inspection of Features in the Territory" (SIFT) project and were categorised as "Class C1" features, i.e. cut features "Assumed formed pre-1978 or illegally formed". These three slopes were inspected under the GEO's "Systematic Identification and Registration of Slopes in the Territory" (SIRST) project in November 1995 by the consultant. Open joints with loose blocks were identified during the inspections of slopes Nos. 11SW-D/C1019 and 11SW-D/C1022. A minor overhang was also observed during the inspection by the SIRST consultant near the slope toe at the western portion of slope No. 11SW-D/C1019.

Record files in BD indicate that a site formation proposal for Lot No. AIL 399 including formation of slope No. 11SW-D/C639 and geotechnical reports prepared by Fugro (HK) Limited were submitted to and approved by BD in December 1979. The geotechnical reports contain no information relating to the natural hillside, as well as the catchwater, above the crest of slope No. 11SW-D/C639.

In 1995, slope No. 11SW-D/C639 was registered under the SIFT and SIRST projects and categorised as a "Class C2" feature, i.e. "formed post-1977". The field inspection carried out as part of the SIRST project noted only "minor cracks" on the slope surface and that the U-channels were partially blocked. No observation was recorded regarding the condition of the hillside above the slope crest.

Maunsell Geotechnical Services Ltd. (MGSL) carried out a boulder study (entitled

"Territory Wide Quantitative Risk Assessment of Boulder Fall Hazards") for the whole of Hong Kong (MGSL, 2001). The MGSL study, which relies primarily on API to locate the boulder fields, indicates that the presence of boulders on the hillside between the catchwater and the crest of slope No. 11SW-D/C639 could not be verified by means of API due to the dense vegetation on the hillside. Therefore, an assessment of the boulder fall hazard in this area was not carried out under the study.

### 3.4 Past Instability

There are no documentary records of previous instability (rockfall, boulder fall or landslide) from the hillside of concern and no instability was noted from the available aerial photographs.

### 3.5 Previous Ground Investigation

Previous ground investigation works comprising boreholes (in 1979) and trial pits (in 1983) were undertaken in connection with the formation of slope No. 11SW-D/C639. There are no records of ground investigation on the hillside of concern above slope No. 11SW-D/C639.

## 4. MAINTENANCE WORKS

### 4.1 Maintenance of Slopes along the Catchwater

In August 1998, WSD appointed Greg Wong & Associates Limited under Agreement No. CE 68/97 to carry out an "Engineer Inspection" (EI) and prepare a Maintenance Manual (MM) for slope No. 11SW-D/C1019. A stability assessment of the slope was recommended in the EI and minor works, including removal of loose rock blocks from the slope surface was recommended as routine maintenance works and the application of shotcrete to the eroded areas as preventive maintenance.

Loose rock blocks shown in the MM, prepared as part of the EI, were located towards the eastern end of the slope, which is not directly above the natural hillside between the BHLC and the crest of slope No. 11SW-D/C639. There was no record of removal of the loose rock blocks from the slope but during an inspection by HCL in January 2003, it was noted that the rock blocks shown in the photographs in the EI were no longer present and had presumably been removed as recommended.

In August 2000, September 2001 and October 2002, WSD carried out routine maintenance inspections (RMI) of slope No. 11SW-D/C1019. According to the RMI reports prepared as part of these inspections, no maintenance works were required.

### 4.2 Recent Construction along BHLC

Since September 2002, construction works along the catchwater have been carried out by the contractor, Chun Wo Construction and Engineering Company Limited under WSD

Contract No. 1/WSD/00(1), "Improvement to Remaining Catchwater of Aberdeen Reservoir Group, Bennet's Hill Lower Construction". The site works were supervised by WSD staff, with one full-time Works Supervisor, one Assistant Inspector of Works and an Inspector of Works. The improvement works comprised construction of a 700 m long and 1 m wide concrete footpath along the BHLC (Figures 2 and 3), and re-construction of two overflow weirs at the southern side of the catchwater (Figure 1). The construction of the concrete footpath required excavation of the existing ground to a depth of 150 mm and therefore involved the excavation of about 100 $m^3$ of material (i.e. 700 m long by 1 m wide by 0.15 m depth).

According to WSD the Contractor was only required to remove materials that had been excavated under the Contract, i.e. those existing rock blocks outside the excavation area would not be removed and would therefore, presumably, remain on site. Since much of the excavation works were of a minor nature, there was no specific contractual requirement for the Contractor to follow or implement any 'trip-ticket' or similar system for disposal of the excavated material. No records were kept of the quantities, the timing or the source of the excavated materials prior to removal from site. As advised by WSD, the excavated material was usually removed off site by the Contractor on a daily basis or otherwise stockpiled on a flat area in a safe manner. According to the resident site staff of WSD, the majority of the excavated material was noted to be soil and not more than five rock blocks removed off site had dimensions greater than 300 mm in size. In September 2002, a large rock boulder ("size would almost fit into the catchwater") was observed by WSD's resident site staff, in the catchwater channel towards the western end of the catchwater (about 300 m from the probable source of the 28 November 2002 rockfall), which was subsequently removed off site by the Contractor. The origin of the rock boulder is unknown and could have been a naturally-occurring boulder that fell from the hillside above BHLC.

## 5. THE INCIDENT

### 5.1 General

The description of the 28 November 2002 rockfall incident is based on information in the Police Incident Report and the GEO Incident Report (No. 2002/11/0164), together with interviews with eye-witnesses.

According to the eye-witnesses, the rockfall incident occurred at about 2:30 p.m. on 28 November 2002 during relatively dry weather. The incident involved a rock block of about 0.2 $m^3$ in volume (Plate 3), that fell from the hillside above slope No. 11SW-D/C639 and bounced over the slope surface before coming to rest at about 6 m from the slope toe. The impact of the rock block on the ground generated several smaller fragments of flyrocks. One of the rock fragments smashed through the side window of a vehicle (Car A) which was parked near the toe of slope No. 11SW-D/C639, about 15 m from the landing point of the rock block (see Figure 2, Plates 2 and 3). As a result, the driver of Car A, the only person in the vehicle, suffered slight injured on his right forearm because of the broken glass. The windscreen of another vehicle (Car B, see Figure 2), which was also parked at the slope toe about 6 m from the landing point of fallen rock block (see Figure 2 and Plate 2), was smashed through by another flyrock. At the time of the incident, there was no one in Car B. A portion of the western end of Yip Hing Street was temporarily closed following the incident.

5.2 Site Observations

Following the rockfall incident, HCL carried out a detailed field inspection of the site on 5 December 2002 and on several subsequent occasions. The rock block involved in the incident had been removed by the time of the inspection by HCL.

The natural hillside above cut slope No. 11SW-D/C1019 (Figures 1 and 2), for the most part, is densely vegetated with shrubs and trees and very few naturally-occurring boulders were observed.

An inspection of the rock (fine ash vitric tuff) cut slope (No. 11SW-D/C1019) uphill of the catchwater channel (see Figure 2 and Plate 5) did not reveal any freshly broken surfaces that might be signs of detachment of rocks. When compared with the WSD's record photograph taken in October 2002 (Plate 6), it would appear that the rock cut slopes had been recently cleared of unplanned vegetation. In the same record photograph, stockpiling of what appears to be material stored in white sacks can be seen along the downhill side of the footpath.

At the time of HCL's inspection on 5 December 2002, the catchwater access footpath had been cleared of the stockpiles and that the construction of the concrete-covered footpath to the south the catchwater had been completed for the section above the study hillside (Plate 5).

The catchwater has a 400 m long granite/concrete paved access path near the western end that was wide enough for a mechanical trolley to pass through from the service road of Aberdeen Lower Reservoir. Beyond the eastern end of the newly paved footpath along BHLC, the access track, which is narrow and unpaved, is covered with dense vegetation and inaccessible to the mechanical trolley. Hence, the only point of egress of spoil by means of a mechanical trolley from the ongoing WSD catchwater improvement contract would be through the western end of the access path.

The natural hillside below the catchwater and above the crest of slope No. 11SW-D/C639 is densely vegetated. There were no signs of major erosion of the surface of the hillside but much of the ground surface is covered with angular cobbles and boulders of tuff (Plate 7).

A few individual rock blocks observed on the hillside between the crest of slope No. 11SW-D/C639 and the catchwater access path (Figure 2) were likely to be of natural origin. These naturally-occurring rock blocks (typically 1 m to 2 m across) were embedded into the ground and showed signs of weathering related to exposure, and may simply have been protrusions of bedrock. There was no evidence on site to suggest that such naturally-occurring rock blocks or boulders were involved in the 28 November 2002 rockfall incident.

Site inspections identified the presence of several clusters of angular rock blocks resting on the ground surface of the hillside below the catchwater access footpath (see Figure 2). Detailed field mapping revealed that the clusters may be classified as comprising two different types of rock blocks that can be distinguished primarily by their surface appearance. One of the rock block types were older-looking with a weathered surface from

exposure (i.e. not related to degree of decomposition) and appeared to have been insitu for some time, while the younger-looking rock blocks had either no surface weathering or are generally less weathered on the surface and typically occur as small clusters of loose boulders or even as single boulders.

The older-looking of the two types of rock block clusters comprise smaller-sized angular blocks (about 300 mm by 200 mm by 100 mm in size with occasional individual blocks up to 1 m across), which have a weathered patina and lichen cover, suggesting that they have been deposited for quite some time (possibly several tens of years). In general, these older-looking rock block clusters are located (see Figure 2) closer to cut slope No. 11SW-D/C639 (i.e. further away from and downslope of the catchwater access path) as compared with the younger-looking rock block clusters.

The younger-looking rock block clusters that are closer to the catchwater access path comprise generally larger-sized rock blocks (about 250 mm by 300 mm by 400 mm in size whilst the individual blocks are up to 0.5 m across) of relatively limited areal extent, with fresh broken surfaces and no weathered patina and lichen cover (see Figure 2 and Plates 7 and 9). Several of these blocks have a soil coating that is yet to be washed off by rainwater and some isolated blocks were found to be resting on tree branches above the ground (Plate 8). The indications are that these younger-looking rock blocks had recently (within the last few months) been deposited on the hillside.

Some of the rock blocks, of both types, are located within an ephemeral drainage line, which is in turn near the outlet of one of the overflow weirs (see Figure 2 and Plate 9). The stability of these rock blocks, especially during extended periods of heavy rainfall, is uncertain.

It was noted that some of the rock blocks are perched on the ground surface in such a condition that they can be displaced by a certain distance (through rolling or sliding, or both) when stepped on by foot, depending on the orientation of the blocks, the local slope gradient, etc.

Detailed site inspections have identified recent impact marks in the form of damaged tree branches below a younger-looking rock block cluster on the hillside below the catchwater access footpath (see Figure 2 and Plate 11). It is not certain whether these impact marks were created by blocks other than the fallen rock block or not. Further downhill, other recent impact marks are also indicated by the presence of fresh rock flour and local loss of lichen cover on some of the older-looking rock blocks (see Plate 12). Downslope of the above older-looking rock block cluster, vegetation was observed to have been flattened along an essentially linear path that leads to the crest of cut slope No. 11SW-D/C639 (see Plate 13). The linear path is consistent/in-line with the impact marks observed on the hard cover and the berm slabs of the cut slope (Plates 14 and 15). No impact marks were observed on the catchwater channel and the catchwater access path. Based on the inspections, the likely trajectory of the fallen rock block, which is fairly well defined by the impact marks, is shown in Figure 2 and Plate 2.

The adjacent hillside below the catchwater access path about 60 m and 30 m to the east and west of the subject hillside respectively was inspected jointly by HCL, the Island Division and the Landslip Investigation Division of the GEO on 14 February 2003. Similar rock

blocks to those found within the subject hillside were observed on the adjacent hillside.

### 5.3 WSD Records

According to WSD, the excavation works for the construction of the footpath along BHLC above the probable source of the rockfall commenced in mid-October 2002 (Plate 6) and was completed by the end of October 2002. Since that time, the Contractor had worked on the eastern side of the probable source of the rock block involved in the incident. The concrete paving works were completed by 26 November 2002. A mechanical trolley was used to transport excavated materials off site, from the eastern end to the western end along the footpath, passing the section above the probable source of the 28 November 2002 rockfall. No accidents (e.g. falling off of materials carried by the mechanical trolley) above the probable source of the rockfall were noted by WSD during the construction period.

According to WSD there were no excavation works on the day of the incident (28 November 2002) and the weather was recorded as 'light rain'. On 28 November 2002, the Contractor was reported to have transported materials (type of material was not specified) to the works area and carried out cleaning of the works area (the section of the catchwater involved was not specified). No record was available to indicate when the material excavated from that section had been removed from site. According to WSD, no tipped or loose rock blocks were identified by their staff on the hillside below the catchwater nor was there any knowledge of any other rockfall incident since the commencement of the works.

## 6. RAINFALL RECORDS

The nearest GEO automatic raingauge (No. H05) to the Study Site is located at Aberdeen Treatment Works, Aberdeen Reservoir Road, about 620 m northwest of the natural hillside above slope No. 11SW-D/C639 (Figure 1). The daily rainfall records of rainguage No. H05 in the preceding month and 24 hours prior to the incident are presented in Figure 4. This shows that within the 31 days preceding the incident, about 29.5 mm of rainfall was recorded.

On the day of the incident, only about 2 mm of rainfall was recorded by rainguage No. H05 prior to the best estimate of the time of the incident (at about 2:30 p.m.) and there was no recorded rainfall in the 4½ hours before the incident. The highest daily rainfall within the 31 days preceding the incident was only 11 mm that occurred on 30 October 2002 (i.e. 29 days before the incident).

The total monthly rainfall recorded by raingauge No. H05 was 4.5 mm, 250.5 mm, 190.5 mm, 295 mm, 390 mm, 725 mm and 255 mm for the months of April to October respectively.

Overall, there was little rain immediately prior to the 28 November 2002 rockfall incident.

## 7. DIAGNOSIS OF THE PROBABLE CAUSES OF THE ROCKFALL INCIDENT

Site inspections of the impact marks along the probable runout path of the fallen rock block suggest that the source area of the 28 November 2002 rockfall is on the hillside below the catchwater access path and above the crest of cut slope No. 11SW-D/C639. Detailed field mapping suggests that the source of the fallen rock block was not a naturally-occurring boulder. The hillside is littered with abundant rock blocks that were probably deposited at different times, as reflected primarily by their surface appearance. Some of these rock blocks were probably tipped over the catchwater access path several tens of years ago based on API, which is corroborated by the condition of the rock surfaces. Site evidence indicates that the fallen rock block probably originated from a rock that was deposited on the hillside below the catchwater access path by human action.

There is some uncertainty as to the precise location of the source area of the 28 November 2002 rockfall. Whilst the impact marks are reasonably well defined, it is not known with confidence whether the fallen rock block was set in motion through impact by another rock block, or whether it moved, for whatever reason, in one go.

The 28 November 2002 rockfall was a surprise in terms of its timing as the incident occurred during the dry season. The nearest automatic raingauge, together with eye-witnesses, point to very little rainfall immediately preceding the failure. Also, there was no obvious sign of surface erosion on the hillside which has a small catchment. It would therefore appear that rainfall was unlikely to have been a direct trigger of the incident. The original condition of the fallen rock block is not known but site inspections of the remaining rock blocks indicate that they can be in a meta-stable state, which could be sensitive to external disturbances.

Given the uncertainties involved, one can only speculate the possible trigger mechanisms of the rockfall. It could be possible that the stability condition of the subject rock block has suffered progressive deterioration with time. This may involve intermittent displacement of any vegetation or other rock blocks (possibly of smaller sizes) providing toe support, during past heavy rainstorms. The fallen rock block is quite sizeable as compared to those remaining on the subject hillside and this may have contributed to a sufficient momentum being gained once the block was dislodged and set into motion. Other possibilities of trigger mechanisms or contributory factors could include human disturbance (such as trespassers along the hillside or further deposition of rock blocks onto the hillside resulting in impact loading or vibration). The possibility of a seismic related trigger is considered remote as this would otherwise have been expected to have triggered multiple rockfalls. Based on the available seismic records kept by the Hong Kong Observatory there was no seismic activity registered on the date of the rockfall incident, the possibility of the rockfall being triggered by an earthquake shock can be ruled out.

## 8. CONCLUSIONS

The 28 November 2002 rockfall incident, which resulted in the slight injury to one person and damage to two cars, involved the dislodgement of a rock block deposited on the steep natural hillside below the access path to the Bennet's Hill Lower Catchwater. There was practically no rainfall preceding the incident and hence rainfall was unlikely to have been

a direct trigger mechanism. There is much uncertainty with regard to the trigger mechanism of the rockfall that took place during the dry season and originated from a hillside that has no previous reported incidents of similar rockfalls or boulder falls based on the systematic landslide records that have been kept by the GEO since the early 1980's.

Possible trigger mechanisms or contributory factors in respect of the 2002 rockfall incident could include human disturbance or gradual destabilisation due to progressive deterioration of any toe support afforded to the subject rock block. The possibility of the rockfall being triggered by an earthquake has been considered but it can be ruled out.

## 9. REFERENCES

Geotechnical Control Office (1986). Hong Kong and Kowloon: Solid and Superficial Geology. Hong Kong Geological Survey, Map Series HGM 20, Sheet 11, 1:20 000 Scale. Geotechnical Control Office, Hong Kong.

Maunsell Geotechnical Services Ltd (2001). Territory Wide Quantitative Risk Assessment of Boulder Fall Hazards. Report prepared in association with ERM for the Geotechnical Engineering Office, Hong Kong.

LIST OF FIGURES

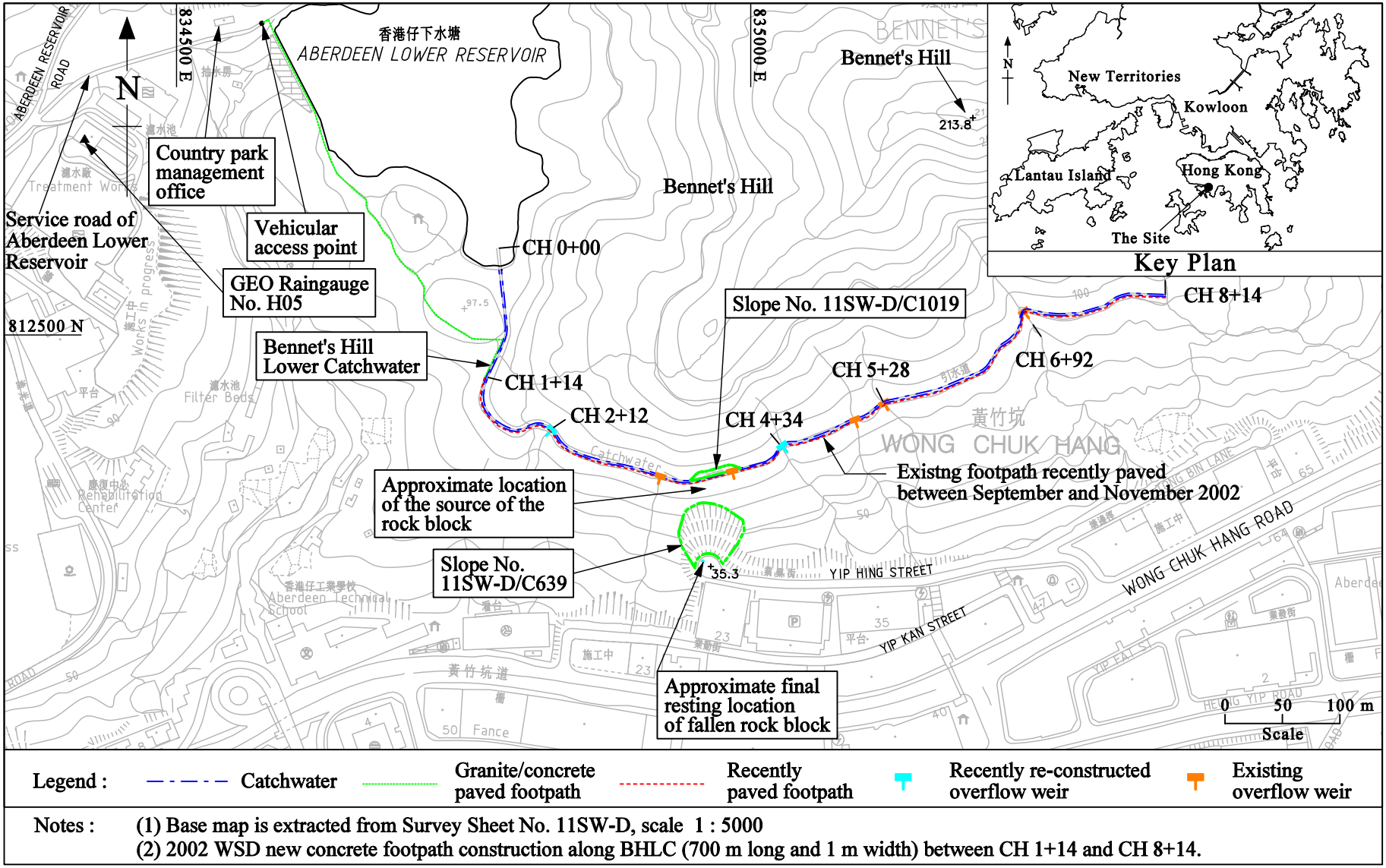



Figure 1 - Site Location Plan

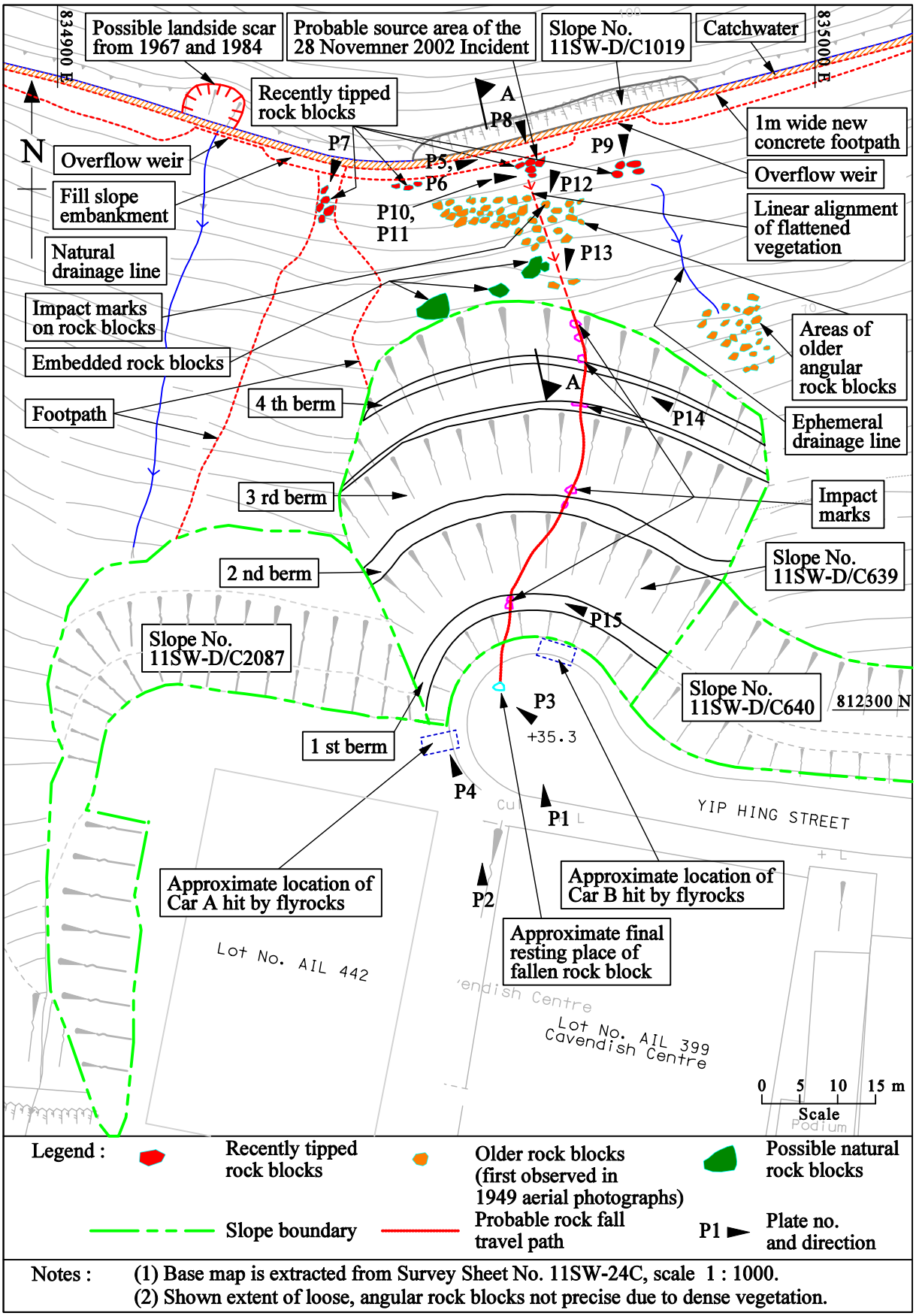



Figure 2 - Site Plan

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

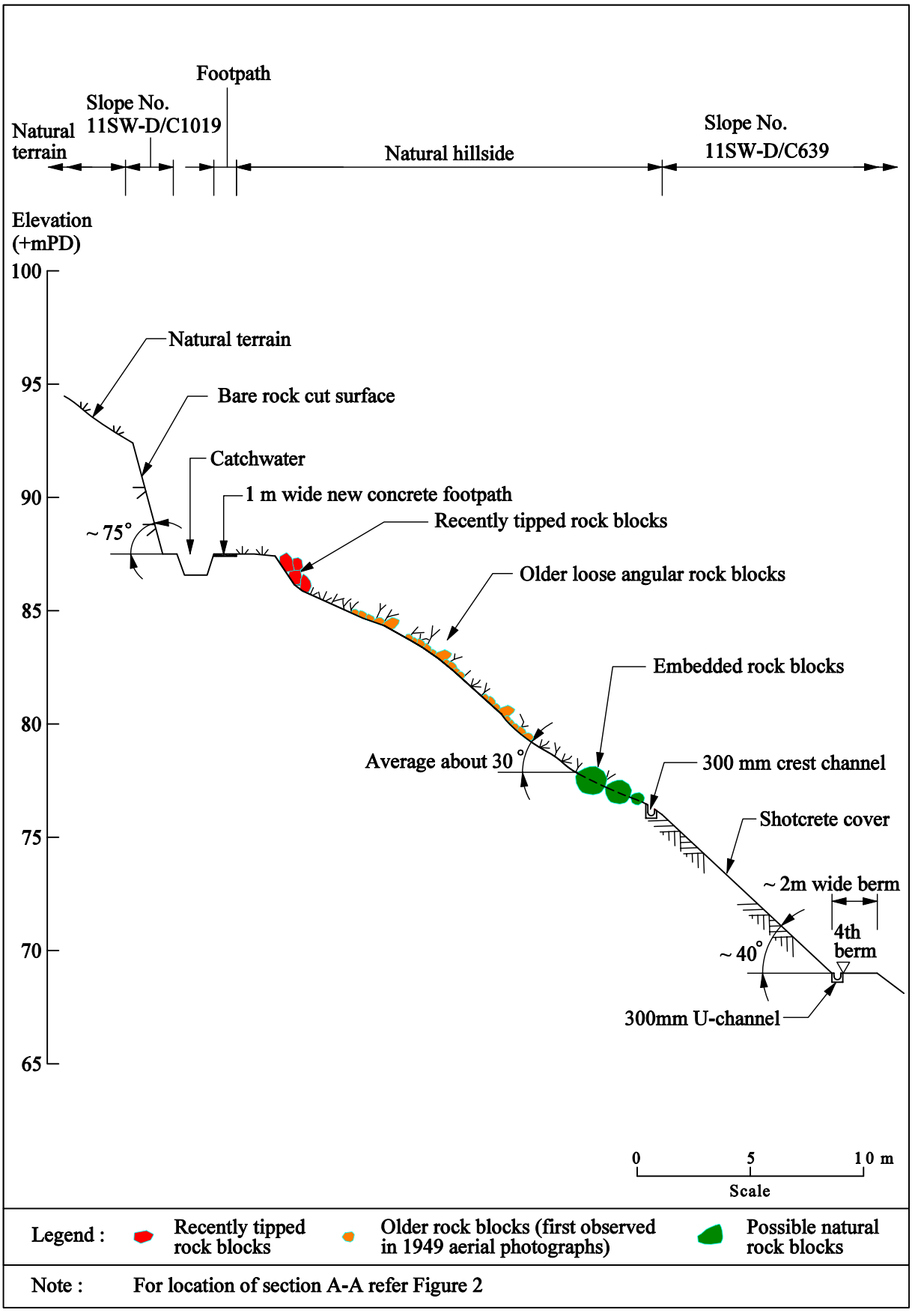
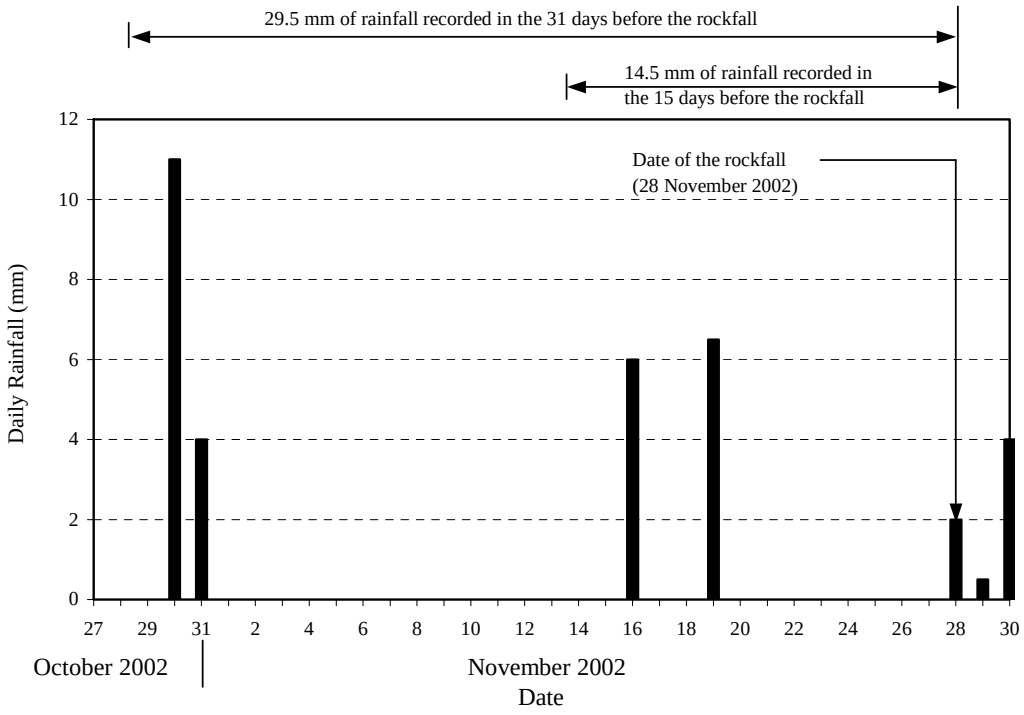
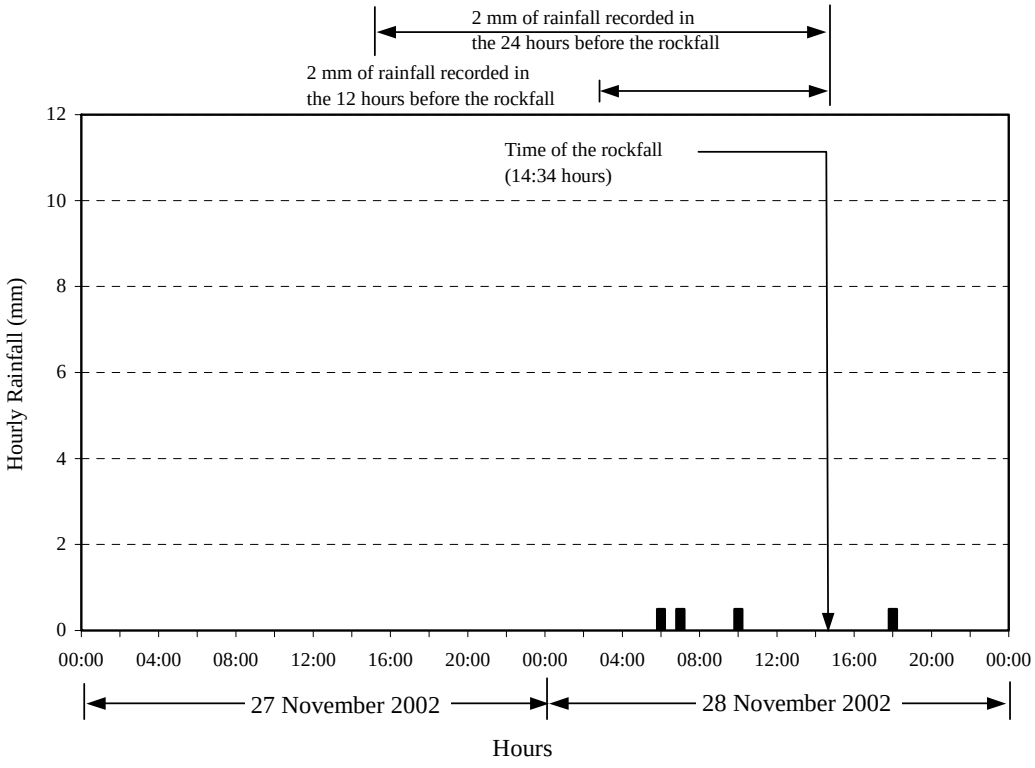



Figure 3 - Section A - A

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




(a) Daily Rainfall Recorded between 27 October and 30 November 2002




(b) Hourly Rainfall Recorded between 27 November and 28 November 2002

Figure 4 - Daily and Hourly Rainfall Recorded at GEO Automatic Raingauge No. H05 in November 2002

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

## LIST OF PLATES

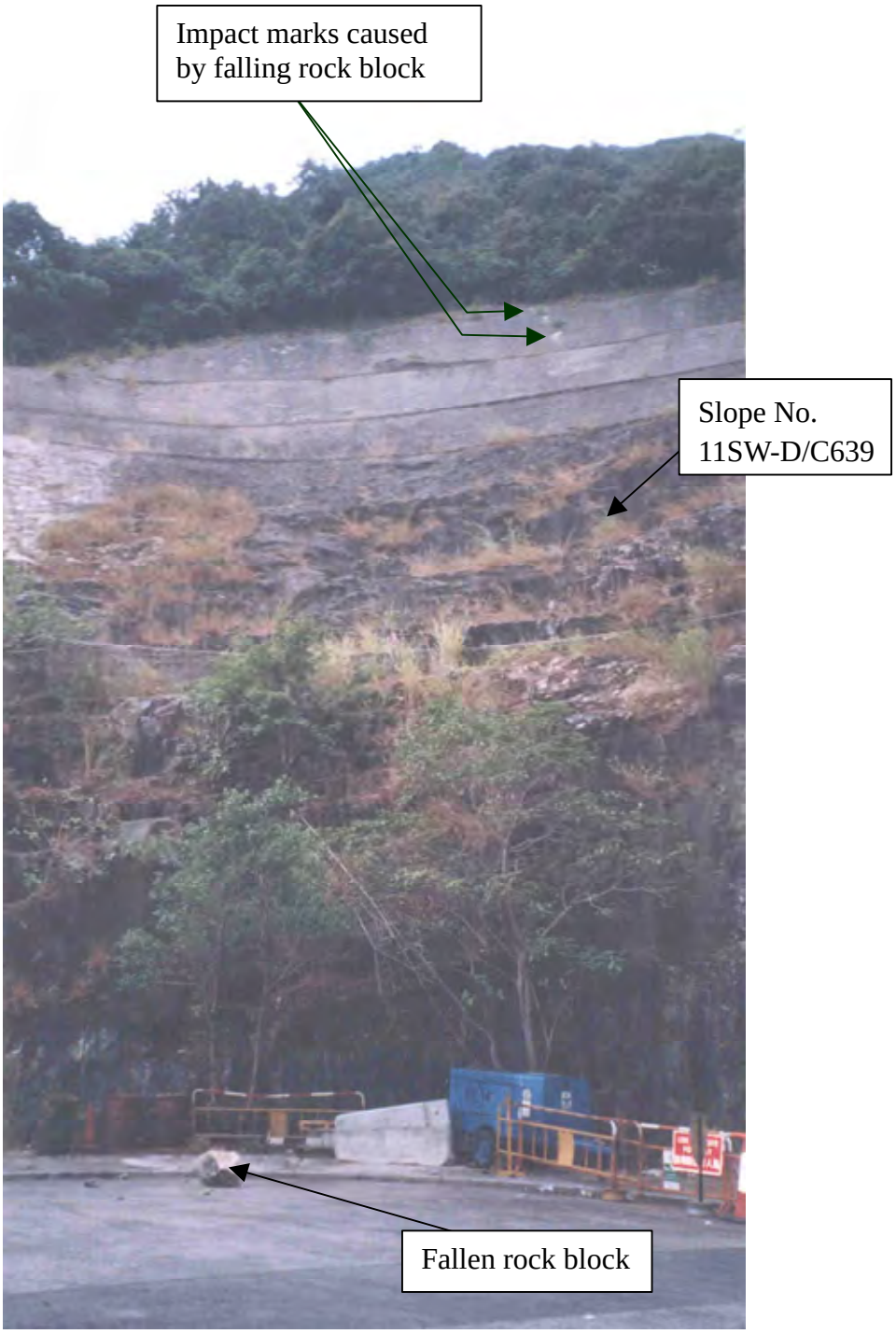



Plate 1 - View of Slope No. 11SW-D/C639 with the Fallen Rock Block at the Slope Toe (Photograph taken by GEO on 28 November 2002)

Notes: (1) See Figure 2 for location and direction of photograph.
(2) Close-up views of the rock block are shown in Plate 3.

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

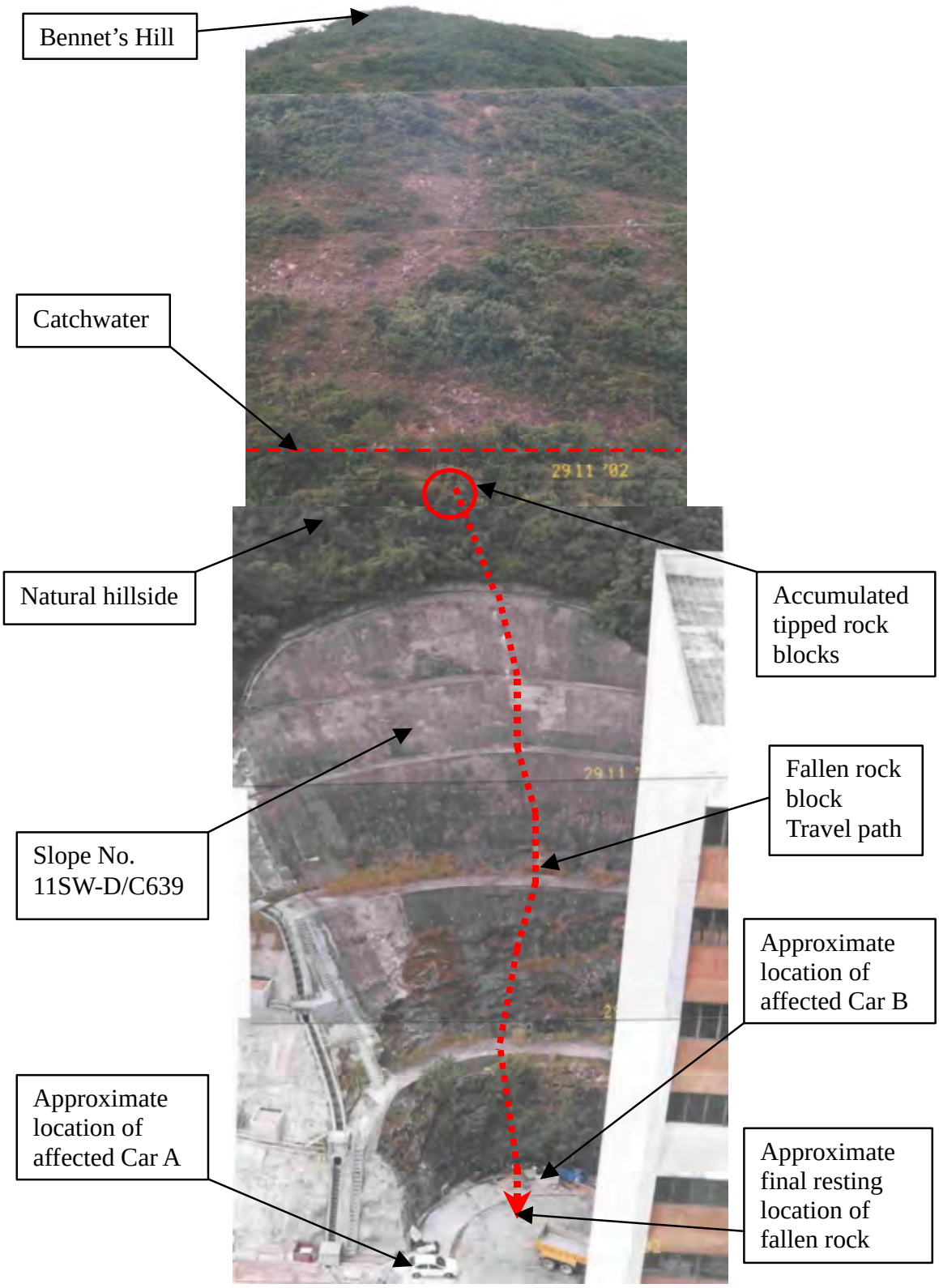



Plate 2 - A General View of the Path taken by the Fallen Rock Block
(Photograph taken by GEO on 29 November 2002)

Note: See Figure 2 for location and direction of photograph.

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

Plate 3 - Close-up Views of the Fallen Rock Block
(Photographs taken by GEO on 28 November 2002)

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


Plate 4 - View of the Affected Car A (Photograph taken by the Driver of Car A on 28 November 2002)


Plate 5 - View of the Catchwater and Slope No. 11SW-D/C1019 (Photograph taken on 5 December 2002)

Note: See Figure 2 for location and direction of photograph.

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

Plate 6 - View of Construction Works along the Catchwater
(Photograph taken by WSD in October 2002)

Plate 7 - Rock Blocks on the Natural Hillside below the Catchwater
(Photograph taken on 5 December 2002)

Note: See Figure 2 for location and direction of photograph.

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

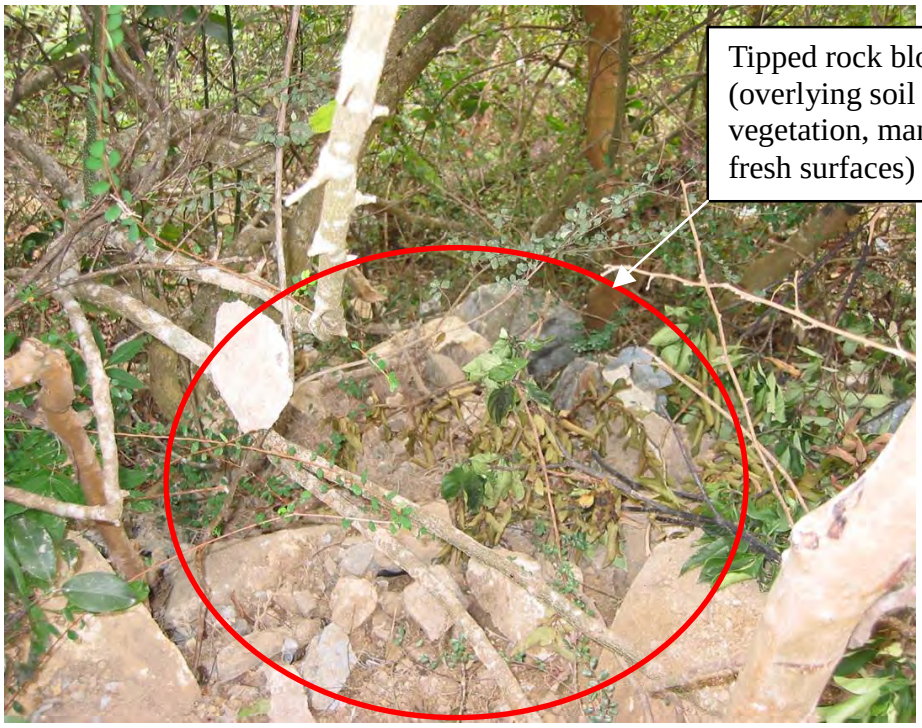



Plate 8 - Tipped Rock Blocks on the Hillside below the Catchwater
(Photograph taken on 5 December 2002)

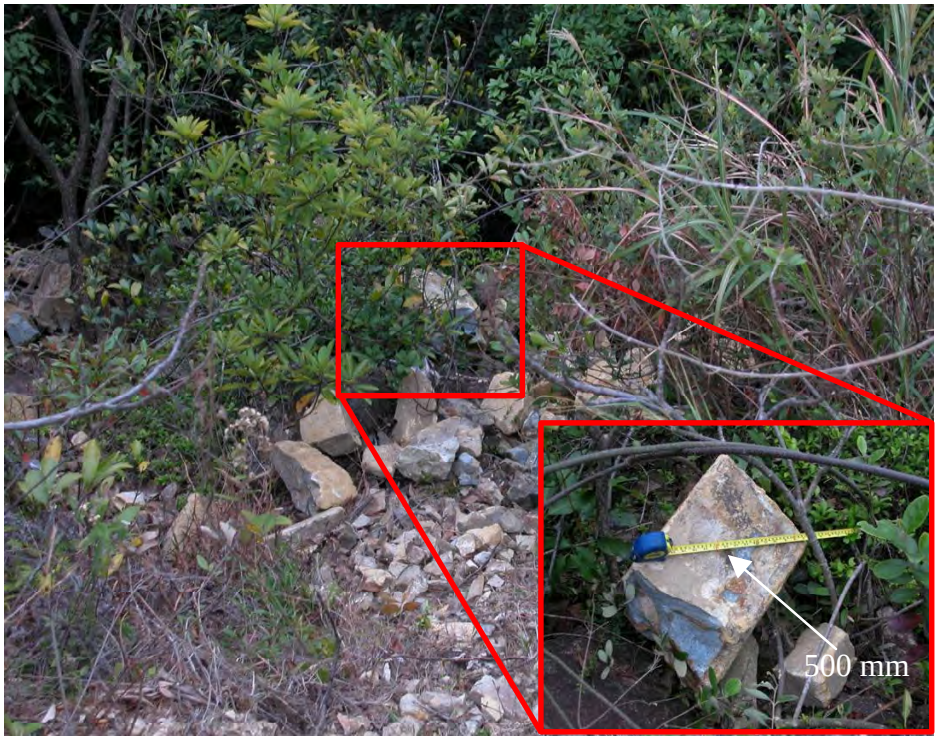



Plate 9 - Tipped Rock Blocks up to 0.5 m across below the Catchwater
(Photograph taken on 14 February 2003)

Note: See Figure 2 for location and direction of photograph.

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


Plate 10 - Tipped Rock Blocks above the Probable Path of the Fallen Rock Block (Photograph taken on 30 January 2003)

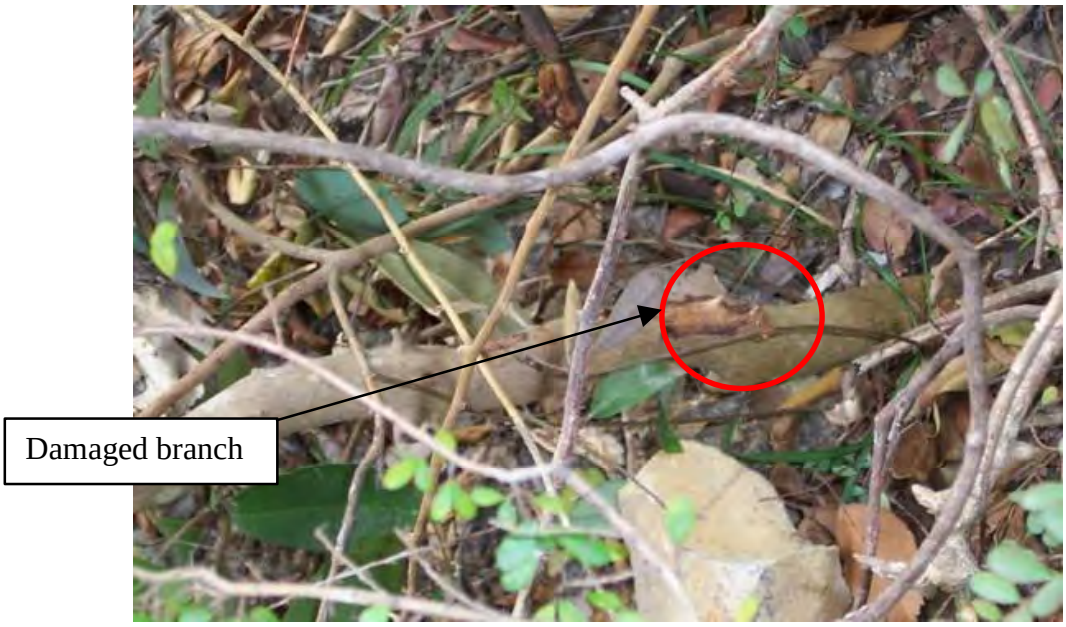



Plate 11 - Damage to the Vegetation (Photograph taken on 30 January 2003)

Note: See Figure 2 for location and direction of photograph.

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


Plate 12 - View of Impact Marks on Rock Blocks
(Photograph taken on 5 December 2002)

Note: See Figure 2 for location and direction of photograph.

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


Plate 13 - View of the Impact Marks on Vegetation and Probable Path taken by Fallen Rock Block (Photograph taken on 30 January 2003)

Note: See Figure 2 for location and direction of photograph.

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

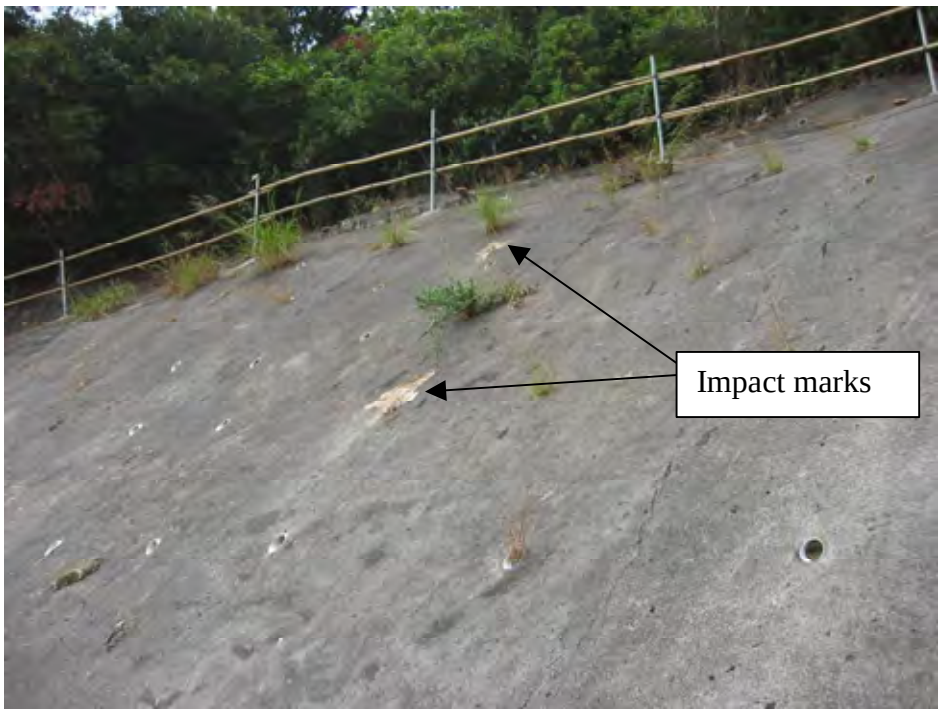



Plate 14 - View of the Impact Marks on Uppermost Slope Batter of Slope No. 11SW-D/C639 (Photograph taken on 5 December 2002)

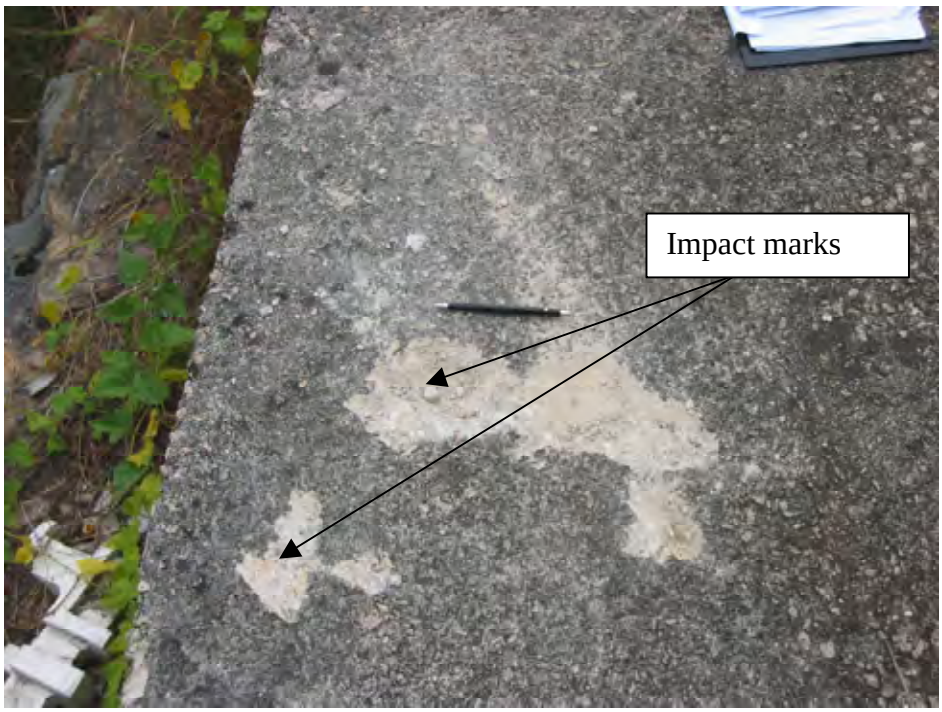



Plate 15 - View of the Impact Marks on Lowermost Berm of Slope No. 11SW-D/C639 (Photograph taken on 5 December 2002)

Note: See Figure 2 for location and direction of photograph.

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

Table of Contents
Table of Contents
Table of Contents

# APPENDIX A

# AERIAL PHOTOGRAPH INTERPRETATION

AERIAL PHOTOGRAPH INTERPRETATION REPORT
YIP HING STREET,
INCIDENT No. 2002/11/0164

## 1. INTRODUCTION

As a result of a rockfall that occurred at 14:34 hours on 28 November 2002 from the hillside below Bennet's Hill and above cut slope No. 11SW-D/C639 at Yip Hing Street, Wong Chuk Hang, Aberdeen (Figure 1 and Plate 1), HCL carried out an API the hillsides around slope No. 11SW-D/C639.

The primary aims of the API were to identify the former topographical setting at the site of the incident, to consider possible origins of the rock block involved in the failure and to look for any evidence of instability in recent and historic aerial photographs.

## 2. SUMMARY OF OBSERVATIONS

The Bennet's Hill Lower catchwater about 20 m north from the crest of slope No. 11SW-D/C639 and Wong Chuk Hang Road (Plate A1) was formed prior to 1949. The slope above the catchwater was vegetated hillside and a fire break was present above the catchwater. Below the catchwater and above Wong Chuk Hang Road was mainly south-facing natural hillside crossed by an east-west trending footpath and a north-south trending footpath. The lower part of the hillside was developed from downhill to uphill in stages to form Yip Kan Street and Yip Hing Street and associated buildings in the early 1960s, late 1970s and late 1990s. Slope No. 11SW-D/C639 was formed between 1980 and 1983. Slope No. 11SW-D/C2087 was formed due to the formation of the adjacent lot between 1998 and 1999.

The embankment at the south side of the catchwater appears to comprise a bouldery fill in 1949 (Plate A1). Two north-south trending boulder fields are visible, one at the location of the crest of slope No. 11SW-D/C639 and the other about 80 m east of slope No. 11SW-D/C639 (Plate A2). Individual small boulders (less than 1m across) appear to be scattered on the hillside. Probable landslide scars were observed on the hillside above the catchwater in the 1967 aerial photographs, with landslide debris deposited on the hillside below the catchwater. When the first three batters of the south facing cut slope No. 11SW-D/C639 were formed between 1980 and 1983 (Plates A3 and A4), a fringe, approximately 4 m wide, of the adjacent terrain was disturbed with vegetation cleared. Several boulders and exposed soil were observed on the natural hillside, particularly in the area above the northeastern end of the slope (Plate A5). Slope No. 11SW-D/C639 was further cut into five batter slope in late 1983. A possible landslide scar was observed in the 1984 photographs near the cut slope above the catchwater. Between 1998 and 1999, south facing three-batter cut slope No. 11SW-D/C2087 was formed adjacent to the lower western end of slope No. 11SW-D/C639 (Plate A1). The southwestern end of slope No. 11SW-D/C639 was modified to form the eastern end of slope No. 11SW-D/C2087 (Figure 2).

3. OBSERVATIONS

| Date of Photograph Aerial Photo No(s) Altitude | Observations |
|---|---|
| 24 April 1949<br>Y01227-Y01228<br>(Old reference 81A/117, 6195-6194)<br>8000’ | Low altitude, high clarity, stereoscopic coverage of entire site.<br>The catchwater and Wong Chuk Hang Road were formed. Between the catchwater and Wong Chuk Hang Road is south facing vegetated hillside crossed by east-west trending and north-south trending footpaths. Two north-south trending drainage lines draining towards the south are observed 25 m west and 80 m east of the present location of slope No. 11SW-D/C639.<br>Several boulders were observed to be scattered on the hillside. Two north-south trending boulder fields were observed, one below the catchwater at the location of the crest of slope No. 11SW-D/C639 and the other about 80 m east of slope No. 11SW-D/C639 (Plate A1).<br>The south, and down-slope, side of the catchwater appears to be a fill embankment with scattered boulders throughout. |
| 1 February 1963<br>Y06970-Y06971<br>(Old reference 6581-6582)<br>2700’ | Low altitude, high clarity, stereoscopic coverage of entire site.<br>Soil erosion was observed on the south facing natural terrain above the catchwater.<br>Area north of Wong Chuk Hang Road was developed. The hillside has been excavated to allow construction of buildings and Yip Kan Street. A construction site and a cut slope at the western end of Yip Kan Street were being formed. |
| 13 May 1967<br>Y13196-13197<br>(Old reference 5357-5358)<br>3900’ | High clarity, stereoscopic coverage of entire site.<br>Yip Kan Street and the associated cut slope were formed. A hut is present on the hillside at the toe of the present location of slope No. 11SW-D/C2087.<br>Probable landslides were observed on the hillside above the catchwater (Figure 1), landslide debris from the landslides has been deposited on the hillside below the catchwater. |
| November 1969<br>2079-2080<br>Estimated to be 2500’ | Low altitude, medium clarity, cover most of the eastern part of site.<br>No significant changes were observed. |
| 24 June 1972<br>1857-1858<br>2500’ | Low altitude, high clarity, stereoscopic coverage of entire site.<br>The hillside has become more densely vegetated. No other significant changes were observed. |
| 20 December 1973<br>8058-8059<br>12500’ | High altitude, high clarity, stereoscopic coverage of entire site.<br>No significant changes were observed. |
| 21 December 1977<br>20554-20555<br>4000’ | Low altitude, high clarity, stereoscopic coverage of entire site.<br>No significant changes were observed. |

| Date of Photograph Aerial Photo No(s) Altitude | Observations |
|---|---|
| 30 November 1978<br>23741-23742<br>4000’ | High clarity, stereoscopic coverage of entire site.<br>No significant changes were observed. |
| 28 November 1979<br>27961-27962<br>10000’ | High altitude, high clarity, stereoscopic coverage of entire site.<br>Lower hillside below the catchwater was being further developed. Hillside north to Yip Kan Street was being excavated. |
| 28 November 1980<br>33380-33381<br>10000’ | High altitude, high clarity, stereoscopic coverage of entire site.<br>Development north of Yip Kan Street continues. Slope No. 11SW-D/C639 was being formed. At the location of the slope, hillside vegetation was being trimmed and the hillside was being excavated. |
| 26 October 1981<br>38971-38972<br>10000’ | High altitude, high clarity, stereoscopic coverage of entire site.<br>The foundation of Kingley Industrial Building No. 33-35 Yip Kan Street was being formed.<br>No significant changes to the subject feature were observed. |
| 10 October 1982<br>44444-44445<br>10000’ | High altitude, high clarity, stereoscopic coverage of entire site.<br>Kingley Industrial Building was constructed.<br>No significant changes to the subject feature were observed. |
| 17 February 1983<br>47901<br>3000’ | High altitude, high clarity, stereoscopic coverage of entire site.<br>Slope No. 11SW-D/C639 was formed in association with Yip Hing Street and site formation work below. It appears the newly formed south facing cut slope comprised three batters. Cavendish Centre, No. 23 Yip Kan Street, located at the opposite site of the subject feature was under construction. |
| 27 September 1983<br>49733-49734<br>4000’ | High altitude, high clarity, stereoscopic coverage of entire site.<br>The crest of Slope No. 11SW-D/C639 was being modified. Cavendish Centre had been constructed. |
| 30 November 1983<br>51318-51319<br>10000’ | High altitude, high clarity, stereoscopic coverage of entire site.<br>It appears that Slope No. 11SW-D/C639 was further cut and finished with a hard surface. |
| 27 January 1984<br>53339-53341<br>2000’ | Low altitude, high clarity, stereoscopic coverage of entire site.<br>No significant changes were observed.<br>Slope No. 11SW-D/C639 is observed to be a cut slope with five batters, four berms and a surface drainage system. The three uppermost batters were covered by a hard surface, the second lower batter was predominantly covered by hard surface but rock exposed at the western part of the slope. The lowest batter appears to be bare rock. The eastern part of the lowest batter was obscured by shadow from the adjacent building.<br>The fringe of slope No. 11SW-D/C639 was disturbed as indicated by the bare surface with sparse vegetation, in particular the area above the northeastern end of the cut slope appears to have boulders present.<br>A possible failure was observed on the hillside above the catchwater along a drainage line north-west of slope No. 11SW-D/C639 (Plate A5). |

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

| Date of Photograph Aerial Photo No(s) Altitude | Observations |
|---|---|
| 2 March 1984<br>53743-53744<br>4000’ | High clarity, stereoscopic coverage of entire site.<br>No significant changes were observed. |
| 7 July 1985<br>A01681-A01682<br>10000’ | High altitude, high clarity, stereoscopic coverage of entire site.<br>No significant changes were observed. |
| 20 September 1986<br>A06079-A06080<br>4000’ | High clarity, stereoscopic coverage of entire site.<br>No significant changes were observed. |
| 9 September 1987<br>A10372-A10374<br>A10404<br>4000’ | High clarity, stereoscopic coverage of entire site.<br>No significant changes were observed. |
| 25 October 1988<br>A14813<br>4000’ | High clarity, single photograph covers entire site.<br>No significant changes were observed. |
| 15 August 1989<br>A17728-A17729<br>4000’ | High clarity, single photograph covers entire site.<br>No significant changes were observed. |
| 14 November 1990<br>A23864-A23865<br>4000’ | High clarity, stereoscopic coverage of entire site.<br>No significant changes were observed. |
| 4 October 1991<br>A27944-A27945<br>4000’ | High clarity, stereoscopic coverage of entire site.<br>No significant changes were observed. |
| 12 May 1992<br>A31020-A31021<br>4000’ | High clarity, stereoscopic coverage of entire site.<br>Vegetation on the hillside at the location at the incident appears denser than previously.<br>No other significant changes were observed. |
| 5 December 1993<br>A37065-A37066<br>4000’ | Medium clarity, stereoscopic coverage of entire site.<br>Southmark, No. 11 Yip Kan Street, was under construction.<br>No significant changes were observed. |
| 5 May 1994<br>CN6957-CN6958<br>4000’ | High clarity, stereoscopic coverage of entire site.<br>No significant changes were observed. |
| 31 October 1995<br>CN11692-CN11693<br>4000’ | High clarity, single photograph covers entire site.<br>Southmark, No. 11 Yip Kan Street, had been constructed.<br>No significant changes were observed. |
| 23 October 1996<br>CN15528-CN15529<br>4000’ | High clarity, stereoscopic coverage of entire site.<br>No significant changes were observed. |

| Date of Photograph Aerial Photo No(s) Altitude | Observations |
|---|---|
| 23 July 1997<br>CN17574-CN17575<br>4000’ | High clarity, stereoscopic coverage of entire site.<br>No significant changes were observed. |
| 23 October 1998<br>CN21061-CN21062<br>4000’ | High clarity, stereoscopic coverage of entire site.<br>No significant changes were observed. |
| 3 November 1999<br>CN24083-CN24084<br>5000’ | High clarity, stereoscopic coverage of entire site.<br>A south facing three-batter slope No. 11SW-D/C2087 was being formed adjoining the lower western part of slope No. 11SW-D/C639. The southwestern end of slope No. 11SW-D/C639 was modified to form the eastern end of slope No. 11SW-D/C2087.<br>No other significant changes were observed. |
| 9 August 2000<br>CN27610-CN27611<br>4000’ | High clarity, stereoscopic coverage of entire site.<br>Slope No. 11SW-D/C2087 was formed, in association with the construction of the development at its toe.<br>No significant changes were observed. |
| 24 May 2001<br>CW31151-<br>CW31152<br>4500’ | Medium clarity, stereoscopic coverage of entire site.<br>No significant changes were observed. |

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

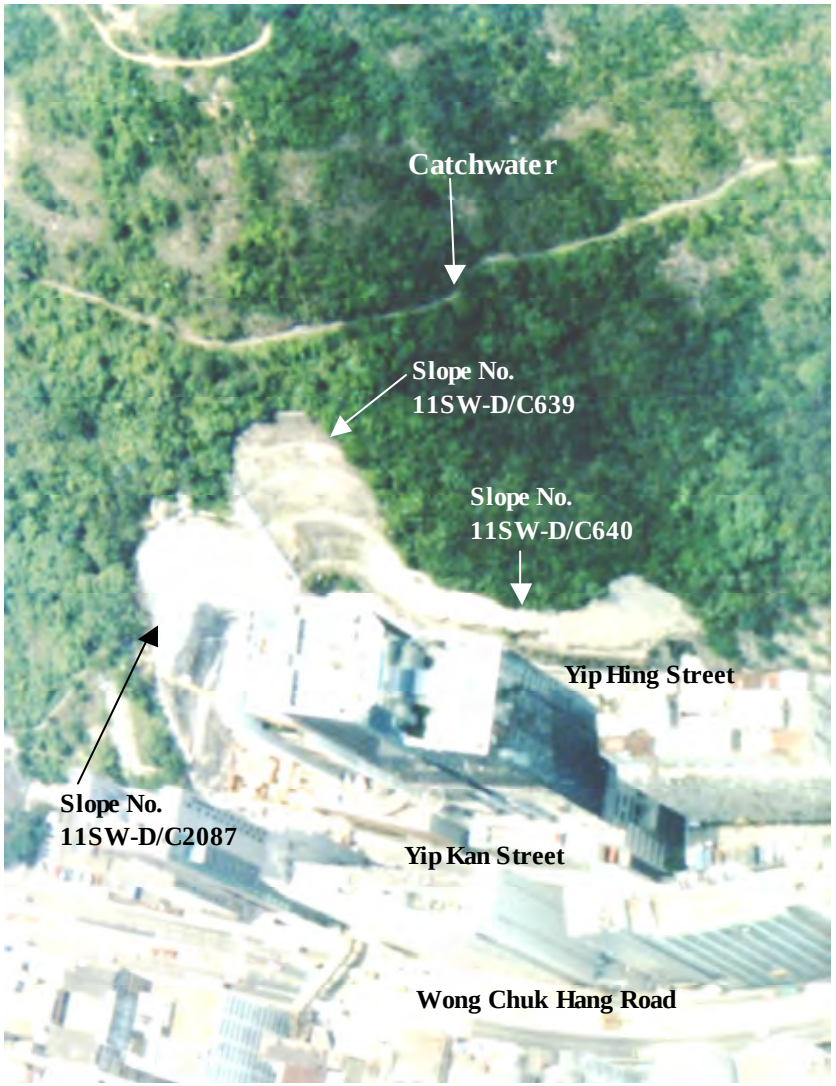



Plate A1 - 2001 Aerial Photograph of the Site

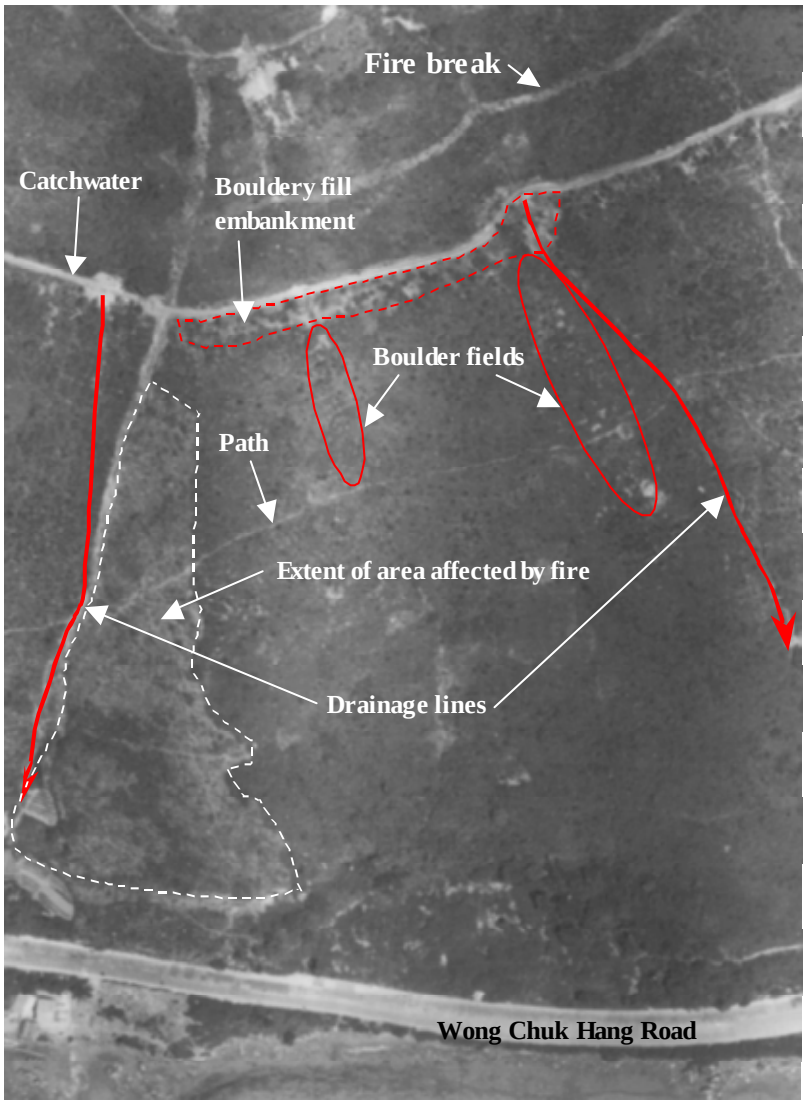



Plate A2 - 1949 Aerial Photograph of the Site

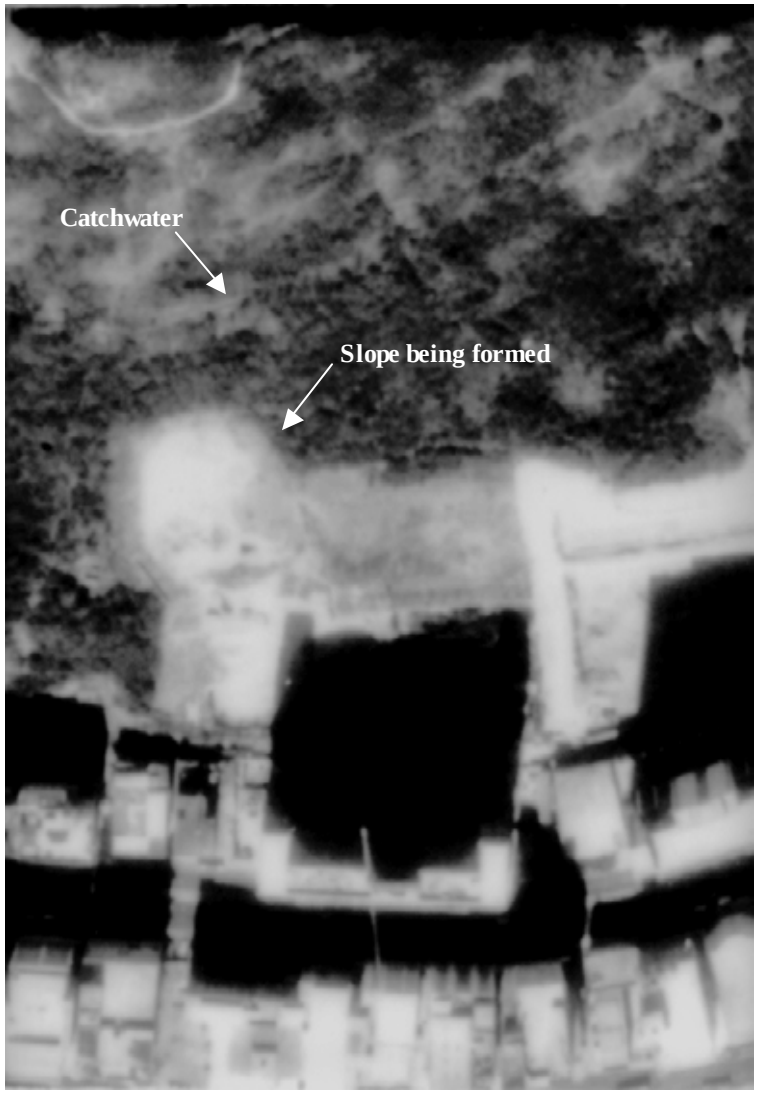



Plate A3 - 1980 Aerial Photograph of the Site

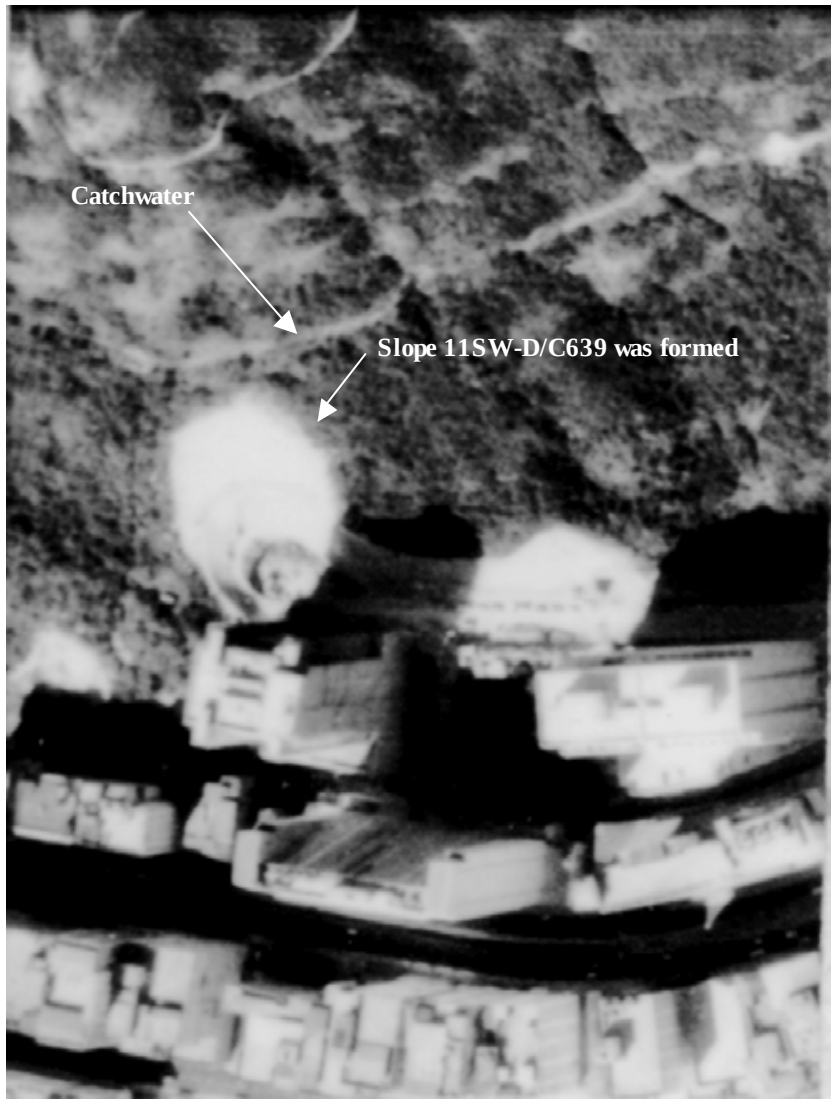



Plate A4 - 1983 Aerial Photograph of the Site

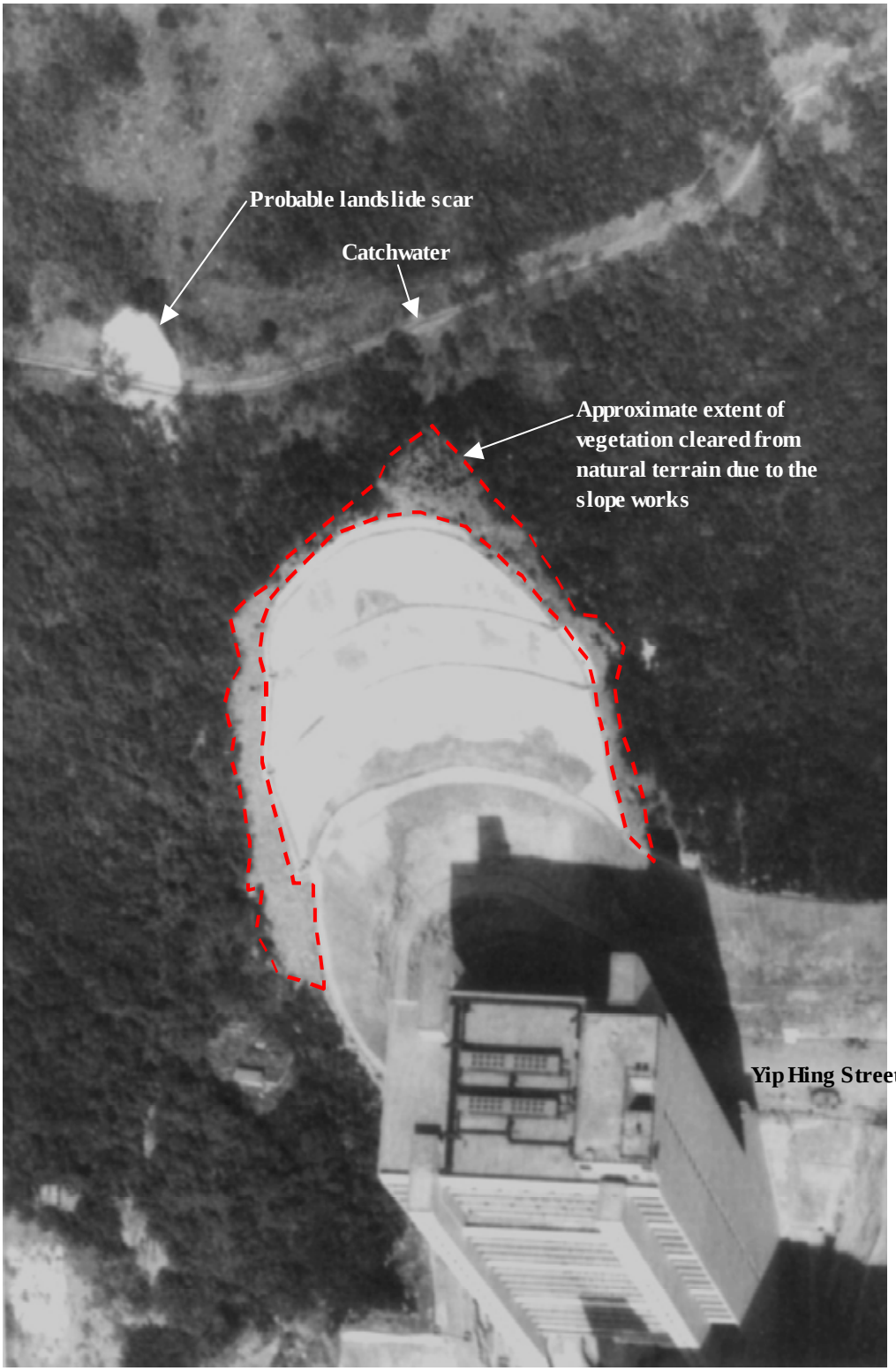



Plate A5 - 1984 Aerial Photograph of the Site

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

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

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

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

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

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

or

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

**讀者可採用以下方法購買土力工程處刊物(地質圖及免費刊物除外):**

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

或

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

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

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

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

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

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

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

For other publications which are free of charge:
Chief Geotechnical Engineer/Standards and Testing,
Geotechnical Engineering Office,
Civil Engineering and Development Department,
Civil Engineering and Development Building,
101 Princess Margaret Road,
Homantin, Kowloon, Hong Kong.
Tel: (852) 2762 5345
Fax: (852) 2714 0275
E-mail: ykhui@cedd.gov.hk

**如欲索取地質調查報告、其他免費刊物及地質圖，請致函：**

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

其他免費刊物:
香港九龍何文田公主道101號
土木工程拓展署大樓
土木工程拓展署
土力工程處
標準及測試部總土力工程師
電話: (852) 2762 5345
傳真: (852) 2714 0275
電子郵件: ykhui@cedd.gov.hk


Table of Contents
Table of Contents
Table of Contents

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

Table of Contents

## GEOTECHNICAL MANUALS

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

斜坡岩土工程手冊(1998)，308頁(1984年英文版的中文譯本)。

Highway Slope Manual (2000), 114 p.

## GEOGUIDES

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

Table of Contents

## GEOSPECS

| | |
|---|---|
| Geospec 1 | Model Specification for Prestressed Ground Anchors, 2nd Edition (1989), 164 p. (Reprinted, 1997). |
| Geospec 2 | Model Specification for Reinforced Fill Structures (1989), 135 p. (Reprinted, 1997). |
| Geospec 3 | Model Specification for Soil Testing (2001), 340 p. |

## GEO PUBLICATIONS

| | |
|---|---|
| GCO Publication No. 1/90 | Review of Design Methods for Excavations (1990), 187 p. (Reprinted, 2002). |
| GEO Publication No. 1/93 | Review of Granular and Geotextile Filters (1993), 141 p. |
| GEO Publication No. 1/96 | Pile Design and Construction (1996), 348 p. (Reprinted, 2003). |
| GEO Publication No. 1/2000 | Technical Guidelines on Landscape Treatment and Bio-engineering for Man-made Slopes and Retaining Walls (2000), 146 p. |

Table of Contents

## GEOLOGICAL PUBLICATIONS

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

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

## TECHNICAL GUIDANCE NOTES

| | |
|---|---|
| TGN 1 | Technical Guidance Documents |

Table of Contents