# SECTION 2: DETAILED STUDY OF SELECTED LANDSLIDES ON SLOPE NO. 11NE-D/C45 HIU MING STREET KWUN TONG

**Halcrow China Limited**

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# FOREWORD

This report presents the findings of a detailed study of a cut slope (No. 11NE-D/C45) at Hiu Ming Street, Kwun Tong, which has been affected by several landslides since its formation in 1966. The report focuses on two landslides, GEO Incident Nos. K93/9/17 and ME2000/08/04, which occurred on 26 August 1993 and 3 August 2000 respectively. The 1993 landslide involved a 20 m wide section of the slope. The resulting debris, with an estimated volume of about 200 $m^3$, destroyed part of the boulder fence and inundated a portion of a tennis court below. The 2000 rockfall involved the detachment of a 15 $m^3$ rock block, which landed in a fenced-off area between the toe of the slope and a playground. No fatalities or injuries were reported as a result of the landslides.

The key objectives of the detailed study were to document the facts about the landslides, present relevant background information and establish the probable causes of the failures. In addition, the study reviews a number of detailed assessments which have previously been carried out on the slope. The scope of the study comprised site reconnaissance, limited ground investigation, desk study and analysis. Recommendations for follow-up actions are reported separately.

The report was prepared as part of the Landslide Investigation Consultancy for Kowloon and the New Territories in 2000 and the First Quarter of 2001, for the Geotechnical Engineering Office (GEO), Civil Engineering Department (CED), under Agreement No. CE 2/2000. This is one of a series of reports produced during the consultancy by Halcrow China Ltd. (HCL).

X D Pan
Project Director
Halcrow China Ltd

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1. INTRODUCTION

On the morning of 3 August 2000, a rockfall (GEO Incident No. ME2000/08/04, hereafter referred to as the 2000 rockfall) occurred on a cut slope (No. 11NE-D/C45) above Hiu Ming Street Playground, Kwun Tong. A large rock block fell from about a 20 m high section of the rock cut slope and landed on a tree planter adjacent to the playground. Landslide debris consisted of a single large block of slightly to moderately decomposed granite (about 3 m x 2 m x 2 m) which was split into two, together with about 0.5 $m^3$ of cobble-sized rock fragments and granitic soil. No fatalities or injuries were reported as a result of the 2000 rockfall.

A number of landslides had previously occurred on the subject slope, including a major landslide (GEO Incident No. K93/9/17) on 26 September 1993. The debris from the 1993 landslide, with an estimated volume of about 200 $m^3$, destroyed a section of boulder fence and inundated part of a tennis court below. No fatalities or injuries were reported following the landslide.

Following the 2000 rockfall, Halcrow China Limited (HCL), commenced a detailed study of the subject slope for the Geotechnical Engineering Office (GEO), Civil Engineering Department (CED), under Agreement No. CE 2/2000.

The key objectives of the study were to document the facts about the 1993 landslide and the 2000 rockfall, present relevant background information and establish the probable causes of the failures. In addition, the study reviews the many assessments that had been carried out on the slope in light of the recent and past failures, and attempts to identify the generic adverse geological factors controlling these failures. The scope of the detailed study comprised site reconnaissance, desk study, limited ground investigation, laboratory testing and engineering analysis. Recommendations for follow-up actions are reported separately.

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

(a) desk study, including a review of relevant documentary records relating to the history of the slope,

(b) aerial photograph interpretation (API),

(c) geological mapping and detailed observations and measurements at the slope, in particular, the 1993 and 2000 landslide scars,

(d) limited ground investigation works,

(e) analysis of rainfall data, and

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

# 2. THE SITE

## 2.1 Site Description

A site location plan is shown in Figure 1. A more detailed site plan, which includes the chainage reference line along the slope toe, is shown in Figure 2. The landslides occurred on a southwest facing cut slope (No. 11NE-D/C45), which forms the northeastern boundary of Hiu Ming Street Playground. A park is located on a level platform behind the crest of the slope, and Hiu Kwong Street runs to the northeast of the park. Panoramic views of the northern, central and southern sections of the slope are presented as Plates 1, 2 and 3 respectively.

Slope No. 11NE-D/C45 is approximately 230 m in length with a maximum height of about 37 m. The slope, along most of its length, consists of two distinct batters, without a separating berm. The lower batter consists of a 10 m to 20 m high rock cut slope, with a slope angle of between 70° and 80°. The upper batter consists of a 20 m to 30 m high soil/rock cut slope, with a slope angle of about 30° to 50°, locally about 20°. A 1.5 m wide and about 30 m long berm is present along part of the northern section of the upper soil portion of the slope between Chainages 150 and 180.

The rock face forming the lower batter is generally not covered, with the exception of occasional patches of shotcrete. Slope stabilisation measures, consisting of a series of concrete buttresses, concrete beams, dowels and rock bolts, have been installed along the rock slope (see Section 3.3). Areas of unplanned vegetation, comprising grass and stunted trees and bushes, are present locally. Much of this vegetation is associated with laterally persistent, shallowly dipping joints.

The soil/rock slope forming the upper batter is generally densely vegetated with trees and small shrubs. This portion of the slope was originally sealed with chunam but the surface is currently obscured by unplanned vegetation. The largest visible patch of chunam at the upper batter is a 30 m long section between Chainages 150 and 180, close to the location of the 1993 landslide. This area of slope was cut back and covered during stabilisation works carried out in 1981 (see Section 3.3). The 1993 landslide scar was sealed with shotcrete.

Slope drainage comprises 300 mm diameter U-channels along the crest and the toe of the slope (Figure 3), both of which drain to the south. Interceptor channels have also been constructed within a natural drainage line above the crest of the rock slope at the northern end of the slope (Figure A3). The interceptor channels drain into a vertical 300 mm diameter steel down-pipe leading to the toe of the slope.

A 6 m high boulder fence is located along the northern end of the slope, from Chainages 130 to 215. Access to the southern section of the slope is prevented by a chain link fence which borders a 2 m to 10 m wide buffer zone along the toe of the slope from Chainage 0 to Chainage 130.

## 2.2 Water-carrying Services

According to information provided by the Water Supplies Department (WSD) and

Drainage Services Department (DSD), water-carrying services in the vicinity of the site consist of a sewer, fresh and salt water pipes and a stormwater drain located along Hiu Kwong Street, some 15 m to 25 m above the crest of slope No. 11NE-D/C45. The alignment and dimensions of these services are shown on Figure 3.

### 2.3 Maintenance Responsibility

According to the Slope Maintenance Responsibility Information System of the Lands Department, the maintenance responsibility for slope No. 11NE-D/C45 lies with the Leisure and Cultural Services Department (LCSD). The Architectural Services Department (Arch SD) is the maintenance agent.

## 3. SITE HISTORY AND PREVIOUS STUDIES

### 3.1 General

The history of slope No. 11NE-D/C45 has been determined from a review of available aerial photographs (detailed observations are given in Appendix A), together with the relevant available documentary information. Information sources consulted during this study are summarised in Table 1. The salient findings are presented in the following sections.

### 3.2 Site Development History

The earliest aerial photographs, taken in 1945, show that the location of slope No. 11NE-D/C45 is a sparsely vegetated natural hillside, consisting of a series of westeast trending ridges separated by incised natural drainage lines. No signs of human disturbance or development are visible at the location of slope No. 11NE-D/C45, though extensive areas of sheet and gully erosion are visible along the ridgelines. The only signs of development are terraced paddy fields covering the lower parts of the hillside, located some 30 m west of the subject slope.

The aerial photographs taken in 1963 show that Tsui Ping Road and a series of H-shaped residential blocks forming Kwun Tong Estate have been constructed on a cut and fill platform located about 100 m to the west of the site (Figure A2). Terraced paddy fields cover the hillside surrounding the subject slope.

The 1964 aerial photographs show that construction of Hiu Kwong Street and adjacent developments to the east of the subject slope are in progress. According to a Binnie & Partners' report (B&P, 1980), the slope and adjacent features "were formed by PWD [Public Works Department] in 1966 during quarrying operations". Slope No. 11NE-D/C45 is first observed on the 1974 aerial photographs (Figure A3), at which time the profile of the slope was essentially the same as that of the present day. The level platforms located both above the crest and at the toe were formed and were being used for storage of construction material and plant. A number of one-storey squatter structures were located on the natural hillside about 40 m to the south of the slope (Figure A3).

The aerial photographs taken in 1980 show that construction of Hiu Ming Street

Playground has commenced. Ongoing upgrading works are visible on the subject slope, consisting of construction of buttresses at the toe of the rock cut slope and trimming of the soil portion of the slope (see Section 3.3). The squatter structures observed in the 1974 aerial photographs have been demolished.

By the time of the 1984 aerial photographs, construction of the playground at the toe and a park at the crest has been completed. Portions of the soil slope have been sealed with chunam, and an interceptor channel is visible along the northern end of the slope, within a natural drainage line (Figure 3).

The 1984 to 1989 aerial photographs show no notable alteration to the slope with the exception of a significant increase in the density of vegetation over the upper portion of the slope. A boulder fence was visible in the 1990 aerial photographs along the northern section of the slope between Chainages 130 and 215. Light tone areas visible on the upper slope portion are probably a result of repairs to the chunam cover. Sometime during the period 1990 to 1991, a concrete buttress was constructed at Chainage 120 (see Section 3.3).

From 1991 onwards, the slope becomes increasingly obscured as a result of dense vegetation. The aerial photographs taken from 1991 to 1999 show no discernible changes other than the scars resulting from the 1993 landslide incidents Nos. K93/9/17 and K93/9/18 (see Section 3.4).

### 3.3 Previous Slope Assessments and Upgrading Works

A summary of previous assessments carried out on slope No. 11NE-D/C45 is presented in Appendix B.

In the 1977/78 Catalogue of Slopes, the subject slope was registered as slope No. 11NE-D/C45. The first assessment report identified for the subject slope was the Landslide Studies Phase 1 Re-Appraisal Report prepared by Binnie & Partners (B&P) for the Geotechnical Control Office (GCO) in June 1977. The condition of the slope was assessed as “fair to poor”. Some loose blocks were noted on the rock face and seepage was recorded. The report recommended “removal of vegetation from chunam and repair. Check drains for leakage. Clear crest drain”. No record has been found as to whether the recommended works were carried out or not.

In November 1979, the GCO carried out a Stage 1 Study on slope No. 11NE-D/C45 (GCO, 1979). The report noted that the rock slope showed signs of instability at some locations and specifically that “low dipping jointing planes (sic) indicate the possibility of sliding failure”. However, by considering the proposed land use (a playground/sports ground) at the time, it was concluded that the risk due to failure was low. It was recommended that “if future development were to take place above or below the slope, then a Stage 2 investigation would need to be carried out, including a joint survey of the lower rock face”. The following maintenance works were also recommended: “(i) clear crest U-drain (ii) remove vegetation from chunamed section of the slope (iii) check watertightness of concrete lined well on the crest of the slope. If unsatisfactory the well should be filled in”. While no record was found to indicate whether the recommended work was carried out or not, the well referred to in the report was located within an area above the crest of the slope that was cut back during upgrading works in 1980.

At the request of the Chief Estate Surveyor/Urban Estates (CES/UE), Scott Wilson Kirkpatrick & Partners (SWKP), the consultants for the Geotechnical Control Branch (GCB), prepared a memo to the Government Geotechnical Engineer/Buildings (GGE/B) dated April 1979 entitled “Geotechnical Checking of Slopes Proposed Temporary Open Space Hiu Ming Street Sau Mau Ping”. The memo stated that during a site visit at slope No. 11NE-D/C45 by SWKP, “There was considerable evidence of rock spalls occurring along the majority of the length of the cut slopes, consisting mainly of small sized boulders; however large boulders had obviously fallen in the past and could equally fall again in the future”. It was recommended in the memo that “Consideration could be given by the designer to the establishment of a rockfall area at the toe of the cut slope”.

Prior to the above site visit, B&P was instructed by the Housing Authority (HA), who were responsible for the construction of Hiu Ming Street Playground, to assess the stability of slope No. 11NE-D/C45, together with the adjacent features in November 1978. The report entitled “Report on the Stability of the Rock Slopes 11NE-D/C44, 11NE-D/C45, 11NE-D/C46 and 11NE-D/C47 at Kwun Tong Estate” was completed in January 1980 (B&P, 1980). The assessment included a detailed rock joint survey, which identified seven pole concentrations. With reference to the “sheeting joints”, the report states that “The joints do not give rise to instability except in isolated instances where local-steepening occurs. In these instances, we recommend the installation of rock bolts or, where the sheeting joints occur near the base of the slope, raking drains”. The report recommended extensive upgrading works including trimming of the slope, removal of unstable blocks, installation of raking drains, construction of buttresses and installation of rock bolts and dowels. The locations of the recommended preventive works are illustrated in a series of annotated photographs. A review of these photographs indicates that at the location of the subsequent major landslide in 1993, the removal of a block with “steep weathered joint” beneath was recommended. No preventive works were recommended at the location of the 2000 rockfall. The proposed upgrading works were not carried out directly. Instead, the report was used as the basis for a later study by Halcrow International Partnership (HIP) on slope No. 11NE-D/C45 (HIP, 1980).

In November 1979, the HA appointed HIP to undertake the design of upgrading work for slope No. 11NE-D/C45. HIP prepared a report entitled “Report on Geotechnical Remedial Works to Existing Slopes 11NE-D/C44, 45, 46, 47 and 11NE-D/FR7 and 14 at Hiu Ming Street, Kwun Tong” (HIP, 1980), which was completed in October 1980. The report included a detailed assessment of slope No. 11NE-D/C45 based, in part, on information from the earlier B&P Report (B&P, 1980). With reference to the sheeting joints, the report states that “sheet jointing is strongly developed, the joint surface dipping directly or obliquely out of the cut rock face at angles of 15 - 25 degrees”. The report concluded that “The overall stability of the rock slope is satisfactory so far as may be determined by examination of the orientation of the jointing exposed in the quarry face. It is unlikely that large scale failure of any section of the rock slopes examined would occur”. The report also states that “There are a number of locations where the stabilisation of individual blocks and wedges is considered necessary, particularly where local failure might occur following movement or fall-out of a rock block acting as a key-stone”. The upgrading works recommended included buttressing, rock bolting, dowels, scaling and cutting back. In addition, it was recommended that small trees growing in joints should be removed. These works were implemented under the supervision of HIP, between late 1980 and early 1981. The locations of the recommended preventive works are illustrated in a series of annotated photographs. A review of these photographs indicates that, at the location of the subsequent 1993 landslide, it was recommended that "Some blocks to be propped with concrete and voids infilled as directed by Engineer" and "Trim to 60° and remove loose blocks". No preventive works were recommended at the location of the 2000 rockfall. No as-built records have been identified but a comparison by HCL between the annotated photographs and the as-built works visible today shows that, in general, the works were completed as per the intention of HIP's design.

In January 1981 the HIP report was checked by SWKP, the checking engineers for the GCB. SWKP had minor comments on specific stabilisation measures and calculations for slope No. 11NE-D/C45. HIP subsequently revised the proposed stabilisation measures following SWKP's comments.

SWKP continued to review the ongoing upgrading works on the rock slope during the course of the upgrading works. In a memo dated June 1981, SWKP made additional minor comments on the occurrence of seepage at the northern end of the slope and unplanned vegetation. They went on to state that "Generally we are satisfied with the stability of the slope". After a site inspection by SWKP in October 1981, SWKP stated that "Generally we do not have any adverse comments to make on HIP's proposal…".

In February 1981, Hiu Ming Street Playground was temporarily handed over to the Urban Services Department (USD), the maintenance of the playground thereby coming under the responsibility of the Architectural Office Maintenance Branch (AOMB). Fugro (HK) Ltd., AOMB's maintenance consultants, carried out a series of site inspections between October 1982 and October 1984. In October 1982, Fugro recommended in a letter to the Government Maintenance Surveyor of the AOMB that, due to strong seepage at the northern end of slope No. 11NE-D/C45, "an interceptor drain be installed at the soil/rock interface and that the chunam surface should be repaired to prevent infiltration". The location of the proposed drain was between Chainages 220 and 230. In October 1984, Fugro carried out a detailed visual inspection of the slope along its toe and reported to the AOMB that the interceptor drain was installed in April 1984, and that "there are still some fallen rock fragments left at the toe of slope No. 11NE-D/C45. There are no obvious, large, potentially unstable rocks on the slope. It is anticipated that minor loose blocks of rock may loosen and fall down from time to time. However, there is no major cause for concern as long as the toe of the slope is fenced off from the public".

In June 1985, Freeman Fox (Far East) Ltd. (FF) initiated a detailed review of the subject slope for the HA, in preparation for the permanent allocation of Hiu Ming Street playground at the slope toe to the USD. A report was prepared in March 1986 and included a review of previous assessments on slope No. 11NE-D/C45 and an extract of the summary of this review is given in Appendix C. The report recommended further inspections, local stabilisation works and the construction of a boulder fence. No specific recommendations were made at the locations of the 1993 landslide or the 2000 rockfall. A standard design for a boulder fence was included in the report, but the assumed design event to be mitigated against was not stated.

In October 1985 a meeting between USD, AOMB, GCO, HD and FF was held to discuss the status of the slopes behind Hiu Ming Street Playground. During the meeting, the GCO stated that "the overall stability of the slopes is considered satisfactory at its current condition and in view of the current land use", that "there is currently a sterilized zone bounded by chain link fence along the slope toe. This zone should remain sterilised should land be permanently allocated to USD", and that "all the slopes behind the playground have already been included in the Landslip Preventive Measures Programme. However, the risk is considered as low for these slopes, and they were given a low priority". Later in October 1985, GCO further clarified to the HA about the LPM status of the slope. The memo stated that the previous statement on the LPM status should read "GCO stated that all the slopes behind the playground have been taken into consideration when selecting slopes for inclusion in the Landslip Preventive Measures Programme, as those slopes are under AOM's maintenance responsibility. The risk and consequence of these slopes are considered to be comparatively low and they have not been included in the 85/86 & 86/87 LPM programme".

In May 1989 HA prepared a report, entitled "Rock Slope Behind Hiu Ming Street Playground, Rock Slope Stability Appraisal Report No. 1". The report was based on discontinuity surveys and detailed inspections carried out by HD's Term Geotechnical Consultant, Acer Consultants (Far East) Ltd., and was limited to the northern section of the subject slope, between about Chainages 150 and 230, and to the southern section of the adjacent slope (No. 11NE-D/C44). With respect to the sheeting joints, the report stated that "the sheeting joint set (P5) is found to be common in both rock slopes. However, these joints do not give rise to overall instability except where local overhanging could occur". The report also stated that "The overall stability of the slopes is considered to be adequate. However, some preventive work to the rock face are still proposed to be carried out". Details of the proposed preventive works, consisting mainly of local stabilisation of individual blocks are presented as a series of annotated photographs. No stabilisation works were recommended at the location of the 1993 landslide. The location of the 2000 rockfall is outside the study area of the report.

The stabilisation/mitigation measures recommended in both the 1986 FF report and the 1989 HA report, consisting of the construction of a boulder fence, concrete buttresses, installation of rock bolts and dowels and removal of unstable rock blocks, were carried out under the Tsui Ping Road – Phase 4 Redevelopment Contract. The works were completed by October 1990. A comparison by HCL with the as-built drawing shows that as far as can be discerned based on site inspection, the works were completed generally as recorded.

In mid-1992, the GEO initiated a consultancy agreement entitled "Systematic Inspection of Features in the Territory" (SIFT) to search for slopes not included in the 1977/78 Catalogue of Slopes and to update information on previously registered features, by limited site inspections and study of aerial photographs. Slope No. 11NE-D/C45 was categorised as a Class "C1" slope, i.e. a slope "formed or substantially modified before 30.6.78", notwithstanding the stabilisation/mitigation works carried out in 1990.

Following the landslide (see Section 3.4) in December 1993, the Mainland East Division of the GEO recommended that slope No. 11NE-D/C45 be nominated for the LPM selection exercise as "over the years this, and adjacent slopes, have been studied by a number of consultants, and stabilization measures have been taken. Notwithstanding these works, a significant rockfall has taken place". In August 1994, a Stage 1 Study Report (GEO, 1994) and a LPM Selection Nomination Feature Study Report recommended that the slope be excluded from the LPM selection because the "Slope falls within Priority Group 5 under the Direct Risk to Life Category".

In January 1994, the Special Projects Division of the GEO produced a file note on incident No. K93/9/17, based on "field observations and brief review" of relevant files. The note recorded that "The slip occurred in the upper part of a rock slope along a fairly continuous joint plane dipping at around 55°/230°". There was "a sub-vertical release plane of about 6 m high at the back of the slip". The debris consisted of moderately to highly weathered granite with a volume of the order 200 cu.m". The note also recorded that "At the time of inspection, the slope is fairly dry. However according to the landslip card prepared by the ME Division, seepage were observed coming from the base of the slip." The note considered that the failure was a result of "sliding of the block of moderately to highly weathered rock on a steeply-dipping persistent rock joint due to water pressure built up behind the failure block during heavy rainfall". In addition, the file note recorded that the adversely orientated joint on which the failure occurred "had probably been identified during the appraisal in 1989" (HA, 1989). However, "as the joint dips out of the slope face, its persistence cannot be easily assessed".

In 1994, the GEO commenced a consultancy agreement entitled "Systematic Identification and Registration of Slopes in the Territory" (SIRST) to update the 1977/78 Catalogue of Slopes and prepare the New Catalogue of Slopes. The GEO's consultant for the SIRST project, inspected the slope in April 1995. The record of the field inspection indicates that the condition of the cut slope was assessed as "fair", although "reasonable" signs of distress "near crest, mid-portion, and at toe" were noted. Major past instabilities were inferred from the inspection but no signs of seepage were observed. The consequence category of the slope was assessed as "low".

In June 1999, Binnie Black & Veatch Hong Kong Limited (BBV) prepared a Stage 2 Study report on slope No. 11NE-D/C46 for the Arch SD. About a 50 m long section of the southern end of slope No. 11NE-D/C45 was included within the boundary of slope No. 11NE-D/C46. The BBV study noted that " For the rock slope portion [i.e. the southern end of slope No. 11NE-D/C45], upgrading works (including installation of rock bolts, construction of concrete buttresses and scaling of loose blocks) have already been carried out. All the buttresses are in fair conditions. No signs of distress or movement of the concrete buttresses were observed. Therefore, no further upgrading works on the rock slope portion are considered to be necessary".

### 3.4 Past Instabilities

There were no past failures in the natural terrain in the proximity of the subject slope recorded in GEO's Natural Terrain Landslide Inventory (NTLI). The API carried out for this study identified a single relatively large relict landslide scar on the natural hillside about 30 m to the north of the slope (Figure A2) on the 1963 aerial photographs.

The GEO's landslide database has records of three previous landslides on slope No. 11NE-D/C45, namely Incidents Nos. K86/9/1, K93/9/17 and K93/9/18. The locations of the incidents are shown in Figure 2. No fatalities or injuries were reported to have occurred as a result of the incidents.

On 8 September 1986, Incident No. K86/9/1 involved a minor rockfall with an estimated volume of 0.5 $m^3$ and was recorded in the GEO Incident Report to have occurred as a result of infiltration. The source of the rock block that failed was about 8 m to the south of the location of the 2000 rockfall, and probably from above the same sheeting joint that formed the basal release surface to the 2000 rockfall.

On 26 September 1993, Incident No. K93/9/17 occurred within the northern section of slope No. 11NE-D/C45 (Figure 2 and Plates 4 to 6). The GEO Incident Report described the failure as a “rockfall” within “weathered rock”. The possible cause of the failure was stated as “infiltration” and “blocked/broken drains”. The debris from the landslide, with an estimated volume of about 200 $m^3$, inundated part of the tennis courts below and destroyed the boulder fence that had been constructed along the toe of the slope. While the Incident Report does not record any seepage, the Landslip Card for the incident indicates seepage from the joint forming the basal release surface. The release surfaces exposed by the landslide were extensively stained black and reddish brown (Plate 5), indicating weathering associated with flowing groundwater along possibly open joints. Following the landslide, urgent repair work comprising removal of landslide debris, reconstruction of the boulder fence and provision of reinforced shotcrete over the landslide scar were carried out.

Incident No. 93/9/18 is reported to have occurred within the surface colluvium cover at the far southern end of the slope, at approximately Chainage 0, and involved about 15 $m^3$ of debris.

A memo dated March 1992 from the Arch SD to the GEO, records “two large rocks have fallen from the slope behind the playground”. The locations of these two rockfalls, as shown on a sketch plan attached to the memo, are shown in Figure 2. No other details are given in the memo. These were not recorded in the GEO’s landslide database as no GEO Incident Reports were prepared.

In addition to the above recorded landslides, there appears to be a failure scar adjacent to, and directly to the south of, the 2000 rockfall (Figure 2). An insitu block is visible in a poor quality site photograph taken by HIP in May 1980 (Plate 7), located adjacent to the block which failed in the 2000 rockfall, but this block was no longer observed in a site photograph taken by FF in July 1985 (Plate 8). There is no record of a failure at this location but such occurrence, which might have been unreported to the GEO, could not be ruled out. It is also possible that the block was removed during stabilisation works in the early 1980’s, although no record of such stabilisation works at this location has been found.

The occurrence of many minor fallen rocks and ravelling of the rock slope is mentioned in various documents and correspondence reviewed in the preparation of this report (see Section 3.3). In general, however, neither the location nor the size of these rockfalls were recorded in detail.

# 4. DESCRIPTION OF THE 2000 ROCKFALL

## 4.1 Timing of the 2000 Rockfall

The timing of the 2000 rockfall has been established from an interview with a member of staff of the LCSD, who was in charge of a booking office for the tennis and basketball courts near the toe of slope No. 11NE-D/C45. The LCSD staff member informed that the night shift security guard, on duty between 2 and 3 August 2000, had reported hearing a loud noise and observing that a rock/boulder had fallen off the slope at about 06:00 hours on 3 August 2000.

## 4.2 Description of the 2000 Rockfall

Photographs of the location of the 2000 rockfall in May 1980 and July 1985 are presented as Plates 7 and 8 respectively. Photographs of the scar and the fallen rock block are presented as Plates 9 and 10 respectively. A cross-section (Section 1-1) through the landslide site and a sketch are presented as Figures 4 and 5 respectively.

The landslide involved the detachment of a granite rock block of about 15 $m^3$ in volume and a small volume (about 0.5 $m^3$) of granitic soil from the crest of slope No. 11NE-D/C45. The rock block fell into a tree planter located about 1 m from the slope toe. The rockfall destroyed a tree in the planter and damaged the brick planter wall. The planter is located within a fenced off buffer zone (Section 3.3) constructed along the slope toe. No fatalities or injuries were reported as a result of the 2000 rockfall.

## 4.3 Observations Made Following the 2000 Rockfall

HCL carried out the first inspection of the landslide site at 16:30 hours on 3 August 2000. There was light rain during the inspection. At that time, no access to the landslide scar was available.

The fallen rock block (Plate 10), which measured approximately 3 m x 2.5 m x 2.2 m in size, had split into two pieces that lay about 0.3 m apart. A 1 mm thick layer of clay (Plate 10) has been exposed on the upper surface of the fallen rock block (with respect to its insitu position), as a result of a smaller rock block breaking away from the fallen block during the fall.

On the side of the rock block, which was exposed prior to the landslide, a 0.5 m long blue line of spray paint could be seen (Plate 10). Also, a short section (about 0.2 m) of moss-covered chunam was noted at what would have been the base of the southern side release surface of the granite block.

The decomposed granite debris at the slope toe comprised reddish brown angular coarse sand with fine to medium gravel of quartz and feldspar and occasional cobble-sized moderately decomposed granite fragments. The debris was wet and had blocked the U-channel located about 1 m from the slope toe. A small quantity of debris, estimated at about 0.5 $m^3$, was retained directly below the scar on the basal release surface formed by a sheeting joint (Figure 4).

An initial inspection of the landslide scar was carried out by HCL on 15 December 2000. Further inspections were made in March 2001 on scaffolding erected in connection with the ground investigation for LPM works (under contract No. GE/2000/13) on the subject slope. The scar is defined by three joints (Figure 5 and Plate 11). The rear release surface comprises a set of sub-parallel joints with a mean orientation of 70°/246° and is about 3.5 m wide and 3.5 m high. The upper 1 m of the rear release surface is completely to highly decomposed granite with corestones of moderately decomposed granite (PW 50/90), the rest comprises slightly decomposed granite. The joint surface is generally clean except towards the north where it is heavily stained, probably as a result of through-flow of groundwater (Figure 5). The rear release surface is generally rough textured but essentially planar and stepped between the parallel set of joints.

The northern side release surface is about 1.8 m wide at the base, decreasing to about 1.5 m wide at the boundary between slightly decomposed rock and the zone of soil with corestones (Figure 5). Its height is about 3 m, with a mean orientation of 78°/305°. The joint surface is essentially planar and is generally coated with a 4 mm to 6 mm thick layer of light brown clay which was firm at the time of the inspection on 15 December 2000, having probably dried and increased in strength since the 2000 rockfall. The surface towards the top is slickensided, with slickensides orientated between 3º and 9º from horizontal dipping into the slope.

Above the rock portions of the rear and side release surfaces is a 1 m to 1.5 m thick layer of completely to highly decomposed granite, within which there are overhanging and sometimes loosened, boulders (corestones) of moderately decomposed granite. Tree roots protrude from the top of the soil layer. Above this soil layer is an about 1 m high thick band of subvertically jointed moderately decomposed granite (Figure 5 and Plate 9).

The basal release surface is about 3.5 m wide and 2.5 m long with a mean orientation of 37°/232° (Figure 5). At the northwestern end of the basal release surface, tree roots are present. A 5 mm thick layer of light brown soft to firm clay was found over an area of about 0.2 m x 0.2 m near the intersection of the three release surfaces (Plate 12). A close inspection of the basal release surface revealed other small accumulations of firm clay (about 1 mm thick and less than 3 mm in diameter) within minor depressions over much of the granular granitic rock surface. The firm nature of the clay indicates that the clay had probably accumulated sometime prior to the failure, suggesting that the joint was partially open prior to the 2000 rockfall.

An accumulation of about 0.5 $m^3$ of landslide debris comprising granitic soil was present at the toe of the basal release surface. The joint surface in front of, and continuous with, the basal release surface appears stepped with its inclination decreasing to about 27º towards the front face of the rock slope (Figure 4). At that location, the joint is observed to be separated from an underlying, sub-parallel sheeting joint by a 50 mm high step (Plate 9).

The continuation of the joint forming the basal release surface is observed to become steeper to the southeast from an inclination of about 37° to greater than 45°, and appears to terminate against the sheeting joint below (Figure 5). The joint forming the basal release surface would therefore not appear to be part of the persistent sheeting joints that traverse the cut slope. However, the joint does appear to be closely associated with the sheeting joints and is only present directly above the sheeting joint.

A granite slab of about 50 mm thick at the rear of the landslide scar, the front face of which forms the rear release surface, was observed to terminate against the joint forming the basal release surface (Plate 11). However, the joint forming the basal release surface terminates against the joint surface behind the 50 mm thick slab (Plate 11). At the southern end of the intersection between the basal and rear release surfaces, a small void (about 50 mm wide by 200 mm high) is present and tree roots were noted to be growing within this void (Plate 11).

It is considered that the rear and basal joint surfaces may have developed as a result of unloading, possibly exploiting pre-existing structural weaknesses. The complex terminations at their intersection support this postulation.

During the site inspections after the 2000 rockfall, seepage was observed at many locations along the subject rock slope. In addition, signs of seepage in the form of staining below the sheeting joints were visible along almost the full length of the slope. The strongest seepage observed was at the northern end of the slope between Chainages 200 and 225, which is covered in moss (Plate 1). Heavy seepage at this location had also been recorded in many of the previous slope assessment reports (see Section 3.3). It was observed that the interceptor drains constructed within a natural drainage channel above the rock slope were totally blocked with vegetation debris, and water was flowing from the interface between the chunam and rock (Plate 13). The estimated water flow on the surface of the rock slope was about 0.5 l/min per linear metre of slope and was probably a result of both seepage from the rock slope and surface water flow from the natural drainage channel above. The water was foul smelling and consequently water samples were taken for laboratory testing. Results from the laboratory testing of the water samples showed an unusually high chloride level for groundwater, but no indication of the source of the foul smell was identified.

At a number of locations along the slope, the rock blocks above the sheeting joint appear to have been offset by between 100 mm and 200 mm, indicating possible movement along the sheeting joint (Plate 14).

## 5. SUBSURFACE CONDITIONS

### 5.1 Geology

Sheet 11 of the Hong Kong Geological Survey 1:20 000 scale map series HGM20 (GCO 1986), indicates that the solid geology of the landslide site and its surroundings comprises fine- to medium-grained granite (Figure 6). A southwest to northeast trending photogeological lineament, probably a fault, is indicated as crossing the valley located at the southern end of the slope.

Cut slope No. 11NE-D/C45 generally comprises slightly decomposed medium- to coarse-grained granite, with an upper soil portion generally formed in completely to highly decomposed granite with corestones (PW50/90).

The granite is variably jointed with joints being generally medium to widely spaced.

Persistent sheeting joints are visible over the full length of the rock slope (Plates 1, 2 and 3). Other prominent joint orientations are subvertical and are generally either parallel or perpendicular to the slope face. A more detailed discussion of joint orientation and joint characterisation is presented in Section 5.4.

## 5.2 Previous Ground Investigation

A number of previous assessments have been carried out on slope No. 11NE-D/C45, (see Section 3.3). The locations of the previous trial pits and boreholes are indicated on Figure 2. Boreholes HA7 and HA8, sunk as part of a ground investigation carried out for a slope stability study by B&P (1980), are the nearest boreholes to the 2000 rockfall and the 1993 landslide respectively.

Borehole HA7, located at the slope crest (67.5 mPD) about 16 m northeast of the 2000 rockfall location (Figure 2), encountered fill material to a depth of 1.5 m. The rest of the borehole was in slightly decomposed granite to a depth of 20.67 m (i.e. at 45.33 mPD), with the exception of moderately decomposed granite encountered between 63 mPD and 60.9 mPD. Joints were recorded in the rock core with inclinations of 30°, 45° and 70°. Several joints were noted to have kaolin, chlorite, iron and manganese infill and some joint surfaces had weathered to a highly decomposed granite. The thicknesses of the infills were not recorded.

Borehole HA8, located at the slope crest (67.5 mPD) about 15 m west northeast of the 1993 landslide location (Figure 2), encountered fill material to a depth of 1 m. Below the fill, highly decomposed granite was encountered to 55.2 mPD, with moderately decomposed granite from 55.2 mPD to 49.5 mPD. Between 49.5 mPD and 48 mPD, highly decomposed granite was logged but poor core recovery between 51 mPD and 49.5 mPD indicates that the severely weathered band could be up to 3 m thick. Below 48 mPD, the granite was slightly decomposed. Joints within the rock core were recorded with inclinations of 30°, 45°, 70° and subvertical. Iron, manganese, chlorite and kaolin infill was noted, although no thicknesses of the infill were recorded.

Impression packer tests were not carried out in either borehole. Piezometers were installed in both boreholes, although Halcrow buckets were apparently not installed. A review of the water levels recorded from the piezometers is presented in Section 5.5

## 5.3 Current Ground Investigation

Ground investigation works comprising two slope surface strips (SS1 and SS2) and a trial trench (TT1) were carried out on slope No. 11NE-D/C45 between 7 December 2000 and 2 January 2001. An inspection of a third slope strip (S4) excavated as part of the LPM study on the slope in March 2001, has also been carried out to supplement the information from the two previous slope strips. The locations of the slope strips and the trial trench are shown on Figure 2. Slope strip logs and trial trench logs are presented as Appendix D.

The slope strips SS1, SS2 and S4 were excavated through the shotcrete, placed as part of the urgent repair works, over the 1993 landslide scar. All three slope strips were excavated from about 1 m above the base of the rear release surface, then across the basal release surface of the landslide to the edge of the scar (Figure 2). A cross-section (Section 2-2) through the 1993 landslide site and a sketch are presented as Figures 7 and 8 respectively. All measurements along the slope strips are recorded from the top of the slope strips.

Highly decomposed granite (HDG) was exposed in the slope strips at the base of the rear release surface. Iron and manganese stained relict joints orientated at 58º/115º, 77º/228º and 65º/017º were observed within the exposed HDG. In slope strip S4, a narrow vein of mica was also observed with an orientation of 72º/185º, indicating that hydrothermal alteration had occurred within the granite at this location.

From about 1 m to 12 m along slope strips SS1 (Plate 15) and SS2 and from 2.9 m to 9.6 m along slope strip S4, loose to medium dense silty fine to coarse sand with angular gravel sized quartz and occasional boulder-sized fragments of completely decomposed granite (CDG) was exposed. Roots from some small bushes have grown within the upper 50 mm to 100 mm of soil within this section. Small depressions up to 300 mm deep within the soil at this section were infilled with very loose granitic soil and also contained fragments of old chunam/shotcrete surface which were probably debris from the 1993 landslide. However, the underlying soil had some relict structures indicating that it is insitu. At about 6 m to 6.7 m along slope strip S4, a planar, manganese and iron oxide stained joint surface was observed, with an orientation of 42º/223º. This is adversely orientated with respect to the slope face and may be parallel to the basal release surface for the 1993 landslide. At about 8.5 m along slope strip S4, a daylighting, shallow dipping (15º/221º) iron oxide and manganese stained joint with up to an 8 mm thickness of white kaolin clay infill is present. The portion of the slope (i.e. base of the 1993 landslide scar) along this section of the strips is typically inclined at about 40º to 45º to the horizontal, increasing to about 60º immediately below the rear release surface.

From 12 m to 16 m along slope strip SS1, 12.1 m to 19.3 m along slope strip SS2 and 11.9 m to 14.2 m along slope strip S4, highly to moderately decomposed granite was exposed. This is considered to represent the sheeting joint surface, at the toe of the 1993 landslide scar, which can be traced along the rock slope either side (Plate 2). The sheeting joint surface is typically orientated at 22º to 25º/250º.

Trial trench TT1 was excavated between 10.5 m and 12 m along slope strip SS2 (Plate 16). This confirmed that HDG observed in slope strip SS2 at that location was an insitu weathered band, at least 1 m thick above and associated with the sheeting joint, which is present at the toe of the 1993 landslide scar. The HDG contained a planar fabric, roughly parallel to the underlying rock surface and is interpreted as exfoliation fractures. The insitu HDG is also present from 9.6 m to 11.9 m along slope strip S4, which was also noted to contain steeply dipping manganese and iron oxide stained joints, with orientations similar to the rear and side release surfaces, 75º/228º and 80º/310º respectively, of the 1993 landslide. The rock cut slope below the 1993 landslide scar was observed to have up to a 100 mm thickness of HDG present in places, indicating severe weathering along steep joints to depths greater than 17 m below the slope crest.

5.4 Joints Characterisation

The roughness of the joint forming the basal release surface of the 2000 rockfall was characterised on a 0.2 m by 0.2 m grid, using both 80 mm diameter and 420 mm diameter plates. Data are plotted on a stereonet in Figure 9. A section along the centreline was plotted in Figure 10 and the roughness angle (i) determined. The mean roughness angle varied from 8° for the 420 mm plate to 14° for the 80 mm plate. Over the sampled length, the wavelength of the surface was determined to be about 0.4 m with an amplitude of up to 0.2 m.

The joint forming the basal release surface of the 2000 rockfall continues to the southeast, and was observed to become steeper from an inclination of about 37°, adjacent to the scar of the 2000 rockfall, to greater than 50° about 2 m further southeast. To assess the effect of this steeper portion of the continuation of the joint surface on the joint roughness characterization, a roughness survey of the 2 $m^2$ area adjacent to the basal release surface of the 2000 rockfall was also carried out on a 0.2 m by 0.2 m grid. (Refer to basal release surface (sheeting joint) in Figure 5). This additional data, combined with the data from the basal release surface are plotted on a stereonet in Figure 11. A section along the centreline of the extended survey area is presented in Figure 12. The roughness angle for the 80 mm plate decreased to 12° indicating an overall smoother surface whilst the roughness angle for the 420 mm plate remained at 8°. The wavelength and amplitude of the larger surface area remained unaltered.

The sheeting joint surface at the toe of the 1993 landslide was exposed only over a 4 m length along slope strips SS1 and SS2. The largest portion of the sheeting joint was covered with insitu CDG and HDG (Figure 8). The exposed surface of the sheeting joint was characterised by measuring dip angles and orientations along the centreline of both strips at 0.2 m intervals using the 80 mm diameter and 210 mm plates. The 210 mm plate was used instead of the 420 mm plate, because of the restricted access of the 0.5 m wide slope strips. The readings are plotted on a stereonet in Figure 13.

A section along the centreline of slope strip SS2 was plotted in Figure 14, and the roughness angle (i) determined. The roughness angle varied from 12° for the 210 mm plate to 16° for the 80 mm plate. The rear release surface (Figure 7) of the 1993 landslide scar has a mean orientation of 74°/230°. The southern side release surface could not be accessed during the inspection; however, it is estimated that the surface is orientated at about 75°/310°.

A rock joint survey was carried out along the toe of slope No. 11NE-D/C45 and adjacent slope No. 11NE-D/C44 with the primary purpose of determining whether the basal release surface of the 2000 landslide could be identified elsewhere on the slope and what variability in inclination, particularly localised steepening, could be observed. Six pole concentrations were identified, labelled Sets A to F, in Figure 15. A preliminary stereonet assessment of the rock joint data, indicates that both planar and wedge failure mechanisms are kinematically possible. Observations at the rock slope during the rock joint survey show that potential rock wedges have been identified in previous assessments (e.g. B&P, 1980) and potential failure mitigated against through installation of rock bolts.

Essentially in terms of planar failure Set A, with a mean orientation of about 35°/231°, represents a set of adversely orientated joints. The joints are not persistent and are only developed along a small section at the northern end of the slope. Set B, with a mean orientation at 80°/248° and the spread of poles from this concentration, represents the rear release surfaces at both landslides. Set C, with a mean orientation of 77°/330°, represents the side release surfaces for both the 1993 landslide and the 2000 rockfall.

Only minor preferential weathering was observed along joints at the toe of the slope. No evidence was found of weathered bands adjacent to the sheeting joints of similar thickness to the band identified in trial trench TT1 at the 1993 landslide scar and possibly indicated in borehole HA8.

Typically, the subvertical joints are planar and manganese stained while the sheeting joints are undulating and iron stained. Seepage and seepage stains are predominantly observed below the sheeting joints and, to a much lesser extent, adjacent to subvertical joints.

### 5.5 Groundwater Conditions

The only piezometers identified in the vicinity of the 2000 rockfall and 1993 landslide were installed in boreholes HA7 and HA8 during the ground investigation works carried out in 1979 (Figure 2). The piezometers were monitored from May 1979 to January 1980.

The piezometer in borehole HA7 was installed at a depth of 17.50 m (59 mPD) with a response zone from 17 m to 22.2 m below ground level (bgl). The tip of the piezometer is 15.5 m below the rockhead (defined as Grade III or better rock). Groundwater at between 12 m and 14.5 m bgl was recorded during the monitoring period (Figure 4).

Two piezometers were installed in borehole HA8. The upper piezometer was installed within HDG about 5 m above the rockhead at 15 m bgl (52.5 mPD), with a response zone between 14.5 m and 15.5 m bgl. The piezometer remained dry throughout the monitoring period. The second piezometer was installed within slightly decomposed granite about 2.5 m below the rockhead at 22 m bgl (45.5 mPD), with a response zone between 21.5 m and 25.7 m bgl. Groundwater was recorded between 10.5 m and 20.5 m bgl (Figure 7), during the monitoring period. The higher water levels recorded were 4.5 m above the level of the upper piezometer, which remained dry through the same monitoring period. This observation may be explained if the response zone of the lower piezometer intercepted a sheeting joint with groundwater flow.

The presence of natural drainage channels at the northern and southern ends of the slope have probably concentrated water flows in the past. However, as a result of the past development, the topography of the area has been altered to such a degree that it is not possible to assess the relative influence of these channels on the current hydrogeology of the slope.

## 6. ANALYSIS OF RAINFALL RECORDS

### 6.1 General

The two nearest GEO automatic raingauges to the 1993 and 2000 landslides are raingauge Nos. K03 and K08 (Figure 1). Raingauge No. K03, the nearest raingauge to the site, is located at PMG Radio Monitoring Station, Hong Ning Road, about 0.8 km west of the landslide site. Raingauge No. K08 is located at FDBWA Szeto Ho Secondary School, Kai Tin Road, Lam Tin, about 1.1 km south-southeast of the landslide site. The raingauges record and transmit rainfall data at 5-minute intervals via a telephone line to the GEO. These records have been analysed to determine the characteristics of the rainstorms associated with the landslides.

6.2 The 2000 Rockfall

The daily rainfall recorded by raingauge No. K03 over a period of one month preceding and three days following the incident is presented in Figure 16. For the purposes of rainfall analysis, it is assumed that the landslide occurred at 6:00 hours on 3 August 2000, which is defined by the eye-witness accounts (Section 4.1).

Hourly rainfall recorded at raingauge No. K03, between 2 August and 3 August 2000 is also presented in Figure 16. The hourly rainfall data show a rainfall peak of 77 mm between 05:00 hours and 06:00 hours on 3 August 2000. Table 2 presents the estimated return periods for the maximum rolling rainfalls recorded at GEO raingauge No. K03, for various durations based on historical rainfall data recorded at the Hong Kong Observatory (Lam & Leung, 1994). The one-hour maximum rolling rainfall between 05:00 hours and 06:00 hours on 3 August 2000 was the most severe compared with the other selected durations, with a corresponding return period of about three years.

A comparison of the 3 August 2000 rainstorm with that of other past major storms recorded by raingauge No. K08 is presented in Figure 17. Since data are missing from raingauge No. K03 for the rainstorm in September 1993, data from raingauge No. K08, the second closest raingauge, has been used for the purposes of comparing different rainstorms. The 3 August 2000 rainstorm was less severe than several other previously recorded significant storms, since installation of raingauge No. K08 in 1983.

6.3 The 1993 Landslide

Since data are missing from raingauge No. K03 for the rainstorm in September 1993, raingauge No. K08, the second closest raingauge, has been used for the rainfall analysis. For the purposes of rainfall analysis, it is assumed that the landslide occurred at 18:00 hours on 26 September 1993 (Section 3.4), as recorded in the GEO Incident Report.

The daily rainfall recorded by raingauge No. K08 over a period of one month preceding and two days following the landslide is presented in Figure 18. The one-hour rainfall prior to the failure at about 18:00 hours was less than 20 mm.

Table 3 presents the estimated return periods for the maximum rolling rainfalls recorded at raingauge No. K08, for various durations based on historical rainfall data recorded at the Hong Kong Observatory. The 4-day maximum rolling rainfall (427.5 mm) prior to 18:00 hours on 26 September 1993 was the most severe compared with the other selected durations, with a corresponding estimated return period of about 5 years. Whilst it is acknowledged that this simplified method of rainfall analysis does not necessarily give the true return period for a particular site as several contributory factors are not taken into account (Wong & Ho, 1996b), nonetheless it provides an indication of the likely relative severity of the various rainfall characteristics assessed.

A comparison of the 26 September 1993 rainstorm with that of other past major storms recorded by raingauge No. K08 is presented in Figure 17. The rainstorm was less severe than several other previously recorded significant storms since the installation of the raingauge in 1983.

## 7. DIAGNOSIS OF THE PROBABLE CAUSES OF THE LANDSLIDES

### 7.1 Mode and Sequences of the 2000 Rockfall and 1993 Landslide

The mode of the 2000 rockfall involved principally sliding failure along an adversely orientated joint. Persistent subvertical joints provided the northern and rear release surfaces. The southern release surface was exposed prior to the failure as a result of a previous failure or scaling of an adjacent block. The rock block most likely free-fell from the slope, as no impact features are visible on the slope surface. The block apparently came to rest at the point of impact at the toe of the slope as there are no signs of bounce or travel after the initial impact.

The mode of failure of the 1993 landslide probably also involved principally sliding failure along an adversely orientated and undulating joint within a preferentially weathered zone associated with this joint. Persistent subvertical joints provided the southern and rear release surfaces. No northern release surface was required as the basal release surface, formed by the sheeting joint, daylighted on the surface of the soil/rock slope forming the northern flank of the 1993 landslide. The morphology of the landslide debris, as identified from photographs, comprised a single lobe of material which indicates that the landslide occurred essentially as a single rapid event.

### 7.2 Probable Causes of the 2000 Rockfall and 1993 Landslide

The close correlations between the rainstorm on the night of 2 August and early morning of 3 August 2000 and the 2000 rockfall, and the rainstorm in the morning and afternoon of 26 September 1993 and the 1993 landslide, indicate that rainfall most probably triggered both landslides.

There is evidence from site observations that, as a result of progressive deterioration of the slope, the joints controlling both the 2000 rockfall and the 1993 landslide were open or partially open prior to failure, namely:

(a) the presence of clay infill and root growth along the joint planes that formed the release surfaces of the 2000 rockfall (Plate 11),

(b) the release surfaces exposed by the 1993 landslide were extensively stained black and reddish brown indicating weathering associated with through-flow of groundwater

(Plate 5), and

(c) apparent movement along the sheeting joints evidenced by offsetting against the face of the slope (Plate 14).

The development of transient cleft water pressures in these open joints most probably initiated both the failures. The possible sources of water were probably a combination of subsurface groundwater flow along the sheeting joints (as evidenced by the seepage, staining and vegetation growth observed below the sheeting joints) and direct infiltration of surface water into open joints at the crest of the slope. The lack of surface drainage provisions other than crest and toe drains and the interceptor drains, would have resulted in significant surface water flows on the upper soil/rock section of the slope.

Analysis of the effect of possible presence of water at the joint forming the rear release surface of the 2000 rockfall, was carried out and the results are presented in Appendix E. This preliminary analysis, based on the analysis of planar failure presented in Hoek & Bray (1981), indicates that the factor of safety is greater than 1.2 when dry, decreasing to 1 when there is between 1 m and 1.5 m vertical head of water in the rear release surface. Based on field observations of partial blockage of the open joints by roots, clay infill and probable chunam dentition (moss-covered chunam observed at base of fallen rock block see Section 4.3), it is considered likely that a vertical water head in the back release surface of greater than about 1.5 m could have developed.

Detailed characterisation of the sheeting joints that formed the basal release surface of both the 2000 rockfall and 1993 landslide demonstrates the tendency of such joints to show variable dip (i.e. waviness) over relatively short distances. The tendency of such joints to locally steepen may have resulted in steep and adversely orientated joints occurring immediately behind the slope face and this may have contributed to the failures.

## 8. DISCUSSION

The detailed review of the past slope assessments indicates that, in general, the previous assessments on the slope have recognised the potential for minor failures. A buffer zone and boulder fence were provided for along the toe of the slope to prevent access by the public. The stabilisation works carried out were undertaken only to guard against the incidence of major failures.

Notwithstanding the above, it is clear that the major landslide in 1993 was much larger than that allowed for by the provision of the buffer zone and boulder fence. A review of the previous assessments shows that the buffer zone and boulder fence were not explicitly designed to mitigate against any specified design event. The 2000 rockfall came to rest within the buffer zone and did not affect any areas used by the general public.

Common generic factors that contributed to both the 2000 rockfall and the 1993 failure are as follows:

(a) the presence of adversely orientated, undulating sheeting joints that daylight across the slope. The sheeting joints provide basal release surfaces to the failures and conduits for subsurface groundwater flow and the development of water pressure,

(b) the presence of persistent subvertical joints forming rear and side release surfaces and also the development of water pressure, and

(c) progressive deterioration of the slope, resulting in the development of open, partly clay-infilled joints allowing increased water ingress.

Possible evidence of downslope groundwater flow within the sheeting joints is provided by the monitoring data from borehole HA8. While no response was recorded in the upper piezometer, a piezometric level 4.5 m above the upper piezometer was recorded in the lower piezometer. This observation could be explained if the response zone of the lower piezometer intercepted a sheeting joint with groundwater flow or a confined groundwater aquifer under artesian conditions.

The results from laboratory testing on water samples taken from the seepage at the northern end of the rock slope showed an unusually high chloride level for groundwater, the source of which will need to be investigated further. The source of the foul smelling water noted at the location of the seepage was not confirmed by the laboratory testing and may be related to rotting vegetation (fallen leaves, etc.) at the slope crest or from a green algae growing on the rock face.

The adversely orientated joint (steeper than the adjacent sheeting joint) which formed the basal release surface of the 2000 rockfall would only have become visible after the failure or removal of the adjacent block, which is assumed to have occurred sometime between 1980 and 1985. This may explain why no stabilisation works were carried out at that location following the slope assessments in the late 1970's and early 1980's. During the site inspection after the 2000 rockfall, paint and chunam were observed along what was the edge of the southern side of the failed block, which would only have become exposed after failure or scaling off of the adjacent block. None of the slope assessment reports reviewed (see Section 3.3) record stabilisation works at this location. At the time the chunam was placed, the adversely orientated joint contributing to the 2000 rockfall would have been clearly exposed. It may be postulated that a careful inspection of the block involved in the 2000 rockfall might have indicated that the block was potentially unstable, and that additional stabilisation measures were required.

The 1993 landslide was controlled by the presence of a steeply dipping and undulating basal release surface, together with open persistent joints forming the side and rear release surfaces. The joints forming the basal and southern release surfaces appear to have been identified in earlier studies (e.g. HKHA, 1989). The GEO concurred with this observation in their file note prepared after the 1993 landslide, in which it is stated that the "steeply dipping joint had probably been identified during the appraisal [HKHA, 1989] in 1989".

The ground investigation works carried out for this study attempted to characterise the basal release surface as exposed in the landslide scar. However, this was only partially successful as insitu CDG and HDG obscured the release surface. The section that was characterised showed a variation in dip from about 10° to 34° which was generally significantly steeper than that which might have been measured on the slope face prior to failure (i.e. 22° to 25°). It is considered that it would have been difficult for field mapping prior to the major failure to have identified the slightly open nature of the joint forming the rear release surface, given the dense vegetation and chunam cover over the upper section of the slope. In addition, it is possible that at the time of the initial slope inspection in 1980, the joints may not have been open, and that they might have only become more open due to progressive deterioration of the slope. Consequently, it is considered difficult for a routine slope assessment to have predicted the major landslide in 1993. This would have been especially true with respect to assessments carried out before the early 1980's that predated the first technical paper on local experience which discussed the potential undulating nature of sheeting joints (e.g. Richards & Cowlands, 1982).

It is noteworthy that the 1993 landslide occurred following a rainstorm with a return period of only about 5 years, despite the fact the slope had previously been affected by rainstorms of significantly greater intensity (see Section 6.3). A possible explanation of this is that the slope became more prone to direct infiltration due to progressive deterioration arising from minor movements and effects of tree root action associated with unplanned vegetation resulting in opening up of the joints. Deterioration may have occurred in a series of intermittent phases initiated by successive periods of heavy rainfall.

## 9. CONCLUSIONS

It is concluded that both the 2000 rockfall and 1993 landslide were most likely triggered by rainfall, with estimated maximum return periods of about 3 and 5 years respectively.

The slope has a history of instability that can be traced back to the late 1970's. The most significant of these failures was the 1993 landslide which involved the failure of about 200 $m^3$ of predominantly rock that destroyed a section of boulder fence located along the toe of the slope. The probable principal cause of the landslide was the development of transient elevated cleft water pressure within an adversely orientated, undulating and probably open sheeting joint associated locally with a relatively thick band of weathered material.

The principal causes of the 2000 rockfall were similar to the 1993 landslide, involving the development of transient elevated cleft water pressure within adversely orientated open and partly clay-infill joints. The occurrence of the 1993 landslide and the 2000 rockfall after only moderately heavy rainfall, on a slope which had previously been affected by significantly more intense rainstorms, was possibly a result of progressive deterioration of the slope condition allowing increased water ingress into the slope through the open or dilated joints.

A series of geotechnical assessments has been carried out on the slope resulting in three phases of stabilisation works in 1980/81, 1984 and 1990. It is evident that the 2000 rockfall was examined in its insitu position prior to the recent failure, judging from paint and attached chunam on the fallen block.

As for the major landslide in 1993, the steepness and severely weathered nature of the sheeting joint may not be readily apparent from mapping of exposure in the rock face during the numerous examinations by several consultants at different times which failed to identify the hazard. A review of borehole data, however, suggests the potential for thick weathering (up to 3 m) along sheeting joints. For further works on this slope and in similar settings, the possibility of persistent sheeting joints with increase in dip away from exposure in the rock face would need to be considered and investigated. The growth of unplanned vegetation on the subject slope is both indicative of the presence of water and weathering products and has been a major factor in the progressive deterioration of the rock mass.

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Richards, L.R. & Cowlands, J.W. (1982). The Effect of Surface Roughness on the Field Shear Strength of Sheeting Joints in Hong Kong Granite. Hong Kong Engineer, October 1982, pp 39-43.

Wong, H.N. & Ho, K.K.S. (1996a). Travel distance of landslide debris. Proceedings of the Seventh International Symposium on Landslides, Trondheim, Norway, vol. 1, pp 417-422.

Wong, H.N. & Ho, K.K.S. (1996b). Thoughts on the Assessment and Interpretation of Return Periods of Rainfall. Discussion Note DN 2/96, Geotechnical Engineering Office, Hong Kong, 12 p.

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Table 1 - Summary of Sources of Information (Sheet 1 of 3)

| Information Source | Reference | Principal Relevant Content/Comment |
|---|---|---|
| Published Reports and Documents | Hong Kong & Kowloon: Solid and Superficial geology, Hong Kong Geological Survey Map Series HGM 20, Sheet 11, 1:20 000 scale<br><br>Geology of Hong Kong Island and Kowloon Geological Memoir No. 2<br><br>Geotechnical Area Studies Programme Report I: Hong Kong and Kowloon | Background Geological and Geomorphological Information of Area |
| Planning Division, GEO | Aerial Photographs 1945, 1949, 1954, 1963, 1964, 1974, 1978, 1980, 1984, 1986, 1987, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999.<br><br>SIRST Report for Slope No. 11NE-D/C45<br><br>Natural Terrain Landslide Inventory<br><br>Terrain Clarification Map | Site History and Geomorphology of the Slope and Surrounding Area<br><br>Construction Date, Geometry and General Condition<br><br>Details of Natural Terrain Failures in the Area Based on High Level Aerial Photographs |
| Slope Safety Division, GEO | SIRST Report for Slope No. 11NE-D/C45 | Geometry, Field Observation and General Condition of Slope No. 11NE-D/C45 |

Table 1 - Summary of Sources of Information (Sheet 2 of 3)

| Information Source | Reference | Principal Relevant Content/Comment |
|---|---|---|
| Mainland East Division, GEO | GCME 2/E2/86 (E) Pt. 3, folio 13 | Incident Report No. K86/9/1 and Details of the Landslide |
| | GCME 2/E2/93 (E)K, Pt. 1, folio 28 | Incident Report No. K93/9/17 and Details of the Landslide |
| | GCME 2/E2/93 (E)K, Pt. 1, folio 29 | Incident Report No. K93/8/18 and Details of the Landslide |
| | GCME 2/E1/11NE-D/C45 | Background Information Relating to History of the Slope |
| | GCMd 3/2/36 | Report on the Stability of the Rock Slopes 11NE-D/C44, 45, 46, 47 and 11NE-D/FR7 and 14 at Hiu Ming Street, Kwun Tong Volume II, Binnie & Partners (HK) Ltd., January 1980. |
| | GCME 6/7/1994 | Stage 1 study Report Cut Slope No. 11NE-D/C45 Hiu Ming Street Playground Kowloon |
| Special Projects Division, GEO | GCSP 2/D9/29-1 | Landslip Incident at Hiu Ming St., Sau Mau Ping Incident No. K93/9/17 |
| Geotechnical Information Unit (GIU) | GIU Ref. OG66557997 | Cut Slope 11NE-D/C45 East End of Hiu Ming Street, Kwun Tong Stage 1 Study Report S1 40/79 Existing Slopes Division |
| | GIU Ref. 12238 | Report on Geotechnical Remedial Works to Existing Slopes 11NE-D/C44, 45, 46, 47 and 11NE-D/FR7 and 14 at Hiu Ming Street, Kwun Tong, Halcrow International Partnership October 1980 |
| | 1977/78 Catalogue of Slopes | Field Sheet for Slope No. 11NE-D/C45 |

Table 1 - Summary of Sources of Information (Sheet 3 of 3)

| Information Source | Reference | Principal Relevant Content/Comment |
|---|---|---|
| Housing Department Geotechnical Engineering Section | Geotechnical Maintenance Unit (GMU) Library Code No. SR 4052 | Rock Slope Behind Hiu Ming Street Playground, Rock Slope Stabilisation Appraisal Report, Hong Kong Housing Authority May 1989 |
| | GMU Library Code No. SR 4084 | Report on the Stability of the Rock Slopes 11NE-D/C44, 45, 46, 47 and 11NE-D/FR7 and 14 at Hiu Ming Street, Kwun Tong Volume II Binnie & Partners (HK) Ltd. January, 1980 |
| | GMU Library Code No. 4122 | Report on the Review of Information and Requirements for Slopes Behind Hiu Ming Street Playground Freeman Fox (Far East) Ltd. March 1986 |
| | Drawing No. 62/4/CE/91 | As-built drawing for Kwun Tong (TPR) Estate Phase 4 |
| Hong Kong Observatory | Isohyets of Rainfall | Rainfall Distribution in Hong Kong from 3 August 2000 and 26 September 1993 |
| Water Supplies Department | Letter Reference (2) in WSD/MSE 674/20/2/99, Pt. 2 T/J 2 | Watermains along Hiu Kwong Street and Hiu Ming Street |
| Drainage Services Department | | No Existing Utility in the Vicinity of Landslide Location |

Table 2 - Maximum Rolling Rainfall at GEO Raingauge No. K03 and Estimated Return Periods for Different Durations Preceding the Landslide of 3 August 2000

| Duration | Maximum Rolling Rainfall (mm) | End of Period (Hours) | Estimated Return Period (Years) |
|---|---|---|---|
| 5 minutes | 12 | 06:00 hours on 3 August 2000 | 2 |
| 15 minutes | 26 | 06:00 hours on 3 August 2000 | 2 |
| 1 hour | 77 | 06:00 hours on 3 August 2000 | 3 |
| 2 hours | 84.5 | 06:00 hours on 3 August 2000 | 2 |
| 4 hours | 94.5 | 06:00 hours on 3 August 2000 | 1 |
| 12 hours | 94.5 | 06:00 hours on 3 August 2000 | 1 |
| 24 hours | 137.5 | 06:00 hours on 3 August 2000 | 1 |
| 2 days | 181.5 | 06:00 hours on 3 August 2000 | 1 |
| 4 days | 216.5 | 06:00 hours on 3 August 2000 | 1 |
| 7 days | 216.5 | 06:00 hours on 3 August 2000 | 1 |
| 15 days | 277.5 | 06:00 hours on 3 August 2000 | 1 |
| 31 days | 464 | 06:00 hours on 3 August 2000 | 1 |

Notes:
(1) Return periods were derived from Table 3 of Lam & Leung (1994).
(2) Maximum rolling rainfall was calculated from 5-minute data.
(3) The use of 5-minute data for durations between 4 hours and 31 days results in better data resolution, but may slightly over estimate the return periods using Lam & Leung's (1994) data, which are based on hourly rainfall for these durations.

Table 3 - Maximum Rolling Rainfall at GEO Raingauge No. K08 and Estimated Return Periods for Different Durations Preceding the Landslide of 26 September 1993

| Duration | Maximum Rolling Rainfall (mm) | End of Period (Hours) | Estimated Return Period (Years) |
|---|---|---|---|
| 5 minutes | 7.5 | 07:15 hours on 26 September 1993 | 1 |
| 15 minutes | 21 | 07:15 hours on 26 September 1993 | 1 |
| 1 hour | 24 | 07:20 hours on 26 September 1993 | 1 |
| 2 hours | 38.5 | 06:55 hours on 26 September 1993 | 1 |
| 4 hours | 58 | 08:00 hours on 26 September 1993 | 1 |
| 12 hours | 116.5 | 12:00 hours on 26 September 1993 | 1 |
| 24 hours | 197.5 | 10:00 hours on 26 September 1993 | 2 |
| 2 days | 303.5 | 18:00 hours on 26 September 1993 | 3 |
| 4 days | 427.5 | 18:00 hours on 26 September 1993 | 5 |
| 7 days | 428 | 18:00 hours on 26 September 1993 | 3 |
| 15 days | 558.5 | 18:00 hours on 26 September 1993 | 3 |
| 31 days | 558.8 | 18:00 hours on 26 September 1993 | 1 |

Notes:
(1) Return periods were derived from Table 3 of Lam & Leung (1994).
(2) Maximum rolling rainfall was calculated from 5-minute data.
(3) The use of 5-minute data for durations between 4 hours and 31 days results in better data resolution, but may slightly over estimate the return periods using Lam & Leung's (1994) data, which are based on hourly rainfall for these durations.

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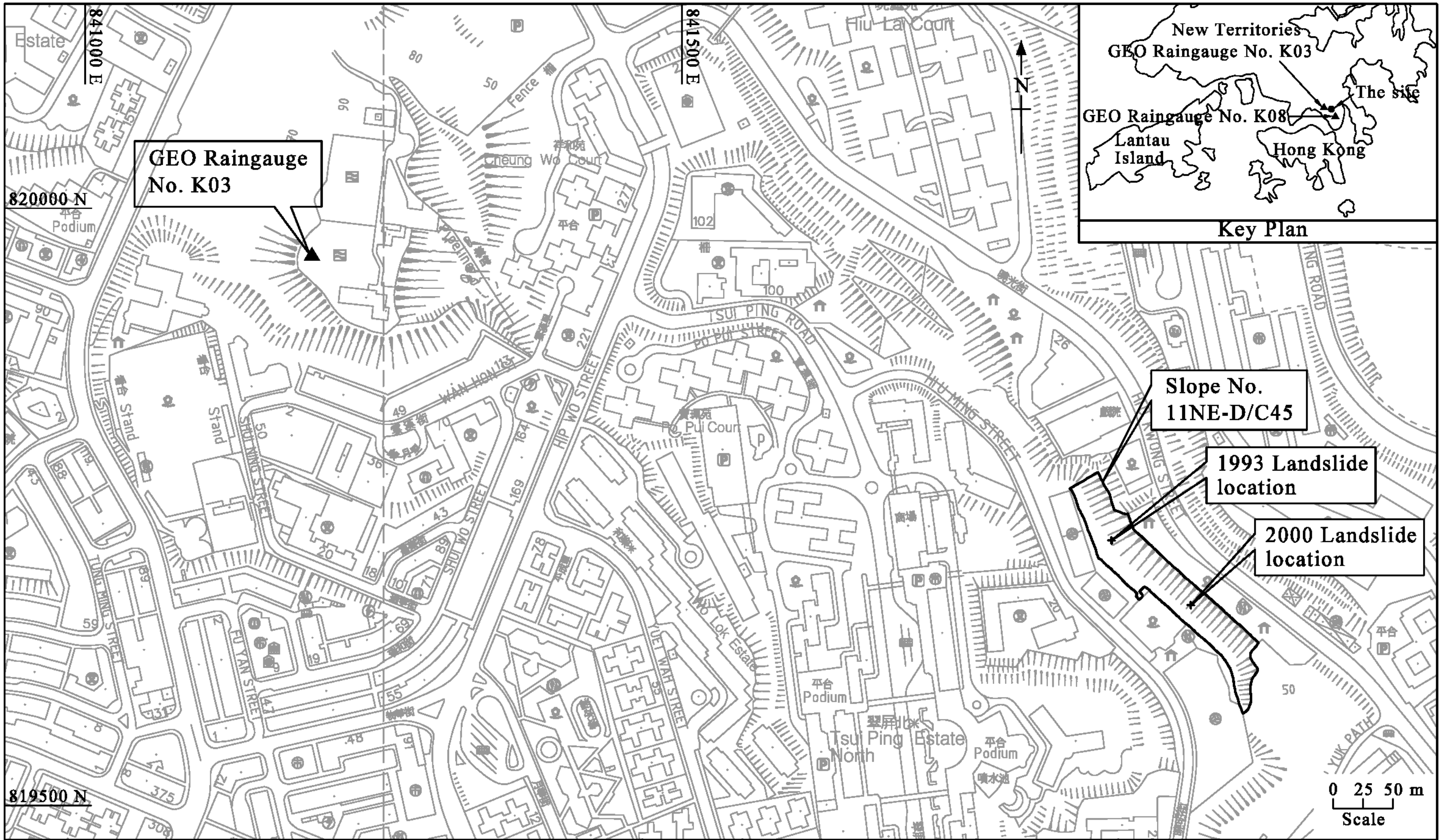
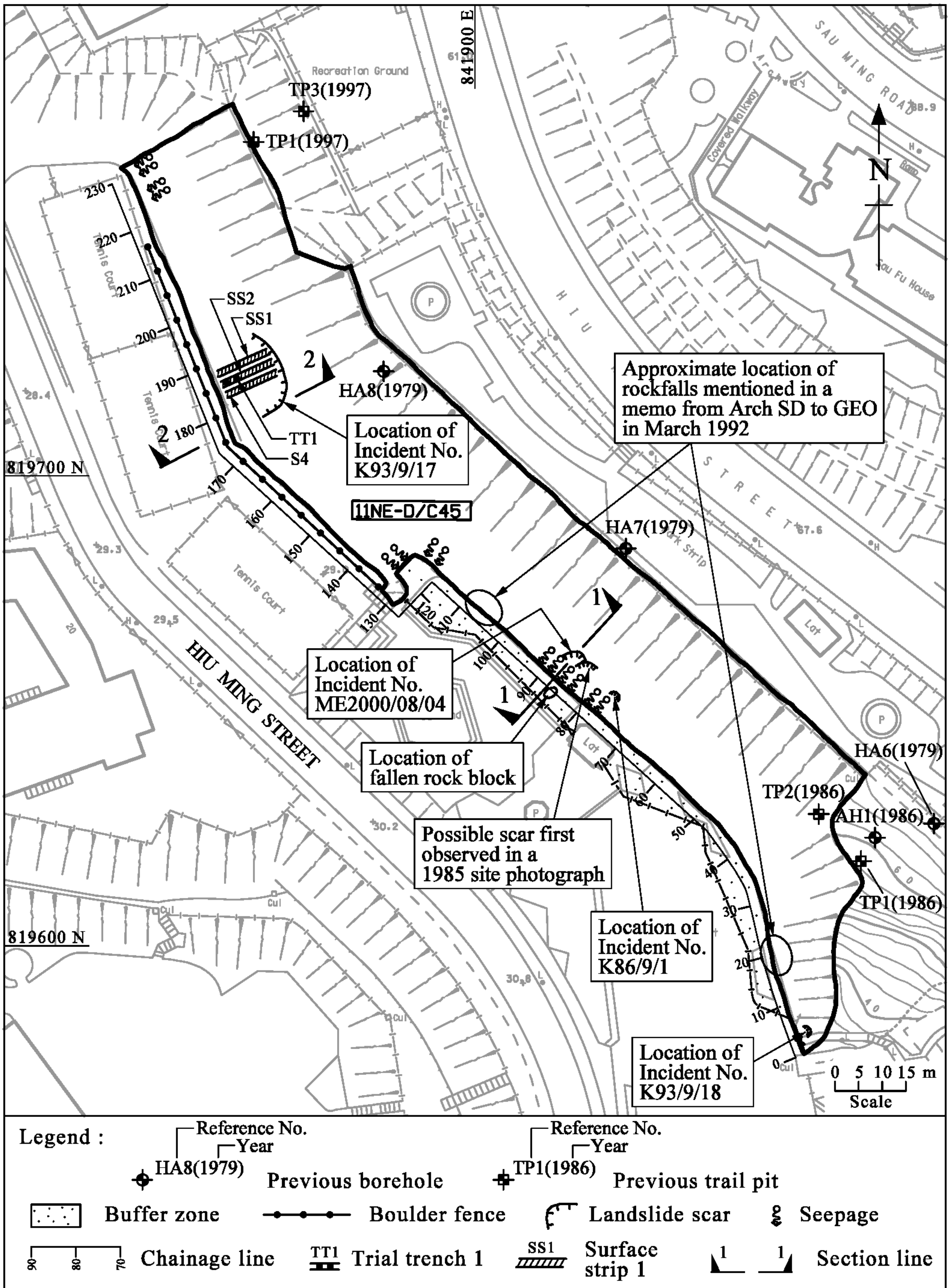



Note : Base map is extracted from Survey Sheets Nos. 11NE-C & 11NE-D, scale 1:5000.

Figure 1 - Site Location Plan




Notes : (1) Base map is extracted from Survey Sheet No. 11NE-18D, scale 1:1000.
(2) Refer to Figures 4 & 7 for Sections 1-1 & 2-2 respectively.

Figure 2 - Location Plan of the Landslides and Ground Investigation

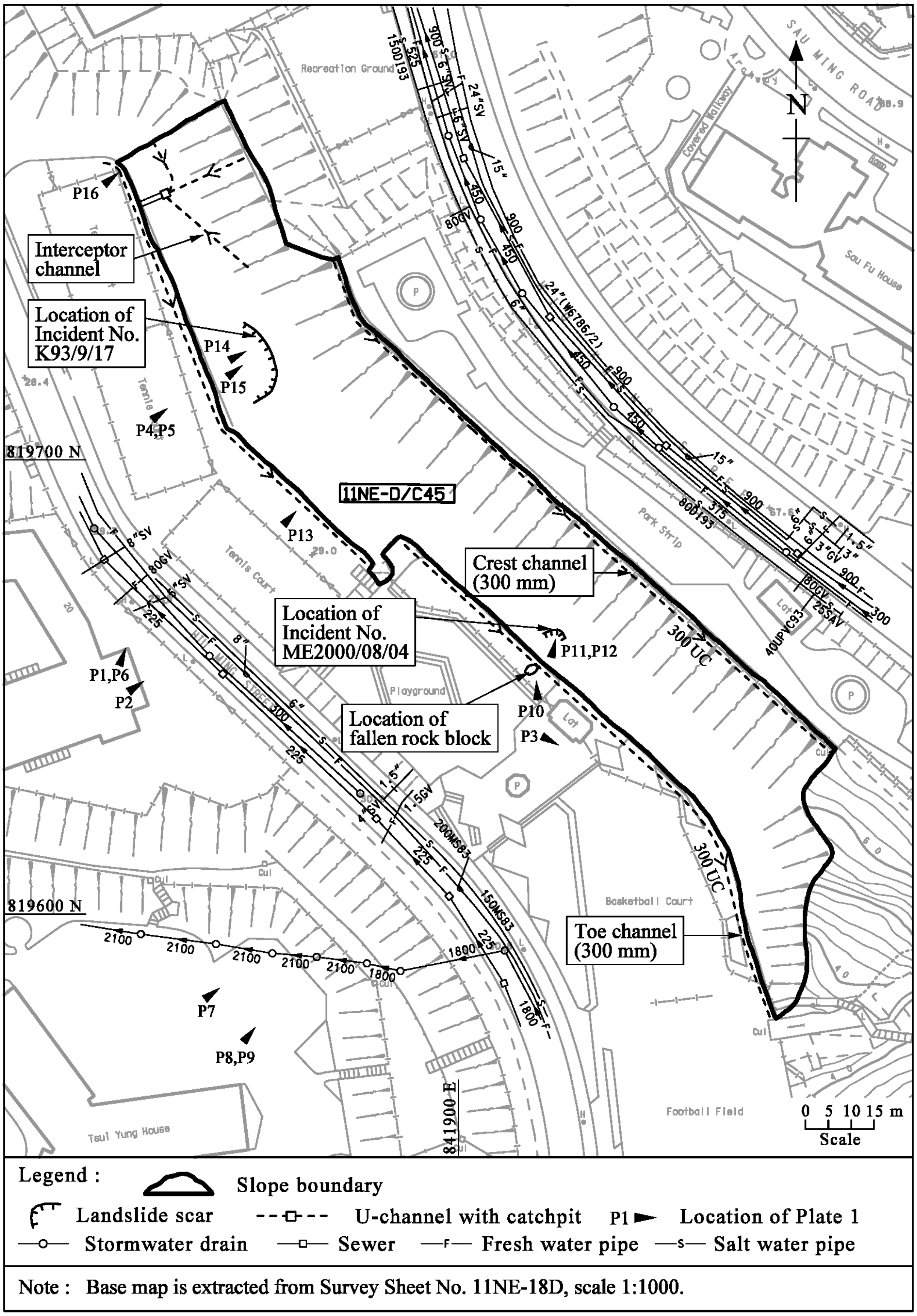
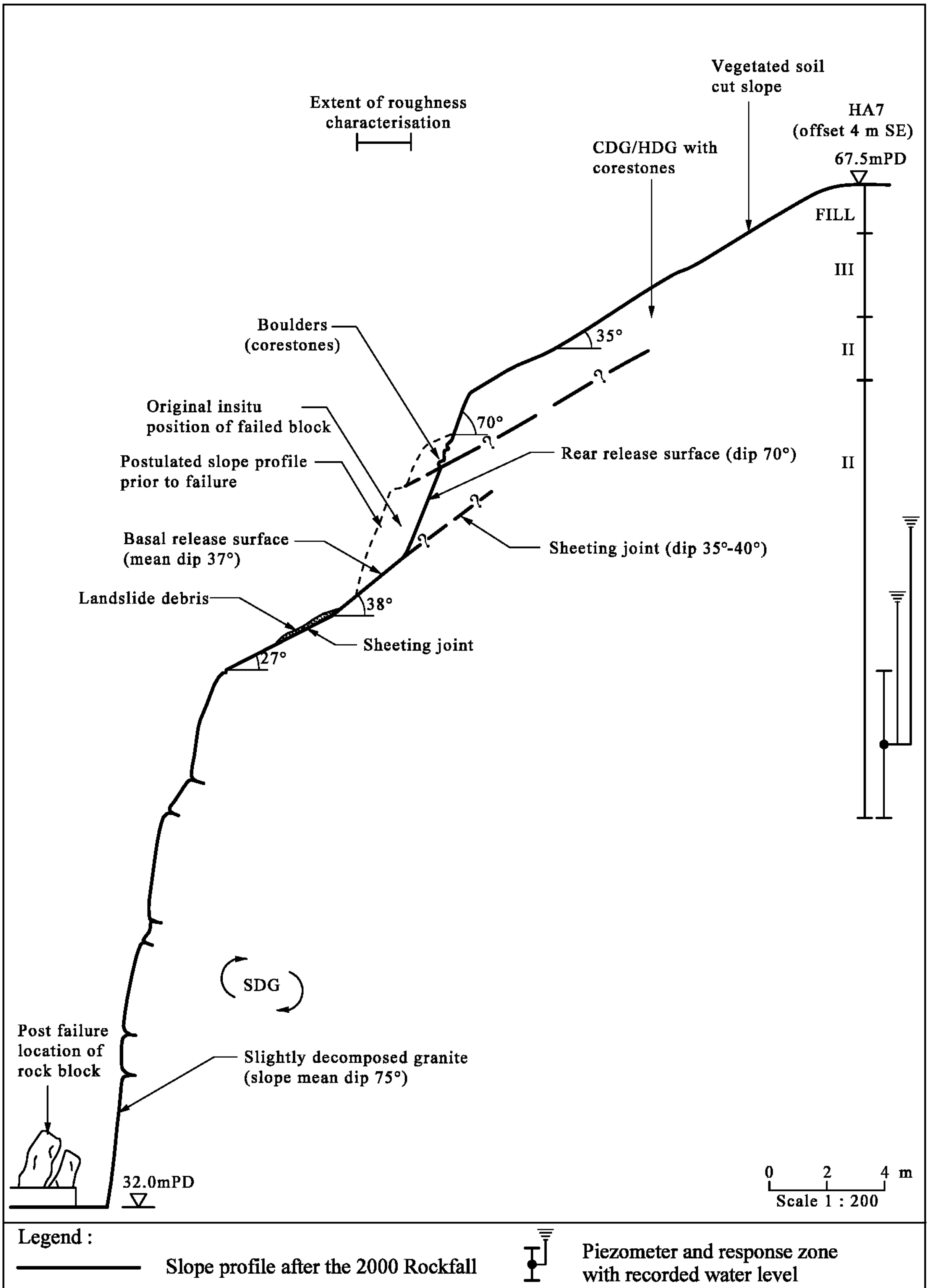
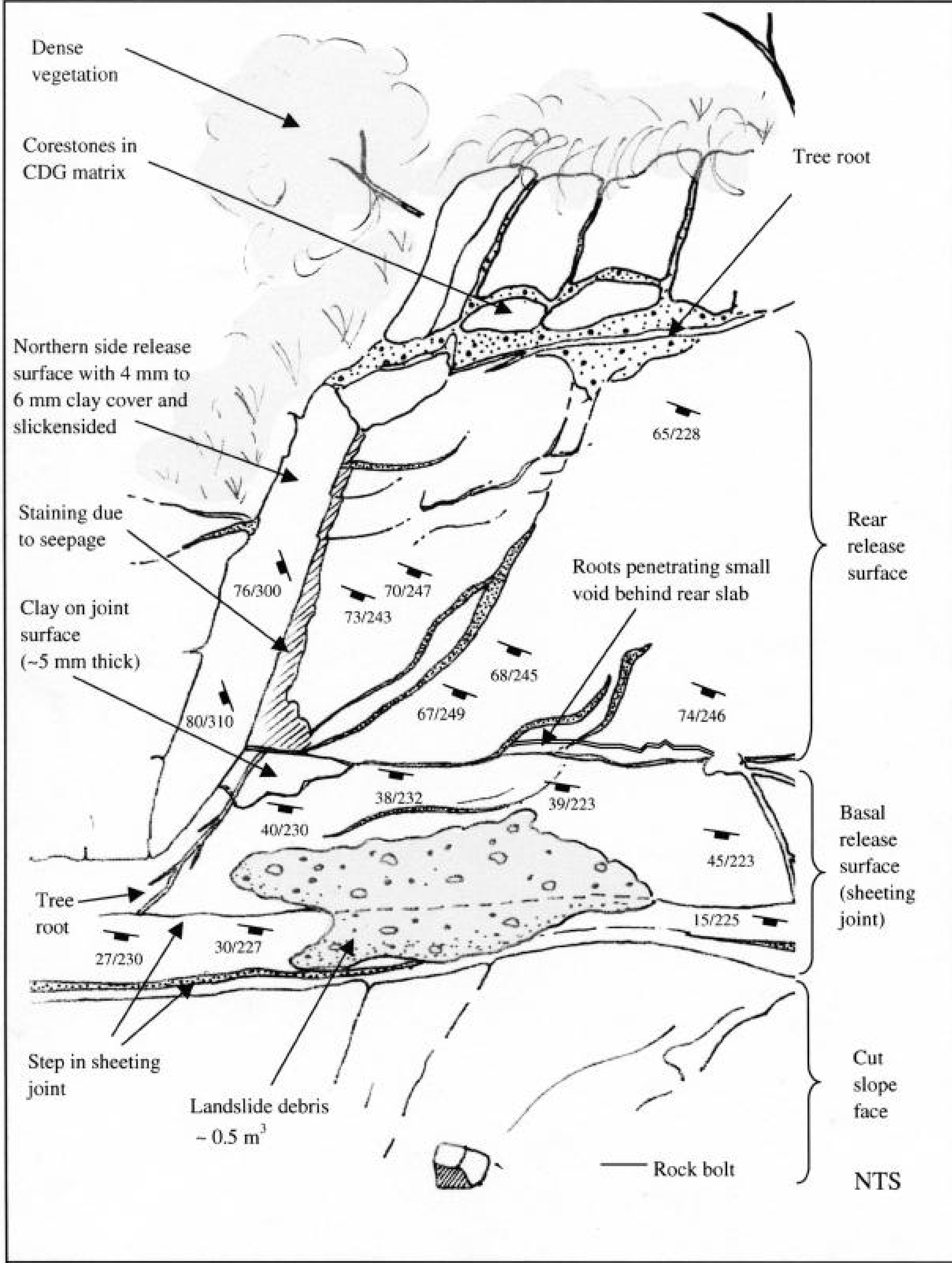



Figure 3 - Plan of Utilities and Locations of Plates



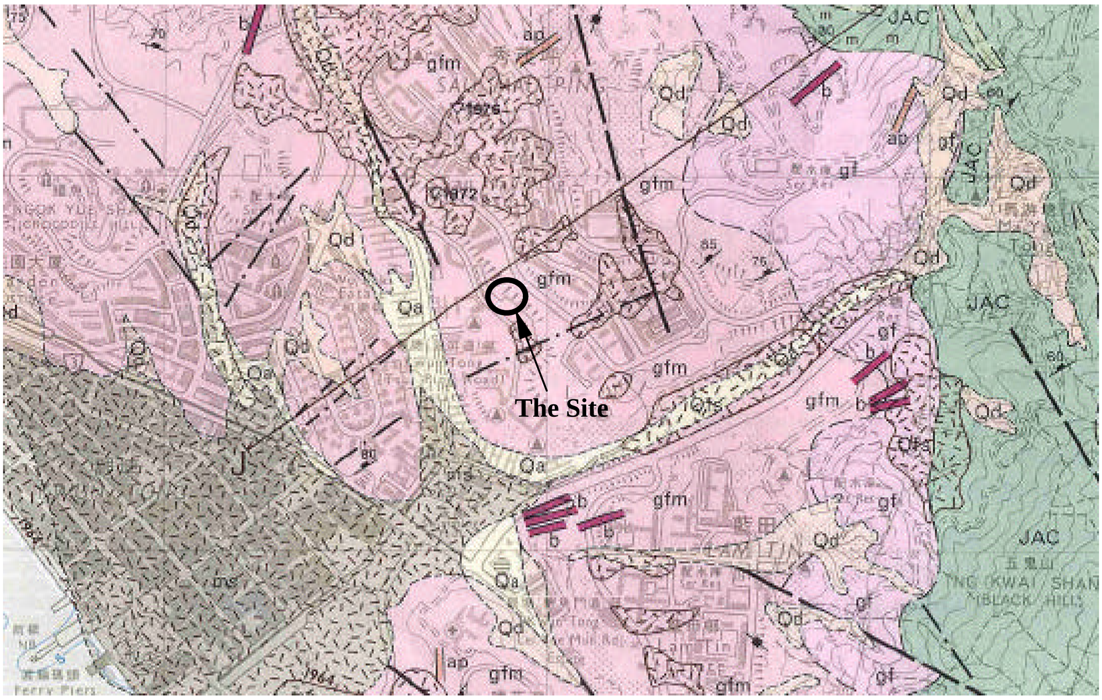

Note : Refer to Figures 10 & 12 for details of the roughness characterisation.

Figure 4 - Cross-section 1-1 through the 2000 Rockfall




| | |
|---|---|
| Legend: | 74/242 Dip angle/dip direction of rock joint |
| Notes: | (1) Sketch is based on Plate 9 and site observations<br>(2) Not to scale |

Figure 5 - Sketch of the Scar of the 2000 Rockfall




SCALE 1:20 000

LEGEND:

SUPERFICIAL DEPOSITS

- Fill; sanitary fill - natural earth and waste
- Qa — Alluvium - clay/silt, sand and gravel; well sorted to semi-sorted
- Qd — Debris flow deposits - unsorted sand, gravel, cobbles and boulders; clay/silt matrix
- Marine sand, part silty

SOLID GEOLOGY

- JAC — Fine ash vitric tuff
- e — Eutaxite
- gf — Fine-grained granite
- gfm — Fine- to medium-grained granite
- b — Basalt
- ap — Aplite

GEOLOGICAL LINES

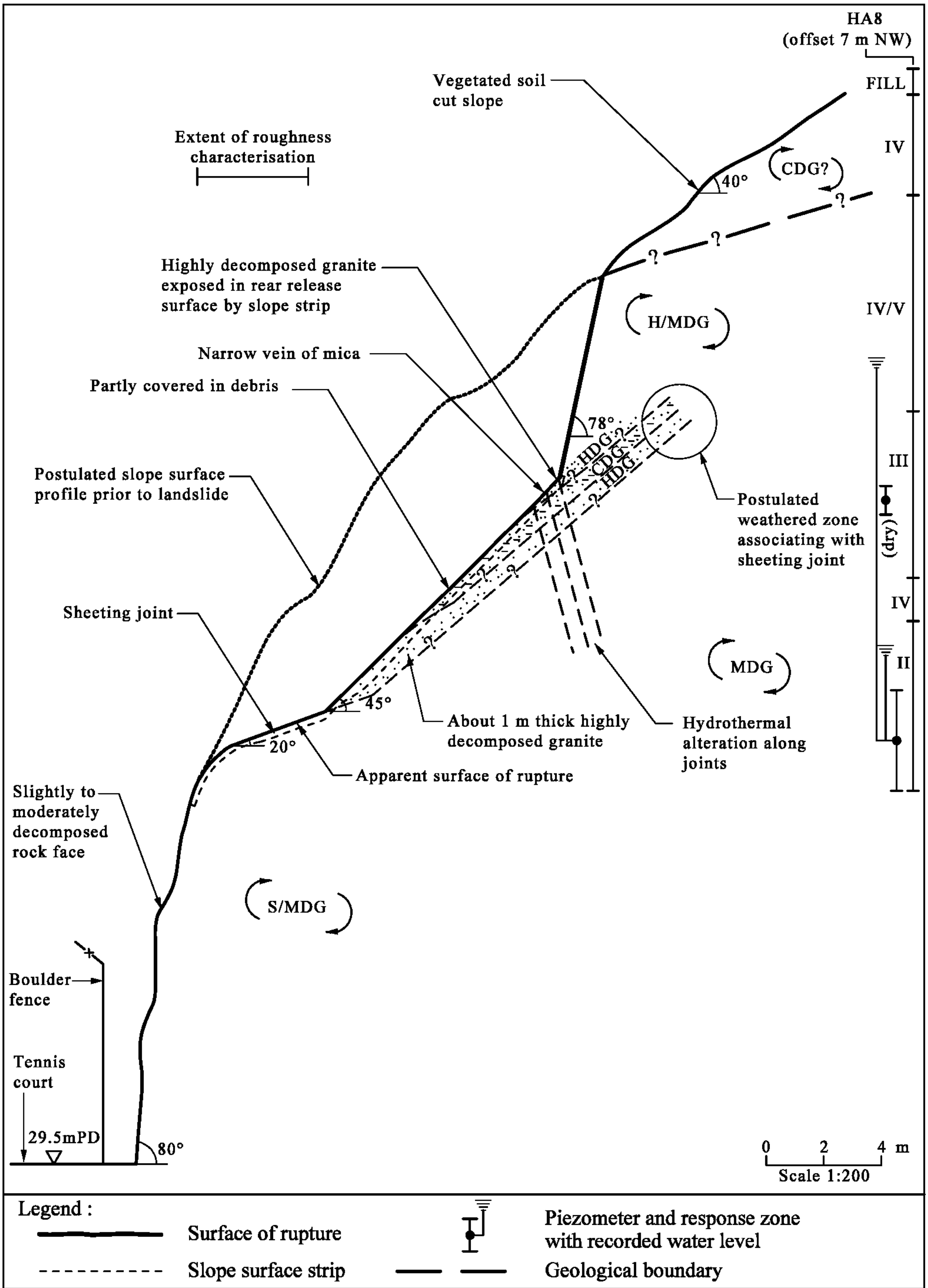
- Geological boundary, superficial deposit
- 1982 — Fill boundary
- Geological boundary, solid rock
- Fault
- Mineral vein
- Photogeological lineament

STRUCTURAL SYMBOLS

- 20 — Bedding
- 20 — Intrusive contact
- 20 — Jointing

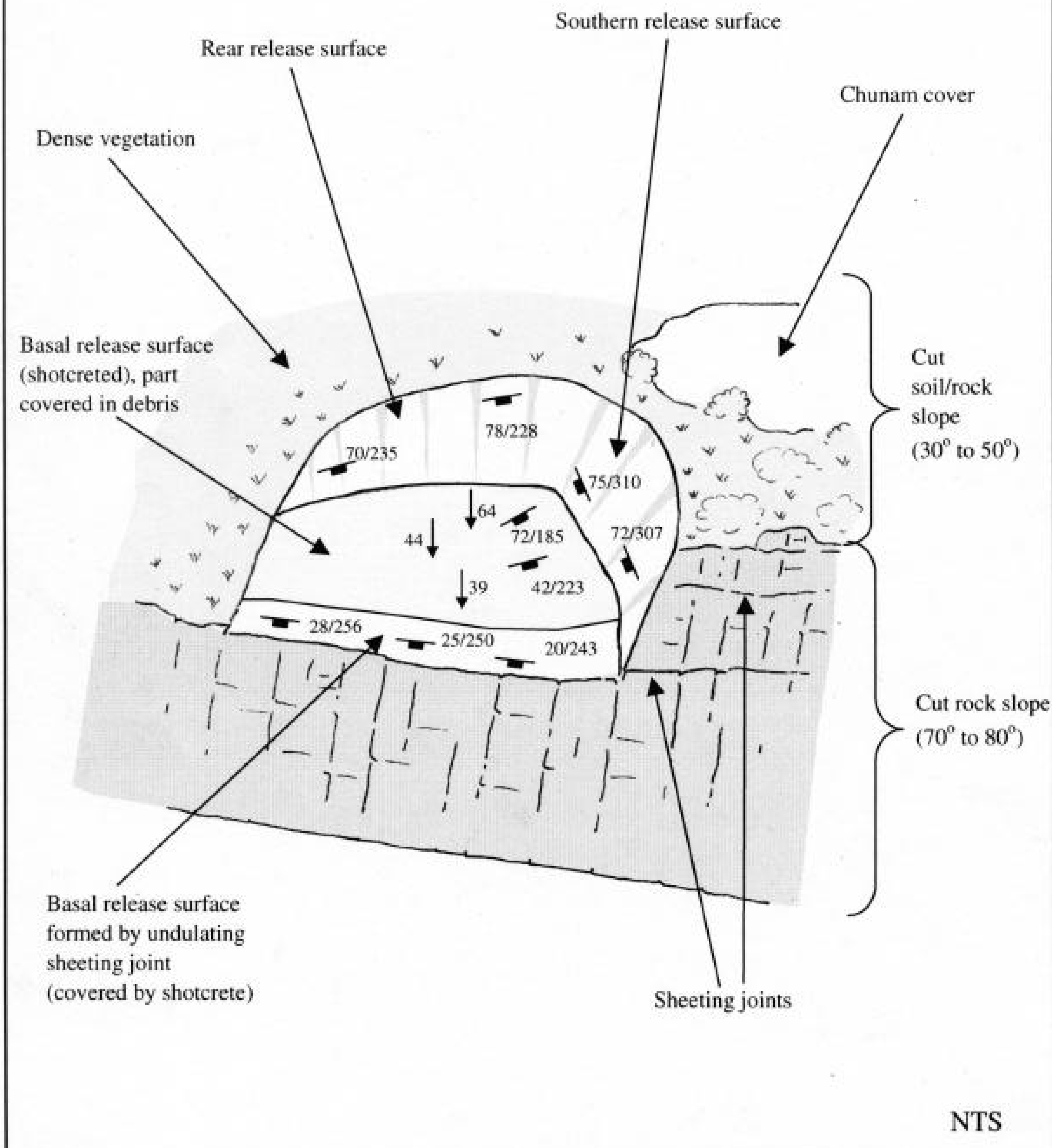
Note: Extracted from Hong Kong Geological Survey Sheet 11 (1:20,000), Map Series HGM 20 (GCO, 1986).

Figure 6 - Regional Geology of the Landslide Site




Note : Refer to Figure 14 for details of the roughness characterisation.

Figure 7 - Cross-section 2-2 through the 1993 Landslide




Legend: 74/242 Dip angle/dip direction of rock joint
39/264 Inclination of shotcrete surface

Note: (1) Sketch is based on Plate 6 and site observations.
(2) Not to scale.

Figure 8 - Diagrammatic Sketch of the Scar of the 1993 Landslide

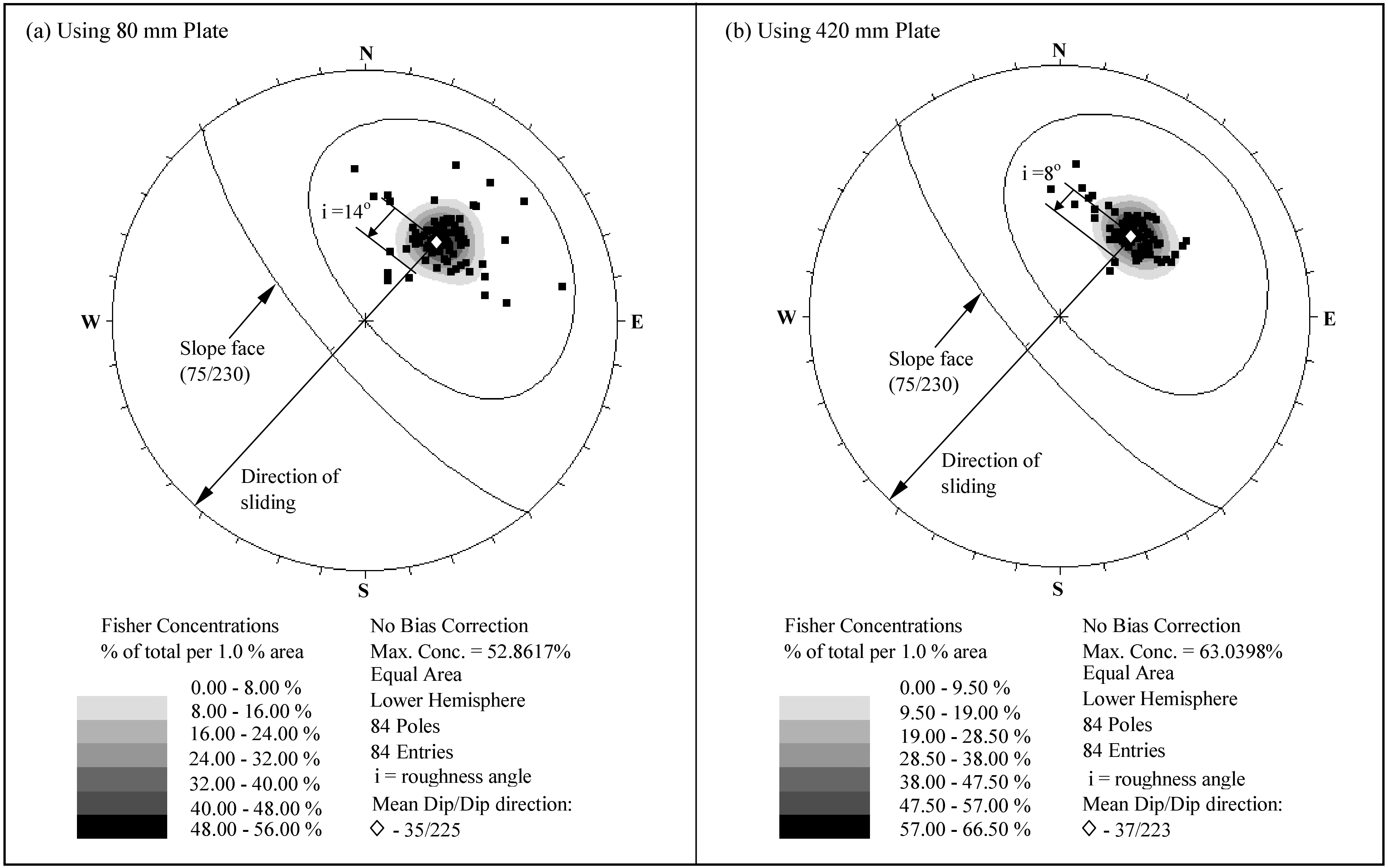
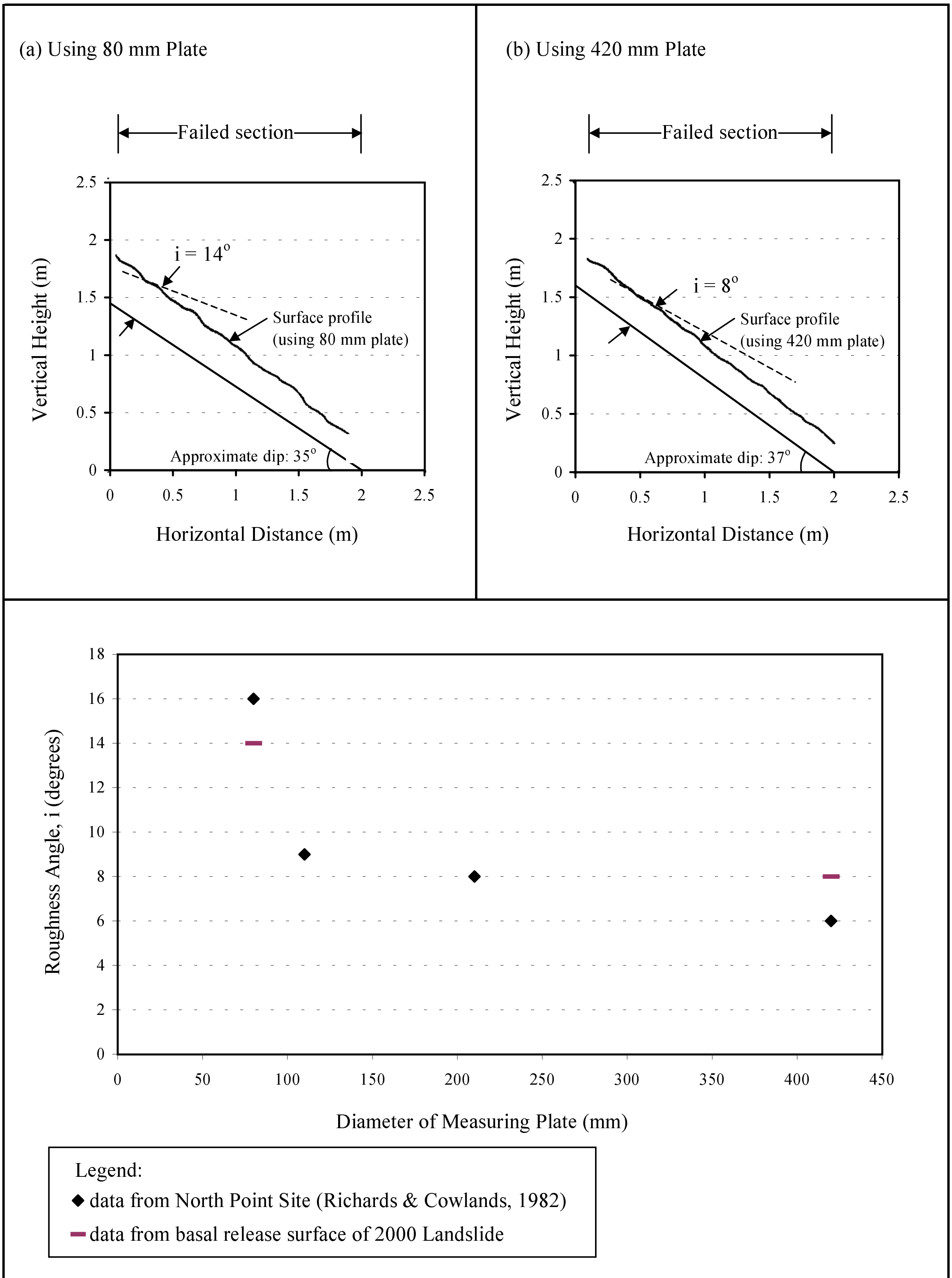



Figure 9 - Stereonets for Roughness Characterisation of Basal Release Surface for the 2000 Rockfall




Notes: (1) Refer to Figure 4 for location of the profile.
(2) i value is determined from joint orientation data measured from a 200 mm x 200 mm grid on the basal release surface (Figure 9).

Figure 10 - Profile of Basal Release Surface for the 2000 Rockfall

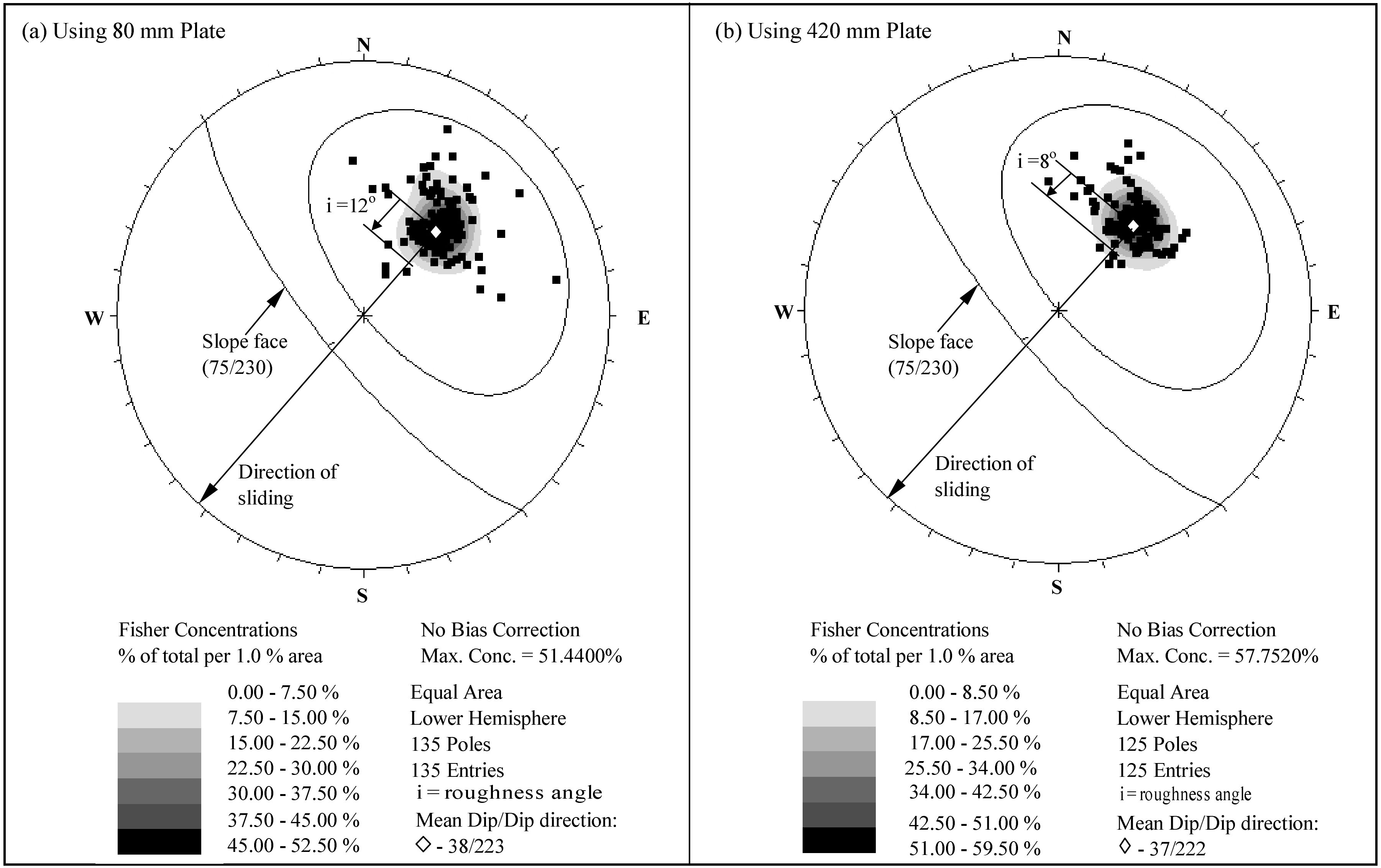
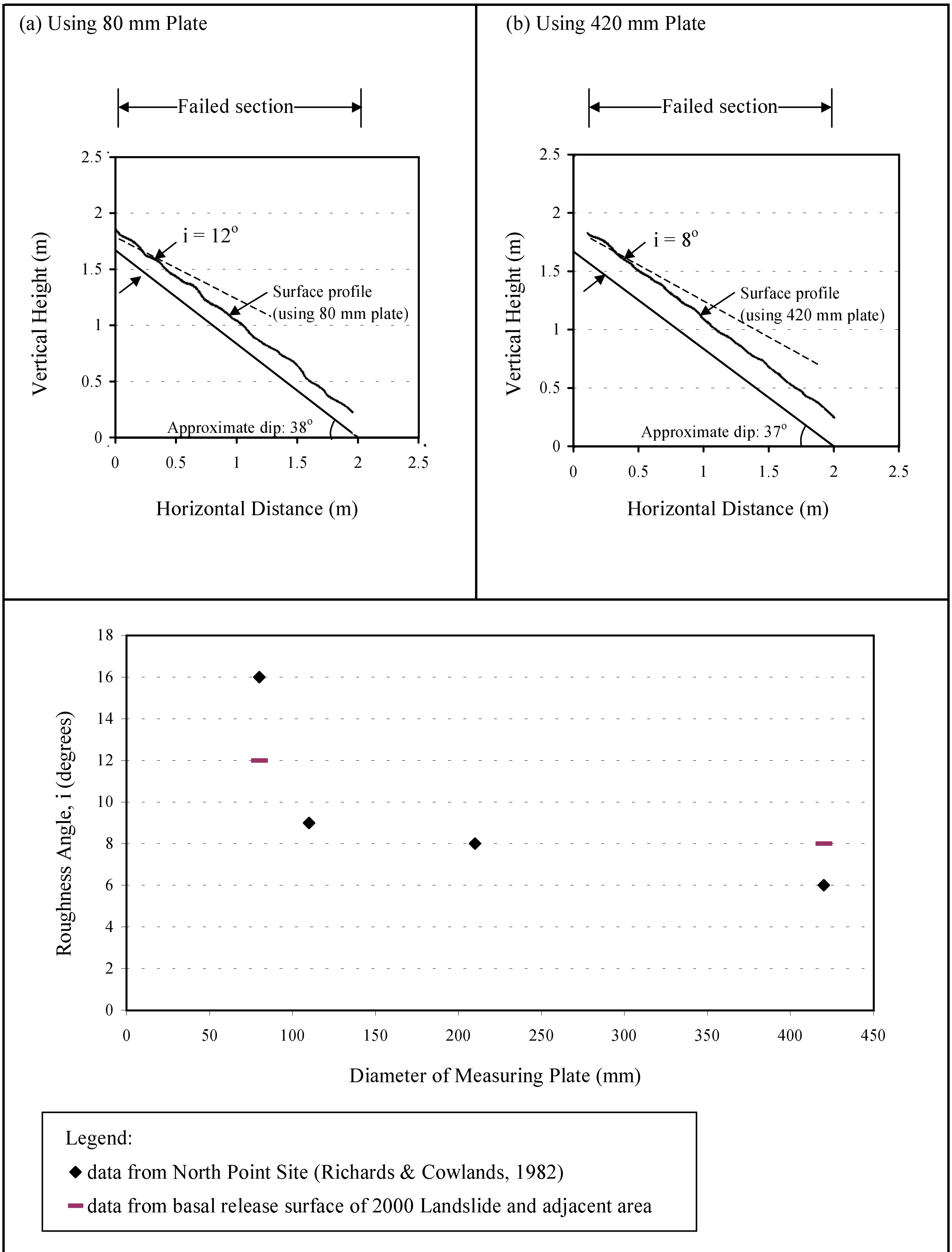



Figure 11 - Stereonets for Roughness Characterisation of Basal Release Surface of the 2000 Rockfall Including the Adjacent Joint Surface




Notes: (1) Refer to Figure 4 for location of the profile.
(2) i value is determined from joint orientation data measured from a 200 mm x 200 mm grid on the basal release surface (Figure 11).

Figure 12 - Profile of Basal Release Surface of the 2000 Rockfall Including the Adjacent Joint Surface

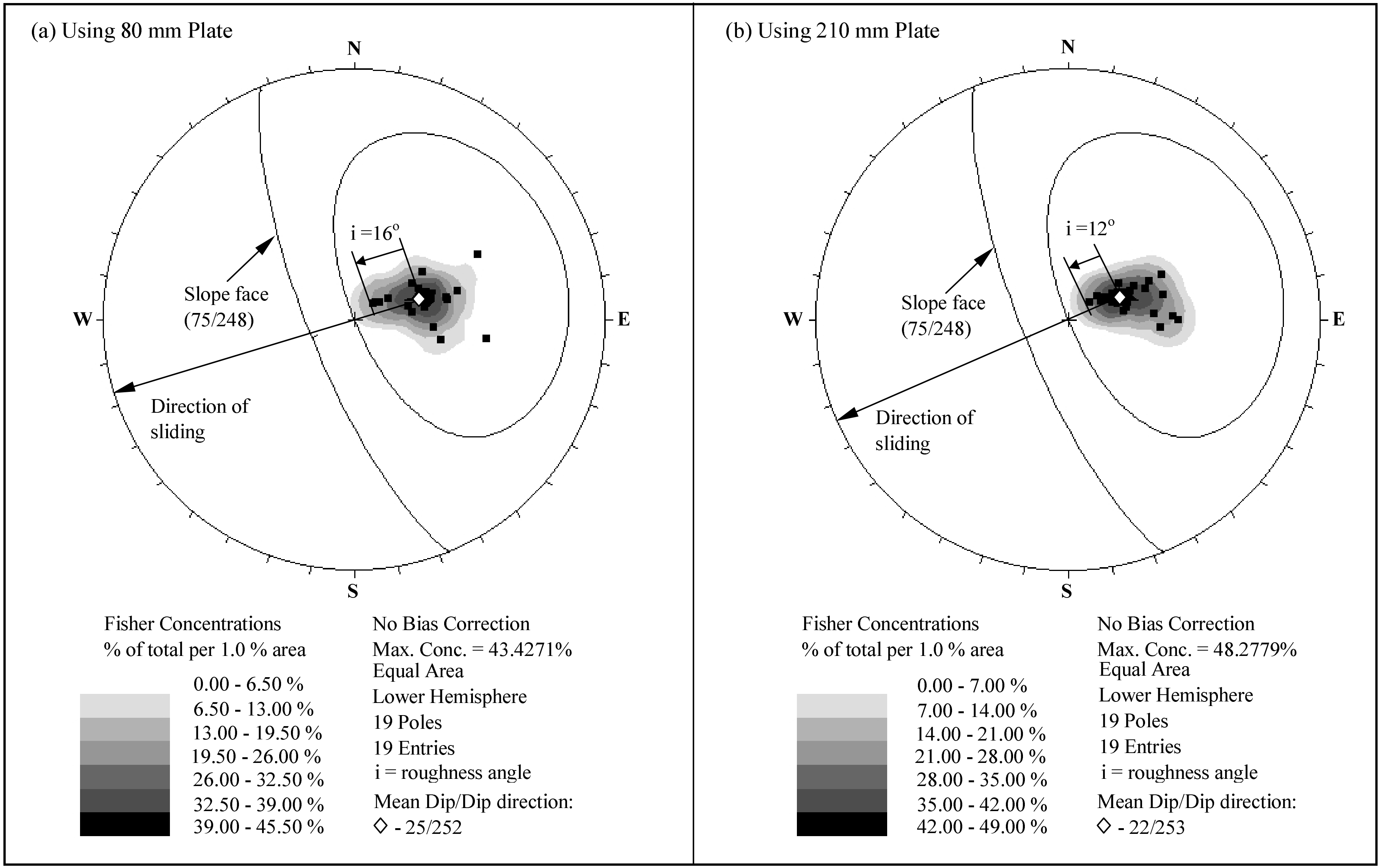
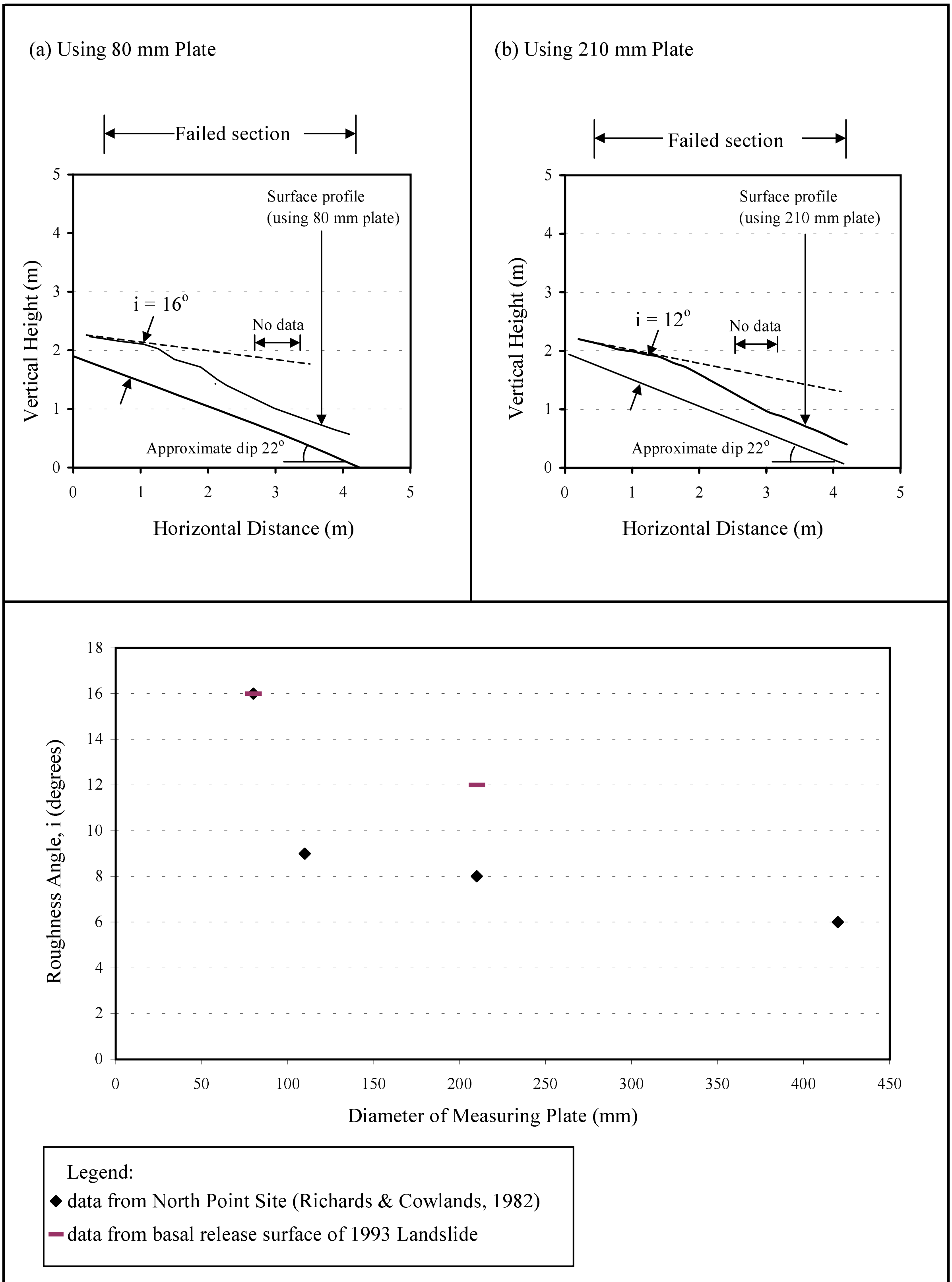
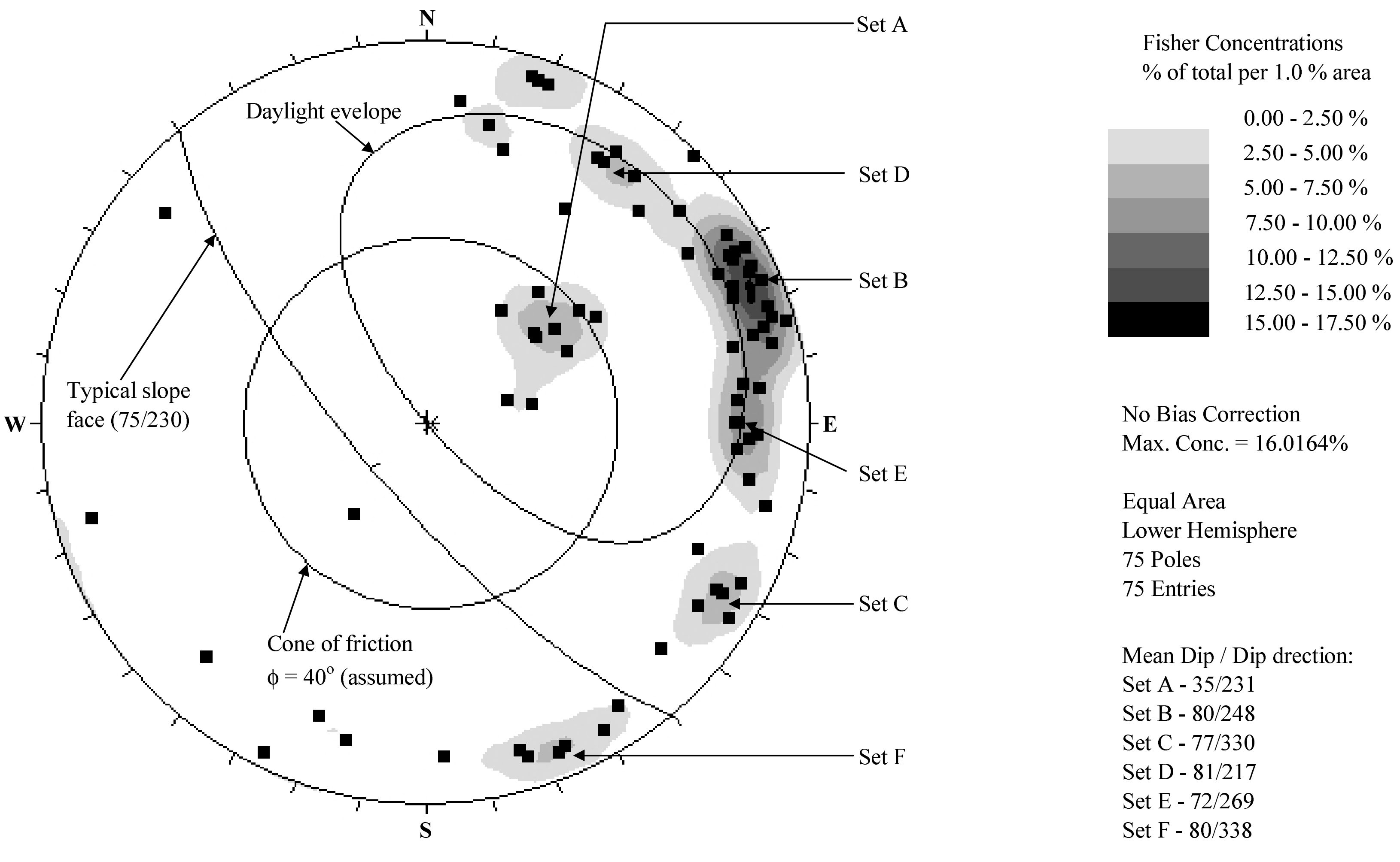



Figure 13 - Stereonets for Roughness Characterisation of Sheeting Joint at the 1993 Landslide from Measurements along SS1 and SS2




Notes: (1) Refer to Figure 7 for location of the profile.
(2) i value is determined from joint orientation data measured from SS2 at an 200 mm interval (Figure 13).

Figure 14 - Profile of Sheeting Joint at the 1993 Landslide




Note:

locations of the 1993 and 2000 Landslides.

Figure 15 - Stereonet of the Measured Orientations of Discontinuities at Slope Nos. 11NE-D/C44 and 11NE-D/C45

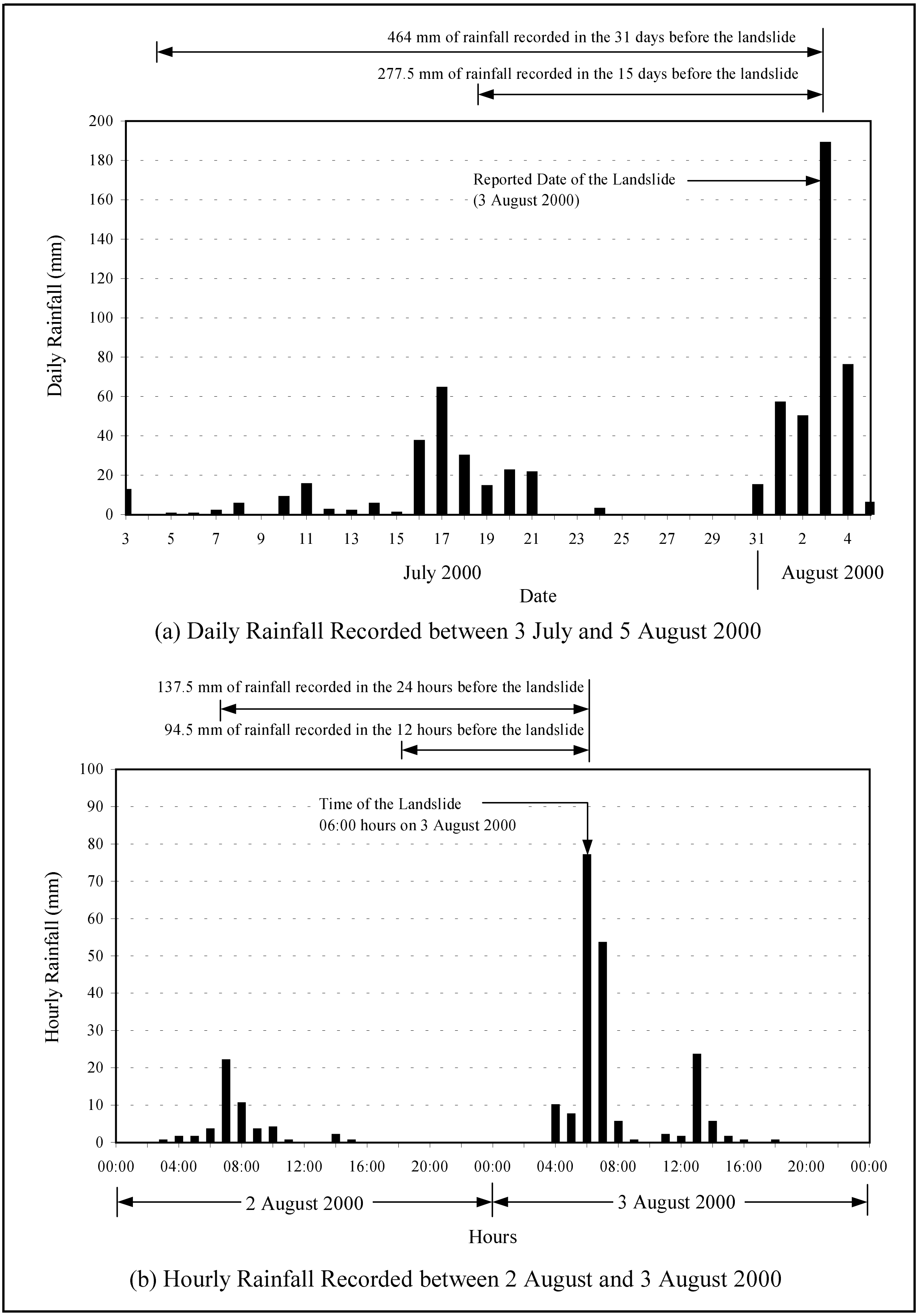
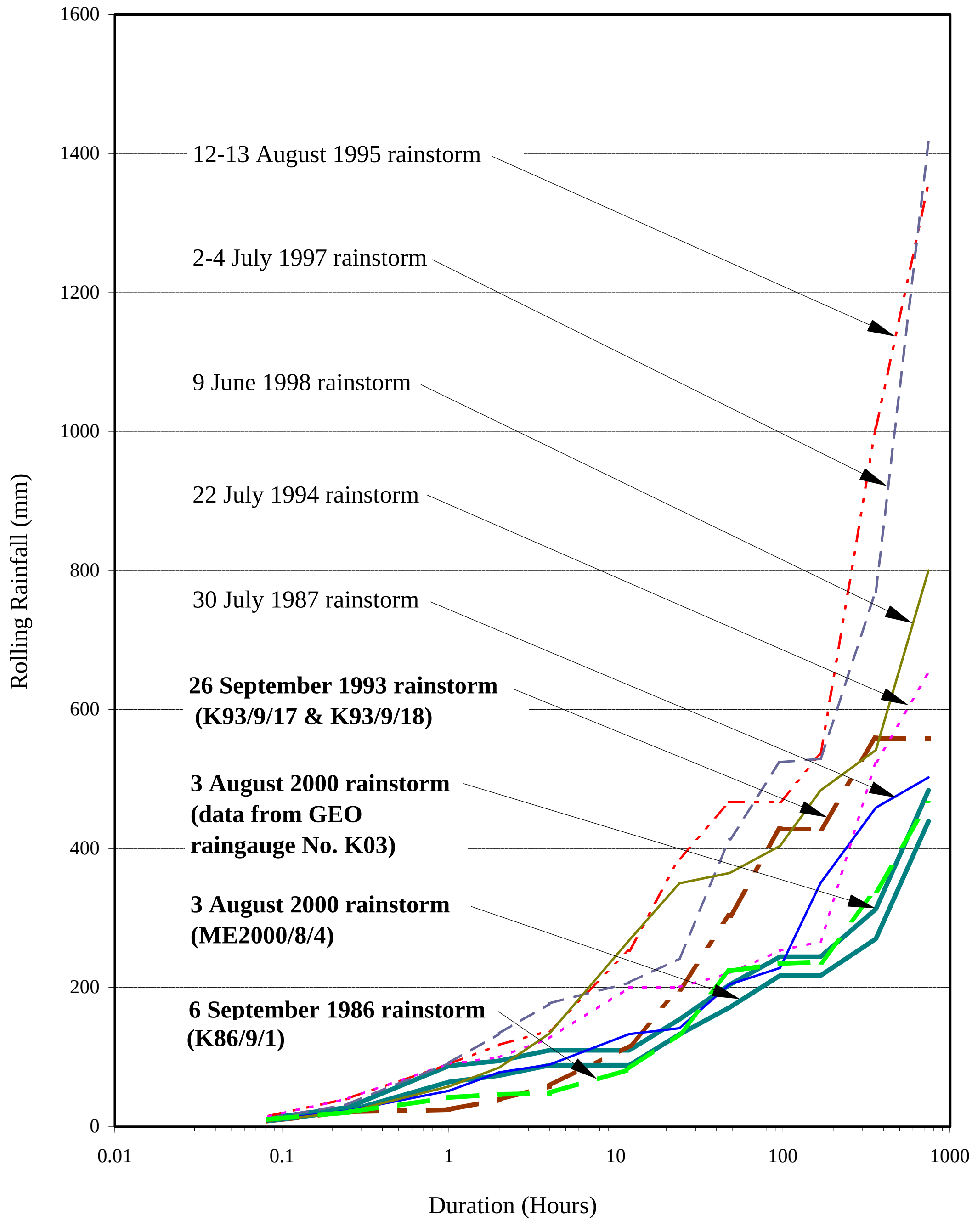



Figure 16 - Daily and Hourly Rainfall Recorded at GEO Raingauge No. K03 in August 2000




Notes: (1) Rainfall data are 5-minute interval from GEO raingauge Nos. K03 and K08.
(2) Data from GEO raingauge No. K03 from September 1993 has errors, therefore data from GEO raingauge No. K08, the second closest raingauge, had been used for comparison.

Figure 17 - Rolling Rainfall at GEO Raingauge No. K08 for Selected Major Rainstorms

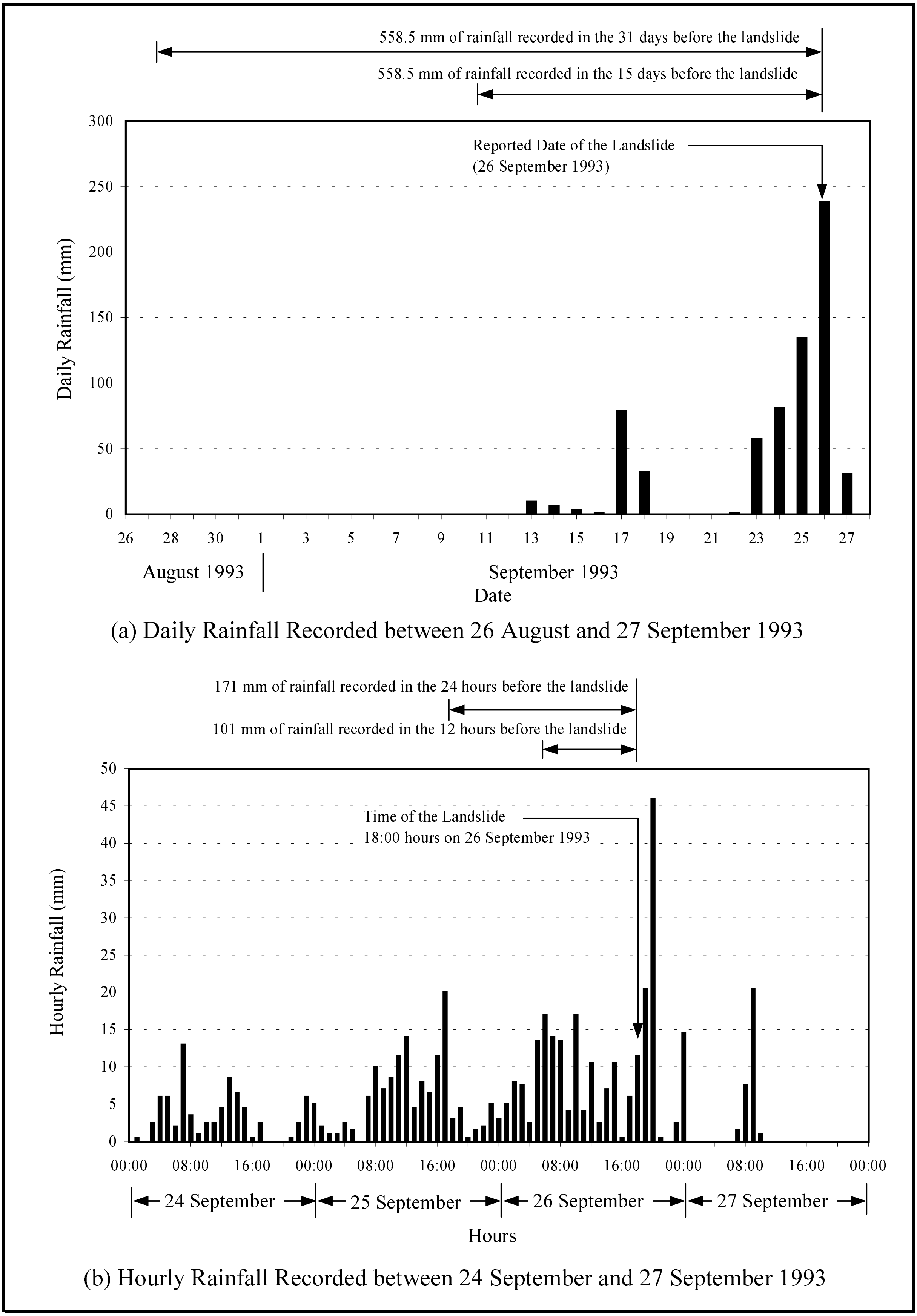



Figure 18 - Daily and Hourly Rainfall Recorded at GEO Raingauge No. K08 in September 1993

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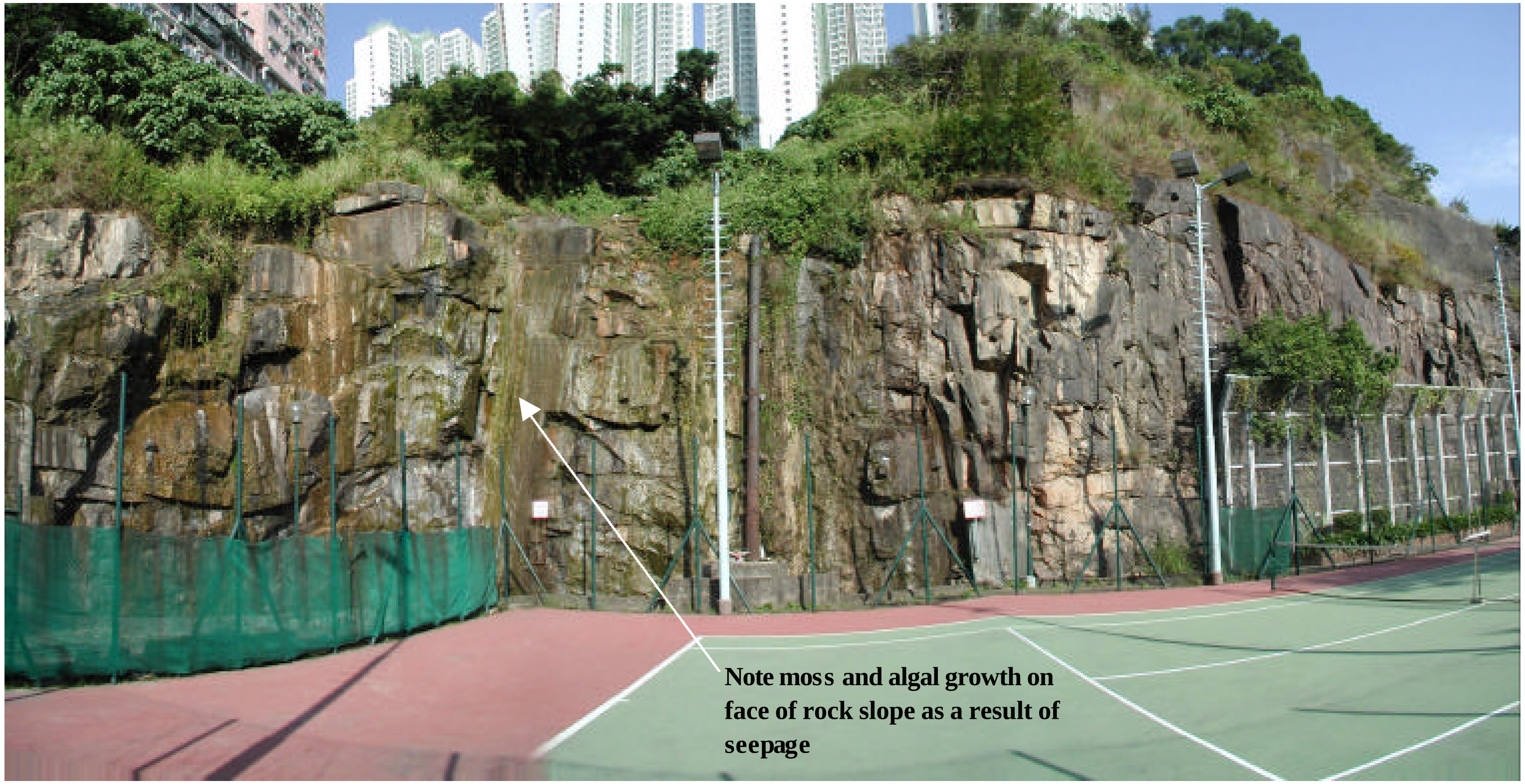



Plate 1 - Panoramic View Showing Northern Section of Slope No. 11NE-D/C45 Looking North
(Photograph Taken on 22 November 2000)


Plate 2 - Panoramic View Showing the Central Section of Slope No. 11NE-D/C45 Looking Northeast
(Photograph Taken on 22 November 2000)

Plate 3 - Panoramic View Showing Southern Section of Slope No. 11NE-D/C45 Looking Southeast
(Photograph Taken on 10 August 2000)

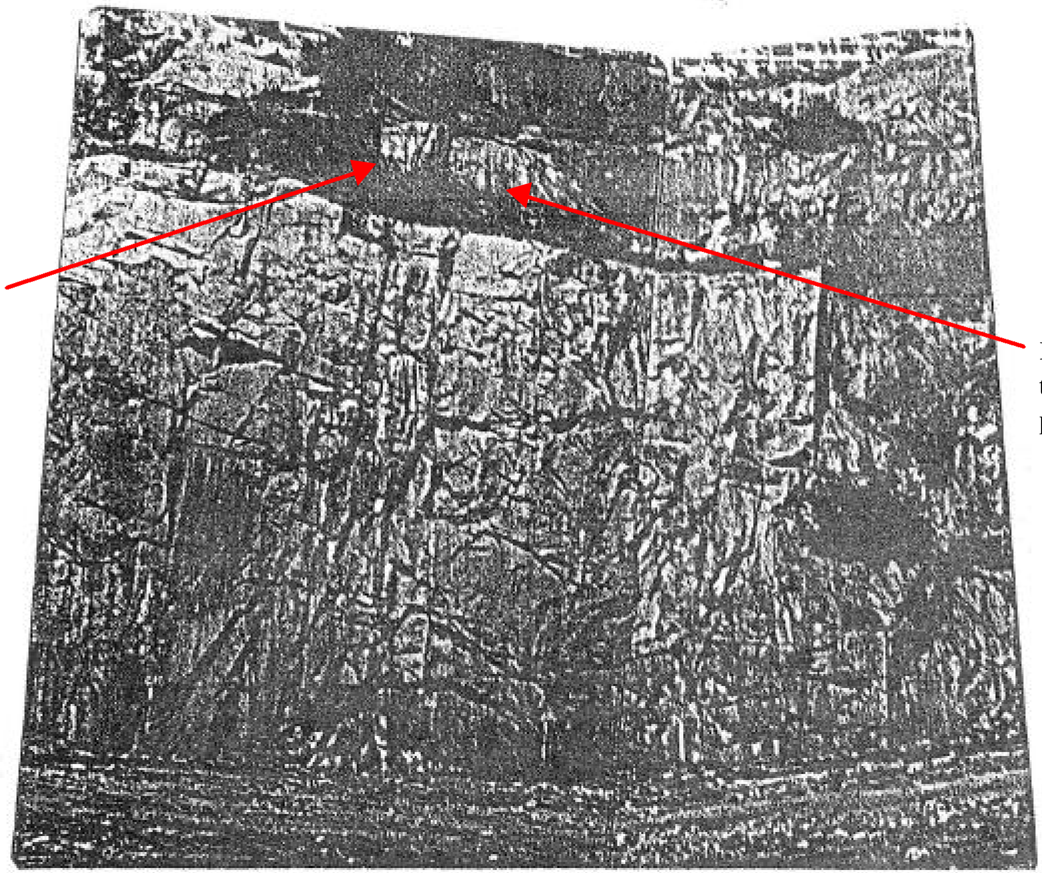

Note: Plate 4 is extracted from Freeman Fox, 1986

Plate 4 - View of the Location of the 1993 Landslide Taken about 8 Years before the Failure (Photograph Taken in July 1985)

Note: Plate 5 is extracted from GEO Incident Report No. K93/9/17

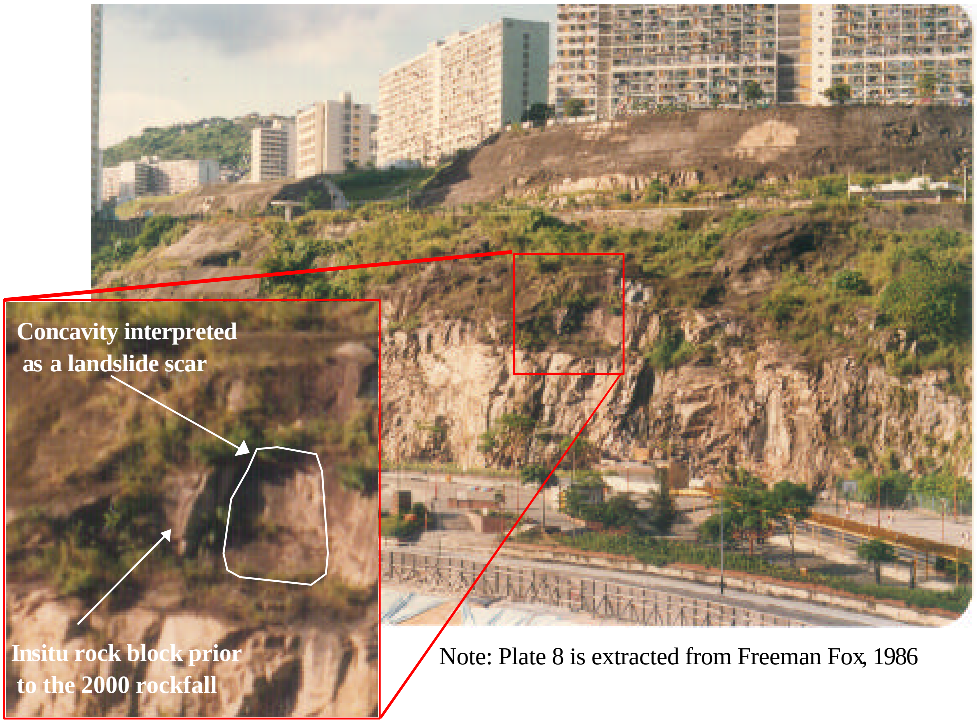
Plate 5 - View of the 1993 Landslide (Photograph Taken in September 1993)

Plate 6 - View of the 1993 Landslide Scar after Completion of Remedial Works
(Photograph Taken on 22 November 2000)




Note: Plate 7 is extracted from Halcrow International Partnership, 1980

Plate 7 - View of the Location of the 2000 Rockfall Taken about 20 Years before the Failure (Photograph Taken in May 1980)

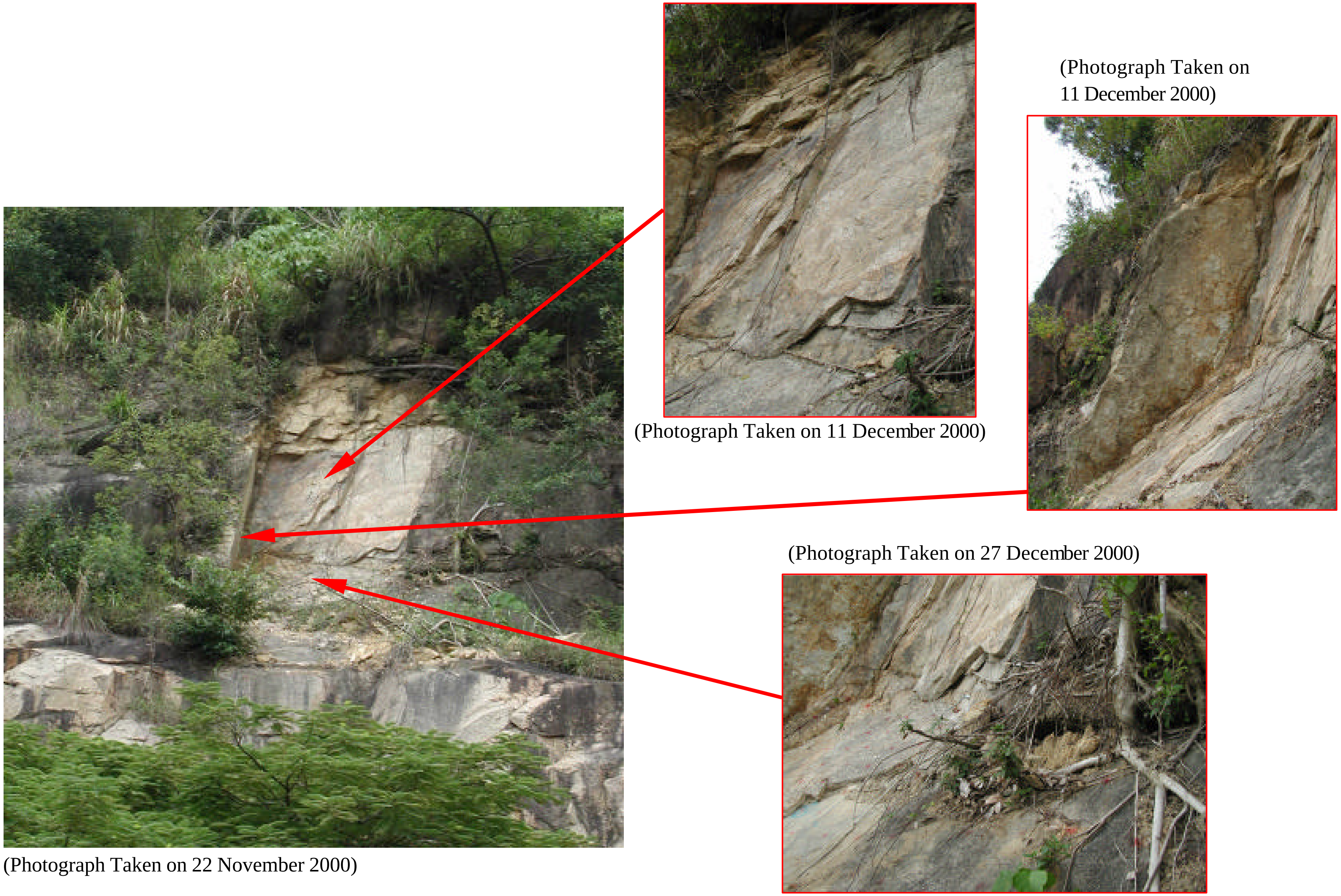



Note: Plate 8 is extracted from Freeman Fox, 1986

Plate 8 - View of the Location of the 2000 Rockfall Taken about 15 Years before the Failure (Photograph Taken in July 1985)


Plate 9 - View of the 2000 Rockfall Scar (Photograph Taken on 10 August 2000)


Plate 10 - View of Fallen Block from the 2000 Rockfall
(Photograph Taken on 4 August 2000)



(Photograph Taken on 22 November 2000)

(Photograph Taken on 11 December 2000)

(Photograph Taken on 11 December 2000)

(Photograph Taken on 27 December 2000)

Plate 11 - Detailed View of the Release Surfaces of the 2000 Rockfall

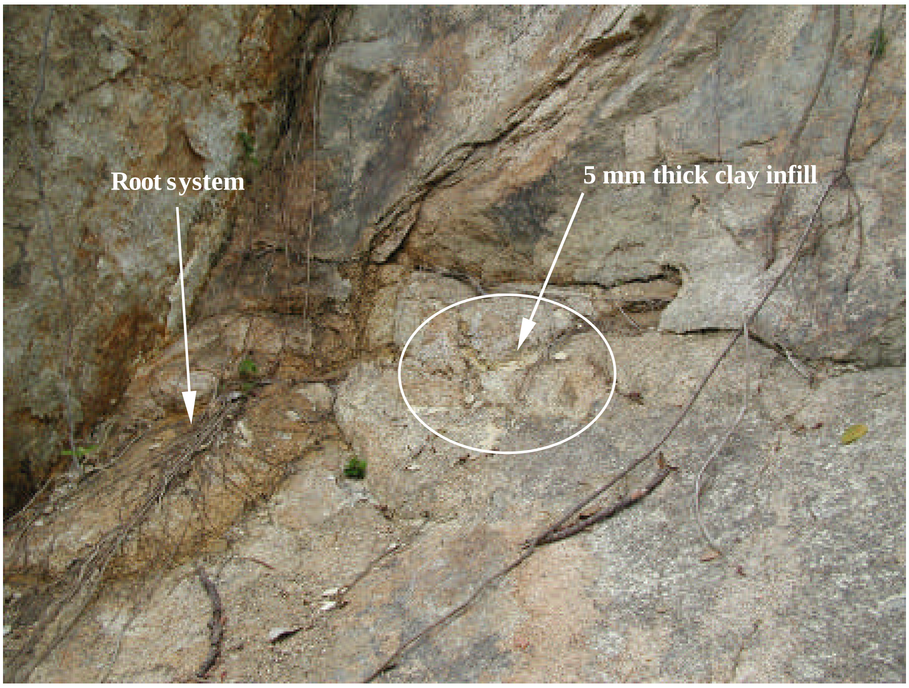



Plate 12 - Detail of the 5 mm Thick Clay Layer on the Basal Release Surface of the 2000 Rockfall (Photograph Taken on 11 December 2000)

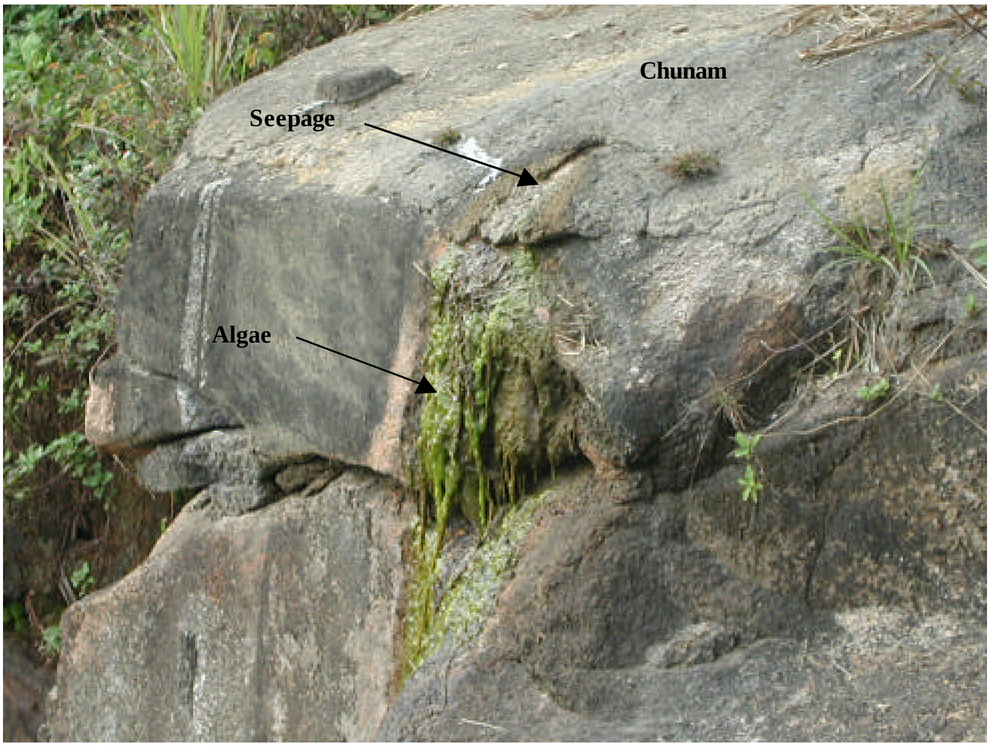



Plate 13 - Detailed View Showing Seepage between Chunam and Rock Interface at the Crest of the Northern End of Slope No. 11NE-D/C45 at Chainage 225 (Photograph Taken on 6 December 2000)


Plate 14 - Detailed View of Offset Block above a Sheeting Joint at Chainage 150
(Photograph Taken on 15 December 2000)


Plate 15 - View of Surface Strip SS1 Revealing Completely to Highly Decomposed Granite at the 1993 Landslide Scar (Photograph Taken on 27 December 2000)

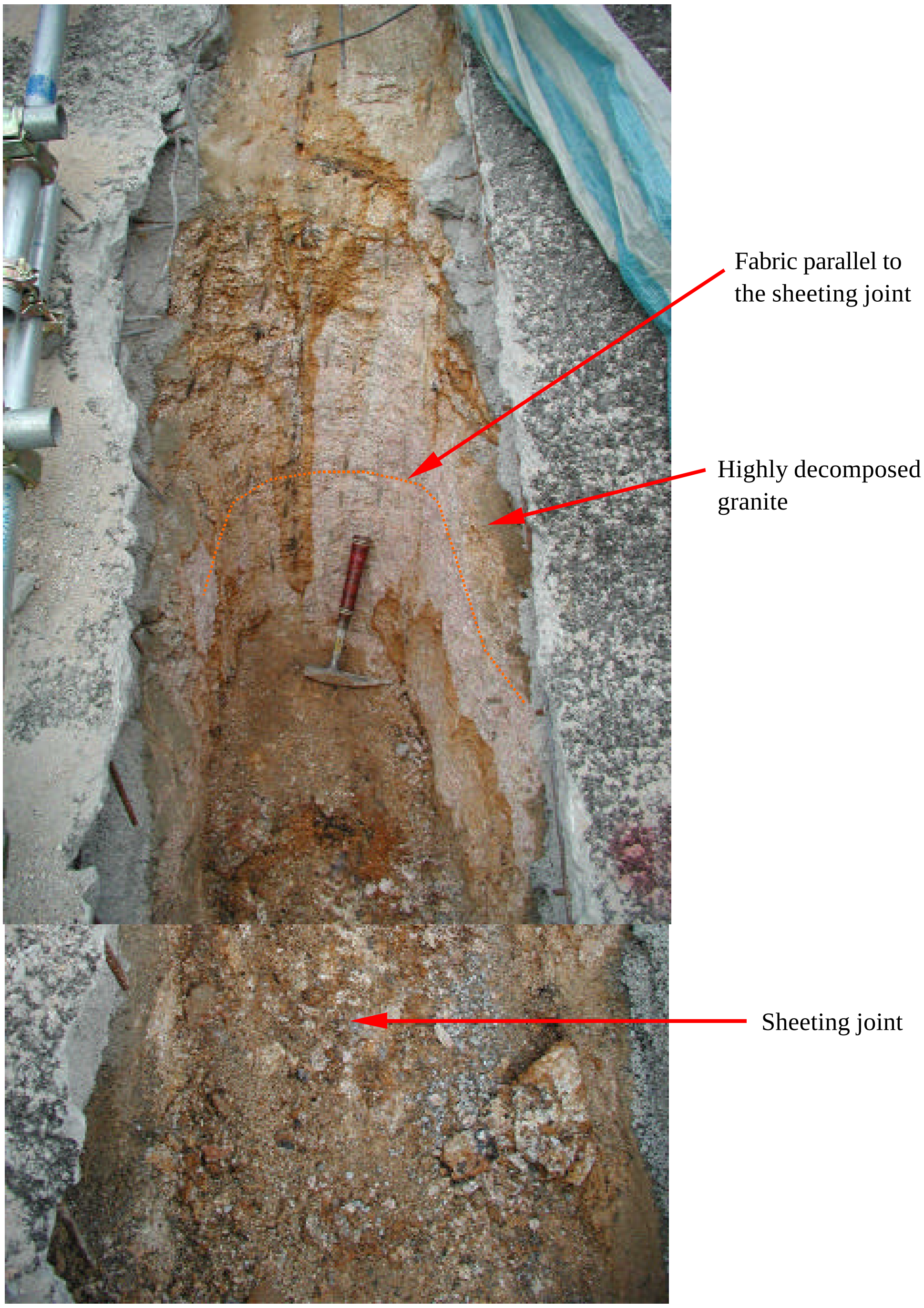



Plate 16 - View of Trial Trench Showing Highly Decomposed Granite above Sheeting Joint at the 1993 Landslide Scar (Photograph Taken on 27 December 2000)

# APPENDIX A

# AERIAL PHOTOGRAPH INTERPRETATION

# CONTENTS

## A.1 GEOMORPHOLOGY

The location plan of the subject feature is shown in Figure A1. The key geomorphological features, interpreted from the 1963 aerial photographs taken prior to formation of the slope, are shown in Figure A2.

Prior to the formation of the slope the site was natural hillside, with no visible signs of disturbance. A series of west to east trending sub-parallel ridges and incised drainage channels, descending from a prominent north to south trending ridge (Figure A2) form the major geomorphological features of the terrain. Extensive areas of sheet and gully erosion are visible along the ridgelines. The deeper of these gullies appear to be over 4 m deep, based on estimations from the aerial photographs.

The locations of the four landslide incidents are also marked on Figure A2. The three rock failures all occurred on or close to the west to east trending ridgelines.

## A.2 SITE HISTORY

The following site history has been interpreted from the aerial photographs taken between 1945 and 1999.

| YEAR | OBSERVATIONS |
|---|---|
| 1945 | High altitude and very grainy aerial photographs.<br><br>The location of the cut slope is natural hillside covered with sparse vegetation. The ridgelines show extensive sheet and gully erosion. The only visible developments are terraced paddy fields located on the lower slopes and covering the floor of the valley to the west of the site. (The geomorphology of the site is described in detail based on the 1963 photographs, see below). |
| 1949 | Additional agricultural terraces have been formed on the lower slopes, and a number of one-storey structures, presumed to be farming/residential building are visible on the floor of the valley to the west of the site. |
| 1954 | High altitude grainy aerial photographs.<br><br>No significant visible change. |
| 1963 | Figure A2 presents a geomorphological interpretation based on the 1963 aerial photographs. The subject feature is not yet formed. Tsui Ping Road is formed and follows its present alignment. To the east of the road is a series of H-shaped high rise residential blocks (Kwun Tong Estate). The residential blocks are located on a level platform below and east of an area of hilly terrain that is part of the foothills of Tai Sheung Tok. The western ends of a series of west to east trending ridges have been cut to |

| YEAR | OBSERVATIONS |
| --- | --- |
| | form this level platform. |
| | The natural terrain, east of the platform, consists of a series of west to east trending sub-parallel ridges and incised drainage channels, descending from a prominent north to south trending ridge (Figure A2). Extensive areas of sheet and gully erosion are visible along the ridgelines. The deeper of these gullies appear to be over 4 m deep, based on estimations from the aerial photographs. No areas of exposed rock are visible. |
| | Numerous boulders are visible along the floor of both the north and south drainage channels. Isolated boulders, interpreted as partly exposed corestones, are also visible on the flanks of the channels. |
| | The ridgelines are generally bare of vegetation and the slopes below are sparsely vegetated with grass and stunted trees and shrubs. Two minor relic landslide scars (shown on Figure A2) are visible on the flanks of the northern drainage channel. The lower slopes and the valley floor are still under cultivation at the time the photographs were taken. |
| 1964 | High altitude aerial photographs. |
| | Extensive earthworks for the construction of Hiu Kwong Street and the adjacent developments are in progress. Formation of the subject feature and Hui Ming Street has not yet commenced. |
| 1974 | The subject feature, Hiu Ming Street below and Hiu Kwong Street above have been formed (Figure A3). The residential blocks of Sau Mau Ping Estate to the east of the subject feature have also been constructed. |
| | The subject feature has been cut between two prominent natural drainage channels, which form the northern and southern ends of the cut slope, cutting into two parallel west to east trending ridges, which are separated by a minor drainage line. Fill slopes with toe retaining walls have been constructed within both the northern (slope No. 11NE-D/FR14) and southern (slope No. 11NE-D/FR7) drainage channels. Areas of natural hillside are preserved on the flanks of the drainage channels to the north and south of the cut slope. A number of one-storey squatter type structures and areas of disturbed ground (abandoned agricultural terraces), are visible on the flanks of the southern channel. |
| | The lower section of the subject feature consists of a cut rock slope, inclined at between 70° and 80° from horizontal. Discontinuous horizontal lineaments are visible traversing the rock face; these have been interpreted as sheeting joints. Isolated patches of vegetation are visible along these features and dark toned strips, assumed to be staining, are visible below. At about half slope height the inclination of the slope reduces to about 40°. This upper section of slope appears to have been |

| YEAR | OBSERVATIONS |
|---|---|
| | excavated along the rock/soil interface, thereby forming an uneven profile. Towards the crest of the feature sections of the slope have been cut into soil; discontinuous berms are visible along these sections.<br><br>Only very sparse vegetation is visible on the feature and the adjacent fill slopes. The natural slopes to the north and south are thinly vegetated, with grass and shrubs. Both the platforms above and below the subject feature are being used for storage of construction materials. |
| 1978 | The upper section of the subject feature, the fill slopes to the north and south and the surrounding natural hillside, show a significant increase in vegetation cover. A number of additional squatter structures have been constructed on the flanks of the drainage channel to the south of the feature. |
| 1980 | Hiu Ming Street Playground and associated sporting facilities are under construction. What appears to be ongoing upgrading works are visible on the subject feature. The works include regrading of parts of the northern section and the construction of at least four number concrete buttresses along the centre and southern section of the slope.<br><br>The squatter type structures visible in the 1978 aerial photographs have been demolished. |
| 1984 | Construction of the playground and associated sporting facilities has been completed, and an area of landscaped garden has been constructed at the crest of the feature.<br><br>The upper section of the northern end of the feature has recently been sealed with chunam, and a crest drain, traversing the northern drainage channel has been constructed. The fill slope above (slope No. 11NE-D/FR14) has also been stripped of vegetation. Many moderately mature trees and bushes are visible on the upper section of the slope. |
| 1986 | Apart from an increase in vegetation there is no significant visible change. |
| 1987 | No significant visible change. |
| 1990 | A boulder catching fence has been constructed along the toe of the northern section of the slope. A concrete path is visible running down the flank of southern drainage channel; the light coloration of the path indicates it was probably recently constructed.<br><br>A number of light toned areas are visible on the slope, these are most probably related to slope upgrading works, possibly regrading of the upper section of the slope. |

| **YEAR** | **OBSERVATIONS** |
|---|---|
| 1991 | A large concrete buttress has been constructed in the centre of the slope. Dark toned vertical streaks are visible over much of the rock slope; these are most likely indicative of seepage. |
| 1992 | No significant visible change. |
| 1993 | A light toned elongated area at the crest of the southern section of the slope is visible (Figure A1). It is likely to be have been formed as a result of a minor shallow failure within soil at the crest of the cut slope. |
| 1994 | The scars resulting from Incident Nos. K93/9/17 and K93/9/18 are visible. Repair works are ongoing at the location of Incident No. K93/9/17. The possible minor failure visible in the 1993 photographs is still visible. |
| 1995 | The scar resulting from Incident No. K93/9/17 has been shotcreted and the boulder catching fence repaired.<br><br>The footpath located along the southern drainage channels has been widened. |
| 1996 | No significant visible change. |
| 1997 | A light toned area, interpreted as a minor shallow failure, is visible above the adjacent slope (Slope No. 11NE-D/C44) to the north of the subject feature (Figure A1).<br><br>Much of the upper section of the slope is densely vegetated with relatively mature trees and shrubs. |
| 1998 | No significant visible change. |
| 1999 | The upper section of the feature is almost totally obscured by dense vegetation, otherwise no significant change is visible. |

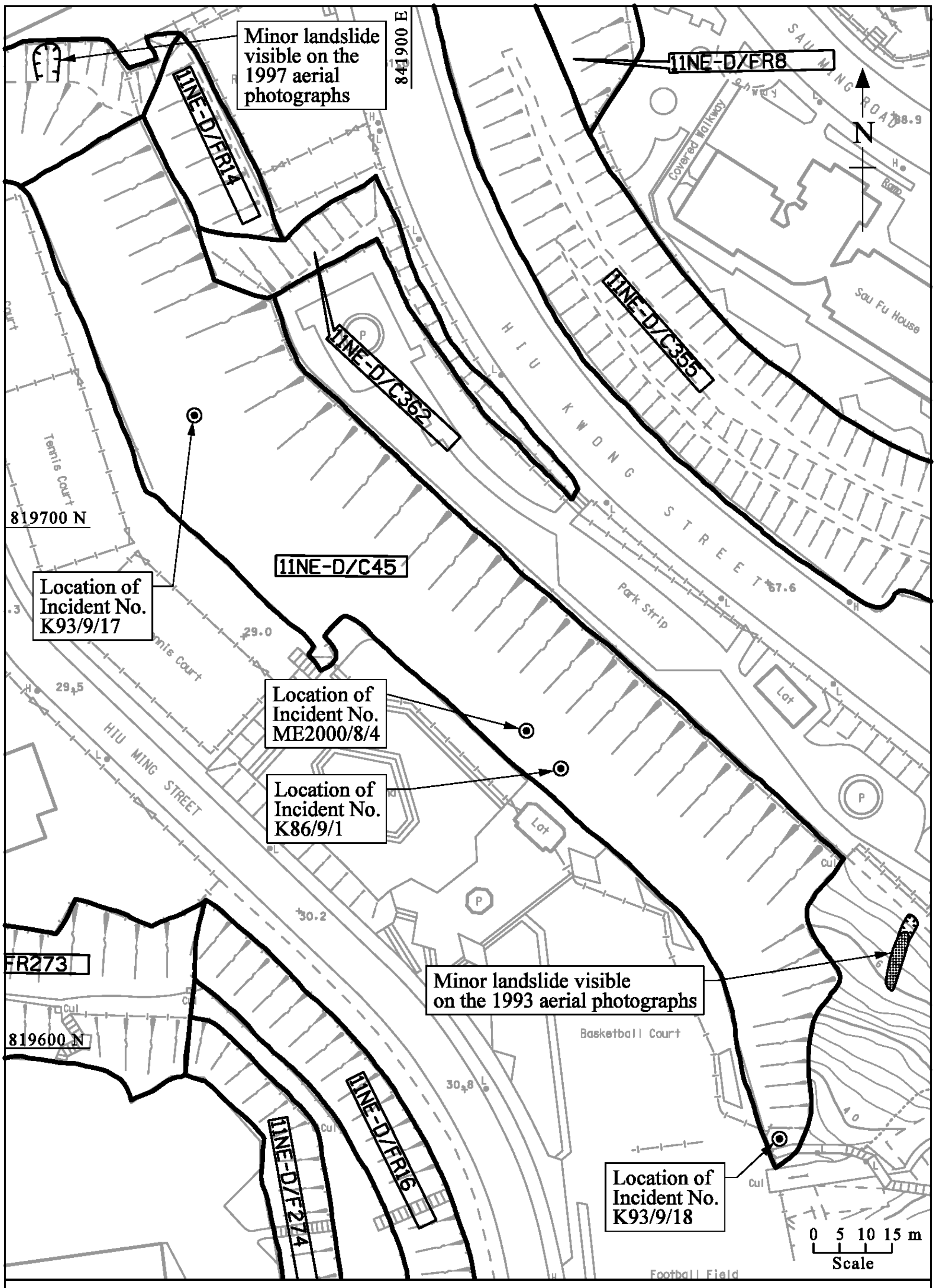
## A.3 LIST OF AERIAL PHOTOGRAPHS

A list of aerial photographs used in this API is shown below:

| Year | Photograph Nos. | Altitude |
|---|---|---|
| 1945 | Y00570-71 | 20,000’ |
| 1949 | Y01643-44 | 8600’ |
| 1954 | Y02646-47 | 20,000’ |
| 1963 | Y07910-11 | 2700’ |
| 1964 | Y12904-05 | 20,000’ |

| **Year** | **Photograph Nos.** | **Altitude** |
|---|---|---|
| 1974 | 10441-42 | 4000’ |
| 1978 | 24179-80 | 4000’ |
| 1980 | 30882-83 | 10,000’ |
| 1984 | 54038-39 | 4000’ |
| 1986 | A06379-80 | 4000’ |
| 1987 | A09035-36 | 4000’ |
| 1990 | A23672-73 | 4000’ |
| 1991 | A27407-08 | 4000’ |
| 1992 | A30391-92 | 4000’ |
| 1993 | A35609-10 | 4000’ |
| 1994 | A38105 (stereopair not available) | 4000’ |
| 1995 | CN11272-73 | 4000’ |
| 1996 | CN15614-15 | 4000’ |
| 1997 | CN17163-64 | 4000’ |
| 1998 | CN21318-19 | 4000’ |
| 1999 | CN23024-25 | 8000’ |

## LIST OF FIGURES




Note : Base map is extracted from Survey Sheet No. 11NE-18D, dated October 1992 (Scale 1:1000).

Figure A1 - Location Plan Showing Locations of Previous Instabilities

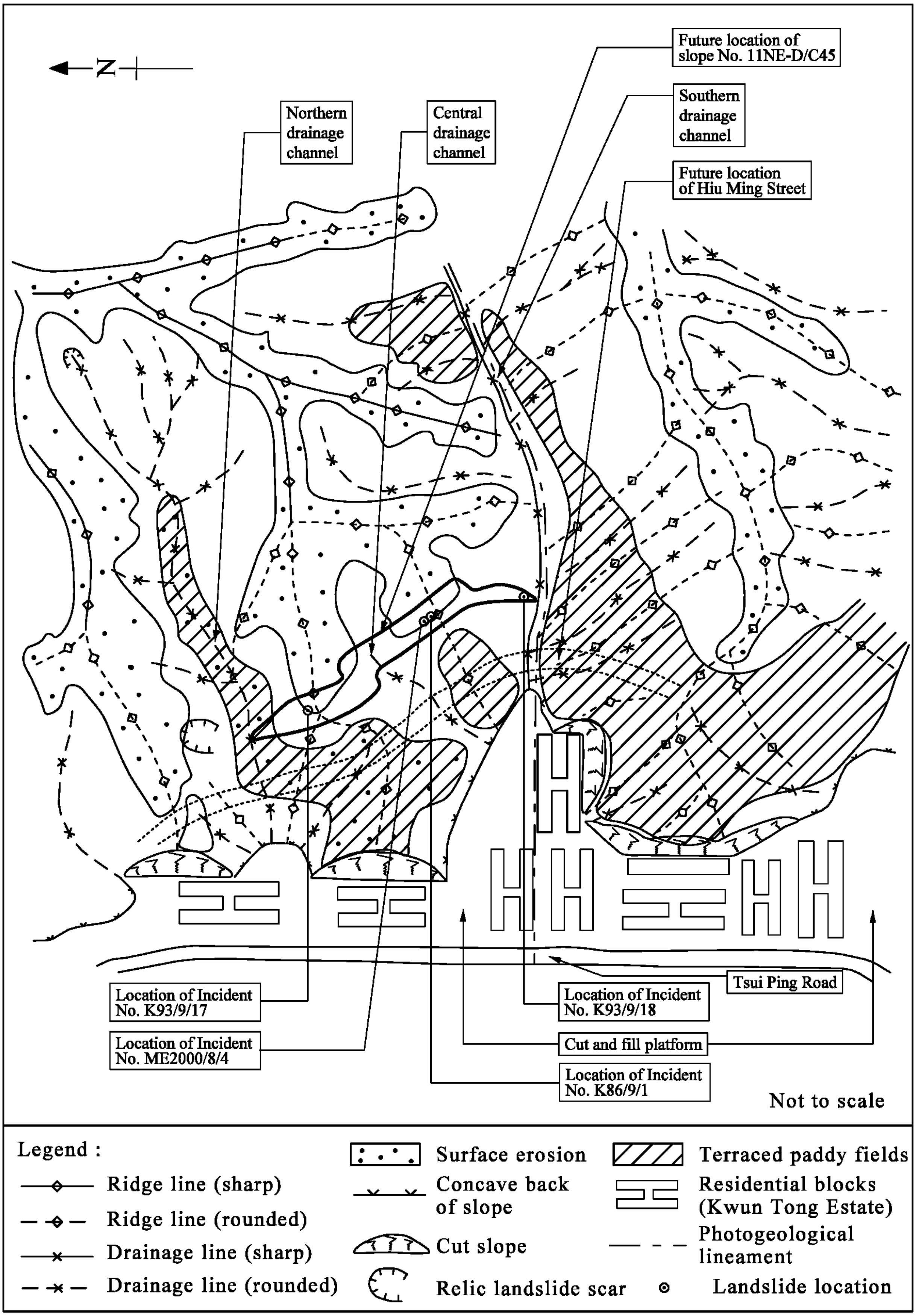



Figure A2 - Aerial Photographic Interpretation Based on Photographs Taken in 1963

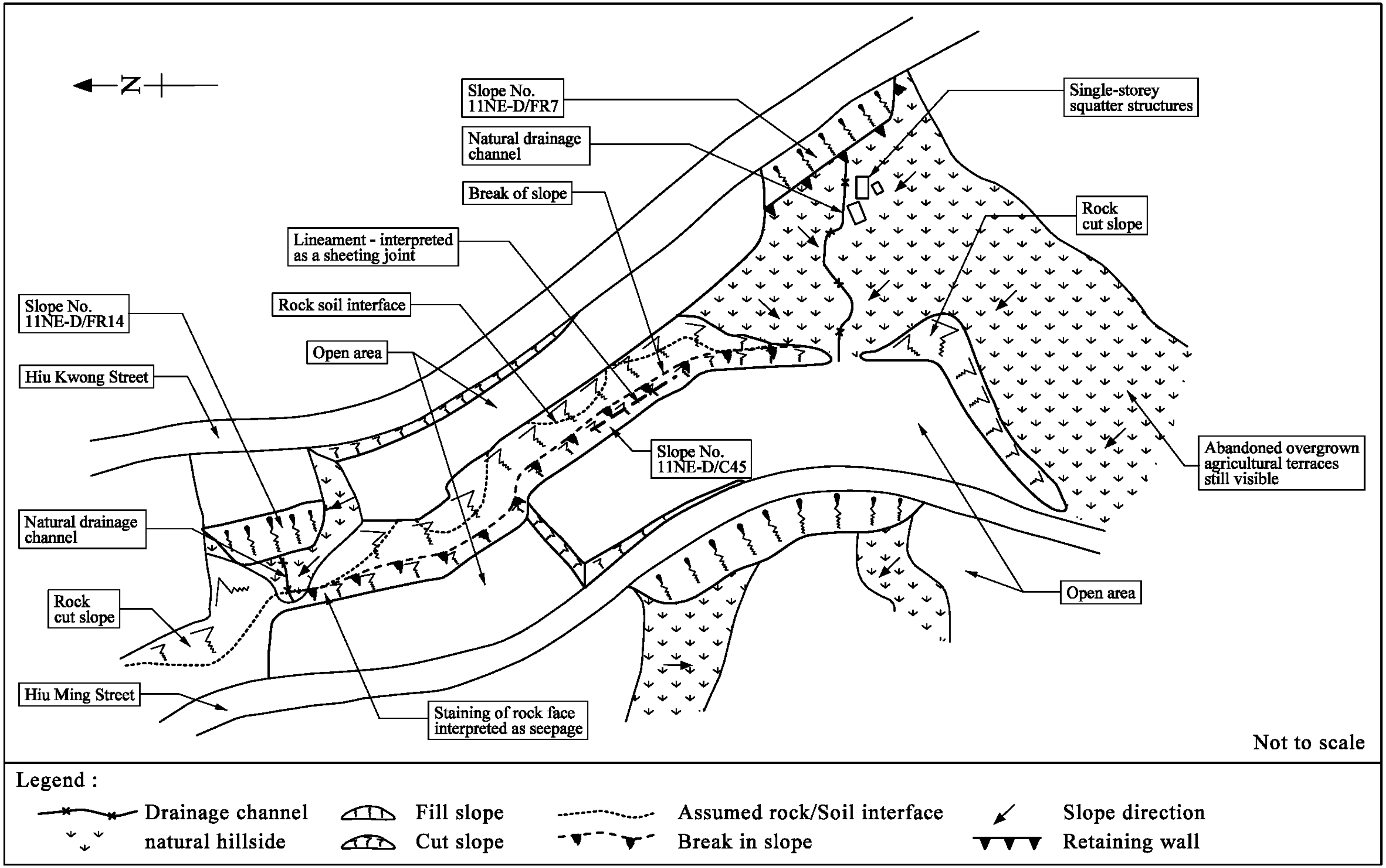



Figure A3 - Aerial Photographic Interpretation Based on Photographs Taken in 1974

# APPENDIX B

## SUMMARY OF PREVIOUS ASSESSMENTS

Table B1 - Summary of Previous Assessments (Sheet 1 of 2)

| Title | Prepared By | Prepared For | Date | Remark |
|---|---|---|---|---|
| Landslide Studies Phase 1 Re-Appraisal Cut & Natural Slopes & Retaining Walls | Binnie & Partners (HK) | GCO | Jun. 1977 | Recommendation of removal of vegetation from chunam and repair; checking of drains for leakage and clearing of crest drain. Annual inspection was recommended. |
| Geotechnical Checking of Slopes Proposed Temporary Open Space Hiu Ming Street Sau Mau Ping | Senior Engineer Public Works | Government Geotechnical Engineer Buildings | Apr. 1979 | The memo stated that, "There was considerable evidence of rock spalls occurring along the majority of the length of the cut slopes" and recommend that "Consideration could be given by the designer to the establishment of a rock fall area at the toe of the cut slope". |
| Stage 1 Report S1 40/79 | Existing Slopes Division, GCO | - | Oct. 1979 | No further study required. A Stage 2 investigation would be carried out if future development took place above or below the slope. |
| Report on the stability of the Rock Slopes 11NE-D/C44, 11NE-D/C45, 11NE-D/C46 and 11NE-D/C47 at Kwun Tong Estate, Volume I and II | Binnie & Partners (HK) | HKHA | Jan. 1980 | Preventive works of rock bolts & dowels, buttresses, removal of vegetation and loose rocks to rock slope portion; and of cut back, provision of adequate weepholes & surface drainage to soil slope part, were recommended to be carried out. |
| Report on Geotechnical Remedial Works to Existing Slopes 11NE-D/C44, 45, 46, 47 and 11NE-D/FR7 and 14 at Hiu Ming Street, Kwun Tong | Halcrow International Partnership | HKHA | Oct. 1980 | The report was prepared for the redevelopment of Kwun Tong Estate. Remedial works recommended included scaling of loose rock blocks, rock bolting, buttressing and provision of drainage. Works were completed in 1/1981. |
| Letter dated on 11/10/1982 (Ref No.:RWC/7851/P68/2830) from Fugro to GMS, AOMB | Fugro (HK) Ltd | Architectural Office Maintenance Branch | Oct. 1982 | Considerable seepage was noted at junction of slope Nos. 11NE-D/C44 and 45. Repair to chunam surface and construction of an interceptor drain at the soil/rock interface was recommended. |

Table B1 - Summary of Previous Assessments (Sheet 2 of 2)

| Title | Prepared By | Prepared For | Date | Remark |
|---|---|---|---|---|
| Letter dated on 5/12/1984 (Ref. JWS/PWW/GU-M/P68/1690) from Fugro to GMS/AOMB | Fugro (HK) Ltd | Architectural Office Maintenance Branch | Dec. 1984 | The interceptor drain was installed in April 1984 for slope No. 11NE-D/C45. |
| Visual Inspection Report for Slope No. 11NE-D/C45 | Fugro (HK) Ltd | GEO | Sept. 1984 | No maintenance work or further work was recommended or required. |
| Report on the Review of Information and Requirements for Slopes Behind Hiu Ming Street Playground | Freeman Fox (Far East) Limited | HKHA | Mar. 1986 | Stabilization measures and rockfall control measures comprising dowelling, infilling, removal of loose blocks and 'boulder catching fence' were recommended. |
| Rock Slope Behind Hiu Ming Street Playground, Rock Slope Stabilization Appraisal Report | Hong Kong Housing Authority | - | May 1989 | The report concludes that 'the overall stability of the slopes are considered to be adequate. However, some preventive work to the rock face are still proposed to be carried out.' |
| Stage 1 Study Report for Feature No. 11NE-D/C45, Hui Ming Street Playground | Design Division, GEO | - | Jul. 1994 | The report noted signs of distress and recommended maintenance. |
| LPM Selection Nomination Features Study Report | Design Division, GEO | - | Jul. 1994 | Slope falls within Priority Group 5 under the Direct Risk-to-life Category. Slope is recommended to be excluded from LPM Selection. |
| File Note on GEO Incident No. K93/9/17 | Special Projects Division, GEO | - | Jan. 1994 | The file note recorded that the landslide occurred "along a fairly continuous joint plane dipping at around 55/230". |
| Systematic Identification and Registration of Slopes in the Territory | Maunsell Geotechnical Services | GEO | Apr. 1995 | The field inspection indicated that the condition of the slope was "fair", the consequence category was "low" and major past instabilities were inferred. |
| Stage 2 Study report on Slope No. 11NE-D/C46 | Binnie Black & Veatch Hong Kong Limited | Arch SD | Jun. 1999 | The study noted that upgrading works had already been carried out at slope No. 11NE-D/C45 and no further works were considered necessary. |

# APPENDIX C

## EXTRACT FROM FREEMAN FOX (FAR EAST) LTD. MARCH 1986 REPORT

## PREVIOUS REPORTS/DISCUSSIONS

### HIP'S COMMENTS ON B & P'S REPORT

B&P's Report: Proposed to trim back the slope at Section 7-7 to 50°. Although the portion of the slope at Section 6-6 is potentially unstable, the stone pitching surface is in a good condition with no signs of distress. No preventive works are required.

HIP's Report: Slope along Section G-G (Referred as 7-7 by B&P) has been trimmed back to 45°.

### RELEVANT DISCUSSIONS BETWEEN SWKP AND HIP

| COMMENTS BY SWKP | | REF. | RESPONSE FROM HIP | REF. |
|---|---|---|---|---|
| SOIL SLOPE : | | | SOIL SLOPE : | |
| | a) Perched water table on top of rock head | memo dated 16/1/81 | a) HIP disagreed | letter dated 6/3/81 |
| At. Ch345-350 | b) Water seepage could cause deterioration of chunam surface. | memo dated 16/1/81 & memo dated 22/6/81 | b) Regular inspection & maintenance. | letter dated 6/3/81 letter dated 15/9/81 |
| | c) Lower Perched water level with no fines concrete toe wall and drainage channel. | memo dated 16/1/81 | c) HIP disagreed, no action. | letter dated 6/3/81 |
| ROCK SLOPE : | | | ROCK SLOPE : | |
| Ch. 155 | a) Effect of the growth of the tree on stability - require regular inspection & monitoring for signs of movement of blocks. | memo dated 16/1/81 memo dated 22/6/81 | a) HIP disagreed, no action. | letter dated 6/3/81 |
| Ch.235 to 240 | b) Require design calculations for the bolted concrete beam. | memo dated 16/1/81 | b) Provided. | letter dated 6/3/81 |
| Ch. 270 | c) Remove loose blocks at mid-height. | memo dated 16/1/81 | c) Work carried out. | letter dated 6/3/81 |
| Ch. 345 | d) Remove erodible material below catchpit opening and pack void with no fines concrete. | memo dated 16/1/81 | d) Work carried out. | letter dated 6/3/81 |
| Ch. 345 | e) Install vertical pipe as an alternative to drain surface water from the slope crest to the toe. | memo dated 16/1/81 | e) HIP disagreed, no action. (FFP's remark : Work done) | letter dated 6/3/81 |
| Ch.345-350 | f) Considerable water seepage leads to loosen blocks - require measures to discourage public access to the toe. | memo dated 22/6/81 | f) Regular inspection and maintenance, together with a chain link fence were suggested to be erected at the slope toe by the AO(M) maintenance contractors. (FFP's remark : work carried out). | letter dated 15/9/81 |

### OUTSTANDING ITEMS/WORKS TO BE RESOLVED/CARRIED OUT (AS PER DISCUSSIONS SWKP/HIP)

1. Regular inspection and maintenance of both soil and rock slopes at Ch.345 to 350.

### AOMB/FUGRO'S COMMENTS/RECOMMENDATIONS DURING MAINTEN9 MAINTENANCE WORKS

1. Seepage from rock face at junction of Slope C44 and C45 : same as for Slope C44, see Appendix B1
2. Minor rock fall at Ch. 150-250 : Fugro recommended that a fence to be errected to limit public access. Ref. : letter dated 31/8/84/
3. Rock fall : Fugro considered that there are no obvious, large, potentially unstable rock on the slope. It is anticipated that minor loose rock may loosen and fall down. However, there is no major concern as long as the toe of slope is fenced off from public, Ref. : letter 5/12/84.

### F.F.E.'S COMMENTS/ASSESSMENTS

1. Agreed with HIP's recommendations that both the soil and rock slopes at Ch.345 to 350 would require regular inspection and maintenance.
2. Agreed with B&P that no preventive works would be required for the stone pitching walls at the slope crest.
3. Agreed with HIP's response on soil slope item (a) and (c) and rock slope item (a) to SWKP's comments.
4. Rock slope stabilisation measures, such as removal of loose blocks, infilling of voids and joints with no fines concrete/mass concrete, installation of rock dowels are recommended (See Figure 4).
5. It is considered that the installation of horizontal drains and shotcrete on the rock face is not required, see Appendix B1.

SHEET 2 OF 2

| Hong Kong Housing Authority<br>Freeman Fox (Far East) Limited | REVIEW OF INFORMATION AND REQUIREMENTS FOR SLOPES BEHIND HIU MING STREET PLAYGROUND | REVIEW SUMMARY/COMMENTS ON SLOPE 11NE-D/C45 | Appendix B2 |
|---|---|---|---|

# CHRONOLOGICAL HISTORY OF THE SLOPES

- 1978 - 1980 Binnie & Partners (B&P) carried out a geotechnical investigation at the request of the Hong Kong Housing Authority (HKHA).
  The results are presented in the following reports :
  Volume I : "Report on the Stability of the Soil Slopes 11NE-D/C44, 11NE-D/C45, 11NE-D/C46, 11NE-D/C47, 11NE-D/FR7 and 11NE-D/FR14 at Kwun Tong Estate" dated January 1980.

  Volume II : "Report on the Stability of the Rock Slopes 11NE-D/C44, 11NE-D/C45, 11NE-D/C46 and 11NE-D/C47 at Kwun Tong Estate" dated January 1980.

- 1979 - 1980 Halcrow International Partnership (HIP) were requested by HKHA to undertake stability assessment and design of remedial measures for the soil and rock slopes that overlook the site.
  The results are presented in a report entitled "Report on Geotechnical Remedial Works to Existing Slopes 11NE-D/C44, 45, 46, 47 and 11NE-D/FR7 and 14 at Hiu Ming Street, Kwun Tong" dated October 1980.

- 12/1979 HIP submitted their drawings and calculations to GCB for comments.

- 3/1980 Site works (Stage I) started.

- 1/1981 Site works (Stage III) completed.

- 2/1981 Site was handed over to Urban Service Department (USD). Maintenance works was carried out by Architectural Office Maintenance Branch (AOMB).

- 1/1981 - 12/1982 Various comments and responses on the HIP's submission were exchanged between GCB's checking engineers, Scott Wilson Kirkpatrick & Partners (SWKP) and HIP.

- 3/1981 - 9/1982 As a result of GCB/SWKP's comments (memo dated 16/1/81), HIP carried out groundwater monitoring for Slope 11NE-D/FR7 during the period between March 1981 and September 1982.

  The results of groundwater monitoring together with re-assessment of the stability of the retaining wall are presented in a report entitled "Piezometer Monitoring at Slope 11NE-D/FR7 at Tsui Ping Road" dated Oct. 1982.

- 10/1982 - 12/1984 Various comments and recommendations concerning seepage on rock face of Slope 11NE-D/C44 & C45, and minor rock fall on slope 11NE-D/C45 were made by AOMB's Consultant, Fugro (HK) Ltd. Subsequently, an interceptor drain was constructed to collect the flow from soil/rock interface at Slope 11NE-D/C45 and a fence was constructed toe of Slope 11NE-D/C45 to limit public access.

Figure 2

# APPENDIX D

# SURFACE STRIP LOGS

| Halcrow China Limited | SLOPE STRIP RECORD | Sheet 1 of 2 |
|---|---|---|

**Agreement No. CE 2/2000**
Landslide Investigation Consultancy for Kowloon and the New Territories in 2000 and the First Quarter of 2001
Detailed Study of Selected Landslides on Slope No. 11NE-D/C45, Hiu Ming Street, Kwun Tong

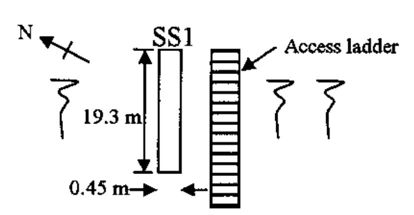
| Slope Strip No.: SS1 | Co-ordinates: 841859 E 819732 N<br>Crest Level: +49.21 mPD | Logged By: IO Date: 19 Dec 00<br>Checked By: MD Date: 20 Dec 00 |
|---|---|---|
| | Co-ordinates: 841849 E 819721 N<br>Toe Level: +38.81 mPD | Date Constructed: 14 Dec to 16 Dec 00<br>Date Reinstated: 30 Dec 00 |

| Distance from Datum (m) | Slope Angle | Reduced Level (mPD) | Samples and Tests | Description | Legend | Grade | Discontinuities Dip/Dip Direction | Discontinuities Nature & Infilling |
|---|---|---|---|---|---|---|---|---|
| 0.00 – 0.85 | 80° | | | Weak to moderately weak, reddish yellow, highly to moderately decomposed medium grained GRANITE with some brown and black stained relict joints. | | IV/III | 77/228<br>58/115<br>65/017 | Fe/Mn<br>Fe/Mn<br>Fe/Mn |
| 0.85 – 10 | 45° | | | Extremely weak to very weak, light reddish brown and pinkish brown occasionally greenish grey, completely deconposed medium grained GRANITE (loose silty clayey medium to coarse SAND with much angular fine gravel of quartz). Occasional managanese and iron stained joints. | | V | | |

REMARKS: Slope strip at the location of the 1993 landslide.

Small Disturbed Sample
Large Disturbed Sample
Undisturbed Sample
Block Sample
Insitu Density Test
Water Sample
Seepage
N-Schmidt Hammer Test

PLAN (not to scale)

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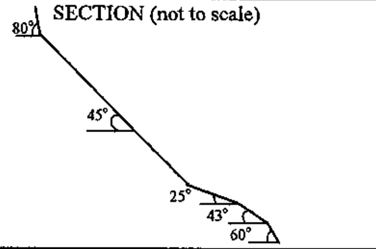


| Halcrow China Limited | SLOPE STRIP RECORD | Sheet 2 of 2 |
|---|---|---|

**Agreement No. CE 2/2000**

Landslide Investigation Consultancy for Kowloon and the New Territories in 2000 and the First Quarter of 2001

Detailed Study of Selected Landslides on Slope No. 11NE-D/C45, Hiu Ming Street, Kwun Tong

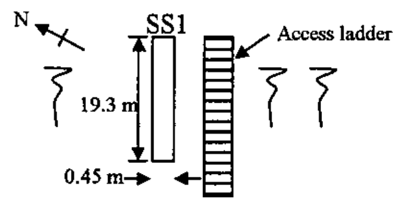
| Slope Strip No.: SS1 | | |
|---|---|---|
| | Co-ordinates: 841859 E 819732 N<br>Crest Level: +49.21 mPD | Logged By: IO Date: 19 Dec 00<br>Checked By: MD Date: 20 Dec 00 |
| | Co-ordinates: 841849 E 819721 N<br>Toe Level: +38.81 mPD | Date Constructed: 14 Dec to 16 Dec 00<br>Date Reinstated: 30 Dec 00 |

| Distance from Datum (m) | Slope Angle | Reduced Level (mPD) | Samples and Tests | Description | Legend | Grade | Discontinuities: Dip/Dip Direction | Discontinuities: Nature & Infilling |
|---|---|---|---|---|---|---|---|---|
| 11.80 | 45° | | | As sheet 1 of 2 | | V | | |
| | 25° | | | Weak becoming moderately weak, pink stained reddish yellow, highly to moderately decomposed medium grained GRANITE. | + + | IV/ III | | |
| | 25°<br>60° | | | Moderately strong, light red, moderately decomposed medium grained GRANITE. | + + | III | | |
| | | | | End of slope strip at 19.30 m | | | | |

REMARKS: Slope strip at the location of the 1993 landslide.

- Small Disturbed Sample
- Large Disturbed Sample
- Undisturbed Sample
- Block Sample
- Insitu Density Test
- Water Sample
- Seepage
- N-Schmidt Hammer Test

PLAN (not to scale)

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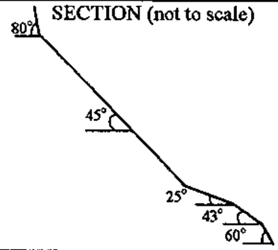


| Halcrow China Limited | SLOPE STRIP RECORD | Sheet 1 of 2 |
|---|---|---|

**Agreement No. CE 2/2000**
Landslide Investigation Consultancy for Kowloon and the New Territories in 2000 and the First Quarter of 2001
Detailed Study of Selected Landslides on Slope No. 11NE-D/C45, Hiu Ming Street, Kwun Tong

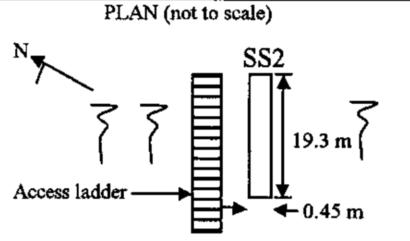
| Slope Strip No.: SS2 | | |
|---|---|---|
| | Co-ordinates: 841860 E 819731 N<br>Crest Level: +49.48 mPD | Logged By: IO Date: 19 Dec 00<br>Checked By: MD Date: 20 Dec 00 |
| | Co-ordinates: 841850 E 819720 N<br>Toe Level: +38.54 mPD | Date Constructed: 14 Dec to 16 Dec 00<br>Date Reinstated: 30 Dec 00 |

| Distance from Datum (m) | Slope Angle | Reduced Level (mPD) | Samples and Tests | Description | Legend | Grade | Discontinuities: Dip/Dip Direction | Discontinuities: Nature & Infilling |
|---|---|---|---|---|---|---|---|---|
| 0.00 – 0.61 | 80° | 49.48 | | Weak to moderately weak, reddish brown, highly to moderately decomposed medium grained GRANITE with some brown and black stained relict joints. | | IV/III | 80/220 | Fe/Mn |
| 0.61 – 10 | 46° | | | Extremely weak to very weak, light reddish brown and pinkish brown occasionally greenish grey, completely deconposed medium grained GRANITE (loose silty clayey medium to coarse SAND with much angular fine gravel of quartz). Occasional managanese and iron stained joints. | | V | | |

REMARKS: Slope strip at the location of the 1993 landslide.

Small Disturbed Sample
Large Disturbed Sample
Undisturbed Sample
Block Sample
Insitu Density Test
Water Sample
Seepage
N-Schmidt Hammer Test

PLAN (not to scale)

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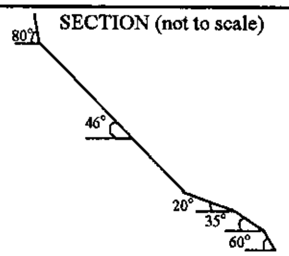


| Halcrow China Limited | SLOPE STRIP RECORD | Sheet 2 of 2 |
|---|---|---|

**Agreement No. CE 2/2000**
Landslide Investigation Consultancy for Kowloon and the New Territories in 2000 and the First Quarter of 2001
Detailed Study of Selected Landslides on Slope No. 11NE-D/C45, Hiu Ming Street, Kwun Tong

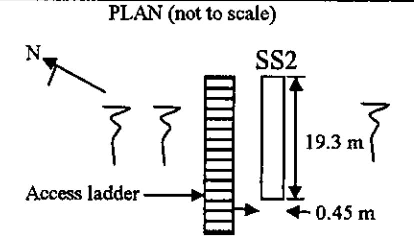
| Slope Strip No.: SS2 | | |
|---|---|---|
| | Co-ordinates: 841860 E 819731 N<br>Crest Level: +49.48 mPD | Logged By: IO Date: 19 Dec 00<br>Checked By: MD Date: 20 Dec 00 |
| | Co-ordinates: 841850 E 819720 N<br>Toe Level: +38.54 mPD | Date Constructed: 14 Dec to 16 Dec 00<br>Date Reinstated: 30 Dec 00 |

| Distance from Datum (m) | Slope Angle | Reduced Level (mPD) | Samples and Tests | Description | Legend | Grade | Discontinuities: Dip/Dip Direction | Discontinuities: Nature & Infilling |
|---|---|---|---|---|---|---|---|---|
| 11.00 | | | | As sheet 1 of 2 | | V | | |
| 12.10 | 46° | | | Weak, pink stained with reddish yellow, mottled dark bluish grey and white, highly decomposed medium grained GRANITE. | | IV | | |
| 19.30 | 20°<br>35°<br>60° | | | Weak becoming moderately weak, pink stained reddish yellow, mottled dark bluish grey and white, highly to moderately decomposed medium grained GRANITE. | | IV/III | | |
| | | | | End of slope strip at 19.30 m | | | | |

REMARKS: Slope strip at the location of the 1993 landslide.

Small Disturbed Sample
Large Disturbed Sample
Undisturbed Sample
Block Sample
Insitu Density Test
Water Sample
Seepage
N-Schmidt Hammer Test

PLAN (not to scale)

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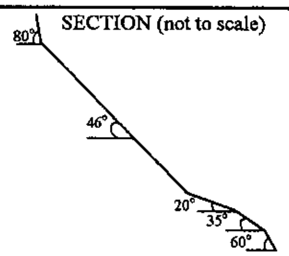


| Halcrow China Limited | SLOPE STRIP RECORD | Sheet 1 of 2 |
|---|---|---|

**Agreement No. CE 2/2000**
Landslide Investigation Consultancy for Kowloon and the New Territories in 2000 and the First Quarter of 2001
Detailed Study of Selected Landslides on Slope No. 11NE-D/C45, Hiu Ming Street, Kwun Tong

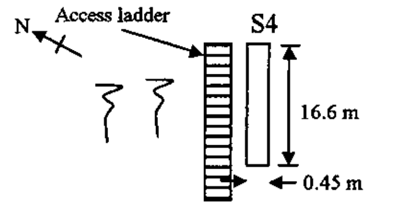
| Slope Strip No.: S4 | Co-ordinates: 841861 E 819730 N<br>Crest Level: +49.21 mPD | Logged By: MD Date: 20 Mar 01<br>Checked By: JT Date: 23 Mar 01 |
|---|---|---|
| | Co-ordinates: 841852 E 819729 N<br>Toe Level: +38.81 mPD | Date Constructed: 1 Mar to 5 Mar 01<br>Date Reinstated: 31 Mar 01 |

| Distance from Datum (m) | Slope Angle | Reduced Level (mPD) | Samples and Tests | Description | Legend | Grade | Discontinuities Dip/Dip Direction | Discontinuities Nature & Infilling |
|---|---|---|---|---|---|---|---|---|
| 0.00 – 2.90 | 80° | | | Very weak, reddish brown and pinkish grey occasionally greenish grey, completely to highly decomposed medium grained GRANITE. (loose to medium dense, slightly silty clayey medium to coarse SAND with much angular fine gravel-sized quartz. Occasional manganese and iron oxide stained steeply dipping joints.<br><br>0.8 m to 1.2 m steeply dipping narrow vein of grey mica (muscovite) | | IV/V | 76/348<br>82/345<br>72/185<br>62/015 | Fe/Mn<br>Fe/Mn<br>Mica<br>Fe/Mn |
| 2.90 – 9.60 | 45° | | | Extremely weak to very weak light reddish brown and pinkish brown occasionally greenish grey, completely deconposed medium grained GRANITE. (loose silty clayey medium to coarse SAND with much angular fine gravel of quartz) Occasional managanese and iron stained joints.<br><br>6.05 m to 6.7 m manganese and iron oxide stained planar joint surface<br><br>8.6 m shallow dipping manganese and iron oxide stained joint with up to 8 mm thick white clay (kaolin) infill | | V | 42/223<br>15/221 | Fe/Mn<br>Kaolin |
| 9.60 | | | | See Sheet 2 of 2 | | IV | 70/235 | Fe/Mn |

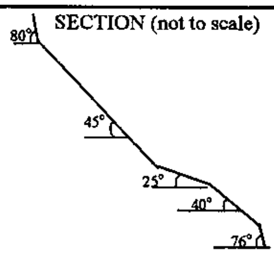
REMARKS: Slope strip at the location of the 1993 landslide.

Small Disturbed Sample
Large Disturbed Sample
Undisturbed Sample
Block Sample
Insitu Density Test
Water Sample
Seepage
N-Schmidt Hammer Test

PLAN (not to scale)




SECTION (not to scale)



| Halcrow China Limited | SLOPE STRIP RECORD | Sheet 2 of 2 |
|---|---|---|

**Agreement No. CE 2/2000**

Landslide Investigation Consultancy for Kowloon and the New Territories in 2000 and the First Quarter of 2001

Detailed Study of Selected Landslides on Slope No. 11NE-D/C45, Hiu Ming Street, Kwun Tong

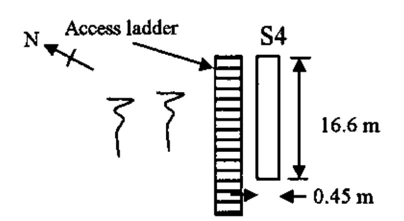
| Slope Strip No.: S4 | | |
|---|---|---|
| | Co-ordinates: 841861 E 819730 N<br>Crest Level: +49.01 mPD | Logged By: MD Date: 20 Mar 01<br>Checked By: JT Date: 23 Mar 01 |
| | Co-ordinates: 841852 E 819729 N<br>Toe Level: +38.87 mPD | Date Constructed: 1 Mar to 5 Mar 01<br>Date Reinstated: 31 Mar 01 |

| Distance from Datum (m) | Slope Angle | Reduced Level (mPD) | Samples and Tests | Description | Legend | Grade | Discontinuities: Dip/Dip Direction | Discontinuities: Nature & Infilling |
|---|---|---|---|---|---|---|---|---|
| 11.90 | 42° | | | Very weak, reddish brown and pinkish grey, occasionally greenish grey, highly decomposed medium grained GRANITE. (medium dense to dense, silty medium to coarse SAND with much angular fine gravel) Occasional iron oxide and manganese stained joints. | | IV | 66/201 | Fe/Mn |
| 14.2 | 25° | | | Weak becoming moderately weak, pink stained reddish brown, highly to moderately decomposed medium grained GRANITE (Sheeting joint surface). | | IV/III | | |
| 16.6 | 40° | | | Moderately strong, light reddish brown and pinkish grey, moderately decomposed medium grained GRANITE. | | III | | |
| | 76° | | | End of slope strip at 16.6 m | | | | |

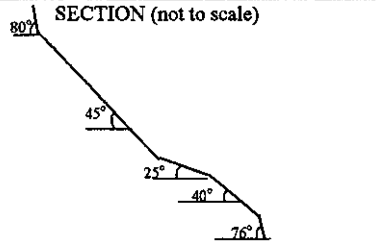
REMARKS: Slope strip at the location of the 1993 landslide.

Small Disturbed Sample
Large Disturbed Sample
Undisturbed Sample
Block Sample
Insitu Density Test
Water Sample
Seepage
N-Schmidt Hammer Test

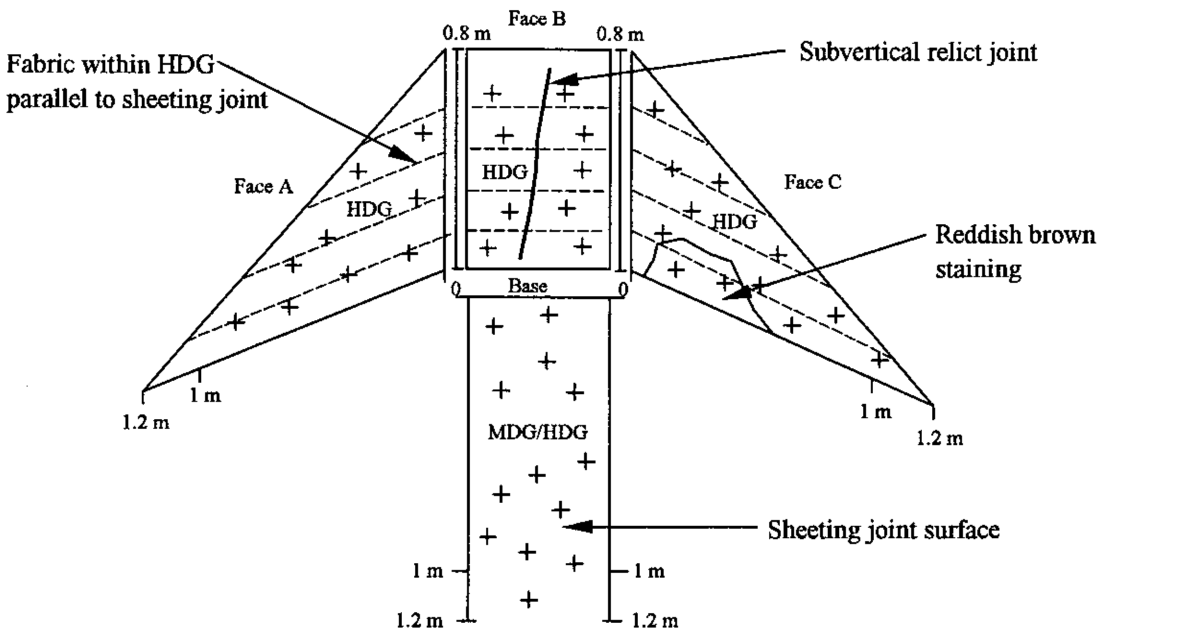
PLAN (not to scale)




SECTION (not to scale)



| Halcrow China Limited - Agreement No. CE 2/2000<br>Landslide Investigation Consultancy for Kowloon and the New Territories in 2000 and the First Quarter of 2001<br>Detailed Study of Selected Landslides on Slope No. 11NE-D/C45, Hiu Ming Street, Kwun Tong | TRIAL TRENCH RECORD | | Sheet 1 of 1 |
|---|---|---|---|
| | TRIAL TRENCH NO. TT1 | Excavation Date: 28/12/00 | Backfilling Date: 03/01/01 |
| | Top: Co-ordinates: Ground Level: | Logged By: IO | Date: 28/12/00 |
| | Bottom: Co-ordinates: Ground Level: | Checked By: MD | Date: 29/12/00 |



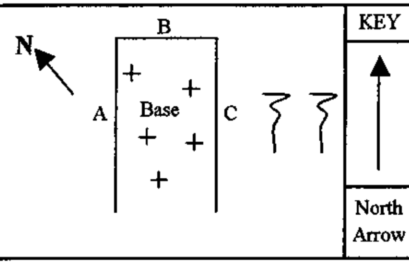

**Description**

Weak to moderately weak, pink stained reddish brown, highly decomposed medium grained GRANITE with brown and black stained relict joints.

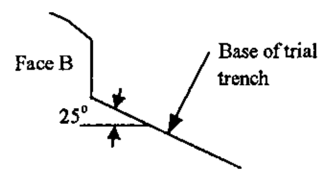
Base:
Moderately weak to moderately strong, pink stained reddish brown, highly to moderately decomposed medium grained GRANITE.

| SYMBOL | SAMPLES / TEST / WATER |
|---|---|
| | Small Disturbed Sample |
| | Large Disturbed Sample |
| | U100/U76 |
| | Undisturbed Sample |
| | Block Sample |
| | Insitu Density Test |
| | Water Sample |
| | Seepage |

PLAN ( not to scale )




SECTION (B)




**REMARKS**

Shoring: No
Stability: Stable
Maximum Depth: 0.8 m — Average Depth: 0.4 m
Maximum Length: 1.2 m — Average Length: 1.2 m
Maximum Width: 0.5 m — Average Width: 0.5 m

Trial Trench TT1 was excavated between 10.8 m and 12 m along slope strip SS2.

# APPENDIX E

# STABILITY ANALYSIS OF THE 2000 ROCKFALL

Halcrow **CALCULATION SHEET**

| No: 1 | Rev: 0 |
|---|---|
| By: MD | Date: 24/5/01 |
| Check By: JSC | Date: 24/5/01 |

Project: **Landslide Investigation Consultancy for Kowloon and the New Territories in 2000 and the First Quarter of 2001**
Subject: **Hiu Ming Street Detailed Study - Planar Failure Analysis 2001 Rockfall**

References/Results

"Rock Slope Engineering" revised third edition
Hoek & Bray, 1981

**1 CALCULATION SUMMARY**

Design parameters for considered slips:

| | | | | |
|---|---|---|---|---|
| Unit Weight of Rock | $\gamma_r$ = | 26.0 | $kN/m^3$. | |
| Drained friction angle of joint | $\phi'$ = | 43 | °. | (assumed 35 deg base friction angle plus i = 8 deg (Figure 10)) |
| Drained cohesion of joint | c' = | 0.0 | kPa. | |
| Unit weight of groundwater | $\gamma w$ = | 9.8 | $kN/m^3$ | |

| Case No. | $\alpha_T$ (deg) | $\alpha_B$ (deg) | $L_{LE}$ (m) | $L_B$ (m) | Zw (m) | W (kN) | Wn (kN) | Wt (kN) | U (kN) | V (kN) | N (kN) | S (kN) | | FOS | Remark |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 70 | 37 | 2.2 | 2.5 | 0 | 180.5 | 144 | 109 | 0 | 0 | 144 | 109 | | 1.237 | |
| | 70 | 37 | 2.2 | 2.5 | 0.5 | 180.5 | 144 | 109 | 6 | 1 | 138 | 110 | | 1.168 | |
| | 70 | 37 | 2.2 | 2.5 | 1 | 180.5 | 144 | 109 | 12 | 5 | 130 | 114 | | 1.069 | |
| | 70 | 37 | 2.2 | 2.5 | 1.5 | 180.5 | 144 | 109 | 18 | 12 | 122 | 120 | | 0.949 | |
| | 70 | 37 | 2.2 | 2.5 | 2 | 180.5 | 144 | 109 | 25 | 21 | 113 | 128 | | 0.818 | |
| | 70 | 37 | 2.2 | 2.5 | 2.5 | 180.5 | 144 | 109 | 31 | 33 | 102 | 139 | | 0.686 | |
| | 70 | 37 | 2.2 | 2.5 | 3 | 180.5 | 144 | 109 | 37 | 47 | 91 | 153 | | 0.558 | |
| | 70 | 37 | 2.2 | 2.5 | 3 | 180.5 | 144 | 109 | 37 | 47 | 91 | 153 | | 0.558 | |

<u>Definitions and Equations:</u> (refer also to Definitions Diagram on Page 2)

$\alpha_B$ Slip plane dip (°)
$\alpha_T$ Tension crack dip (°)
$Z_W$ Depth of water in the rear release joint (m)
$L_B$ Slip plane length (m)
$L_{LE}$ Horizontal width of block (m)
W Block weight (kN/m)
U Water pressure uplift on slip plane (kN/m)
V Water pressure thrust on tension crack (kN/m)
N Force normal to the slip plane (kN/m)
S Force parallel to the slip plane (kN/m)

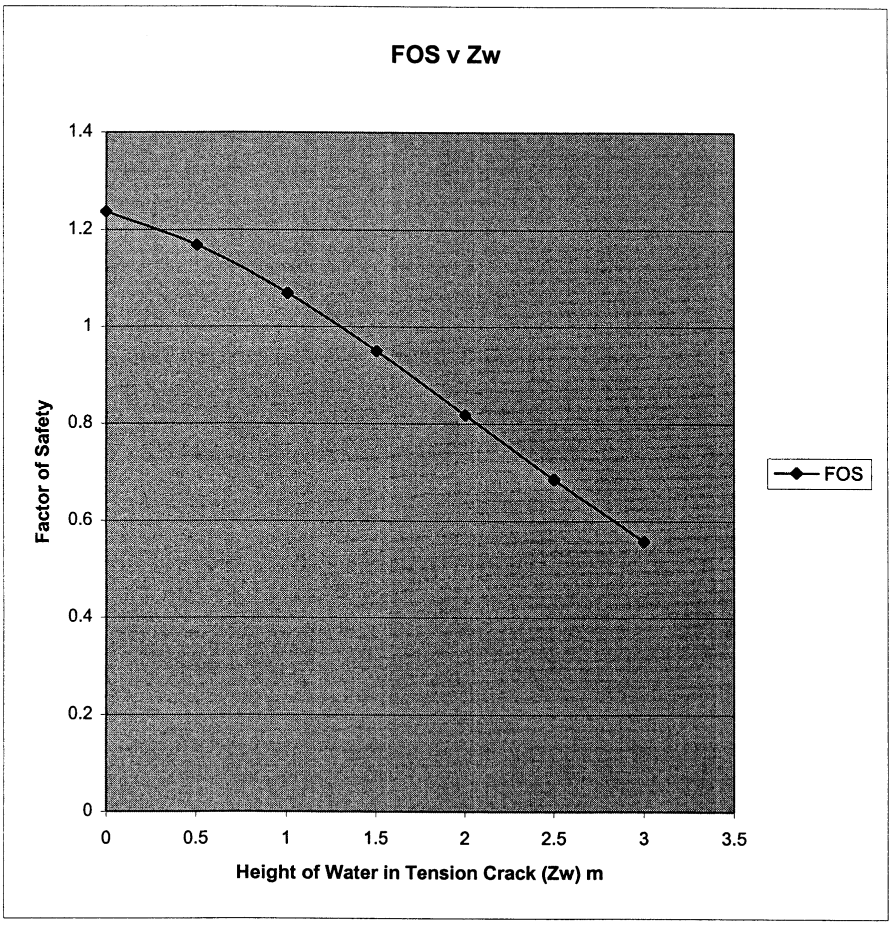
$W_n = W \cos\alpha_B$
$W_t = W \sin\alpha_B$

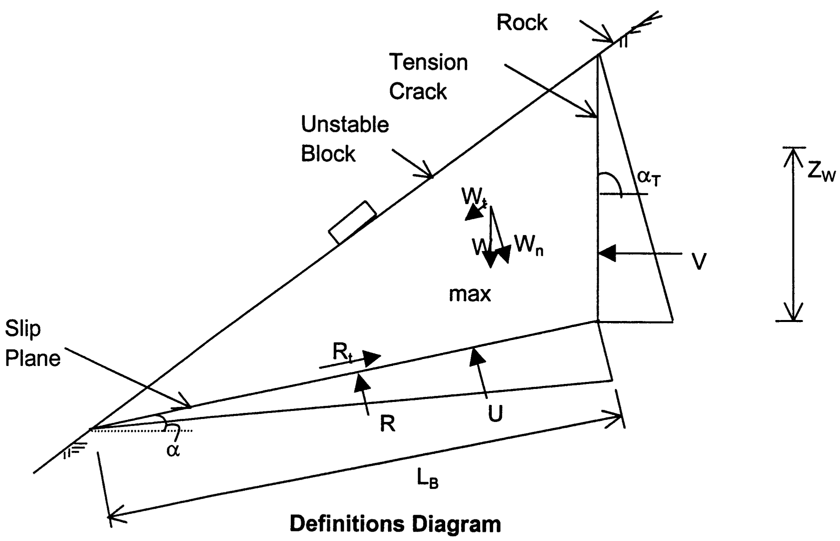
$U = 0.5\, L_B Z_w \gamma_w$
$V = 0.5\, Z_w^2 \gamma_w / \sin\alpha_T$

$N = W_n - U - V \cos\alpha_T$
$S = W_t + V \sin\alpha_T$

$FOS = N \tan\phi / S$

| **HALCROW** | **CALCULATION SHEET** | No<br>2 | Rev<br>0 |
| --- | --- | --- | --- |
| **Project : Landslide Investigation Consultancy for Kowloon and the New Territories in 2000 and the First Quarter of 2001**<br>Subject: **Hiu Ming Street Detailed Study - Planar Failure Analysis 2001 Rockfall** | | By: MD<br>Check | Date 24/05/01<br>Date 24/05/01 |




**Definitions Diagram**