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九華徑上村 26 號
山泥傾瀉事件報告
REPORT ON THE LANDSLIDES AT HUT NO. 26 KAU WA KENG UPPER VILLAGE OF 4 JUNE 1997

土力工程處報告系列第 76 號
GEO REPORT No. 76

合樂亞洲顧問公司
Halcrow Asia Partnership Ltd.

香港特別行政區政府
土木工程署
土力工程處
GEOTECHNICAL ENGINEERING OFFICE
CIVIL ENGINEERING DEPARTMENT
THE GOVERNMENT OF THE HONG KONG SPECIAL ADMINISTRATIVE REGION

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PREFACE

In keeping with our policy of releasing information which may be of general interest to the geotechnical profession and the public, we make available selected internal reports in a series of publications termed the GEO Report series. A charge is made to cover the cost of printing.

The Geotechnical Engineering Office also publishes guidance documents as GEO Publications. These publications and the GEO Reports may be obtained from the Government's Information Services Department. Information on how to purchase these documents is given on the last page of this report.

R.K.S. Chan
Principal Government Geotechnical Engineer
November 1998

FOREWORD

This GEO Report presents the forensic investigation of the 4 June 1997 fatal landslide at Kau Wa Keng Upper Village by Halcrow Asia Partnership for the Geotechnical Engineering Office as part of the 1997 Landslide Investigation (LI) Consultancy.

The LI Consultancy aims to achieve the following objectives through review and studies of landslides :

(a) establishment of an improved slope assessment methodology,

(b) identification of slopes requiring follow-up action, and

(c) recommendation of improvement to the Government's slope safety system and current geotechnical engineering practice in Hong Kong.

The Landslip Investigation Division of the Geotechnical Engineering Office worked closely with the LI Consultants and provided technical input and assistance to the forensic investigation.

M C Tang
Government Geotechnical Engineer/
Landslip Preventive Measures
August 1998

ABSTRACT

On 4 June 1997, two landslides occurred at a slope above Castle Peak Road, Kau Wa Keng. The larger of the two damaged a squatter hut and resulted in one fatality and slight injuries to five other people. The landslide involved the sudden collapse of parts of registered cut Slopes Nos. 11NW-A/C415 and C416 and the hillside above. A comprehensive investigation into the landslides was carried out for the Geotechnical Engineering Office (GEO) during the period June 1997 to February 1998 by GEO's landslide investigation consultants, Halcrow Asia Partnership Ltd (HAP) with input and assistance from the GEO. This detailed study included review of documentary information, analysis of rainfall records, interviews with witnesses to the landslides, site survey, ground investigation, theoretical seepage and stability analyses and diagnosis of the causes of failure.

The investigation concluded that the landslide which resulted in the fatality was probably primarily caused by a significant rise in groundwater pressure in the weathered granite hillside, following very heavy rainfall that immediately preceded the failure.

Details of the investigation and its findings are included in this report.

CONTENTS

1. INTRODUCTION

In the morning of 4 June 1997, two landslides occurred at a slope above Castle Peak Road near its junction with an access road to Chung Shan Terrace, Kau Wa Keng, New Territories (Figure 1). The larger of the landslides, the 'north' landslide (GEO Incident No. MW97/6/16), damaged a squatter hut, No. 26 Kau Wa Keng Upper Village and resulted in one fatality. Five other people were slightly injured. Some of the debris from this landslide was washed downslope onto Castle Peak Road blocking the footpath and two lanes of the carriageway (Plate 1). The other, much smaller landslide, the 'southeast' landslide, occurred close to the squatter hut, damaging two out-houses.

After the landslides, the Geotechnical Engineering Office (GEO) of the Civil Engineering Department (CED) commenced a detailed investigation into the cause of the failures. The investigation was undertaken by GEO's landslide investigation consultants, Halcrow Asia Partnership Ltd (HAP), with geological input from the Hong Kong Geological Survey (HKGS) and assistance from other Divisions within the GEO. Topographic survey of the landslide area was carried out by the Survey Division of the CED.

The investigation was carried out during the period June 1997 to February 1998, and comprised the following key tasks :

(a) review of all known relevant documents relating to the development of the site and the sequence of events leading up to the landslides,

(b) analysis of the rainfall records,

(c) interviews with witnesses to the landslides,

(d) topographic surveys and detailed observations and measurements at the site of the landslides,

(e) geological mapping,

(f) execution of a comprehensive programme of ground investigation by drilling, trial pitting, in situ testing and laboratory testing,

(g) theoretical seepage and stability analysis of the slope that failed causing the fatality, and

(h) diagnosis of the probable causes of failure.

This report presents the findings of the investigation. Full details of the investigation work undertaken and the results obtained are contained in a set of documents, which is placed

in the Civil Engineering Library on the First Lower Ground Floor of the Civil Engineering Building.

2. DESCRIPTION OF THE SITE

The landslides (the north landslide and the southeast landslide) occurred either side of the squatter hut identified as No. 26 at Kau Wa Keng Upper Village, and their locations are shown in Figure 2. The ground that failed comprised parts of cut Slopes Nos. 11NW-A/C415 and 11NW-A/C416 and the hillside above. The natural topography comprises a small, southwesterly trending valley between spurs to the northwest and southeast. An ephemeral stream flows within the valley.

Before the landslides, the cut slopes inclined to the southwest at about 60° to the horizontal, with a maximum height of about 4 m. Photographs taken in August 1996, prior to the landslide, show the hut and the cut slope at the site of the landslides (Plates 2 and 3).

The hillside above Slopes Nos. 11NW-A/C415 and 11NW-A/C416, which were involved in the north landslide, had an overall gradient of about 33°. The southeast landslide was confined to the 60° cut face of Slope No. 11NW-A/C416 and the immediate convex slope at its crest. Both the cut slopes and the hillside were densely vegetated.

In front of Slope No. 11NW-A/C416 was a platform, some 8 m wide, behind the crest of a fill slope, which continues down to Castle Peak Road, 13 m below. The slope below the platform, which includes a fill body in the central portion and cuttings on either side, was registered as Slope No. 11NW-A/C64 in the 1977/78 Catalogue of Slopes (Figure 2). The fill body was not disturbed by the landslides.

The squatter hut, No. 26 Kau Wa Keng Upper Village, was located at the rear of the platform, with its northeastern wall built into the toe of Slope No. 11NW-A/C416 (Figure 3 and Plates 2 and 3). The hut was about 7 m square in plan, of timber frame construction with a corrugated iron roof and walls of plywood and tin sheeting. Ancillary structures of similar construction comprised a 1.5 m square kitchen against the southeast wall of the hut and a 1.5 m square out-house for a toilet, close to the southeast side of the hut.

The probable layout of surface drainage prior to the landslide, as interpreted from site observations after the landslide and available documentary records, is shown in Figure 3. A transverse ditch locally supported by concrete walls, crossed the hillside northeast of the hut. The ditch was observed, at the point shown on Plate 4, to be completely filled with soil that had been there before the 1997 landslides.

The ground that failed in the landslides comprises unallocated Government land.

3. DESCRIPTION OF THE LANDSLIDES

Photographs of the landslides taken in the afternoon of 4 June 1997 are shown on Plates 5 and 6. A cross-section through the north landslide is given in Figure 4.

According to the accounts of witnesses and police records, the north landslide occurred very shortly after 7:25 a.m. on 4 June 1997. The main part of the north landslide involved Slope No. 11NW-A/C416 and a significant portion of the hillside above. A subsidiary part of the north landslide affected the southern end of Slope No. 11NW-A/C415 (Figure 2). The landslide released an estimated 360 m^3 of landslide debris on to the platform. About 280 m^3 originated from the main scar, about 12 m wide and 10 m long, with the remainder from the subsidiary scar, about 8 m wide and 5 m long. The vertical depth of the failure was up to 5 m on the northwest side to less than 1 m on the southeast side of the landslide and was, on average, about 2 m to 2.5 m. The upslope part of the slip surface was extensively exposed and was found over a large part of the exposure to be a planar, undulating pre-existing discontinuity inclined at about 30° to the southwest (Plate 5). When examined at 1:30 p.m. on the afternoon of 4 June 1997, significant seepage was observed over the slip surface within the northern part of the main scarp (Plate 7). The surface of the discontinuity was partly coated with manganiferous deposits and locally infilled with kaolin.

Debris from the north landslide hit the northwest wall of the squatter hut, resulting in the southwest facing front wall being pushed from its original position a distance horizontally of about 2 m to the southeast (Plates 6 and 8). Debris had driven into the west corner of the hut at floor level, heavily distorting the front wall as far as the front door. The front door frame was distorted and compressed, such that at mid-height its original width of about 0.75 m was reduced to about 0.3 m (Plate 9).

The landslide debris spread over the platform and over ran the footpath to the northwest. The debris included firm to stiff, brown, sandy, very clayey silt with occasional cobbles and boulders of highly and moderately decomposed granite, concrete and masonry blocks, trees, bushes, a piece of 25 mm diameter pipe and a telephone pole.

The travel angle of the landslide debris, measured from the crest of the landslide to the distant end of the main body of the debris deposition at the front edge of the platform, was about 30°. According to Wong & Ho (1996), this angle is within the typical range for rain-induced soil cut slope failures in Hong Kong, indicating that the debris mobility of this landslide is comparable to that commonly observed.

Water running off the area of the north landslide eroded a gully about a meter deep in the landslide debris at the crest of Slope No. 11NW-A/C64 and washed about 30 m^3 of debris downslope onto the footpath and two lanes of Castle Peak Road.

The southeastern landslide involved only about 25 m^3 of material, which detached itself from the face of Slope No. 11NW-A/C416 over a width of 6 m (Plate 6). The debris slid over the toe channel, hitting the kitchen and toilet out-houses to the squatter hut.

4. HISTORY OF THE SITE

The site history, summarised in Appendix A, was traced from a sequential series of aerial photographs of the site spanning the period 1945 to 1996 and a review of other available documentary information.

The earliest aerial photographs of 1945 and 1949 show that the site where squatter hut No. 26 was subsequently located and where the 1997 landslides occurred was undeveloped. At that time, Castle Peak Road was a two-lane road traversing the mouth of a small valley on a low embankment to the southwest of the site.

Some time between 1954 and 1959, a track was constructed through the site by cutting into the hillside, thereby creating the cutting which is currently denoted as Slopes Nos. 11NW-A/C415 and 11NW-A/C416. During the same period, a transverse ditch was formed about 10 m upslope of the track (Figure 3 and Plate 4).

Realignment and widening of Castle Peak Road was completed by 1963. Slope No. 11NW-A/C64 beneath squatter hut No. 26 was formed at the time by cutting into the hillside and filling within the small valley. The crest of the fill merged with the access track at that location and formed the platform, which was later occupied by squatter hut No. 26. On completion of the road widening works, the access track north of the site was retained as a footpath to Castle Peak Road with which it was linked by a flight of steps through Slope No. 11NW-A/C64. From about 1963, the southern part of the track to the southeast of the flight of steps and the fill platform appeared to have been abandoned.

The GEO has no records of any previous reported landslides in the vicinity of the site of the 1997 landslides. There are also no past natural terrain failures in the area recorded in GEO's Natural Terrain Landslide Inventory (Evans et al, 1997). From a review of the aerial photographs, it was found that four small-scale landslides might have occurred previously at and above the cut slopes between 1954 and 1963 (Figure 3).

Minor modifications to the platform and the toe of Slope No. 11NW-A/C416 are evident on aerial photographs from 1973, but squatter hut No. 26 is not visible. In 1976, squatter hut No. 26 was recorded by the Housing Department (HD) and is visible on aerial photography. An updating survey carried out by the HD in 1982 recorded that modifications to Squatter hut were made to accommodate the kitchen and toilet facilities.

Under the Non-Development Clearance (NDC) Programme, the GEO inspected Kau Wa Keng Upper Village and Pump Fong Sheung Chuen between January and February 1989. Squatter hut No. 26 was within the NDC boundary of Pump Fong Sheung Chuen delineated for GEO's inspection. The squatter hut was not recommended for clearance after GEO's inspection of the village. In January 1993, the GEO reinspected the two villages to check whether the huts previously recommended for clearance had been cleared and to recommend any further clearance. The hut, which is remote from the main parts of either of the two villages, was not included within the study boundary for the reinspection.

5. ANALYSIS OF RAINFALL RECORDS

Automatic raingauge No. N04 is the nearest raingauge to the site of the landslides. The raingauge is situated on the roof of the building of Kai Kwong Lau at Cho Yiu Chuen, Lai King, approximately 1 km to the west-northwest of the landslides. The daily rainfalls recorded by the raingauge in May and June 1997, together with the hourly rainfalls on 3 and 4 June 1997, are shown in Figure 5.

Records from two other nearby automatic raingauges, K06 and N06, which are approximately 2 km to the east and to the north of the landslides respectively, were also examined. Whilst records from these raingauges showed that the pattern of rainfall was broadly similar, their intensities were noted to be lower than that from raingauge No. N04. The records from raingauge No. N04 are considered appropriate for analysis purposes.

Rain was heavy from the early morning of 4 June 1997 to the time of the north landslide at about 7:25 a.m. The 6-hour and 24-hour rolling rainfalls before the north landslide were 252.5 mm and 263 mm respectively. The 60-minute maximum rolling rainfall of 128.5 mm was recorded between 6:00 a.m. and 7:00 a.m. on 4 June.

Figure 6 presents a comparison of the pattern of the rainfall prior to the 1997 landslides with those of previous major rainstorms recorded by raingauge No. N04 since its installation in 1978. It can be seen that the rainfall preceding the north landslide was the highest recorded by the raingauge for durations less than 8 hours but comparatively less intense than some of the previous rainstorms for rainfall durations of 1 day or more.

6. SEQUENCE OF FAILURE

The sequence of failure was re-constructed from accounts given by witnesses, including those of three occupants of the squatter hut, from records of the incident by the Hong Kong Police Force (HKPF) and the Hong Kong Fire Services Department (HKFSD), and from inspections made by GEO and HAP after the landslide.

The inhabitants of the squatter hut first perceived a risk of flooding early in the morning of 4 June 1997, when they became aware that a 450 mm surface channel beneath the hut was overflowing. The channel both upstream and downstream of the hut was blocked by soil, the latter becoming covered by debris when a minor landslide occurred about 1 m across and 1.5 m high, behind the toilet out-house at around 6:00 a.m. Rainfall was torrential, and substantial runoff was occurring from the slopes above the platform and across the platform itself towards the hut. The occupants made an emergency telephone call, logged by the HKPF at 7:09 a.m. The north landslide occurred shortly after a further emergency call made by one of the inhabitants to the HKPF, which was logged at 7:22 a.m. Immediately before the landslide, trees were seen to fall within an area about "10 feet" wide at the toe of the north landslide area, probably caused by the break out of the landslide. The landslide was sudden and debris ran out rapidly over the fill platform, impacting the northwest side of the squatter hut (Plate 8).

During the landslide, a young boy was trapped by the compressed front door frame of the hut and kitchen furniture (Plate 9). The boy was extricated by the emergency services by about 8:50 a.m. and was pronounced dead by staff at Yan Chai Hospital at 10:15 a.m. The other five occupants of the squatter hut were treated for minor injuries.

Between about 8:50 a.m. and 9:00 a.m., HKFSD officers observed "a few trees falling down" at the location of the southeast landslide near the toilet out-house, where the small landslide had blocked the drain earlier in the morning. However, this landslide had not reached the extent subsequently seen by HAP (Plate 6). It is likely from this evidence that the southeast landslide occurred some time after the north landslide, between about 8:50 a.m. and 1 p.m. Hence, the southeast landslide had no influence on the damage sustained by the squatter hut and the resulting fatality.

7. SUBSURFACE CONDITIONS AT THE SITE

7.1 General

The subsurface conditions at the site were determined using information from desk and field studies. The desk study comprised a review of existing data, whilst the field study included geological mapping and ground investigation.

The rocks at the site were previously mapped at 1:20 000 scale by the HKGS as fine-grained granite (Strange and Shaw, 1986). Coarse-grained granite was shown to the southwest of Castle Peak Road and southeast of the site, in both cases faulted against the fine-grained granite.

Geological mapping of the site as part of this investigation commenced on 4 June 1997 and continued as vegetation and landslide debris were removed during emergency repair works.

Ground investigation commenced on 31 July 1997 and comprised 5 vertical drillholes, 10 standpipe piezometers, 7 trial pits, 2 trial trenches and 10 GCO probes, 9 of which had jet fill tensiometers subsequently installed (Figure 7).

7.2 Geology

Geological and other related features observed by the HKGS at and near the landslide site are shown in Figure 8. A geological section through the site is shown in Figure. 9. The predominant lithology consists of medium-grained, varying locally to coarse-grained, granite. Immediately upslope of the north landslide, weathered granitic rock is overlain by a layer of colluvium, up to about 2 m thick. Colluvium up to 1 m thick was also observed in the main scarp of the landslide.

The granitic material exposed in the scar of the north landslide is generally highly to completely decomposed, but locally varies from moderately decomposed to residual soil. Moderately decomposed granite is also exposed in places on the hillside, and in the stream course east of the failure. In terms of rock mass weathering characteristics, the granitic material varies from PW 0/30 in the main scarp on the southeast side of the landslide, to PW 30/50 in the spur forming the northwest side of the scarp. The core of the spur appears from evidence in shallow excavations to be even less decomposed. The material exposed on the surface of rupture appears mainly to comprise PW 0/30, but trial trenches show that it is closely underlain by typically PW 30/50 and occasionally PW 50/90.

The colluvium observed in the main scarp was a firm to stiff, brown, sandy very clayey silt with occasional gravel, cobbles and boulders of highly to moderately decomposed fine to medium-grained granite, medium-grained granite and aplite. Colluvium was exposed in the trial trench and trial pits behind the main scarp and was proved to extend for about 25 m upslope, terminating against exposed granite (Plate 10). The colluvium in this area comprises firm, dark brown, slightly sandy clayey silt with some gravel and cobbles of granite. Evidence of bioturbation through insect activity was found, resulting in the formation of nest cavities up to about 50 mm to 100 mm across.

The surface of rupture of the north landslide occurred largely on a slightly undulating discontinuity, typically inclined at about 30° to the southwest. The main scarp in the northeast of the failure was inclined at about 42° to the southwest. This surface was partly exposed on 4 June 1997, when it was recorded as about 9 m in width and 8 m long in the direction of landsliding (Plates 5 and 7). It was later exposed for about a further 2 m downslope in a trial trench. The landslide scarp was markedly asymmetric in transverse section and the depth of rupture was observed to be up to 5 m on the northwest side. There, subvertical southeast dipping joints with extremely narrow apertures also acted as release surfaces, in combination with discontinuous joints subparallel to and above the surface of rupture. No tension cracks were observed on 4 June 1997 behind the main scarp. The depth of rupture tapered to about 1 m on the southeast side of the landslide. A narrow discontinuity, locally up to 20 mm wide, was observed extending upslope from the surface of rupture (Plate 7). This discontinuity is interpreted as the unfailed portion of the same discontinuity that largely controlled the surface of rupture. Occasional rootlets were seen growing along this discontinuity and onto the surface of rupture itself, indicating that the discontinuity had possibly been a partly open structure for some time prior to the failure. Significant seepage was flowing out of the discontinuity in the early afternoon of 4 June 1997 and became minimal at about 4 p.m.

Dark brown to black manganiferous deposits partly coated the discontinuities. Kaolin (generally less than 10 mm thick) was observed to locally infill the discontinuities, including those observed on the surface of rupture. A prominent zone (up to 50 mm wide) of extremely closely spaced, subvertical discontinuities with manganiferous infill was noted, striking northwest for more than 10 m across the landslide scar; a similarly striking zone, dipping 60° to 80° to the southwest was observed in trial pit No. TP8 (Figure 7). These may represent minor geological shear zones.

Aplite dykes, from 20 mm to 350 mm thick, had intruded the granite and several were observed in the stream course on the southeast side of the landslide scar, in the landslide scar and in the trial pits and trenches (Figure 7). These dykes were vertical to subvertical and mainly dipped to the northeast. Occasional quartz veins, up to 20 mm thick, also dipped steeply (60° to 80°) to the northeast.

Immediately downhill of the north landslide, the fill forming the platform (Plate 11) consisted of soft to firm, brown and grey, sandy silt with occasional boulder size concrete and granite fragments, iron tubes and steel bars.

The southeast landslide involved completely decomposed granite to granitic residual soil. A thickness of completely decomposed granite of 10 m was proved in borehole No. 5 upslope of the landslide.

7.3 Soil and Rock Properties

A comprehensive series of geotechnical laboratory tests was conducted on soil samples retrieved during the ground investigation. The tests included particle size distribution tests, Atterberg limits tests, triaxial compression tests and permeability tests.

Particle size distribution and Atterberg limits tests were carried out in accordance with Chen (1994). The average fines (i.e. clay and silt) content of the completely decomposed granite (CDG) was found to be 36%, whilst that of the colluvium was 41%. The plasticity index of the fines of CDG ranged from 14% to 44%, and the liquid limit ranged from 40% to 81%. The plasticity index of the fines of colluvium ranged from 33% to 47%, and the liquid limit ranged from 66% to 87%.

Results of the permeability tests carried out in the laboratory on samples of colluvium and completely decomposed granite provided average values of 1×10^{-4} m/s and 7×10^{-5} m/s respectively. Permeability values obtained from the falling head tests in boreholes were on average, 2×10^{-4} m/s for relict jointed completely and highly decomposed granite and 8×10^{-5} m/s for jointed moderately and slightly decomposed granite.

The shear strength properties of the completely decomposed granite and colluvium were assessed by consolidated undrained triaxial compression tests (Head, 1986). The results of the tests are presented in the form of p' - q plots in Figures 10 and 11, and are found to be typical for these materials in Hong Kong. Given the very weak nature of the completely decomposed parent rock and the lack of significant low-strength coating and infilling on the discontinuities, it is taken that the strength of the soil mass would have been close to that of the intact completely decomposed granite (Au, 1996).

7.4 Groundwater Conditions

The groundwater conditions at the site were evaluated from a review of the following observations from the landslide investigation :

(a) a large amount of seepage was observed emanating from the discontinuities in the weathered granite exposed at the main scarp in the early afternoon of 4 June 1997 (Figure 8),

(b) the amount of seepage at the main scarp reduced with time, following cessation of heavy rain in the morning of 4 June 1997 and became minimal at about 4 p.m.,

(c) after the landslide scar had been trimmed back and covered by shotcrete through which weepholes and raking drains were installed, as part of urgent repair works to the failure, seepage was noted from the raking drains and the weepholes during and after heavy rain from June to October 1997 (Figure 8), and

(d) post-landslide groundwater monitoring data from five vertical drillholes (DM1 & DM5, Figure 7) for the period August to October 1997, which included a major rainstorm on 22 August, when 185.5 mm of rain was recorded at raingauge No. N04, over a five hour period.

It is postulated that during heavy rain, water would have infiltrated into the ground via the colluvium layer present at the surface of the hillside in the area immediately upslope of the landslide location and over part of the landslide itself. This colluvium layer, being relatively permeable, would have promoted rapid surface infiltration and downslope subsurface seepage flow of the water. The discontinuities in the weathered granite were locally open, and they would have provided preferential flow paths for subsurface seepage to travel through the weathered granite. The shallow rockhead at the site and the partly coated discontinuities probably acted as less permeable boundaries in the ground. They would have impeded through-flow of water, which would have resulted in the formation of perched water tables.

The hydrogeological setting of the site was therefore favourable to development of groundwater pressure in the weathered soil mass at times of heavy rain, possibly by perching of water partly on the shallow rockhead and partly on coated discontinuities. The water pressure development would have responded fairly quickly with rainfall, as is evident from the 1997 landslide occurring within hours after commencement of heavy rain in the early morning of 4 June and from the rapid reduction in the amount of surface seepage at the landslide scarp after cessation of rain.

Monitoring of groundwater levels in standpipe piezometers in response to the August 1997 rainstorm, indicated that groundwater pressures would probably be established above the

base of the landslide. The groundwater regime will have been altered by the landslide itself, so that the measurements made after the failure may not be entirely representative of groundwater pressures before the landslide. As a best estimate, the groundwater pressure acting on the failed portion of the slope at the time of the landslide might correspond to that of a perched water table at about 1 m to 2 m above the basal surface of the landslide (see Figure 12).

8. THEORETICAL SEEPAGE AND STABILITY ANALYSES

8.1 Theoretical Seepage Analyses

To check the validity of the groundwater model postulated in Section 7.4, seepage analyses have been carried out to predict the rise of a perched water table above the basal surface of the landslide. The analyses are modelled both for the conditions of primary permeability only (with the soil assumed as a homogeneous material), and for where both primary and secondary permeabilities (through discontinuities) apply. The analyses consider saturated seepage flow with allowance for water retention in the soil mass due to changing degree of saturation.

About 280 mm of rain had fallen during the 6 hours prior to the north landslide. Assuming that water would have infiltrated the colluvium and seeped into the underlying partially weathered granite, seepage analysis using the primary permeabilities indicated by the laboratory tests (Section 7.3) shows that a perched water table less than 0.5 m above the basal surface of the landslide would have developed in response to this rainstorm event at the time of the north landslide.

The discontinuity observed coinciding with a significant portion of the surface of rupture was noted to be open in part of the main scarp of the landslide. In addition, other jointing in the vicinity was also observed to be partly open so allowing rapid and concentrated infiltration into the soil mass (Plate 5). For these conditions where both primary and secondary permeabilities apply, the seepage analysis shows that a perched water table of about 1 m to 2 m would have developed above the landslide basal surface.

8.2 Theoretical Stability Analyses

Theoretical stability analyses were carried out to assist the diagnosis of the mechanism and causes of the north landslide. These analyses were aimed to determine the likely range of shear strength parameters of the weathered granite, corresponding to different water levels at the time of failure.

Information obtained from the post-failure ground investigations, laboratory testing, and site observations and measurements was used in the analyses. A representative cross-section of the landslide site and the input parameters adopted in the analyses are shown in Figure 12. Stability analyses were undertaken for the failed section for different groundwater conditions, ranging from zero groundwater pressure to that corresponding to a perched water

table at 2.5 m above the basal surface of the landslide, which in-part corresponds to an adversely dipping discontinuity.

The results of the analyses are summarised in Figure 13. For a factor of safety of 1.0 at failure, the angle of shearing resistance, ø', of the weathered granite was found to be between 32° and 46°, for rises in a perched water table above the basal surface of the landslide of between 1.4 m and 2.5 m. The strength of the decomposed granite measured by laboratory tests lies within this range, and for this strength the analyses show that a rise in water table of about 1.8 m above the basal surface would have been sufficient for failure to have occurred.

Theoretical stability analysis of the landslide was also carried out for the hillside without the presence of the cut slope No. 11NW-A/C416, for the purpose of assessing the effects of the cutting on the stability of the hillside. It was found that the formation of the cut slope would have reduced the theoretical factor of safety of the hillside by about 5%.

9. DIAGNOSIS OF THE CAUSES OF THE FATAL LANDSLIDE

Based on the information collected from this investigation, it is postulated that the north landslide at squatter hut No. 26, Kau Wa Keng Upper Village was principally caused by an increase in groundwater pressure following very heavy rainfall. The landslide involved the sudden failure of a small steep cut slope and a significant portion of the hillside above.

The rainfall preceding the landslide for durations of less than 8 hours was the highest recorded since 1978, when raingauge No. N04 was installed. In particular, the landslide occurred very shortly after a peak 60-minute rainfall of 128.5 mm, which was recorded between 6 a.m. and 7 a.m. on 4 June.

Other factors that would probably have contributed to the landslide include the following :

(a) the presence of a surface layer of more permeable colluvium on the slope above and over the landslide area, the existence of partly open, partly coated discontinuities in adverse orientations and the presence of a shallow rockhead profile provided the hydrogeological conditions that were favourable to surface infiltration of rain water and development of perched water pressure in the weathered granite, and

(b) the presence of the cut slope, which resulted in a reduction in the margin of stability of the hillside.

10. CONCLUSIONS

It is concluded that the 1997 landslide to the north of squatter hut No. 26, Kau Wa Keng Upper Village, that resulted in one fatality, was probably primarily caused by a significant rise in groundwater pressure in the weathered granite hillside, following very heavy rainfall that preceded the failure.

The hydrogeological setting of the site, in particular the presence of partly open discontinuities at adverse orientations, was favourable to rain infiltration and development of perched water pressure in the weathered granite. The cut slope into the hillside would probably have contributed to causing the landslide.

The information obtained from this investigation indicates that the child who died in the landslide was trapped within the front door frame of the hut, whilst the structure was distorted by the landslide debris.

The main body of the southeast landslide occurred some time after the north landslide. The southeast landslide had no influence on the damage sustained by the squatter hut and the fatality.

11. REFERENCES

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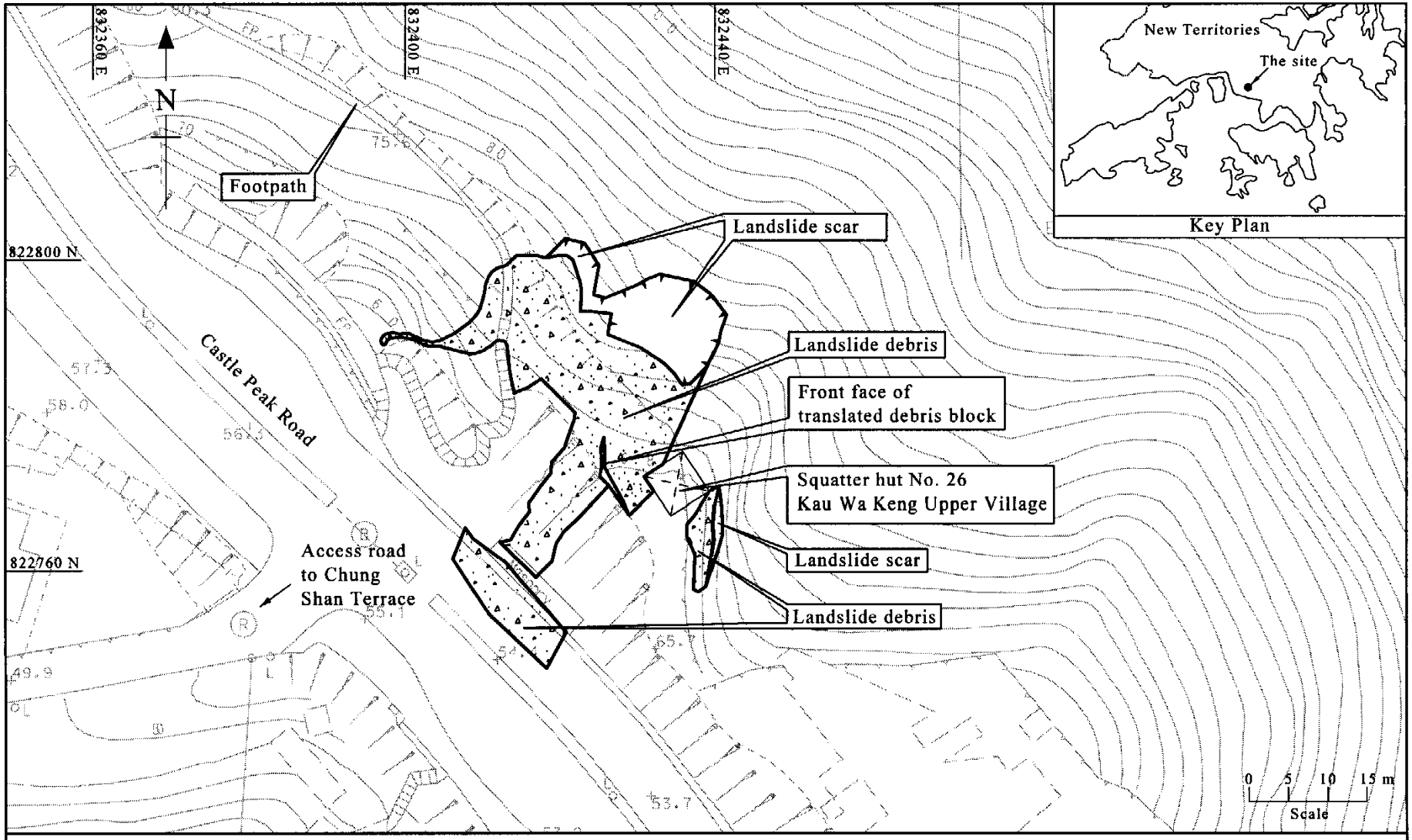
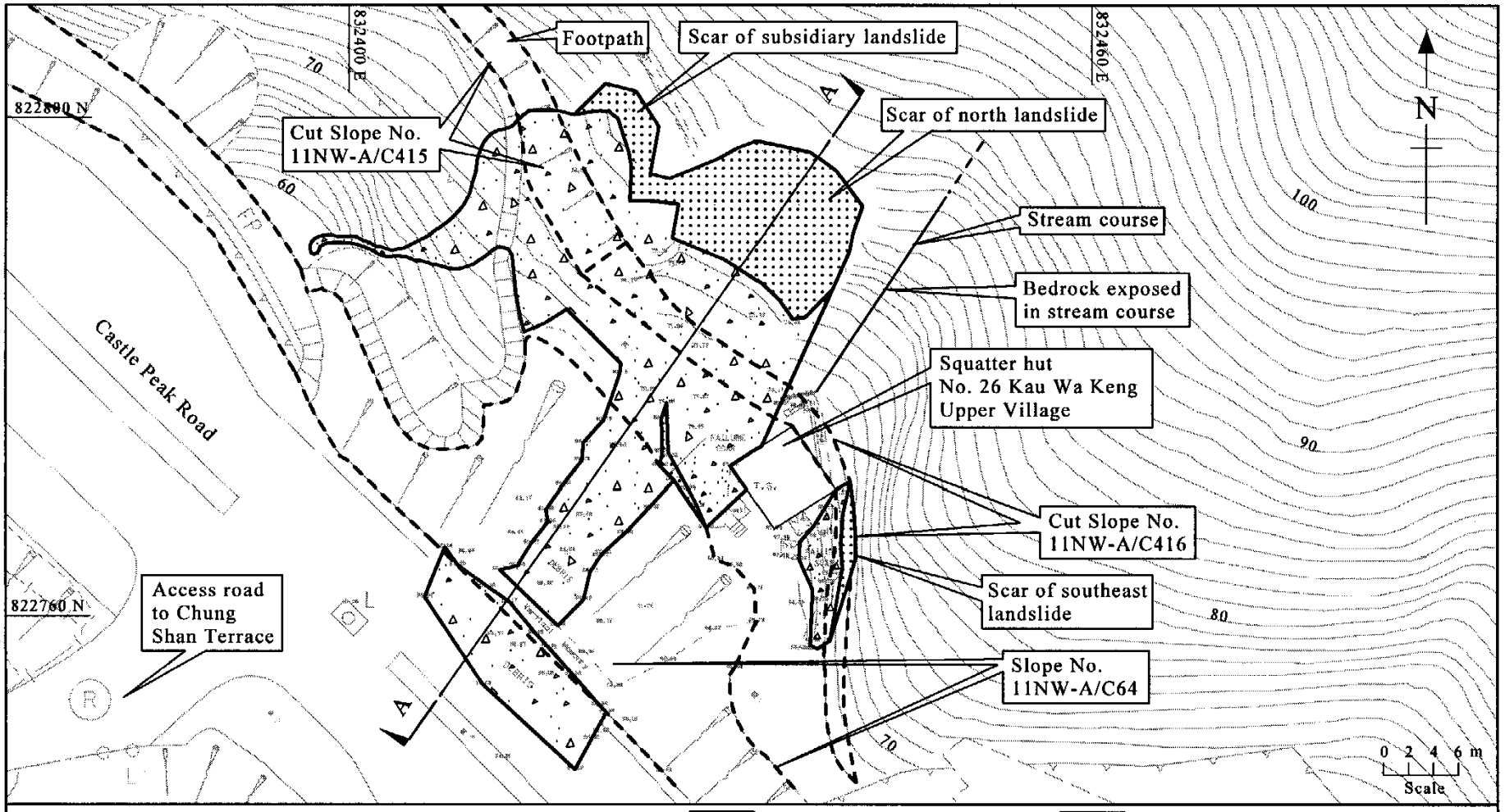
LIST OF FIGURES



Note : Base map is extracted from Survey Sheet Nos. 11NW-2D and 11NW-7B dated October 1992 (Scale 1:1 000).

Figure 1 - Site Location Plan



Notes : (1) See Figure 4 for Section A-A.

(2) Information shown in this figure is based on topographic survey, 1 : 1 000 survey maps, geological mapping, field observations and documentary records.

Figure 2 - Plan of the Landslides

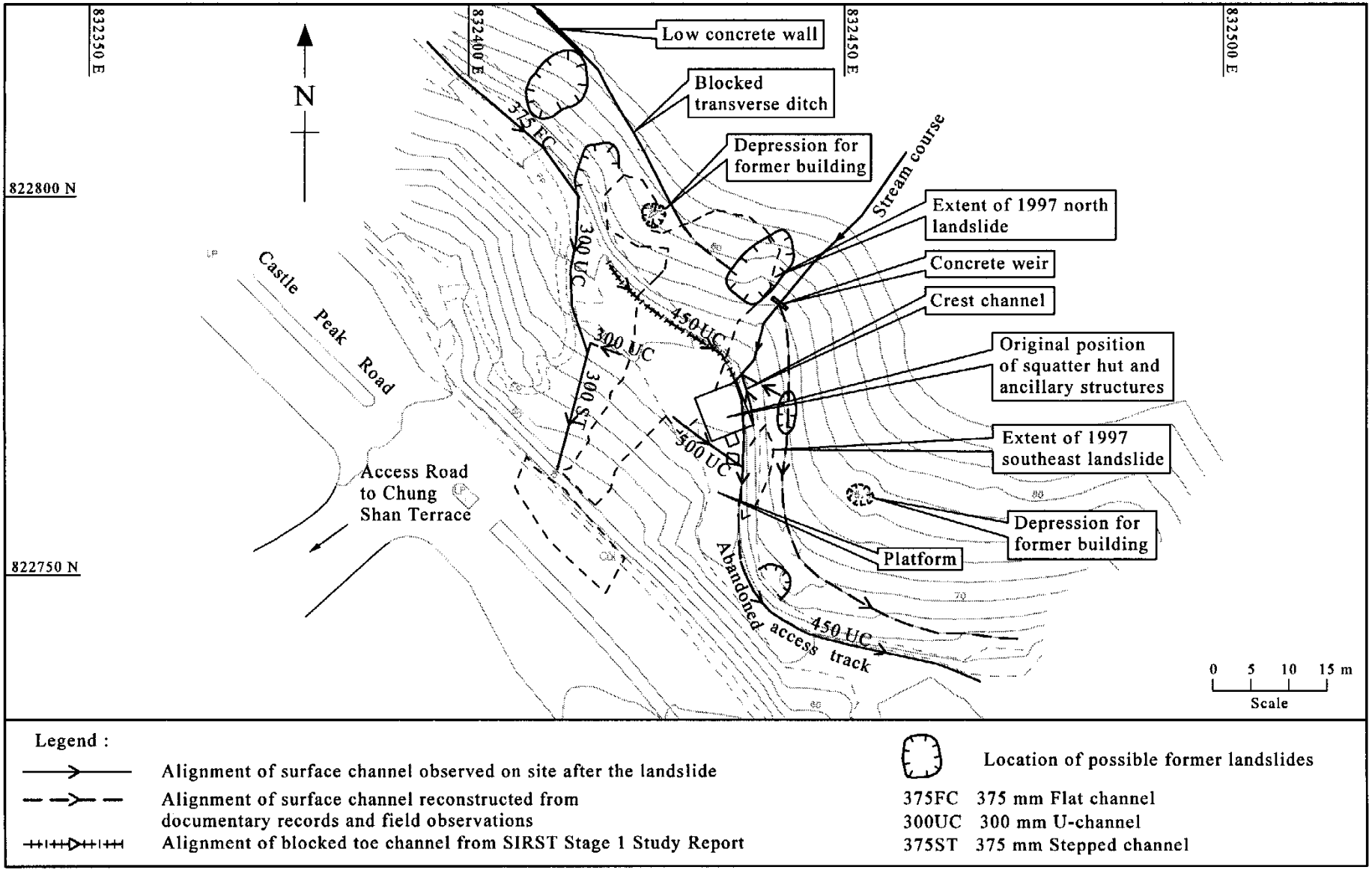
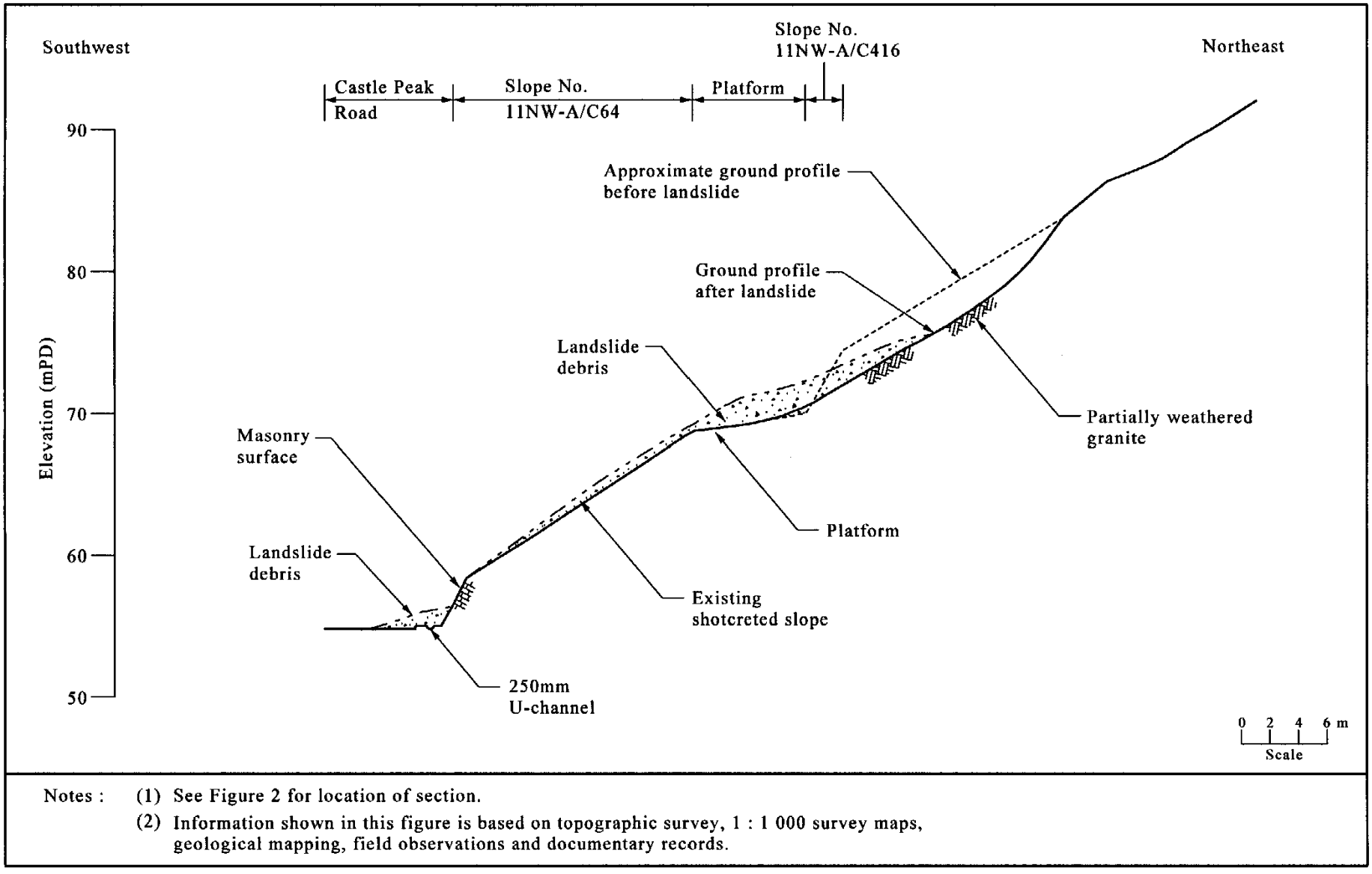


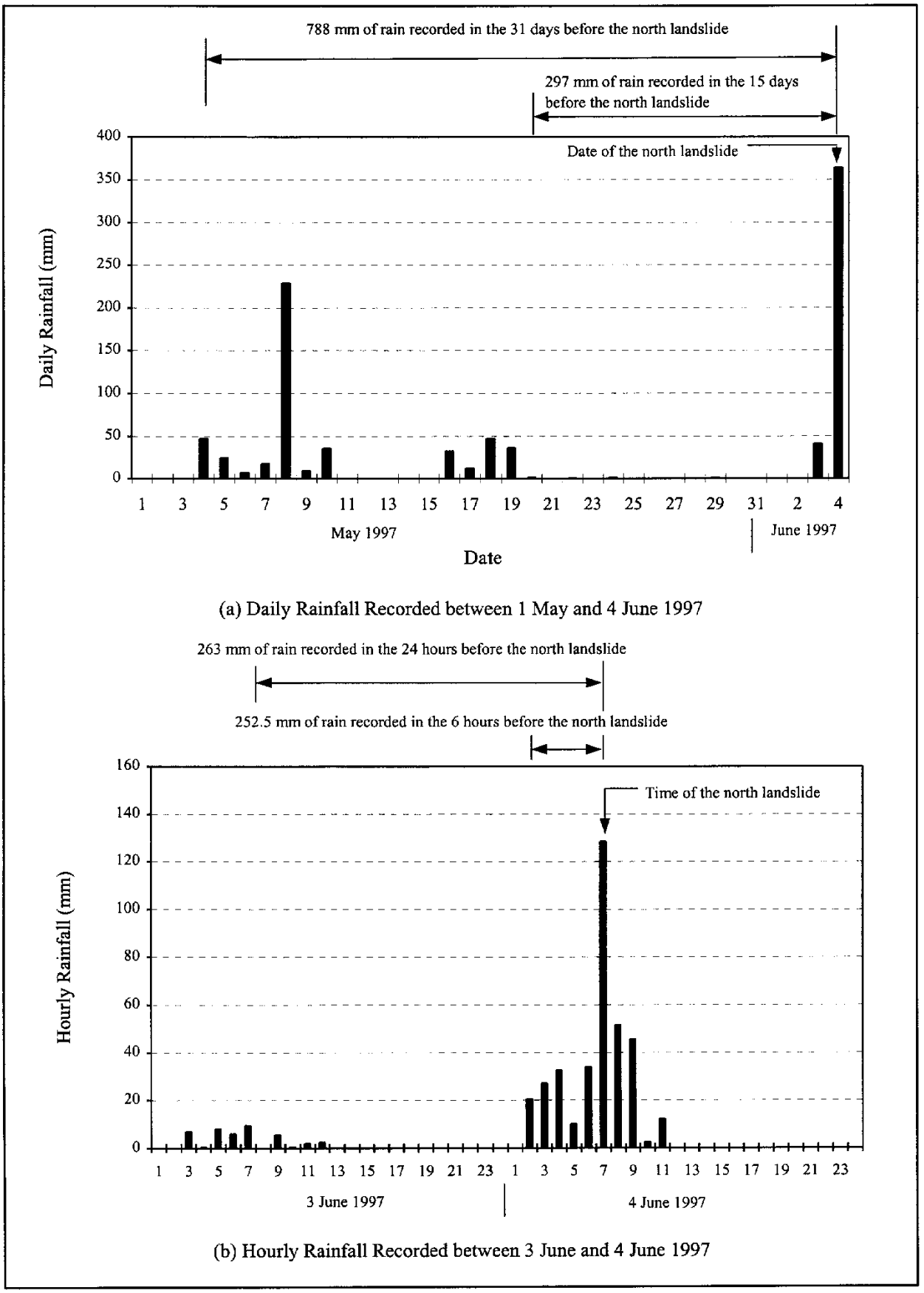
Figure 3 - Pre-landslide Drainage and Other Features



Notes : (1) See Figure 2 for location of section.

(2) Information shown in this figure is based on topographic survey, 1 : 1 000 survey maps, geological mapping, field observations and documentary records.

Figure 4 - Section A-A, North Landslide



(a) Daily Rainfall Recorded between 1 May and 4 June 1997

(b) Hourly Rainfall Recorded between 3 June and 4 June 1997

Figure 5 - Rainfall Records of GEO Raingauge No. N04

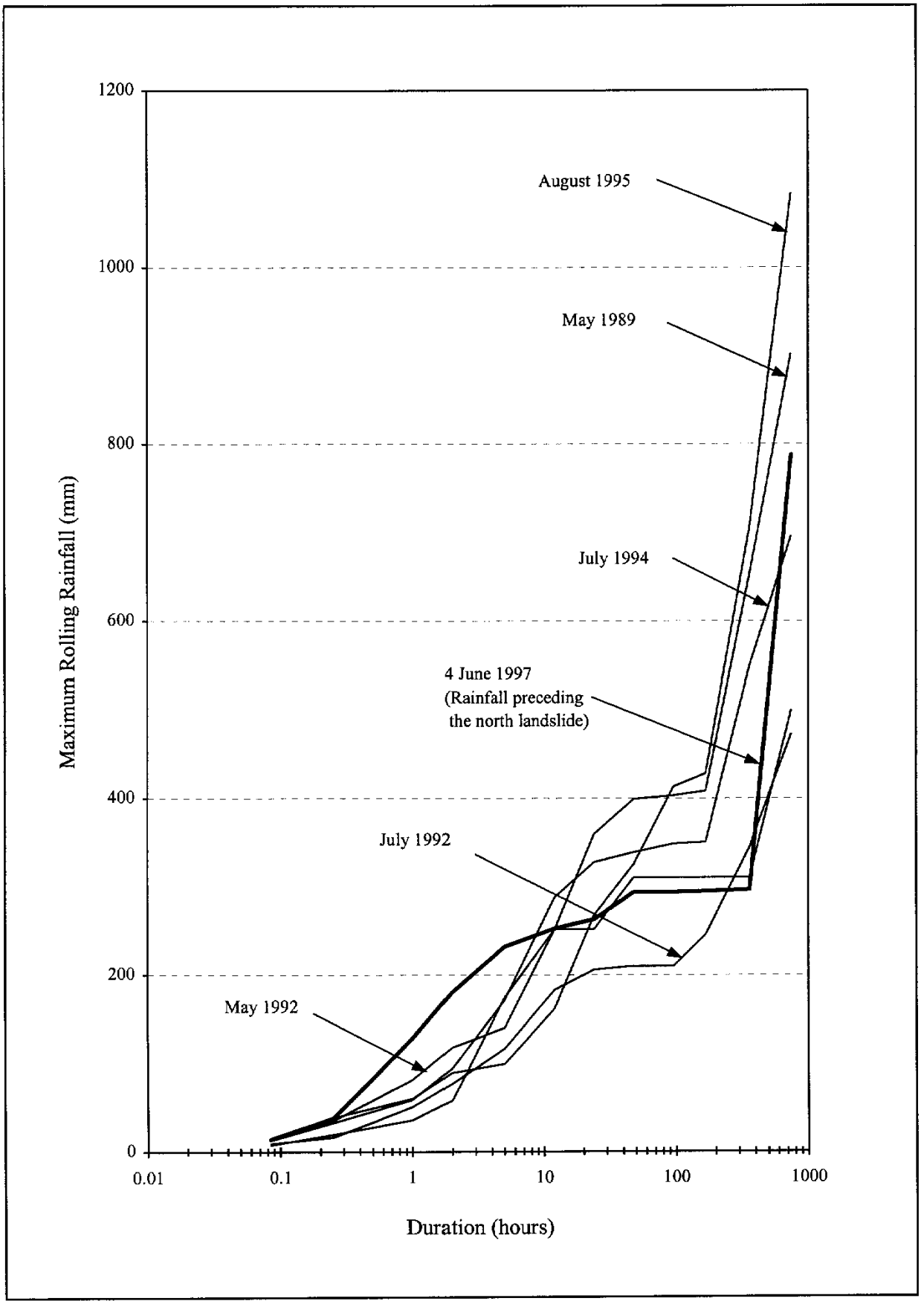
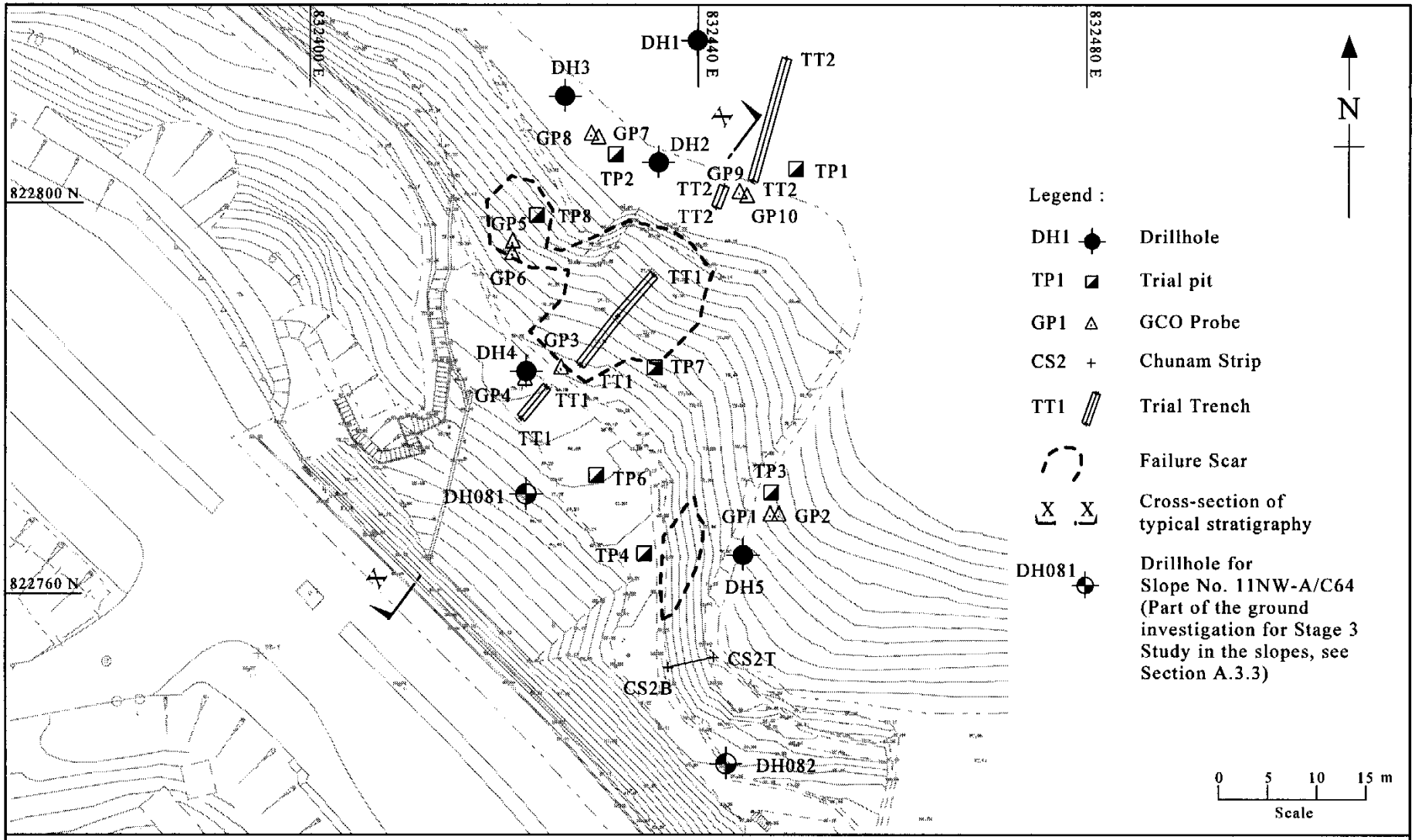
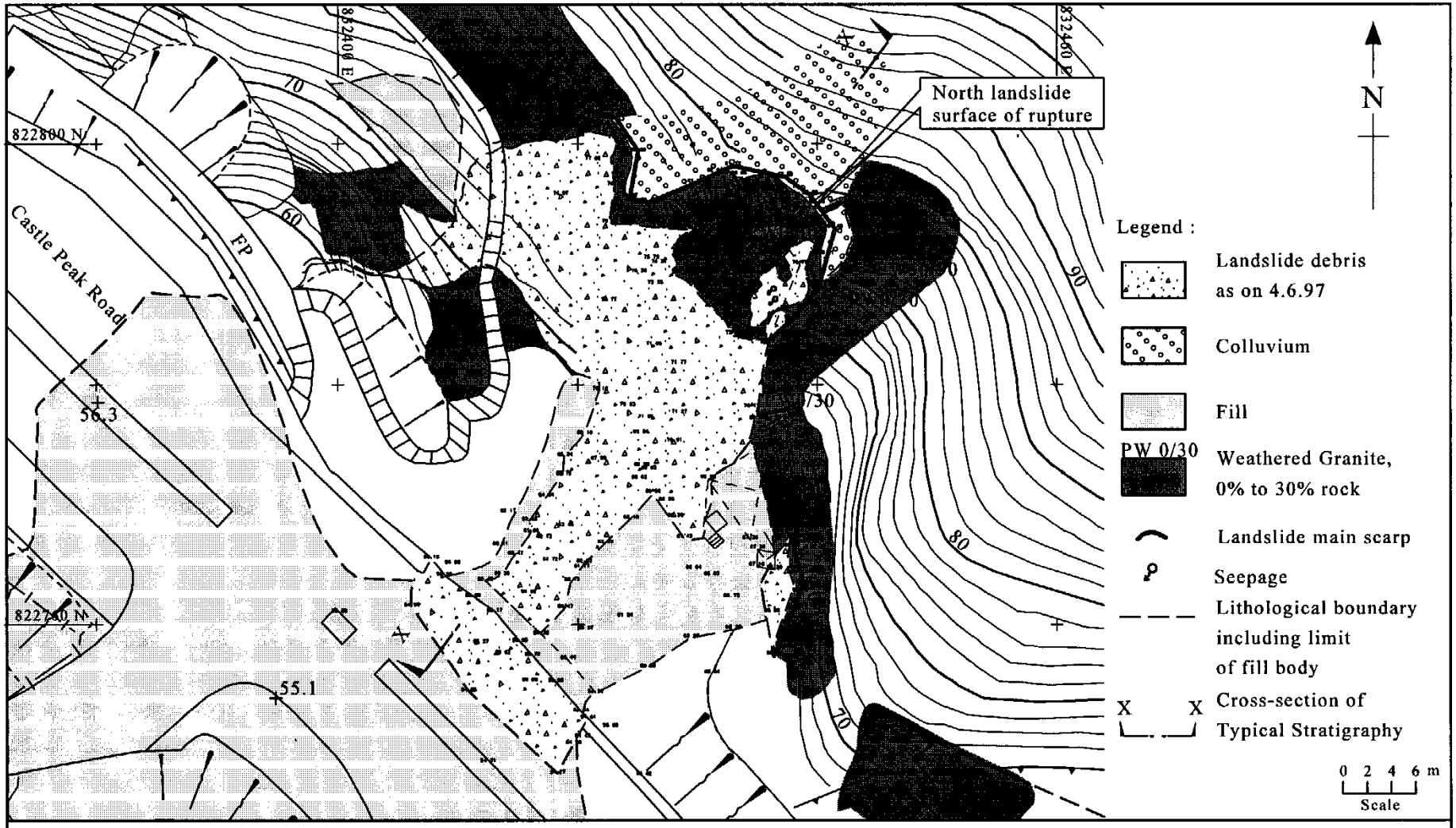


Figure 6 - Maximum Rolling Rainfall at GEO Raingauge No. N04 for Major Rainstorms



Note : Information shown in this figure is based on topographic survey, 1 : 1 000 survey map, geological mapping, field observations and documentary records.

Figure 7 - Location Plan of Ground Investigation Works



Note : Information shown in this figure is extracted from a geological map complied by the HKGS based on geological mapping of the site after the landslide.

Figure 8 - Simplified Geological Map of the Landslides

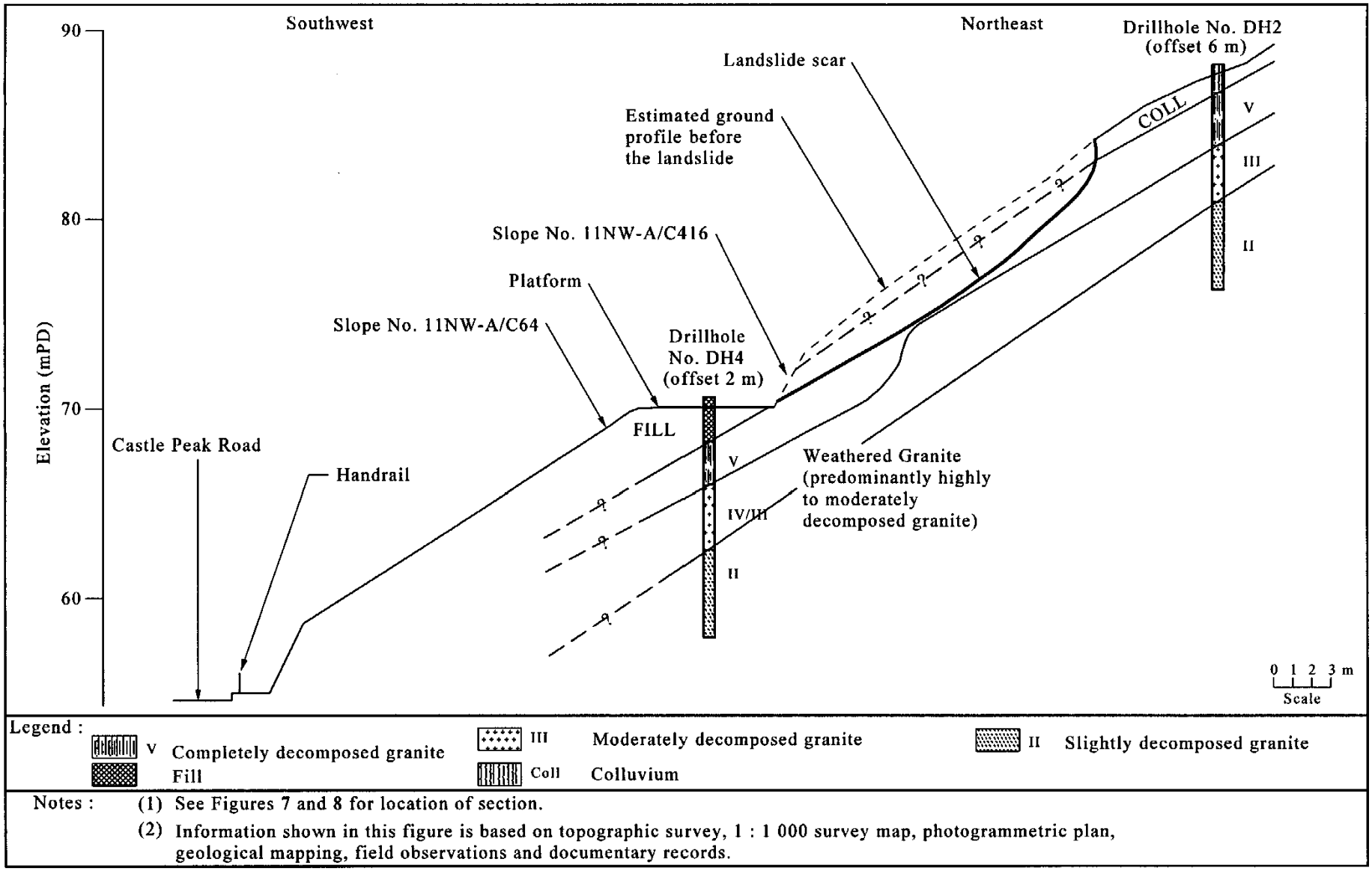
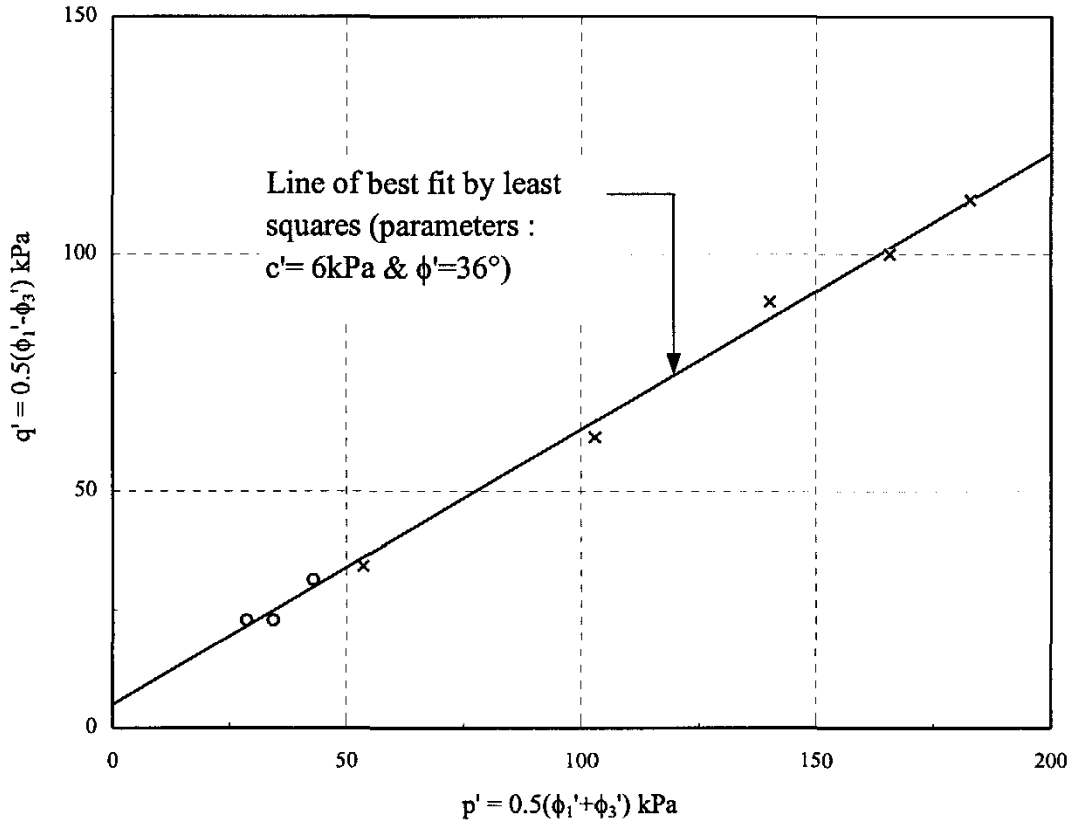


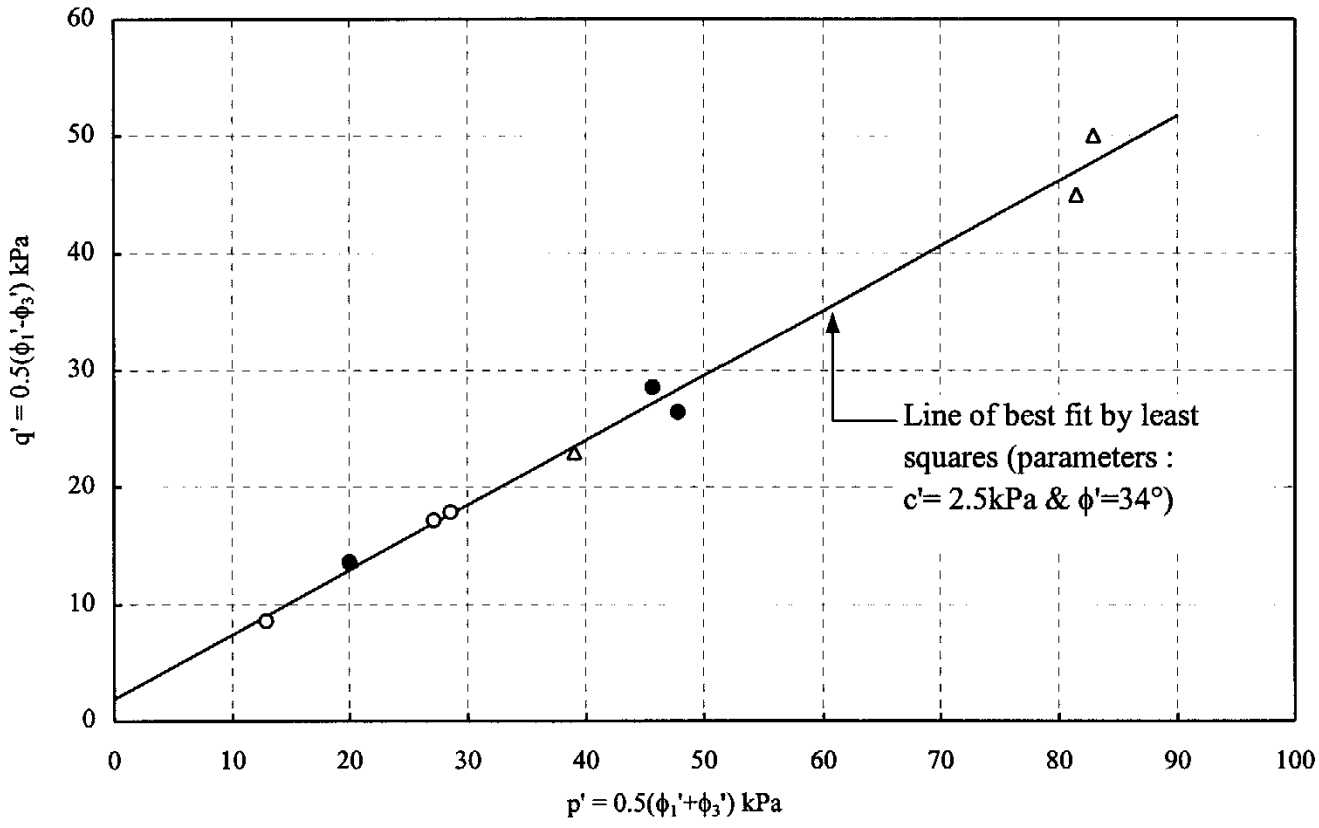
Figure 9 - Section X-X Showing the Typical Stratigraphy through the Landslide Site



Legend:	×	Single-stage test	σ_1'	Major principal effective stress	c'	Cohesion
	○	Multi-stage test (first stage)	σ_3'	Minor principal effective stress	ϕ'	Angle of shearing resistance

Note: Triaxial compression test results correspond to those at the point of maximum deviator stress, i.e. σ_1'-σ_3'.

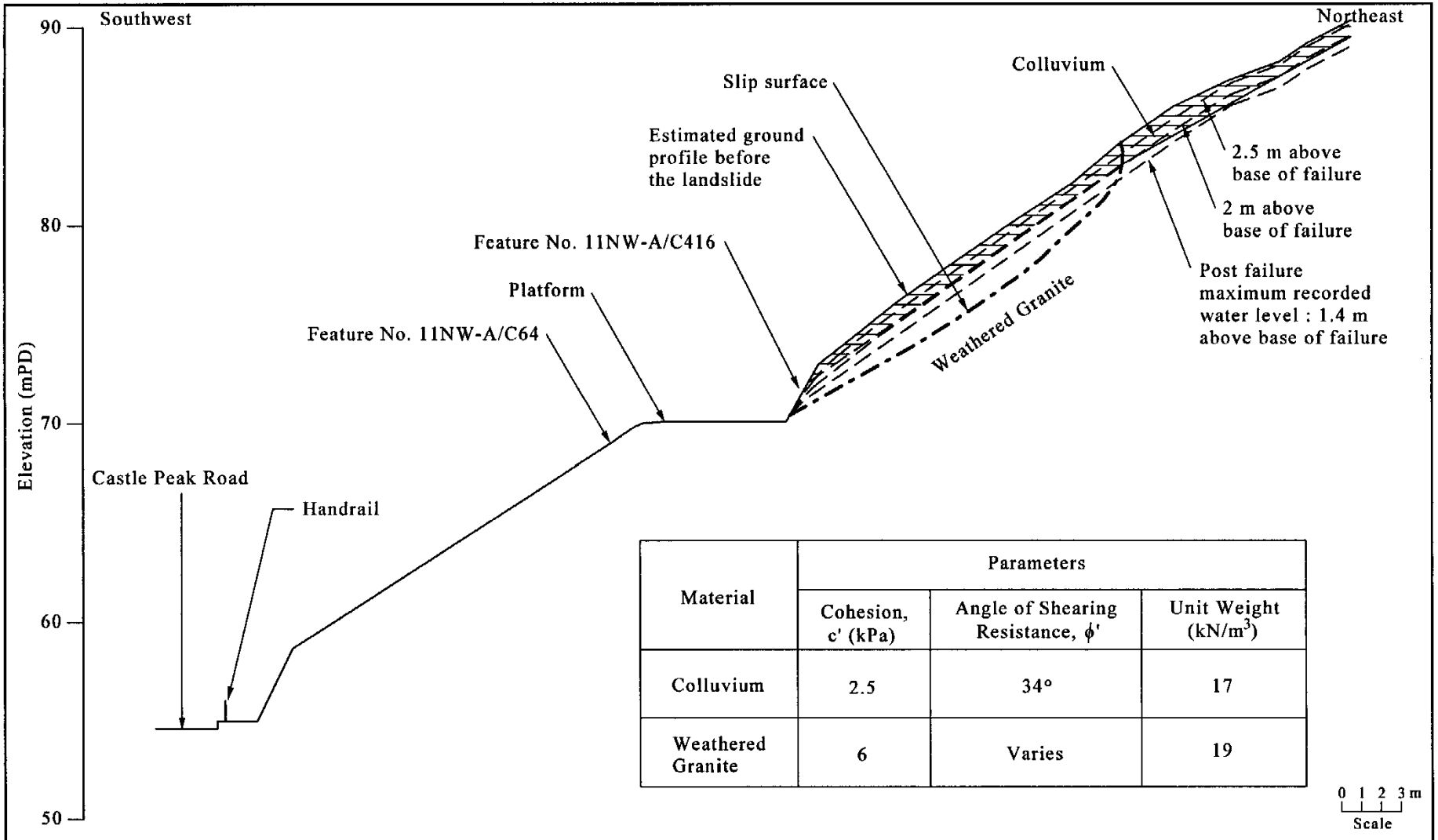
Figure 10 - Triaxial Compression Test Results for Completely Decomposed Granite



Legend:	○	Multi-stage test (first stage)	σ_1'	Major principal effective stress	c' Cohesion
	●	Multi-stage test (second stage)	σ_3'	Minor principal effective stress	φ' Angle of shearing resistance
	△	Multi-stage test (third stage)			

Note: Triaxial compression test results correspond to those at the point of maximum deviator stress, i.e. $\sigma_1'-\sigma_3'$.

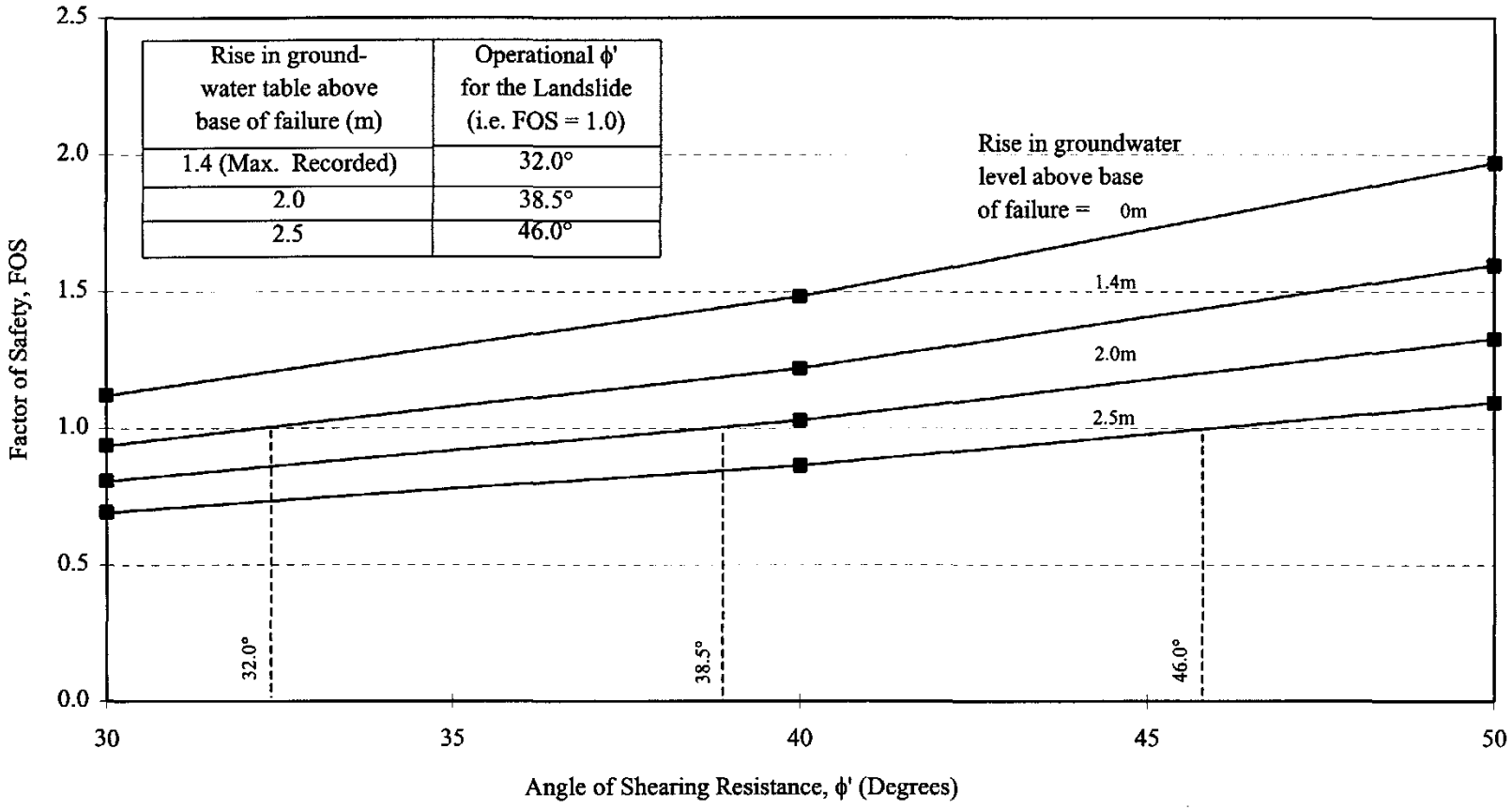
Figure 11 - Triaxial Compression Test Results for Colluvium



Material	Parameters		
	Cohesion, c' (kPa)	Angle of Shearing Resistance, ϕ'	Unit Weight (kN/m^3)
Colluvium	2.5	34°	17
Weathered Granite	6	Varies	19

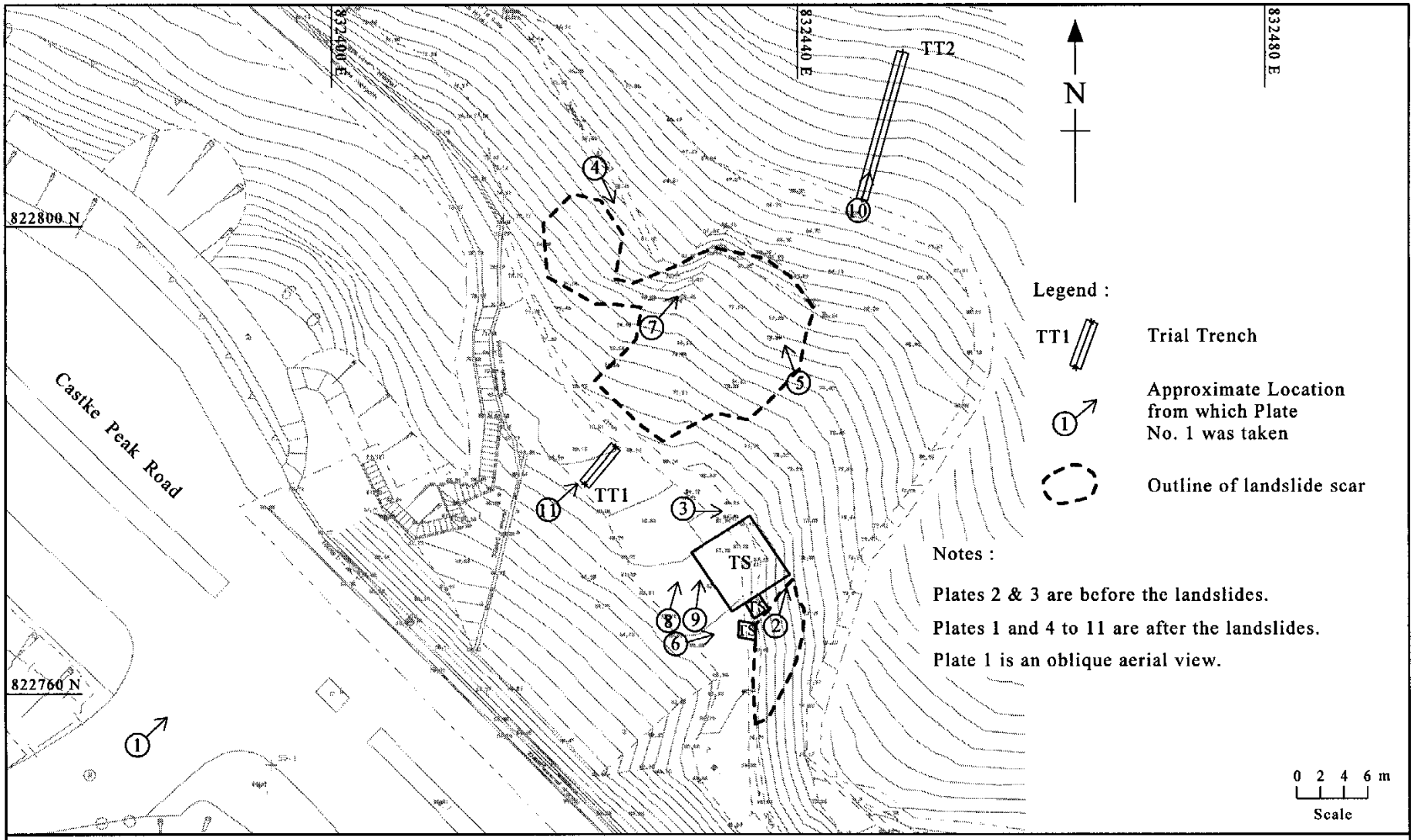
Note : The case of no perched water table was also analysed (see Figure 13).

Figure 12 - Representative Cross-section of the Landslide for Theoretical Stability Analyses



Note: See Figure 12 for details of the analyses.

Figure 13 - Results of Theoretical Stability Analyses



Note : Information shown in this figure is based on topographic survey, 1 : 1 000 survey map, geological mapping, field observations and documentary records.

Figure 14 - Location Plan of Photographs Taken

LIST OF PLATES

Plate 1 - Photograph of the Site of the Landslides Taken in the Afternoon of 4 June 1997 (See Figure 14 for Location)

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Plate 3 - Northern Corner of No. 26 Kau Wa Keng Upper Village Showing the Stream Course (Photograph Taken on 22 August 1996. Reproduced from SIRST Inspection by Binnie Consultants Ltd. See Figure 14 for Location)

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Plate 9 - Damage to Front Door Frame of No. 26 Kau Wa Keng Upper Village (Photograph Taken on 6 June 1997. See Figure 14 for Location)

Plate 10 - Colluvium Overlying Granite in Trial Trench TT2 (Photograph Taken on 25 August 1997. See Figure 14 for Location)

Plate 11 - Landslide Debris Overlying Thin Soil and Fill on the Platform (See Figure 14 for Location)

APPENDIX A

SUMMARY OF SITE HISTORY

CONTENTS

A.1 INTRODUCTION

References

The history of the site has been determined from :

(a) a sequential series of aerial photographs spanning the period 1945-1996,

(b) documentary records from GEO's files,

(c) construction records of Castle Peak Road from the Highways Department, and

(d) records provided by other Government Departments.

A.2 HISTORY OF SITE DEVELOPMENT

At the time of the earliest available sets of aerial photographs (November 1945 and April 1949), the site is shown to lie within a small southwesterly trending valley between two spurs to the northwest and southeast. Except for a footpath traversing the slope between the remains of two small buildings (Figure 3), the valley sides were undeveloped. Castle Peak Road (CPR) was a two-lane carriageway on a low embankment crossing the mouth of the valley.

The realignment and widening of CPR in the area was designed in 1953 and construction progressed northwestwards downslope of the site, commencing some time between November 1954 and October 1959 and being completed by January 1963. The work involved extensive cutting into the hillsides on the upslope side of the old CPR, filling within the line of the valley and widening the road embankment on the downslope side. The new cutting, including an area of fill in its central part, was subsequently designated Slope No. 11NW-A/C64. From the evidence of the design drawing and the 1959 aerial photographs, a new track, possibly for construction access, was benched into the slope uphill of the roadside cuttings. The cuts created for this access track north and south of the site are those subsequently designated Slopes Nos. 11NW-A/C415 and 11NW-A/C416 respectively. The access track generally contoured around the valley sides but had an overall gradient down towards the southeast.

Drawing No. RK 425/2B, Public Works Department (1953)

During the same period (1954 to 1959), a transverse ditch was excavated across the slope uphill of the track to a point 100 m northwest of the valley. The ditch falls progressively to an existing stream in the neighbouring valley about 50 m to the southeast. It was locally retained by concrete walls where it crossed drainage lines and topographic low points. The transverse ditch passed through the central part of the 1997 north landslide site and was supported by a

short length of concrete wall where it crossed the stream course in the floor of the valley. A further section of low concrete wall was provided to retain the transverse ditch northwest of the landslide site. The aerial photographs of January 1963 show that the ditch had become blocked by a landslide (first seen on the 1959 aerial photographs on the northern side of the valley). Given the extensive catchment of the transverse ditch but absence of any erosion at the site of the blockage, it is evident that the transverse ditch carried little or no water by 1963 and was probably inoperative. The ditch was observed on 6 June 1997 to be completely filled with soil that had been there before the 1997 landslide (Plate 4).

The squatter hut involved in the landslides of June 1997 occupied part of the line of the track and the platform formed by the fill in the central part of Slope No. 11NW-A/C64. Filling to create the platform was in progress or had recently been completed by the time of the January 1961 aerial photographs. A short channel excavated some time between 1961 and 1963 crosses the platform from its central part to the channel at the toe of Slope No. 11NW-A/C416 (Figure 3). Most of the surface drainage channels shown in Figure 3 were in place by 1963. The track north of the platform was retained as a footpath and was connected to CPR by a flight of steps through Slope No. 11NW-A/C64.

Between 1963 and the early 1970s vegetation became re-established on the slopes. Aerial photographs of October 1973 show some cutting at the toe of Slope No. 11NW-A/C416 behind the track and stripping of vegetation on the platform itself. The first aerial photograph to show the squatter hut, apparently well established, is that of August 1976. The Hong Kong Housing Authority (HKHA) reported that a hut for domestic purposes was in existence in 1976, when they carried out their squatter structure survey. At that time the recorded dimensions of the hut were 4.6 x 3.4 x 2.1 m. The hut remains visible on subsequent aerial photographs. In 1982, a survey undertaken by HKHA recorded that the hut had been altered to 6.1 x 2.4 x 3.0 m, and that facilities had been augmented to include a kitchen and latrine.

Letter from HKHA, re(13) in SCTW 4/16/70 (438) dated 22 July 1997

HKHA, op, cit

The development of the squatter hut was accompanied by increasing terracing of the slopes to the east. After 1987 the terraced area appears to have been abandoned. Dense vegetation had become re-established at this area by 1992.

A.3 PREVIOUS SLOPE ASSESSMENTS

A.3.1 Slope Registration and Stage 1 Study

Slope No. 11NW-A/C64 was registered in the 1977/78 Catalogue of Slopes by the consultants engaged by the Government to prepare the Catalogue. The first recorded inspection of this slope was carried out by the consultants in June 1977 as part of the registration of the slope in the Catalogue.

Binnie & Partners Field Sheet for Slope No. 11NW-A/C64

The two cut slopes at the rear of the platform, Slopes Nos. 11NW-A/C415 and C416, involved in the landslides were not registered in the 1977/78 Catalogue of Slopes.

In March 1995, the two cut slopes at the rear of the platform were identified by the GEO in the project entitled 'Systematic Inspection of Features in the Territory' (SIFT). The project aims to systematically search for sizeable man-made slopes not previously registered in the 1977/78 Catalogue and to update information on existing registered slopes, based on studies of aerial photographs. The SIFT report on Slope No. 11NW-A/C415 indicated that the slope was formed between 1949 and 1961, and past slope failure was evident. No instability was noted in the SIFT report on Slope No. 11NW-A/C416.

Phase 2 SIFT Study Map Sheet Report 1:1000 Map Sheet Number 11NW-7B, Planning Division, GEO March 1995

In July 1994, the GEO initiated a project entitled 'Systematic Identification and Registration of Slopes in the Territory' (SIRST) to systematically update the 1977/78 Catalogue of Slopes and compile the New Catalogue of Slopes. In October 1995, the cut slope behind the squatter hut was inspected by the consultants appointed by the GEO to undertake the SIRST project. The slope was registered as Slope No. 11NW-A/C416. The squatter hut was noted by the consultants, but detailed inspection of the slope behind the hut was not carried out at that time because of access problems. In August 1996, the slope was inspected again by the consultants and a section directly behind the squatter hut was recorded as 4 m high and inclined at an angle of 60° (Plates 2 and 3). Minor soil erosion and signs of seepage were noted and no emergency works were recommended. A Stage 1 Study Report on the slope was prepared in August 1996 by the consultants recommending further study.

Binnie Consultants Ltd, SIRST Field Sheet for Feature No.11NW-A/C416, August 1996

The other cut slope involved in the north landslide was inspected by the SIRST consultants in October 1995 and was registered as Slope No. 11NW-A/C415. An old minor failure scar was noted in the inspection. No signs of distress were noted on the slope and no emergency action was recommended. A Stage 1 Study Report was prepared in April 1996 recommending further study and Engineer Inspections.

SIRST Stage 1 Study Report for Feature No. 11NW-A/C415, April 1996

A.3.2 Inspection of Slope No. 11NW-A/C64

In April 1995, Slope No. 11NW-A/C64 was inspected by the consultants appointed by the Highways Department (HyD) in a project entitled 'Roadside Slope Inventory and Inspections' to carry out Engineer Inspections on about 4 000 HyD slopes which satisfy GEO's slope registration criteria. The inspection report on the slope stated that "There are squatters at the crest. A footpath is present at the crest of the slope over a significant portion of the slope". The exact locations of the dwellings and the footpath were not recorded. The report recommended routine maintenance works to be carried out and Engineer Inspections to be undertaken every year. It also recommended "detailed stability analysis of the suspect slope" to be undertaken.

Roadside Slope Inventory and Inspections, Slope No. 11NW-A/C64, Fugro Mouchel Rendel Consultants, April 1995

Slopes Nos. 11NW-A/C416 and C415 were not included for inspection in this project.

A.3.3 Actions Under Landslip Preventive Measures Programme on Slope No. 11NW-A/C64

Slope No. 11NW-A/C64 was nominated by the Highways Department in 1995 for inclusion in the 1996/1997 LPM Programme. The slope was selected for inclusion in the Programme by the interdepartmental Landslip Preventive Measures Committee (LPMC) on 30 August 1995. The Stage 3 Study on the slope commenced in early 1996 by LPM consultants engaged by the GEO. The study comprises background information review, ground investigation, soil laboratory testing, and stability analysis to assess the existing stability of the slope and to design and carry out upgrading works as necessary to bring the slope to the current geotechnical standards. Prior to the landslide in 1997, the consultants had carried out ground investigation works and preliminary design of remedial works for the slope.

LPM Selection, Nominated Features Study Report, GEO, May 1995

A.3.4 Non-Development Clearance

Since the mid-1980's, about 72 000 squatters in Hong Kong have been cleared from steep hillside and rehoused for reasons of vulnerability to landslide risk (commonly known as Non-Development Clearance, NDC). The huts needing clearance are identified following studies and inspections by the GEO. Clearance and rehousing of squatters on Government land are implemented by the Lands Department (formerly the Buildings and Lands Department, BLD, before 1993) and the Housing Department (HD) subject to availability of resources.

Under the NDC Programme, the GEO inspected Kau Wa Keng Upper Village and Pump Fong Sheung Chuen between January and February 1989. Squatter hut No. 26 was within the NDC boundary of Pump Fong Sheung Chuen delineated for GEO's inspection. The squatter hut was not included in the clearance recommendations to HD in March 1989. The BLD prepared two clearance programmes, clearance Nos. KT4/89 and KT5/89, for Pump Fong Sheung Chuen in April 1991 and Kau Wa Keng Upper Village in November 1991, respectively. The demolition works identified in clearance No. KT5/89, which resulted in the clearance of 64 huts, were completed in October 1992. However, clearance of 29 huts scheduled for clearance No. KT4/89 was not implemented.

GEO internal memo (from CGE/MW to CGE/LI) ref. GCMW 2/E2/97-4 dated 23 January 1998.

BLD Plan No. KTCP 31B in GEO file GCMd/2/E1/RA4 (W)

BLD Plan No. KTCP 32C in GEO file GCMd/2/E1/RA4 (W)

Records from GEO file GCMd/4/13/RA11

Between January and February 1993, the GEO undertook reinspection of these two villages to check whether the previous recommendations were carried out satisfactorily and to recommend further squatter huts to be cleared. Squatter hut No. 26, which is remote from the main parts of either of the two villages, was not included within the study boundary for the reinspection. The GEO made recommendations for NDC in
these two villages to HD in January and February 1993. The Lands Department (LD) prepared two further clearance programmes, namely clearance No. KT2/94 for Kau Wa Keng Upper Village in June 1994 and clearance No. KT4/95 for Pump Fong Sheung Chuen in March 1995. Clearance No. KT4/95 also took into account the works scheduled in clearance No. KT4/89, which had not been implemented previously. The demolition works for clearance Nos. KT2/94 and KT4/95, which had not been implemented prior to the 1997 landslide, were tentatively programmed to be carried out in June 1997.

Ditto

Ditto

LD Plan No. KTCP77 in GEO file GCMd/4/13/RA11

LD Plan No. KTCP82 in GEO file GCMd/4/13/RA11
Records from GEO file GCMd/2/E1/RA4 (W)

A.4 PREVIOUS LANDSLIDES

According to the GEO's and HD's records, no landslide incidents had previously been reported to have occurred at the sites of the 1997 landslides. There are also no past natural terrain failures in the area recorded in the GEO's Natural Terrain Landslide Inventory. From the study of the old aerial photographs carried out as part of this landslide investigation, four possible previous minor slope failures were observed to have occurred, between 1954 and 1963, in the vicinity of the landslides area (Figure 3). Two of the failures affected the hillside above the 1997 landslides area. The other two affected the crests of Slopes Nos. 11NW-A/C415 and 11NW-A/C416.

HAP facsimile ref RC/IPSS/23.1/829 dated 2 March to HD

Natural Terrain Landslide Inventory Map, contained in the Natural Terrain Landslide Study Phases I and II. Geotechnical Engineering Office, Hong Kong. Special Project Report SPR 5/97.

A.5 REFERENCES

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Fugro Mouchel Rendel (1995). Roadside Slope Inventory and Inspections. Slope 11NW-A/C64. Slope/Retaining Wall Record (6 sheets) and Engineer Inspections (10 sheets).

Geotechnical Engineering Office (1995). Phase 2 SIFT Study. Map Sheet Report. 1:1000 Map Sheet Number 11NW-7B.

Hong Kong Housing Authority (1997). Letter ref. SCTW 4/16/70 (438) to HAP Ltd., dated 22 July 1997.

Public Works Department (1953). Drawing No. RK425/2B.

一九九七年六月四日
九華徑上村 26 號
山泥傾瀉事件報告

合樂亞洲顧問公司

序言

為配合本處公開大眾及岩土工程業人士感興趣的資料的政策，我們把部份內部報告公開予公眾參考，並訂名為土力工程處報告系列。報告的售價將用作補助印製成本。

土力工程處又出版指引文件，成為土力工程處刊物系列。政府新聞處負責銷售這些刊物和土力工程處報告系列，購買詳情載於本報告的末頁。

陳健碩

土力工程處處長
陳健碩
一九九八年十一月

前 言

這份土力工程處報告為一九九七年山泥傾瀉顧問調查的一部份，當中載述了土力工程處委託的合樂亞洲顧問公司(HAP)就一九九七年六月四日引致人命傷亡的九華徑山泥傾瀉事件而進行的詳細調查。

上述的山泥傾瀉顧問調查，旨在透過對山泥傾瀉事件的檢討和研究，達至以下的目的：

(a) 確立更佳的斜坡評估方法；

(b) 鑑別需予採取跟進行動的斜坡；及

(c) 就政府的斜坡安全系統以及本港現行的岩土工程作業提出改善建議。

土力工程處轄下的山泥傾瀉勘測部與山泥傾瀉調查顧問公司緊密合作，並對九華徑山泥傾瀉事件之詳細調查提供技術支援和協助。

土力工程處副處長/防止山泥傾瀉
鄧滿祥
一九九八年八月

撮 要

一九九七年六月四日，青山公路上面的斜坡，九華徑，發生了兩宗山泥傾瀉。 規模較大的山泥傾瀉毀壞了一處寮屋，並導致一人喪生、五人受輕傷。 登記編號11NW－A/C415和11NW－A/C416削坡的一部份，以及削坡頂部的山坡，於這次事件中突然崩塌。 合樂亞洲顧問公司(HAP)，作為土力工程處(GEO)的山泥傾瀉顧問，在土力工程處的協助和配合下，於一九九七年六月至一九九八年二月期間就這次山泥傾瀉展開了全面的調查。 詳細研究工作包括翻查資料文件、分析雨量記錄、訪問山泥傾瀉目擊人士、進行現場調查、場地勘探、以理論方法進行滲流及穩定性分析以及診斷事件的成因。

調查所得結論是：導致一人喪生的山泥傾瀉可能主要是由於崩塌前下了極大的雨，使風化花崗岩山坡內地下水壓力大幅增加所致。

山泥傾瀉調查的詳情及所得的結果載列於本報告內。

目 錄

1. 引言

一九九七年六月四日上午，新界青山公路路邊上面靠近中山台出入路口，在九華徑的斜坡上發生了兩宗山泥傾瀉（圖1）。 規模較大的山泥傾瀉，即'北'山泥傾瀉(土力工程處事件登記編號 MW97/6/16)，毀壞了九華徑上村 26 號寮屋，並導致一人喪生五人受輕傷。 山泥傾瀉的部份泥石被沖刷至斜坡下的青山公路上，堵塞了行人路及兩條車行道（照片1）。 規模較小的山泥傾瀉，即"東南"山泥傾瀉發生於該寮屋的東南側，毀壞了兩間外屋。

土木工程署轄下的土力工程處於事發後，著手對這次山泥傾瀉的成因進行詳細調查。 合樂亞洲顧問公司，作為土力工程處的山泥傾瀉顧問，在香港地質測量組（HKGS）及土力工程處的其他部門協助下，具體承擔了這次調查工作。山泥傾瀉場地的地形測量由土木工程署轄下的測量部承擔進行。

調查工作於一九九七年六月至一九九八年二月間進行，主要項目如下：

(a)就事發地點的發展歷史及山泥傾瀉前一連串發生的事件，翻查所有已知的有關記錄；

(b)分析雨量記錄；

(c)訪問目擊山泥傾瀉的人士；

(d)於事發地點進行地形測量、詳細的觀察及量度；

(e)進行地質測繪；

(f)採用鑽探、現場試驗及室內試驗進行全面的場地勘探；

(g)以理論方法分析導致致命的崩塌斜坡的滲流和穩定性；以及

(h)研判導致崩塌發生的可能原因。

本報告列載這次調查的結果。 調查工作的詳情及所得的結果則載於一套文件中。 該套文件存放於土木工程署大樓地下一樓土木工程圖書館。

2. 事發地點的描述

山泥傾瀉(北山泥傾瀉和東南山泥傾瀉)發生於九華徑上村26號寮屋的兩側(其地點見於圖 2)，崩塌的土體包括編號 11NW－A/C415 和 11NW－A/C416 削坡的其中一部份及其頂部的天然山坡。 此地天然地形為由西北側和東南側的山咀相間而成的 - 西南走向的小山谷。 山谷內有一條間歇性溪流。

削坡向西南方向傾斜，山泥傾瀉發生前，其仰角約為60度，最高約為4米。 一九九六年八月拍攝的照片顯示了位於事發地點的寮屋及削坡在山泥傾瀉發生前的情況（照片2 和3）。

編號 11NW－A/C415 和 11NW－A/C416 削坡頂部上面涉及北山泥傾瀉的山坡，其總坡角約為33度。 東南山泥傾瀉的範圍只限於編號 11NW－A/C416 削坡及毗鄰其頂部的凸坡，凸坡的軸向傾角約為60度。 天然山坡及兩幅削坡上均長滿植物。

編號 11NW－A/C416 削坡坡腳前有一個約八米闊的平台，它位於一幅填土坡頂部的後面。 此填土坡向下延伸至青山公路，高約 13 米。 平台下面的斜坡，中部為填土坡，兩側為削坡，於一九七七/七八年被登記入斜坡記錄冊內，編號為 11NW－A/C64（圖2）。 填土部份山坡並未受山泥傾瀉而損壞。

九華徑上村 26 號寮屋位於平台後部，其東北部牆體同編號 11NW－A/C416 削坡的坡腳相連（圖3 及照片2和3）。 寮屋約為 7 米見方，木質結構，並由波紋鐵皮作屋頂以及由膠合板和馬口鐵板作牆體。 與寮屋有類似結構的附屬建築物包括毗鄰寮屋東南部牆體而建的 1.5 米見方的廚房以及靠近寮屋東南側1.5米見方的衛生間。

從可得文件記錄和事發後的現場觀察結果，可推斷該處地面排水系統的大概位置，如圖3所示。 寮屋東北部山坡地上有一條橫向明溝，溝壁局部為混凝土牆。 從照片4 中所示地點上觀察所見，明溝完全被一九九七年山泥傾瀉前即存在的泥土所充填。

在這次事件中塌下的土地為未被分配用途的政府地。

3. 山泥傾瀉的描述

一九九七年六月四日下午所拍攝到的山泥傾瀉景象載於照片5和6，橫貫北山泥傾瀉的剖面則載於圖4。

根據目擊人士所作的描述以及警方的記錄，北山泥傾瀉發生於一九九七年六月四日上午七時二十五分後極短的時間內。 北山泥傾瀉的主要部份涉及編號11NW－A/C416削坡及其頂部天然山坡的一大部份，次生部份則影響到編號11NW－A/C415削坡的南端（圖2）。 山泥傾瀉將大約360立方米的泥石瀉到了平台上。其中大約280立方米來自約 12 米闊，10 米長的主山泥傾瀉殘痕，其餘的則來自約 8 米闊，5 米長的次山泥傾瀉殘痕。 崩塌的垂直高度在西北部達5 米，在東南部則小於 1 米，平均高度約為 2 米至2.5 米。 滑動面的上半部份廣泛暴露在外，暴露的滑動面大部份為平面波狀的原生不連續面，並以大約30度的角度向西南方向傾斜（照片5）。 一九九七年六月四日下午一點半，在位於北山泥傾瀉邊緣殘痕的滑動面上觀察到有嚴重滲流現象（照片7）。 不連續面部份的表面有鐵錳結核及局部充填有高嶺土。

來自於北山泥傾瀉的泥石撞擊了寮屋的西北牆體，導致西南牆體被從其原來位置向東南水平方向推動了大約 2 米（照片6和8）。 泥石瀉入寮屋西角地面，使遠至前門段的前牆嚴重變形。 前門門框被扭曲和擠壓，使其中部由原來的大約 0.75 米闊減至 0.3 米闊（照片9）。

瀉下的泥石擴散至整個平台上，在西北方則越過行人路。 泥石包括硬至堅硬的褐色砂質至特黏質粉土，其中偶而含有少量強至中度風化花崗岩質卵石和漂石，泥石中還包括了混凝土和砌石牆塊、樹、灌木、一段直徑為 25 毫米的水管和一段電話柱。

山泥傾瀉瀉下的泥石運行角約為 30度，此數值是從山泥傾瀉的頂部測量至堆積在平台前緣的泥石堆的前端之傾角而得。

根據 Wong 和 Ho（一九九六），此運行角屬於典型香港地區雨水引發的削坡崩塌範圍值之內，表明其泥石移動性同一般常見山泥傾瀉類似。

位於編號 11NW－A/C64 斜坡頂部的泥石堆受由北山泥傾瀉區域瀉下的地表水流沖刷而形成一條約一米深的沖溝，並將大約 30 立方米的泥石沖刷至坡下的行人路及青山公路的兩條車行道上。

東南山泥傾瀉塌下的泥石大約只有 25 立方米，來自於編號 11NW－A/C416 斜坡上一幅大約 6 米闊的坡面（照片6）。 泥石滑過坡腳排水渠，撞擊了寮屋外的廚房和衛生間。

4. 事發地點的場地歷史

撮述於附錄A的場地歷史，是透過研究該處拍攝於一九四五年至一九九六年期間的航空照片和翻查現有資料文件而得。

拍攝於一九四五年和一九四九年的最早航空照片顯示，事發地點即 26 號寮屋所在地及一九九七年山泥傾瀉發生處，在當時尚未開發。 當時青山公路位於事發地點東南側的一個矮路堤上，只有兩條行車道，橫越一個小山谷的出口。

一九五四年至一九五九年期間，為修建一條穿越事發地點的小路而削製天然山坡，並建成了如今登記編號為 11NW－A/C415 和 11NW－A/C416 的削坡。同時期在位於此小路上面約 10 米處的山坡上，也建成了一條橫向明溝（圖3 和照片4）。

青山公路拓寬改造工程於一九六三年完成，26 號寮屋下編號 11NW－A/C64 斜坡於同期由削製天然山坡和充填小山谷段而建成。 填土坡頂部和小路匯合並形成了一平台，九華徑上村 26 號寮屋其後建於該平台上。 道路拓寬工程完成後，位於事發地點北部的小路被保留為行人路，並透過一段穿越編號 11NW－A/C64 斜坡的台階與青山公路相連。 大約從一九六三年開始，通往台階東南方向的小路南段及填土平台看來已被廢棄了。

土力工程處沒有任何有關一九九七年山泥傾瀉地點附近區域的過往山泥傾瀉記錄。 土力工程處的"天然山坡山泥傾瀉目錄"(Evans *et al*, 一九九七）中也找不到任何有關天然山坡的過往不穩定記錄。但是，根據對航空照片的判釋，一九五四年至一九六三年期間，削坡及其頂部天然山坡上可能發生過四次小規模的山泥傾瀉（圖3）。

一九七三年後拍攝的航空照片顯示，平台及編號11NW－A/C416斜坡之坡腳曾被輕微改造過，但未見有 26 號寮屋。 到一九七六年，香港房屋署(HD）登記了 26 號寮屋，航空照片上亦顯示了寮屋的存在。 一九八二年香港房屋署進行的新一輪測量顯示，寮屋已經被改造過，並增加了廚房和衛生間。

根據"(寮屋)非發展清拆"計劃，土力工程處於一九八九年一月至二月期間，對九華徑上村及泵房上村進行了視察，26 號寮屋位於此計劃下，劃歸土力工程處視察之泵房上村邊界內 。 土力工程處對該村進行調查後 ，沒有建議清拆該寮屋。 一九九三年一月，土力工程處重新調查了這兩個村莊，以檢查先前的清拆建議是否實施了，並提出進一步清拆的建議。 遠離上述兩村莊的主要範圍的該寮屋，未被包括在這次重新調察的範圍內。

5. 雨量記錄分析

自動雨量計 N04 是距離事發地點最近的雨量計，它座落在荔景祖堯村啟光樓，位於事發地點西西北約 1 公里處。 該雨量計在一九九七年五月及六月所錄得的每日雨量，以及一九九七年六月三日和四日所錄得的每小時雨量，均載於圖 5。

對設在山泥傾瀉現場附近的兩個自動雨量計 K06 及 N06 的雨量數據也進行了分析。 編號 K06 及 N06 雨量計分別離現場以東及北約 2 公里處，該兩個雨量計所錄得的雨量變化與編號 N04 雨量計所錄得的大致相同，但其所錄雨量強度較雨量計 N04 為低，故雨量計 N04 記錄結果被認為較適合用作雨量分析。

由一九九七年六月四日清晨至大約上午七時二十五分北山泥傾瀉發生時，雨勢均頗大。北山泥傾瀉發生前六小時及二十四小時的滾存雨量分別為 252.5 毫米和 263 毫米。 而六十分鐘的最高滾存雨量為 128.5 毫米，於六月四日上午六時至七時錄得。

雨量計 N04 自一九七八年裝置以來，所錄得的過往較嚴重豪雨的雨量變化以及一九九七年山泥傾瀉發生前的雨量變化均載於圖 6，以作比較。 從圖中可見，以少於八小時的降雨時段計算，北山泥傾瀉發生前雨量計 N04 所錄得的雨量為歷史上最高，但以一天或以上降雨時段計算，其要比先前有幾次的降雨量為低。

6. 山泥傾瀉的經過

山泥傾瀉事發經過的重組是根據包括同此事件有關的三名寮屋居民在內的目擊人士的陳述、香港警務處和消防處的事件報告以及土力工程處(GEO) 和合樂亞洲顧問公司(HAP) 於事發後在現場進行的勘察。

一九九七年六月四日清晨，當寮屋居民發覺到寮屋下面 450 毫米的地面排水渠溢流時，他們已察覺到有發生水浸的危險。 當時，寮屋上游和下游的排水渠均被土壤淤塞，下游排水渠其後還被崩塌下的泥石所掩埋。 泥石來自發生在早上六時位於衛生間後面的小規模山泥傾瀉，其範圍大約有 1 米闊、1.5 米高。 當時下著傾盆大雨，平台上面斜坡的徑流很大，水流越過平台並流向寮屋。 根據警務處的記錄，寮屋居民第一次打緊急求助電話的時間為上午七時零九分，第二次則為上午七時二十二分。 北山泥傾瀉發生於第二次緊急求助電話後很短的時間內。 發生山泥傾瀉前隙，在北山泥傾瀉區域的坡腳處大約 10 英尺闊的範圍內，可看到樹木正在倒下；這可能是由於山泥傾瀉爆發所引起。 山

泥傾瀉發生得很突然，塌下的泥石瀉過平台，撞擊寮屋的西北側牆體（照片8）。

山泥傾瀉發生期間，一名男孩被擠壓至變形的前門框及廚房傢俬所圍困（照片9）。 男孩在上午八時五十分被救出，上午十時十五分仁濟醫院職員宣告男孩已死亡。 另外五名寮屋居民因受輕傷而需接受治療。

大約在上午八時五十分至九時期間，在靠近衛生間的東南山泥傾瀉發生地點，即該處較早時已由小規模山泥傾瀉而堵塞了排水渠，消防處職員發現"幾棵樹正在倒下"。 然而，此山泥傾瀉並未達到合樂亞洲顧問公司其後所觀察到的傾瀉範圍(照片6）。 據此可以推斷，東南山泥傾瀉可能發生在上午八時五十分至下午一時之間，並晚於北山泥傾瀉發生時間，因此與導致寮屋被毀壞及人員喪生的事件無關。

7. 事發地點的地下情況

7.1 概述

事發地點的地下情況是根據文件和實地研究所得的質料而確定。 文件研究工作包括翻查現存數據，而實地研究工作則包括地質勘察及場地勘探。

按照1:20 000比例的地質圖上，香港地質測量組測繪事發地點的岩石屬於細粒花崗岩（Strange and Shaw，一九八六）。 在青山公路西南方及事發地點東南方的岩石則為粗粒花崗岩，與細粒花崗岩斷層相接觸。

作為此次調查工作的一部份，對事發地點的地質勘察工作，於一九九七年六月四日展開。 在緊急搶修工程期間，清理了植被及山泥傾瀉的泥石，同時仍然繼續進行地質勘察。

場地勘探工作於一九九七年七月三十一日展開，包括了五個垂直鑽孔、十個開敞式測壓計、七個探井、二個探溝及十個GCO 輕型動力觸探，其中九個隨後安裝了注射充填式張力計(圖7)。

7.2 地質

香港地質測量組在事發現場及附近觀察到的地質及其他特征，載於圖8 ，而橫貫山泥傾瀉地點的地層剖面圖則載於圖9。 事發現場的主要岩性組成為中粒花崗岩，局部為粗粒花崗岩。 緊鄰北邊山泥傾瀉部位的上坡，一層厚達兩米的

坡積物上伏於風化花崗岩層上。 在山泥傾瀉的主滑坡崖，亦觀察到厚度達一米的坡積物。

暴露在北邊山泥傾瀉滑坡崖的花崗岩物質的風化程度一般為強至全風化，局部地方則變為中風化至殘積土。 在山坡及山泥傾瀉東面的水溝裏，亦有中度風化花崗岩出露。 根據岩體風化特性，花崗岩物質的風化程度從在山泥傾瀉東南側的主滑坡崖部位的PW 0/30，變為在滑坡崖西北側山咀部位的PW 30/50。 從淺挖的情況看，取得的岩芯證實山咀部位的風化程度較輕。 破裂面上露出的物質主要為PW 0/30，而從探溝裏觀察表明，緊接其下伏的物質一般為PW 30/50 及偶然為PW 50/90。

在主滑坡崖部位，觀察到的坡積物為硬至堅硬、棕色、含砂的高黏土質粉土，並偶含有成份為高度至中度風化，細粒至中粒的花崗岩、中粒花崗岩及細晶岩的礫石、卵石及漂石。 在主滑坡崖部位之後斜坡上開挖的探溝及探井裏，觀察到有坡積物，並查明其沿斜坡向上延伸約 25 米，於花崗岩出露部位尖滅（照片10）。 此處的坡積物由硬、暗棕色、微含砂的黏土質粉土組成，並含有一些花崗岩礫石和卵石。 同時發現了由昆蟲活動形成的，50 毫米至 100 毫米寬的巢穴構造。

北山泥傾瀉的破裂面（滑動面）大體為一個波狀起伏的不連續面，典型地以30度傾向西南。 在山泥傾瀉東北角的主滑坡崖面則以大約42度傾向西南。 在一九九七年六月四日的山泥傾瀉之後，破裂面部份出露，形成一個 9 米寬和 8 米長的出露帶沿著山泥傾瀉的方向（照片5 和7 ）。 稍後，破裂面在下坡 2 米的探溝裏出露。 在橫斷面上，滑坡崖明顯地不對稱，在西北側觀測到的破裂面深達 5 米。 在那裡，近於垂直傾向東南且裂縫極窄的節理面與在破裂面之上且同其近於平行的不連續面一起，起到釋放面的作用。 在一九九七年六月四日的滑坡後，在主要的滑坡崖面上並沒有觀察到張裂縫。 山泥傾瀉部位的東南角，量得破裂面的深度大約為 1 米。 調查人員觀察到一較窄的不連續面，局部地方達 20 毫米寬，從破裂面延伸到斜坡的上部(照片7)。 按分析此不連續面大致為控制山泥傾瀉破裂面的同一節理面的未破壞部份。 偶然可看到樹的支根沿該不連續面生長，並且沿伸到破裂面本身上，表明該不連續面於山泥傾瀉前的某一段時期內可能為一張開結構。 在一九九七年六月四日午後，大量的滲水從不連續面流出。 到下午四時，滲水量變成非常之小。

暗棕色至黑色的鐵錳結核沉積物，部份地覆蓋在不連續面上。 調查人員觀察到，不連續面局部充填有高嶺土（一般少於 10 毫米厚），在破裂面上亦觀察到有高嶺土。 調查人員發現一分佈極密的垂直並有鐵錳結核物充填的不連續面帶（寬達 50 毫米），其走向西北，穿過滑坡殘痕長約 10 米多。 在編號TP8的探井（圖7 ）裏觀察到一類似走向的不連續面帶，以60度至80度傾向西南。這些表明此處可能為小規模的地質剪切帶。

20 至350 毫米厚的細晶岩脈侵入到花崗岩層中，此現象在山泥傾瀉殘痕東南側的水溝，在山泥傾瀉殘痕本身及在探井和探溝裏，均觀察到（圖7）。 這些岩脈為垂直至近於垂直，並且大都傾向東北。 偶然發現有石英岩脈，厚達 20 毫米，同樣以大傾角（60度至80度）傾向東北。

在緊鄰北山泥傾瀉的山坡下，平台填土（照片11）由軟至堅硬、棕色及灰色、含砂粉土組成，其中偶含有大似漂石大小的混凝土塊及花崗岩碎片、鐵管和鋼棒。

東南方山泥傾瀉涉及到全風化花崗岩至花崗岩殘積土的岩層。 在山泥傾瀉地點上部斜坡處編號為5的鑽孔裏，證實全風化花崗岩的厚度為 10 米。

7.3 土壤與岩石的性質

本次調查中對場地勘探時取得土壤試樣，進行了一系列全面的岩土室內試驗，包括粒徑分佈試驗，阿太堡界限試驗，三軸壓縮試驗和滲透試驗。

粒徑分佈及阿太堡界限試驗是按照 Chen（一九九四)所述而進行。 全風化花崗岩(CDG)的細粒土(即黏土和粉砂）平均含量為36%，而坡積物的細粒土平均含量則為41%，CDG 的細粒土的塑性指數在14%至44%之間，液限則在40%至81%之間。 坡積物的細粒土的塑性指數在33%至47%之間，液限則在66%至87%之間。

在實驗室對樣本進行滲透試驗的結果顯示，坡積物的平均滲透系數為$1x10^{-4}$ m/s而全風化花崗岩的平均滲透系數為$7x10^{-5}$ m/s。 利用降水頭滲透試驗在鑽孔進行滲透試驗得到的結果顯示，有殘餘節理的全風化和強風化花崗岩的平均滲透系數為2×10^{-4} m/s，而有節理的中度風化和微風化花崗岩的平均滲透系數為$8x10^{-5}$ m/s。

全風化花崗岩及坡積物的抗剪強度性質是通過固結不排水三軸壓縮試驗來評估(Head，一九八六)。 試驗結果以p'-q 圖的形式表示載於圖10和圖11， 其結果與香港有關材料的典型性質是一致的。 因全風化母岩的強度極弱且節理中並無特別低強度之表層或充填物，此土體的強度可與完整的全風化花崗岩的強度相似(Au，一九九六)。

7.4 地下水情況

事發地點的地下水情況是根據對山泥傾瀉調查中的下述觀察進行評估而得：

(a)於一九九七年六月四日午後，觀察到有大量的滲水從主滑坡崖出露的風化花崗岩層內的不連續面流出(圖8)，

(b)一九九七年六月四日上午大雨停了之後，觀察到在主滑坡崖滲水的流量隨著時間推移而減小，並於大約下午四時滲水變到很小，

(c)作為山泥傾瀉緊急搶修工程的一部份，滑坡殘痕被往後削整並對新坡面進行噴漿保護工作之後，於一九九七年六月至十月期間，發現在下雨和大雨之後，噴漿混凝土坡面上的導水管和疏水孔有水滲出（圖8），及

(d)事發後，一九九七年八月至十月期間，五個垂直鑽孔（圖7， 編號 DM1 至 DM5 ）內，收集到的地下水監察資料，其中包括八月二十二日的大暴雨，當天編號 N04 雨量計在五小時內錄得 185.5 毫米的雨量。

推想在大雨期間，雨水經位於山泥傾瀉上部山坡地區及其本身部份範圍內的坡積層滲透到地下。 這個坡積層，因相對透水，使地表水快速滲透並增加地下水的滲流。 風化花崗岩層中的不連續面局部張開，為地下滲流在風化花崗岩裏的流動提供了合適的流徑。 在事發地點，淺的基岩面和有部份表層覆蓋的不連續面，可能充當地下低滲透度的界面，水流可能在此界面受阻，形成上層滯水位。

因此在大雨期間，事發地點的水文地質環境有利於風化土體中地下水壓的上升，可能是通過部份在淺基岩面上的滯水，部份在有表層覆蓋的不連續面上的滯水。 水壓的變化對雨量大小的回應相當的快，這個可以從一九九七年山泥傾瀉發生於六月四日清晨大雨開始後的數小時內及在滑坡崖處表面滲水水量在雨停後很快減小中找到證據。

開敞式測壓計監測到的一九九七年八月暴雨時的地下水位，表明地下水位可能高於滑坡底層。 地下水體系由於山泥傾瀉而改變，所以，山泥傾瀉之後測

得地下水壓力不可能完全代表事發前的地下水壓力。 最好的估計為，在山泥傾瀉發生時，作用於崩塌部份斜坡的地下水壓力狀況相當於上層滯水位在滑坡底層面以上 1 米至 2 米之間的情形（見圖12）。

8. 理論滲流及穩定性分析

8.1 理論滲流分析

為了驗證在第七章第四節裏提出的地下水模型，調查中還進行了滲流分析由此來預計上層滯水位會上升至滑坡底層以上。 分析採用了兩個模型：一是假定土體儘具有單一滲透性（假設土層是均質的材料）；二是假定土體具主滲透性和次滲透性(節理滲透性)。 分析時考慮了飽和滲流，並在土體中飽和度變化時允許在土中保留水份。

在北山泥傾瀉前六小時的降雨量大約為 280 毫米。 滲流分析時假設雨水經坡積層滲透到下面的部份風化花崗岩，並使用實驗室測試到的主滲透數據(見第七章第三節）。 分析結果表明此暴雨造成了上層滯水位上升至高出滑坡底面近0.5 米處。

在山泥傾瀉部份主崩塌崖上注意到，同大部份破裂面相一致的節理為張開型。 另外， 在山泥傾瀉區域裏，也觀察到其它節理為部份張開，從而造成了雨水急速和集中滲透到土層(照片5）。 在此具主滲透和次滲透條件的情況下，滲透分析表明上層滯水位會上升至滑坡底面以上達 1 米到 2 米處。

8.2 理論穩定性分析

調查中還用理論方法進行了穩定性分析，以協助判斷北山泥傾瀉的機制和成因。 這些分析旨在確定風化花崗岩層在不同上層滯水位的情況下，該岩層發生崩塌時抗剪強度的可能數值。

分析時採用的資料來自事發後所進行的場地勘探工作、室內試驗、現場觀察和實地量度。 具代表性的橫貫山泥傾瀉地點的剖面圖，以及分析所採用的輸入參數，載於圖12。 在不同的地下水情況下，對崩塌的剖面進行穩定性分析，分析所採用的地下水壓力，從沒有地下水壓到水壓相當於上層滯水位在滑坡底面之上 2.5 米處的情形，此情形接近於假定有不利傾角的節理存在。

分析所得的結果摘要載於圖13。 以崩塌時安全系數為1.0 而言，當上層滯水位在滑坡底面之上從1.4 米上升至 2.5 米時，風化花崗岩的抗剪角ϕ'，在32

度至46度之間。 室內試驗所確定的ϕ'數值在此範圍內。利用此抗剪角進行穩定性分析顯示當上層滯水位上升至滑坡底層之上達 1.8 米時， 會引發滑動。

調查人員還對削坡 11NW-A/C416 形成以前的山坡進行穩定性分析，旨在評估削切山坡對山坡穩定性的影響。 結果發現，削坡工程使得斜坡的理論安全系數減少約5% 。

9. 致命山泥傾瀉成因的診斷

根據此次調查所得的資料，位於九華徑上村編號26寮屋的北山泥傾瀉主要成因是由於豪雨後，地下水壓增加造成的。這次山泥傾瀉涉及小而陡的削坡及毗鄰削坡之上大部份的斜坡突然崩塌。

發生山泥傾瀉前，對不足八小時的持續雨量來說，是崩塌地點附近編號N04雨量計自一九七八年安裝以來，所錄得的最高雨量記錄。 特別是，山泥傾瀉是在六十分鐘降雨量達 128.5 毫米的峰值後的極短時間內發生的，該雨量在六月四日早上六點至七點間錄得。

其他可能引致山泥傾瀉的因素，包括以下幾項：

(a) 在崩塌部位之上的斜坡及崩塌部位，存在較不利，透水的坡積物表層、土體中存在部份張開及部份有表層覆蓋的不連續面，且其方位於不利斜坡的穩定以及淺基岩面的存在為雨水表面滲透和在風化花崗岩層中上層滯水位形成提供了有利的水文地質條件，及

(b) 削坡的形成，導致山坡的穩定性降低。

10. 結論

所得的結論：一九九七年發生於九華徑上村，編號 26 寮屋北側，並導致一人死亡的山泥傾瀉，可能主要是由於事發前的豪雨，使斜坡內風化花崗岩層中的水壓大幅上升所引致。

事發地點的水文地質環境由其是存在有部份張開具不利方位的不連續面，有利於雨水的滲透及在風化花崗岩層內形成上層滯水壓。 削坡的形成也可能促進了山泥傾瀉的發生。

此次調查所得的資料表明，在山泥傾瀉中死去的小孩是由於寮屋結構遭山泥傾瀉的泥石破壞而變形，從而使其被壓在屋子的前門框裏。

東南山泥傾瀉主體的崩塌是在北山泥傾瀉之後某一時間發生的。 因此，東南山泥傾瀉對寮屋的破壞和一人喪生沒有影響。

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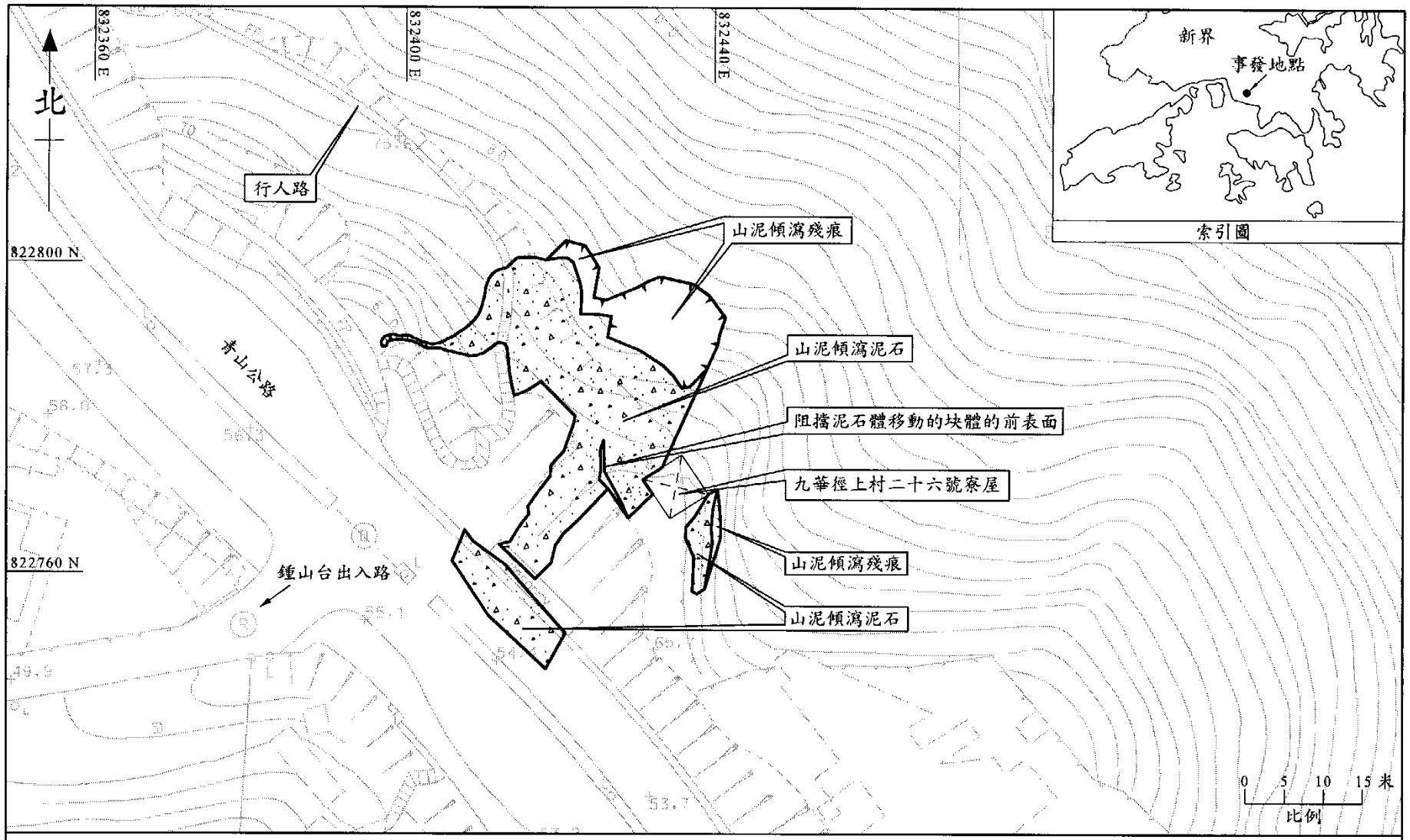
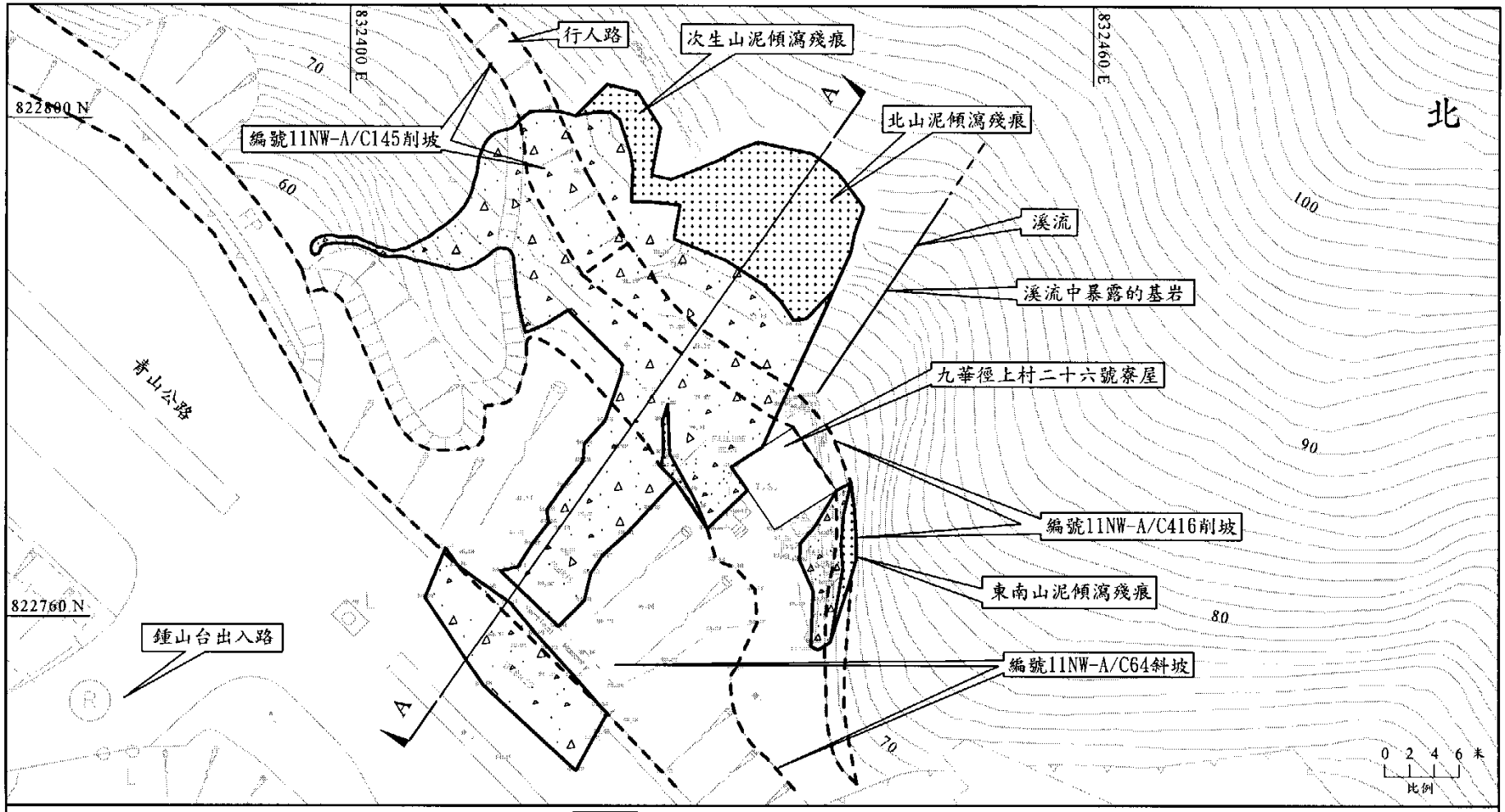
圖



註： 取自一九八九年十月編號11-NW-7B及一九九三年編號11-NW-2D測量圖（比例1:1 000）.

圖1 - 山泥傾瀉位置圖



註: (1) 剖面 A-A 見圖4

(2) 圖中所示資料以地形測量, 1:1000測量圖, 地質勘察, 現場觀察及文件記錄為根據.

圖2 - 山泥傾瀉平面圖

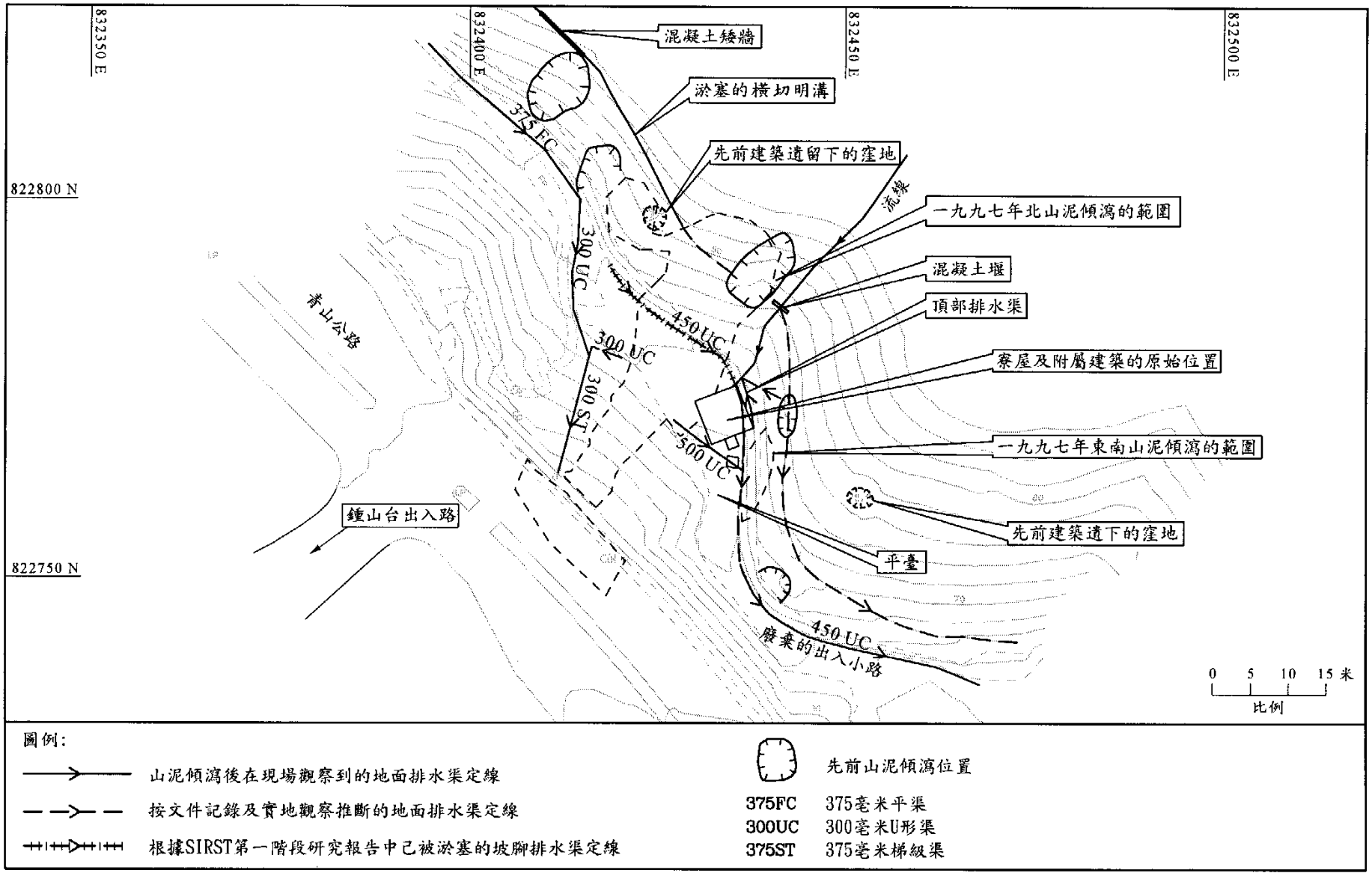
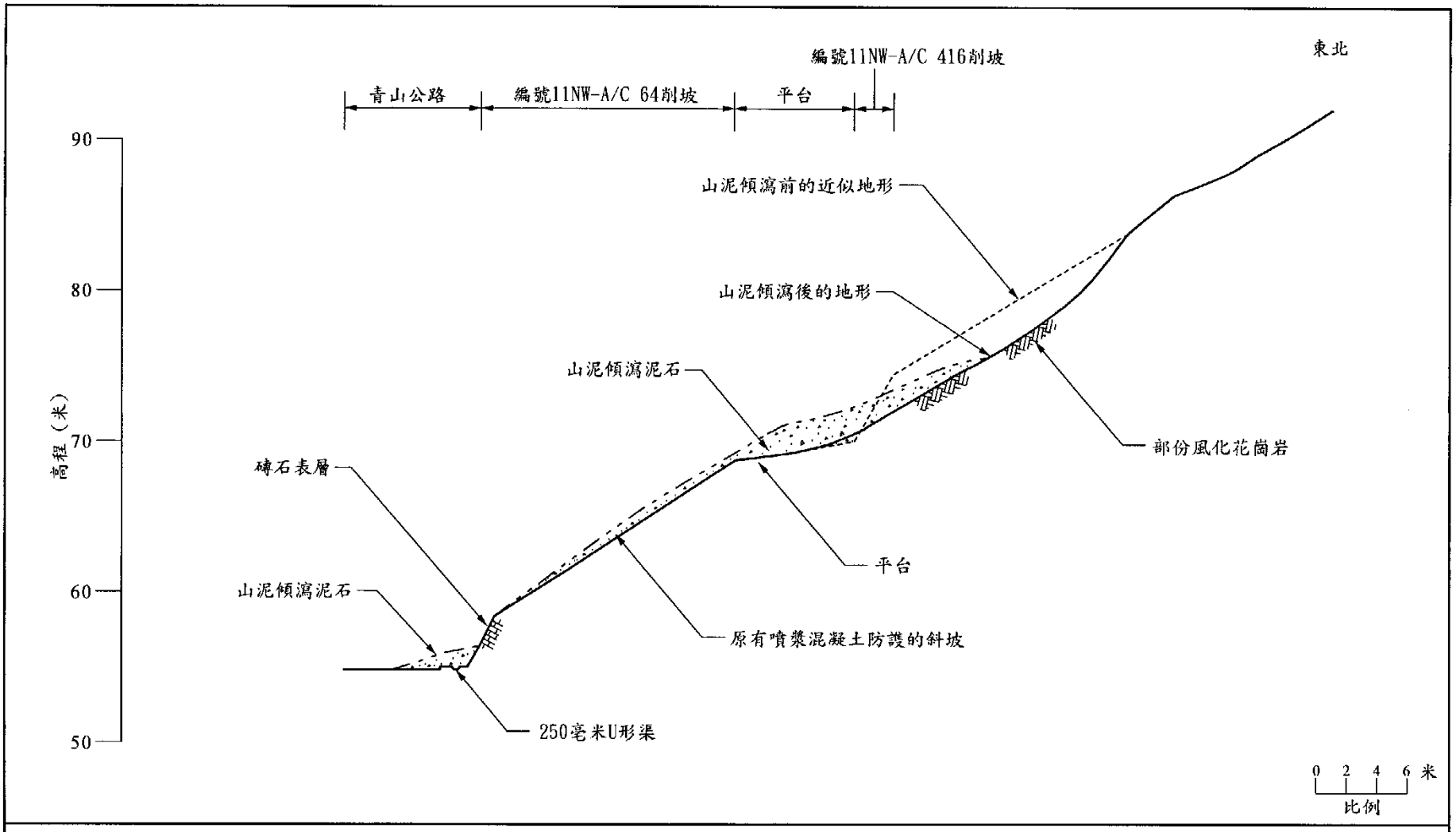


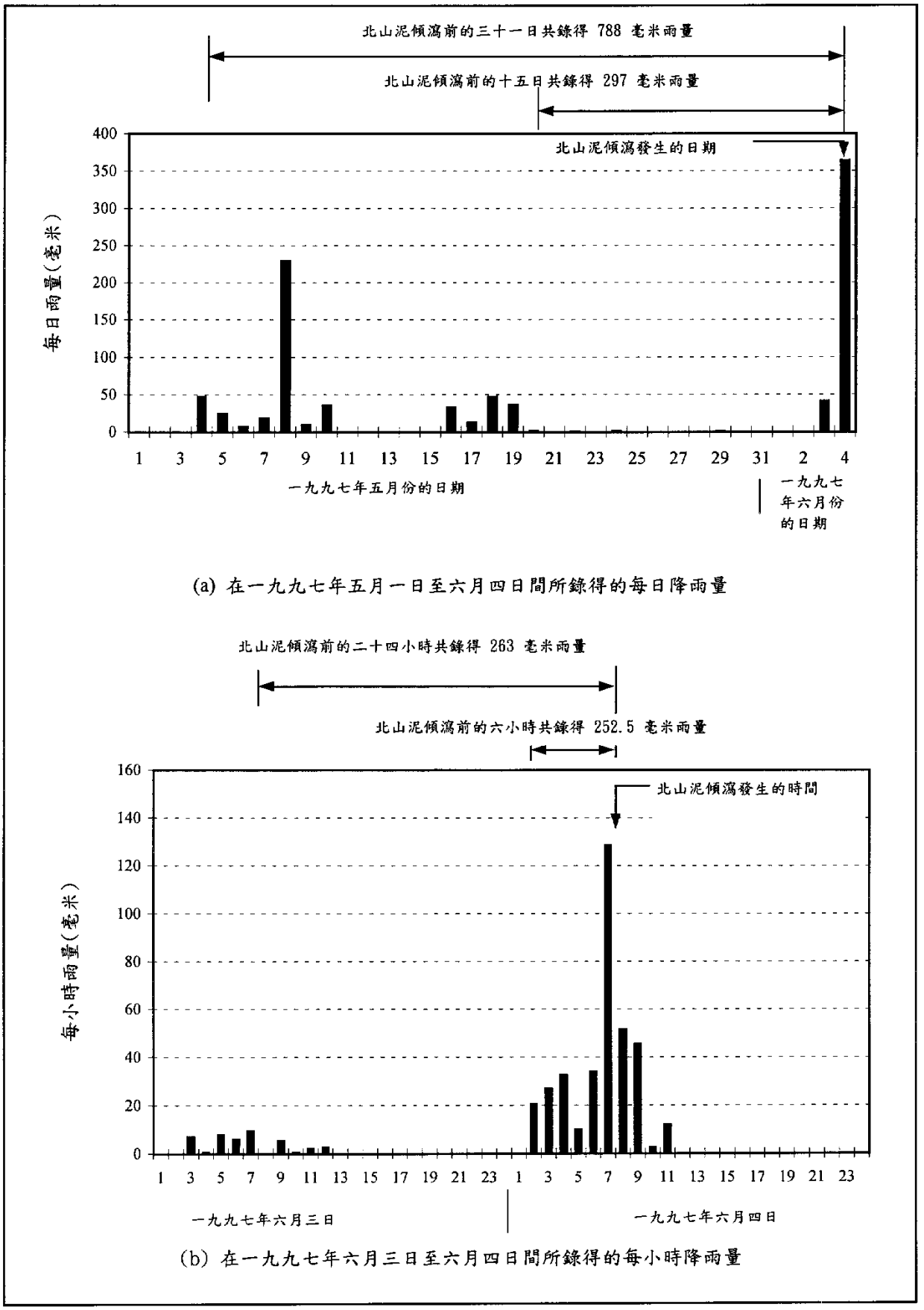
圖3 - 山泥傾瀉前排水系統分佈及其它特徵



註： (1) 剖面的位置見圖2.

(2) 圖中所示資料以地形測量, 1:1 000測量圖, 地質勘察, 現場觀察及文件記錄為根據.

圖4 - 北山泥傾瀉剖面 A-A



(a) 在一九九七年五月一日至六月四日間所錄得的每日降雨量

(b) 在一九九七年六月三日至六月四日間所錄得的每小時降雨量

圖 5 - 土力工程處編號 N04 雨量計的雨量記錄

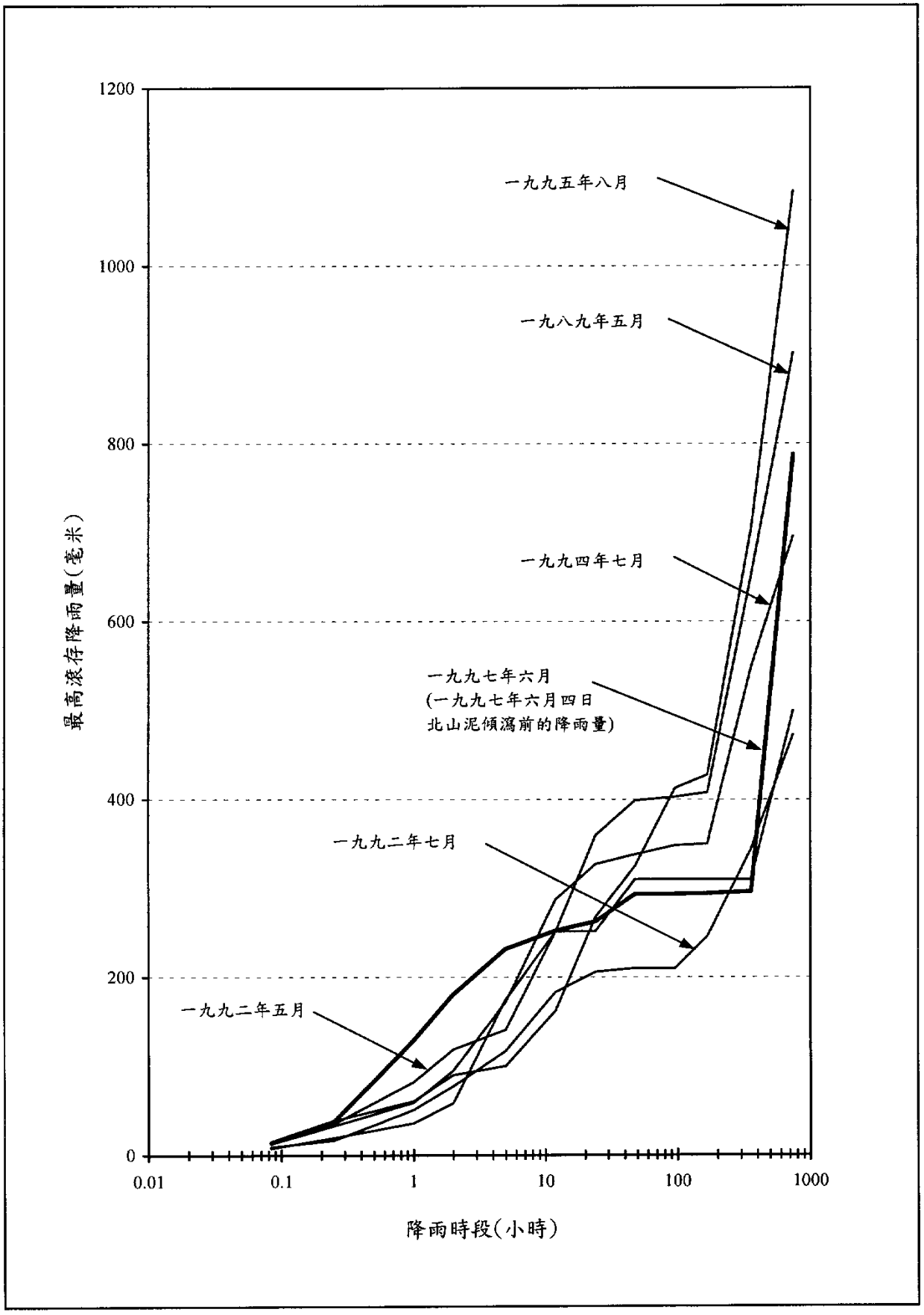
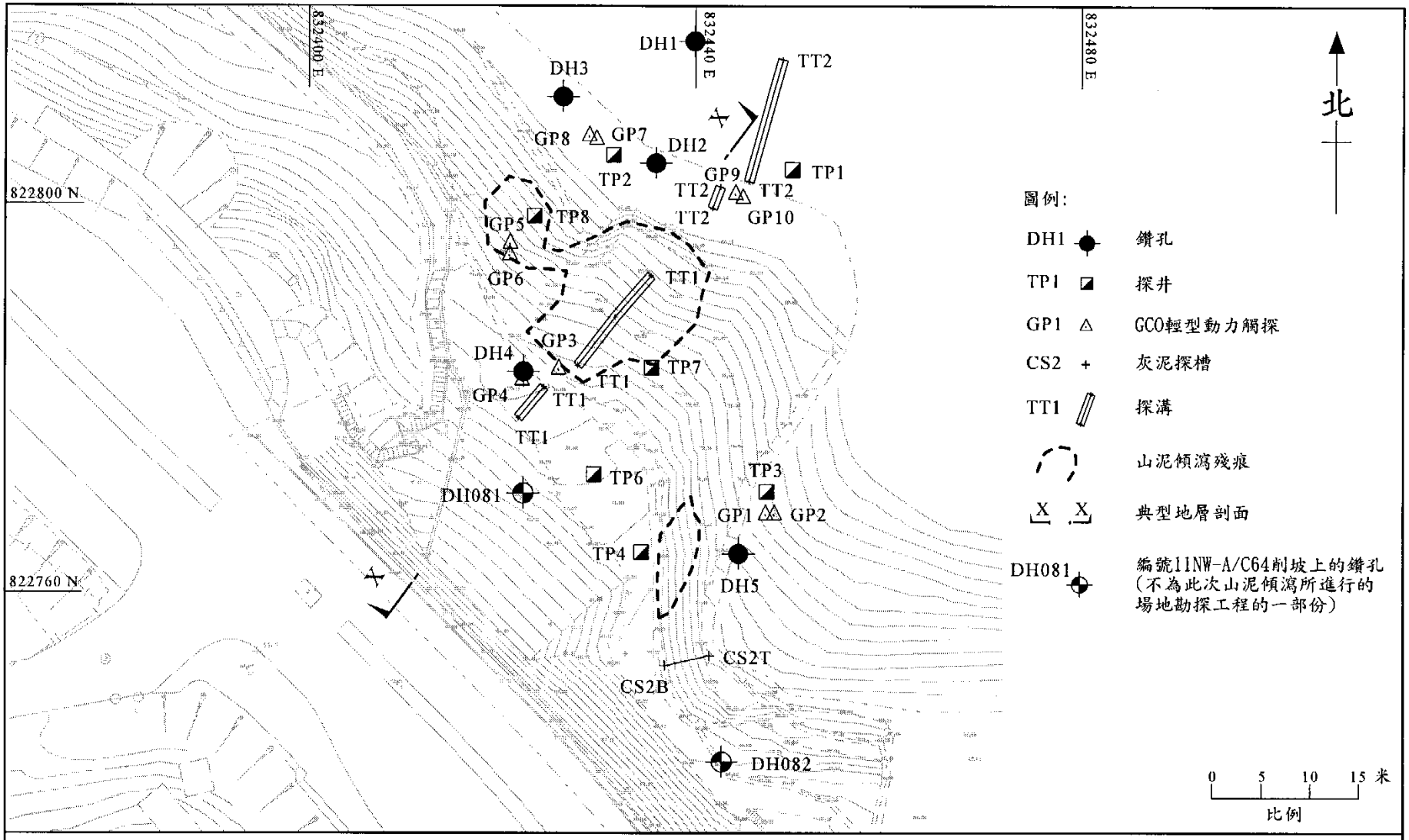
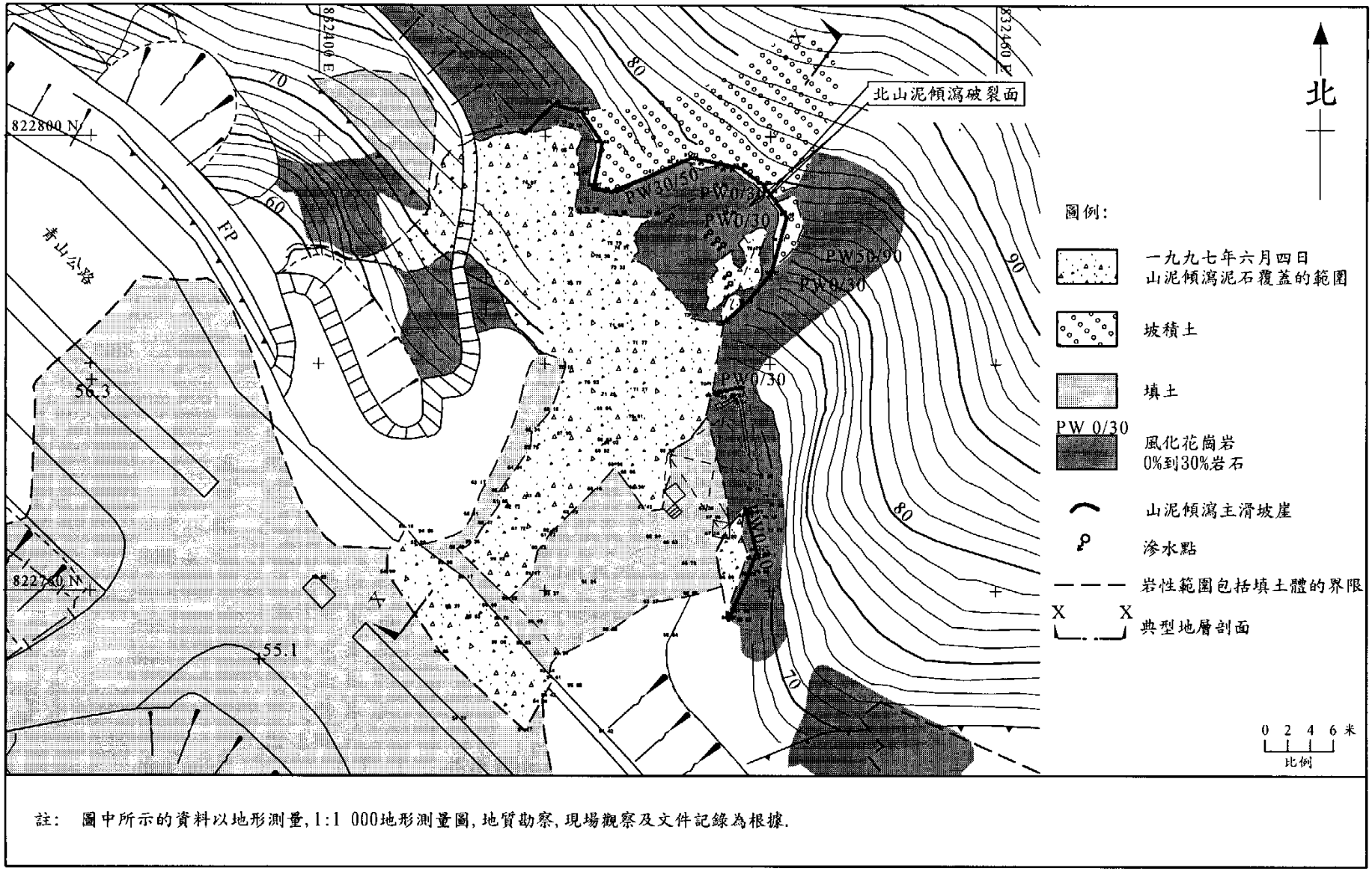


圖 6 - 土力工程處編號 N04 雨量計於歷次豪雨中錄得的最高滾存降雨量



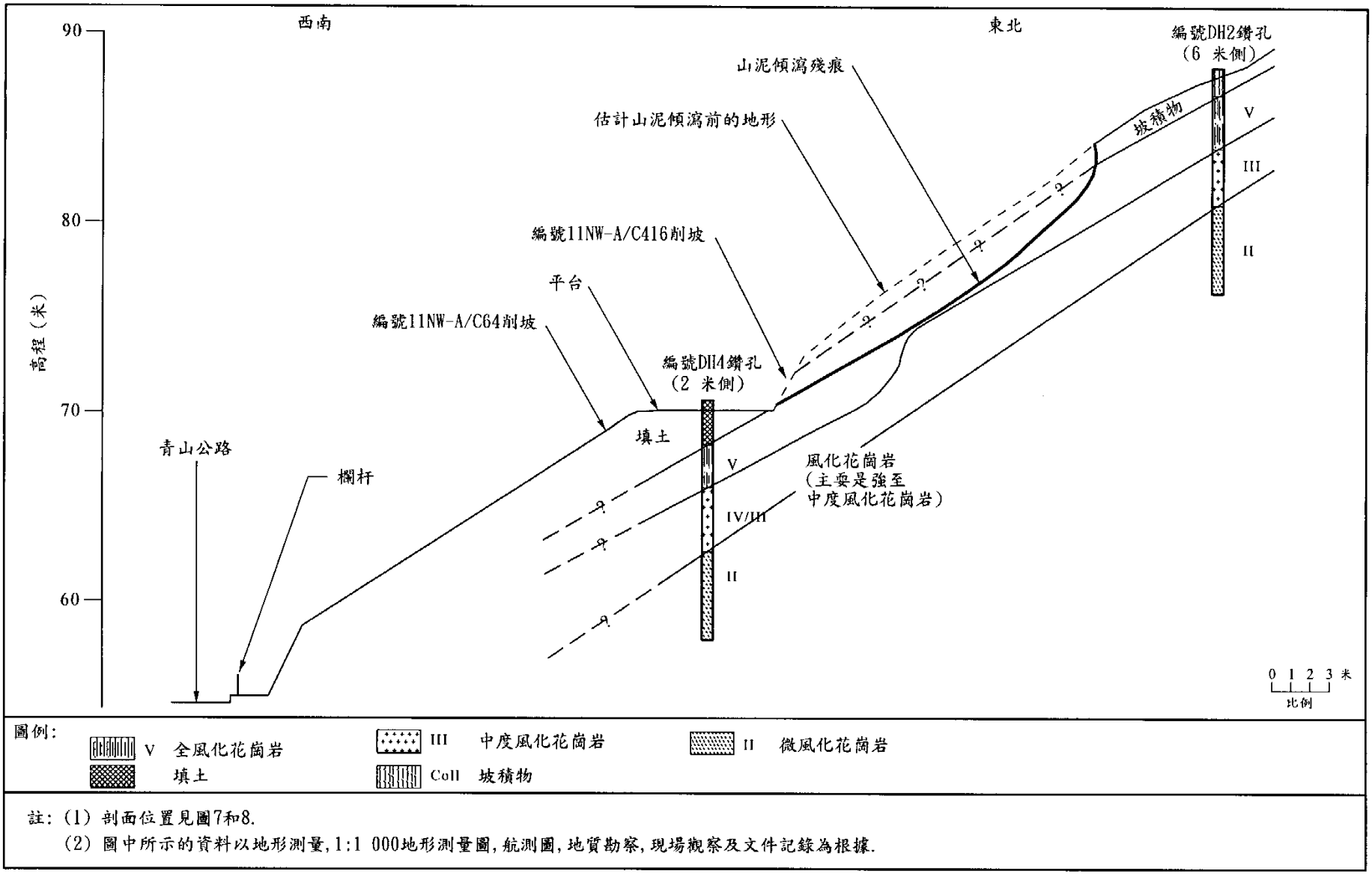
註: 圖中所示的資料以地形測量,1:1 000地形測量圖,地質勘察,現場觀察及文件記錄為根據.

圖7 - 場地勘探工程的位置圖



註: 圖中所示的資料以地形測量, 1:1 000地形測量圖, 地質勘察, 現場觀察及文件記錄為根據.

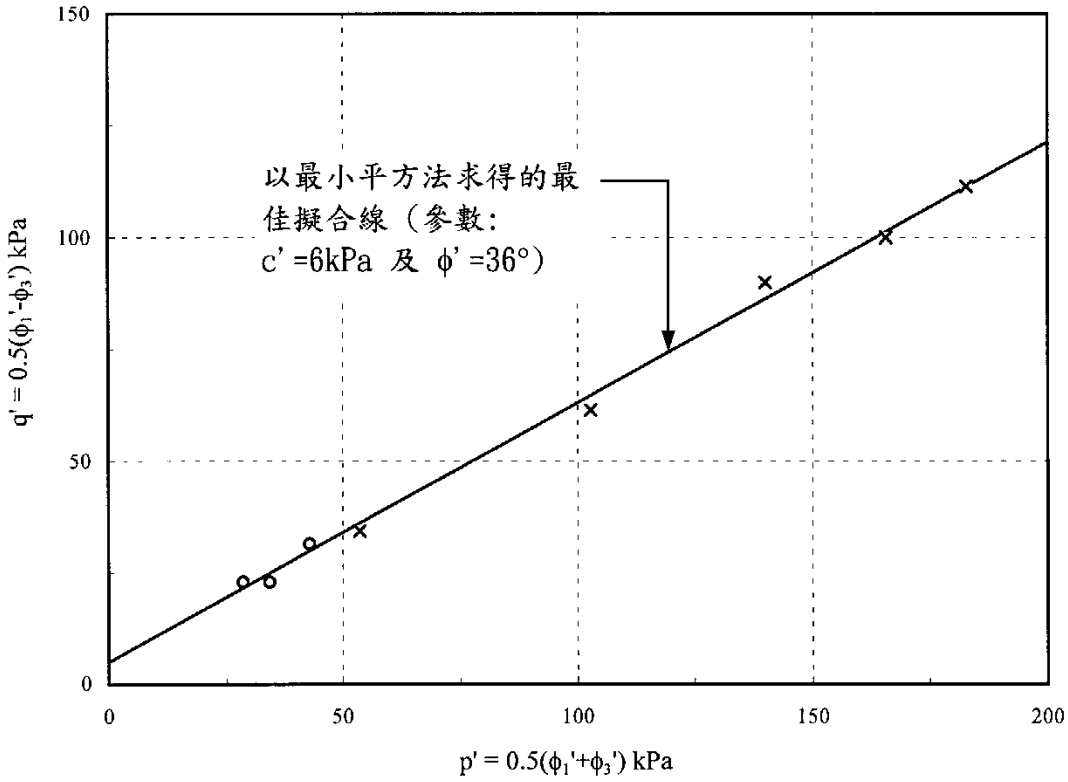
圖8 - 山泥傾瀉範圍的簡化地質圖



註：（1）剖面位置見圖7和8.

（2）圖中所示的資料以地形測量，1:1 000地形測量圖，航測圖，地質勘察，現場觀察及文件記錄為根據.

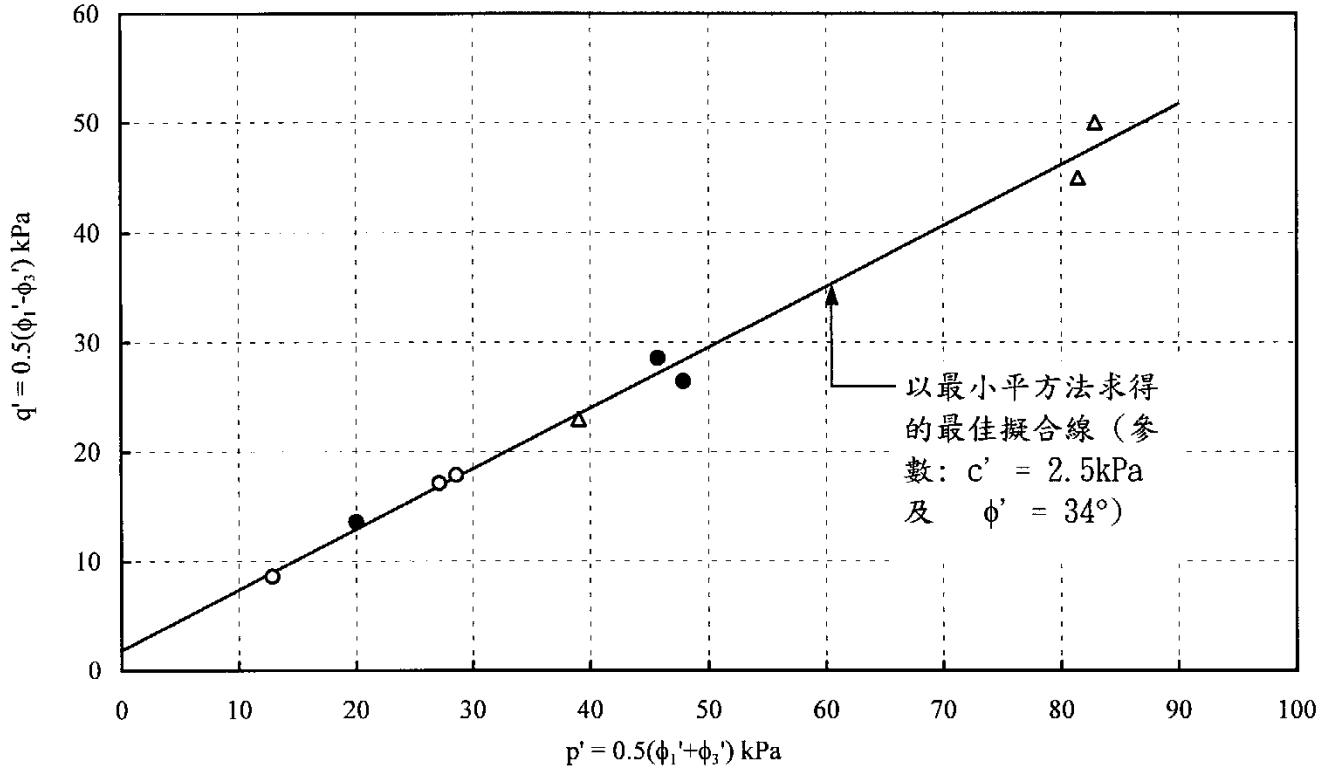
圖9 - 山泥傾瀉地點的典型地層剖面 X-X



圖例:	×	單階段試驗	σ_1'	最大有效主應力	c'	黏聚力
	○	多階段試驗（第一階段）	σ_3'	最小有效主應力	ϕ'	抗剪角

註: 三軸壓縮試驗的結果相應於最大偏應力的結果, 即 $\sigma_1' - \sigma_3'$

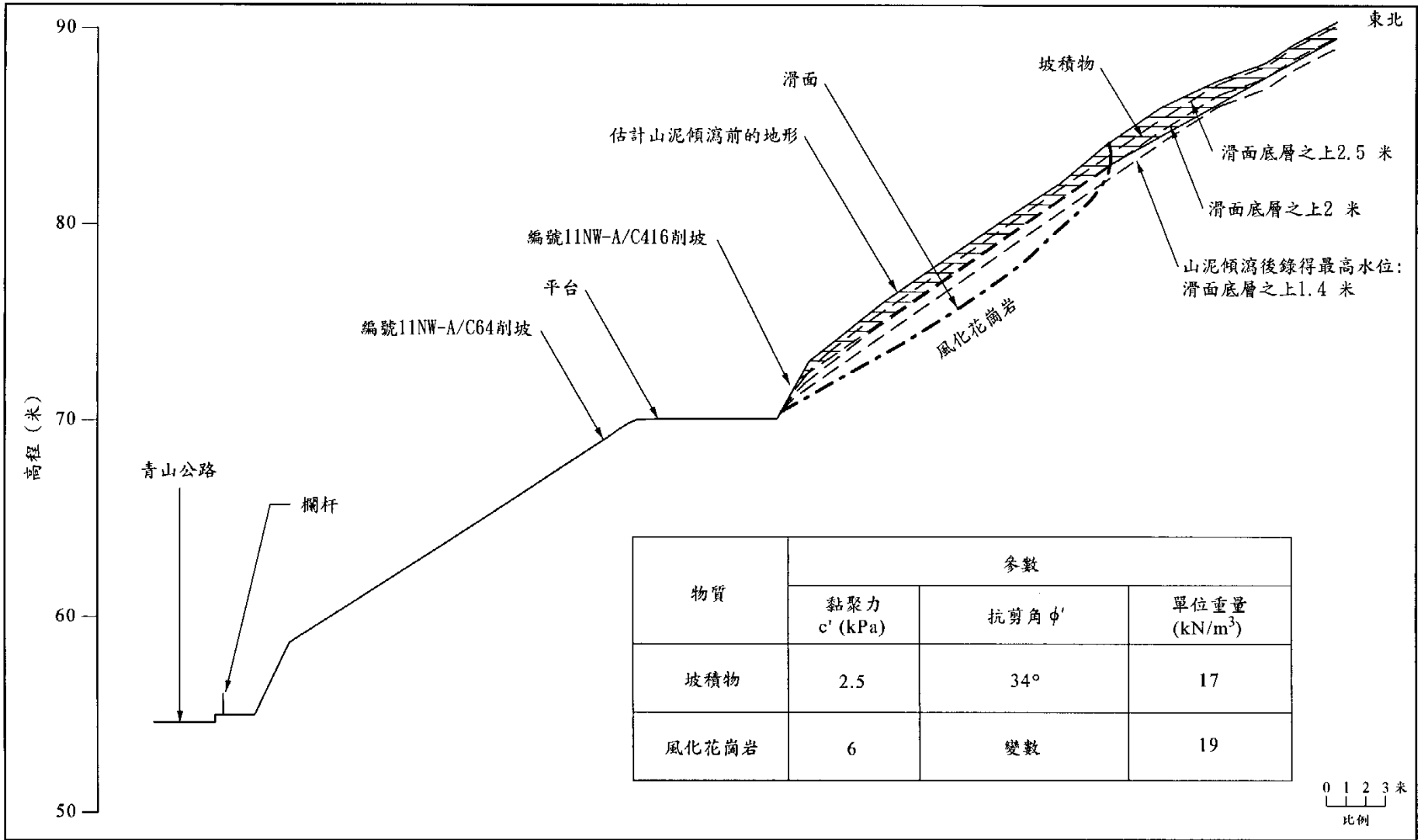
圖 10 - 全風化花崗岩三軸壓縮試驗所得結果



圖例：	○	多階段試驗(第一階段)	σ_1'	最大有效主應力	c' 黏聚力
	●	多階段試驗(第二階段)	σ_3'	最小有效主應力	φ' 抗剪角
	△	多階段試驗(第三階段)			

註： 三軸壓縮試驗的結果相應於最大偏應力的結果，即 $\sigma_1' - \sigma_3'$

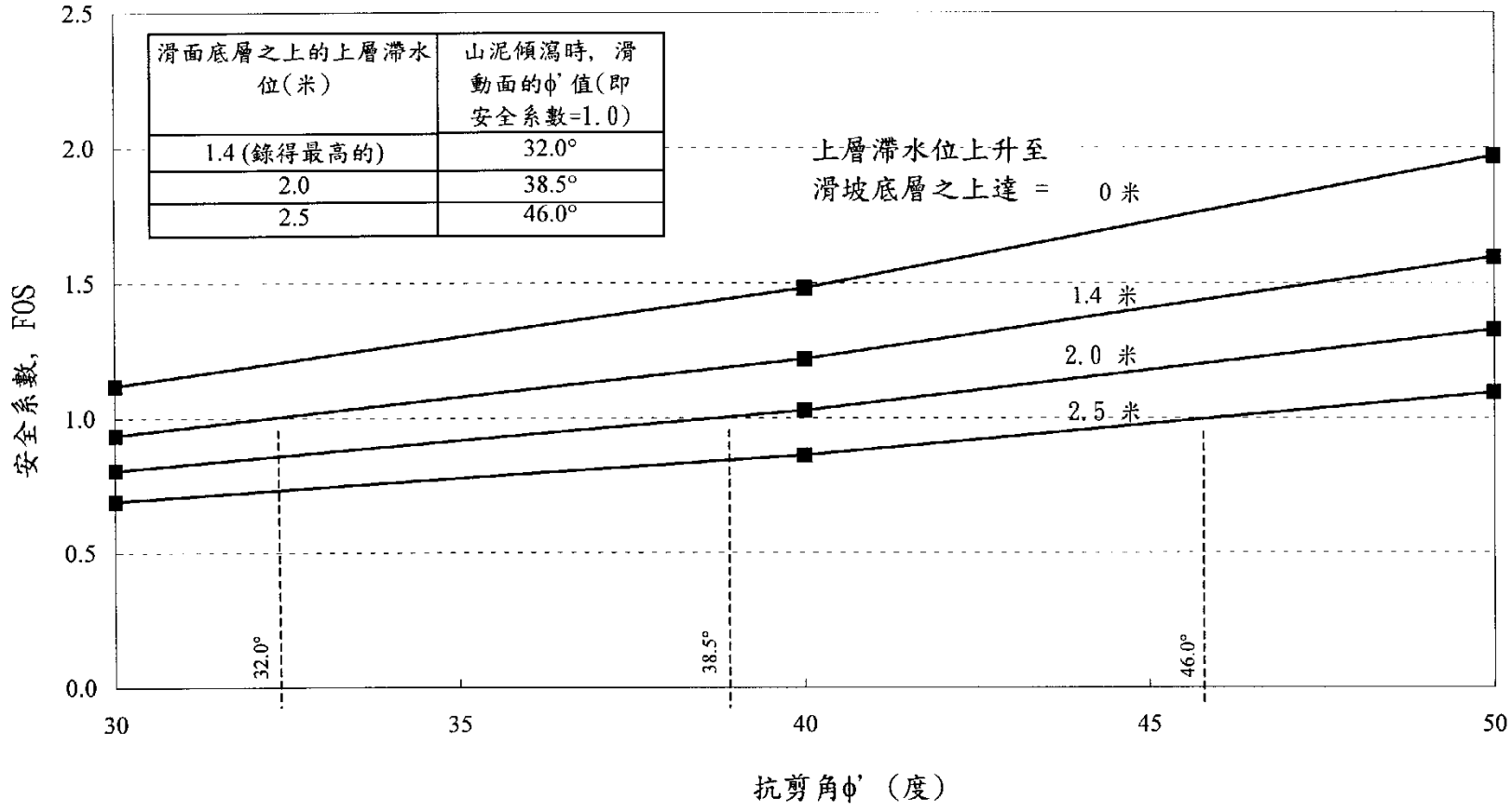
圖 11 - 坡積物三軸壓縮試驗所得結果



物質	參數		
	黏聚力 c' (kPa)	抗剪角 ϕ'	單位重量 (kN/m^3)
坡積物	2.5	34°	17
風化花崗岩	6	變數	19

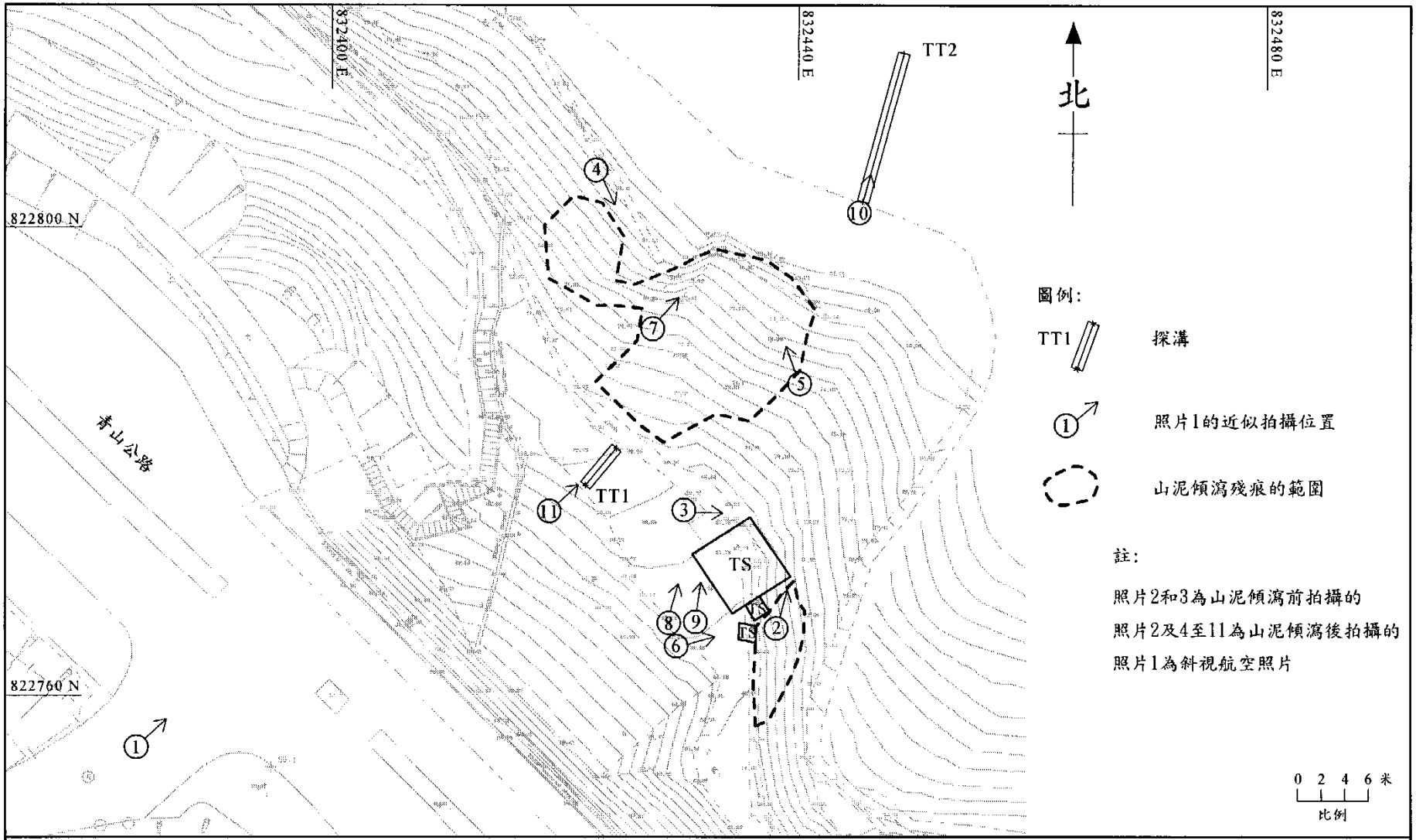
註： 沒有上層滯水位的情況亦有分析(見圖13).

圖12 - 理論穩定性分析所採用具代表性的山泥傾瀉剖面



註：分析詳情見圖 12

圖 13 - 理論穩定性分析結果



註： 圖中所示的資料以地形測量，1:1 000地形測量圖，地質勘察，現場觀察及文件記錄為根據。

圖14 - 照片位置圖

照片

照片1 - 一九九七年六月四日下午攝得的山泥傾瀉現場照片(其位置見圖14)

照片2 - 九華徑上村 26 號寮屋東側房角嵌入了編號為11NW－A/C416 的削坡(一九九六年八月二十二日拍攝，翻印自賓尼所做的SIRST報告，其位置見圖14)

照片3 - 九華徑上村 26 號寮屋北側房角顯示溪流路徑(一九九六年八月二十二日拍攝，翻印自賓尼所做的SIRST報告，其位置見圖14)

照片4 - 填塞了泥土的橫向明溝(一九九七年六月六日拍攝，其位置見圖14)

照片5 - 北山泥傾瀉顯示滑動面的景象(一九九七年六月四日拍攝，其位置見圖14)

照片6 - 東南山泥傾瀉在一九九七年六月六日攝得的景象(其位置見圖14)

照片7— 有滲水的山泥傾瀉滑動面的細節(一九九七年六月四日拍攝，其位置見圖14)

照片8 - 九華徑上村 26 號寮屋的西南部牆體遭到破壞
（一九九七年六月六日拍攝，其位置見圖14）

照片9 - 九華徑上村 26 號寮屋的前門門框遭到損壞（一九九七年六月六日拍攝，其位置見圖14）

照片10 - 在編號 TT2 的探溝裏，花崗岩上覆蓋著坡積物（一九九七年八月二十五日拍攝）

照片11 - 平台上，山泥傾瀉的泥石覆蓋在很薄的土層和填土之上（其位置見圖14）

附錄 A

事發地點歷史摘要

目 錄

參考目錄

A.1 引言

事發地點的歷史是獲取自：

(a) 一九四五年至一九九六年期間的一系列航空照片

(b) 土力工程處的文件記錄

(c) 路政署的青山公路施工記錄

(d) 其他政府部門提供的記錄

A.2 事發地點的歷史發展

從最早的航空照片(一九四五年十一月和一九四九年四月)顯示事發地點是夾在兩條西北及東南向的山咀之間，一個向西南傾的小山谷。 除了一條人行小路橫越兩座保留下來的小建築物之間的斜坡(圖3)，山谷邊部還沒開發。 青山公路是兩車道的道路，座落在一條切斷山谷咀部的矮路堤上。

青山公路在這個地區的取直和加寬工程是在一九五三年設計的，施工是向事發地點下坡的西北方向開展的，工程是在一九五四年十一月至一九五九年十月期間的某個時間開始，於一九六三年一月完成的。 這項工程包括擴泛開挖舊青山公路靠山一側，以及對山谷的加填和加寬下坡一側的公路路堤。新的挖方， 包括其中間部分為填土，後來被登記為編號11NW－A/C64的削坡。 從設計圖則和一九五九年的航空照片的証據顯示，一條新的小徑，可能是施工便道，在路旁的削坡一側形成了階地。 為修建這條便道而削切成的斜坡，北側的部分後來被登記為編號為 11NW－A/C415 的削坡，南側的部分後來被登記為編號為11NW－A/C416 的削坡。 這條便道的總輪廓是沿著山谷的邊緣的，但總體是向東南方向傾斜。

圖則編號RK425/2B
工務局(一九五三)

在同一個時期(一九五四年至一九五九年)，一條橫向的明溝開挖了，它切過了便道靠山一側的斜坡，一直到距離山谷西北方向 100 米的地方。這條明溝逐漸進入到東南側約 50 米附近

的毗鄰山谷中的既有的小溪中。 它在局部上被沿著排水渠和地形低窪處的混凝土擋土牆保護著。 這條橫向的明溝通過了一九九七年山泥傾瀉北部的中心地帶，並且在切過山谷底部溪流時被一個矮混凝土擋土牆支撐著。 另一段矮混凝土擋土牆用來支撐山泥傾瀉事發地點西北部的明溝。 一九六三年的航空照片顯示這條明溝已經被山泥傾瀉泥石堵塞了（首次是從一九五九年的航空照片上觀察到山谷北側的明溝被堵塞了）。 明溝位於廣闊的匯水區但卻沒有任何侵蝕發生在堵塞現場，可能表示，到一九六三年，明溝只有很小甚至沒有流水，也可能是還沒有投入使用。 這條明溝，在一九九七年六月六日觀察到，完全被泥土填埋住了(照片4)。

牽連入一九九七年六月山泥傾瀉的寮屋占用了部分便道和在編號 11NW- A/C64 削坡中部由填土形成的平台。 填土修建平台是逐漸進行的，直到一九六一年一月的航空照片上，才完成了平台的填築。 一條短的排水溝在一九六一年至一九六三年的某個時候開挖了，它穿過平台的中部，直至編號 11NW－A/C416 的削坡坡腳的排水溝(圖3)。 在圖3所見到的大部份表面排水渠在一九六三年已經建成。 平台北側的便道作為人行道被保留下來，通過一組穿過編號 11NW-A/C64 的削坡的階梯與青山公路相連通。

在一九六三年至七十年代初期，斜坡上重新佈滿了植被。一九七三年十月的航空照片顯示，在便道後面的編號 11NW－A/C416 的削坡坡腳進行一些開挖，以及平台本身的植被被剝除。 顯示寮屋已明顯建好了的最早航空照片，是在一九七六年八月的。 香港房屋委員會報告，在一九七六年，一座家庭式的寮屋已經存在，他們進行了寮屋結構的測量，當時的寮屋尺寸記錄是4.6 米× 3.4 米× 2.1 米。 在其後的航空照片上，寮屋仍然可以看到。 在一九八二年，香港房屋委員會進行了測量，記錄的寮屋已經被改建為 6.1 米× 2.4 米× 3.0 米，設施增加了，包括一個廚房和一個衛生間。

香港房屋委員會信件參考（13) in SCTM 4/16/70 (438) 一九九七年七月二十二日

香港房屋委員會，op, cit.

寮屋的擴展是伴隨著斜坡上的台地向東擴展而進行的，一九八七年以後，這個台地看來已經被廢棄了。 到一九九二年，濃密的植被又重新佈滿了這個地區。

A.3 過往的斜坡評估

A.3.1 斜坡登記和第一階段調查

政府委聘以製備斜坡記錄冊的顧問工程師，在一九七七/七八斜坡記錄冊中，登記削坡為編號11NW-A/C64。 第一次有記錄對該削坡進行調查是該顧問工程師於一九七七年六月進行的，作為斜坡記錄冊登記工作的一部份。

賓尼編號 11NW-A/C64 斜坡的現場記錄表

平台後面被牽連入了這次山泥傾瀉的兩個編號為 11NW－A/C415 和 11NW－A/C416 的削坡，卻沒有登記在一九七七/七八斜坡記錄冊中。

在一九九五年三月，平台後面的兩個削坡，通過一個名為"有系統勘察調查全港的斜坡及擋土牆"計劃(SIFT)，被土力工程處鑒定出來。 該計劃的目的是有系統地勘察那些沒有記錄在一九七七/七八斜坡記錄冊中，大型人為開挖的斜坡，補充最新資料在已有的斜坡記錄冊裏，這都是以航空照片的判釋為基礎的。 "有系統調查全港的斜坡及擋土牆" 關於編號 11NW－A/C415 削坡的報告指出，這個斜坡是在一九四九年至一九六一年期間修成的，以往在此處發生過山泥傾瀉是很明顯的。 而"有系統調查全港的斜坡及擋土牆" 關於編號 11NW－A/C416 削坡的報告，沒有觀察到不穩定的記錄。

SIFT 第二階段研究圖則報告，1:1000 圖則編號 11NW-7B，策劃部，土力工程處 一九九五年三月

在一九九四年七月，土力工程處開始一項名為"有系統鑒定和登記全港斜坡及擋土牆"計劃(SIRST)，有系統地對一九七七 /七八斜坡記錄冊進行補充最新資料，編輯新的斜坡記錄冊。 一九九五年十月，土力工程處指定執行"系統鑒定和登記全港斜坡"項目的顧問工程師，對寮屋後面的削坡進行了調查。 這個斜坡被登記為編號 11NW－A/C416 的削坡。 該顧問工程師注意到了這個寮屋，但是當時因為通路問題，沒有對寮屋後面的斜坡進行詳細檢查。 一九九六年八月，該顧問工程師再次對這個斜坡進行了勘察，一段在寮屋後面的斜坡被記錄下來，有 4 米高以及60度的傾角（照片2和3）。 同時注意到有輕微的泥土侵蝕和滲水，但當時沒有提出任何緊急維修工程。 一九九六年八月，該顧問工程師提交的有關該斜坡的第一階段調查報告的草稿中，建議對該斜坡做進一步的調查研究。

賓尼SIRST 編號 11NW-A/C416 削坡的現場記錄表 一九九六年八月

另一個牽連入了這次山泥傾瀉在北方山泥傾瀉地點的削坡，在一九九五年十月，由"有系統鑒定及登記全港斜坡及擋土牆" 計劃的顧問工程師，進行了調查 ，並且登記為編號 11NW－A/C415 的削坡。 勘查時觀察到了一個小且老的滑坡崖。 當時沒有觀察到明顯的斷裂跡象，因此也沒有建議採取任何緊急行動。 一九九六年四月，提交的第一階段調查報告的草稿中推薦該斜坡做進一步的調查研究和工程師檢查。

SIRST 編號 11NW-A/C415 削坡的第一階段調查報告
一九九六年四月

A.3.2 編號 11NW－A/C64 削坡的勘查

一九九五年四月，路政署指定的顧問工程師，進行一項名為"公路旁的斜坡目錄和勘察"的項目，對大約 4000 個屬於路政署且滿足土力工程處的斜坡登記標準的斜坡進行勘察，編號 11NW－A/C64 削坡的調查報告指出"斜坡頂部有寮屋，人行道出現在斜坡的頂部及斜坡大部份的位置"。 住處和人行道的準確位置沒有記錄下來。 報告建議做例行的維修工程，以及每年進行一次的工程師檢查，還建議進行"斜坡的詳細穩定性分析"。

公路旁斜坡目錄和勘察，
編號 11NW－A/C64 削坡
輝固、蒂碩、高鋒組合一九九五年四月

編號 11NW－A/C416 和 11NW-A/C415 的削坡，沒有被包括在這個項目的調查工作裏。

A.3.3 在防止山泥傾瀉計劃中對編號 11NW-A/C64 削坡所採取的行動

編號 11NW－A/C64 的削坡，在一九九五年被路政署提名包括在一九九六/一九九七年度的防止山泥傾瀉計劃中。該斜坡是在一九九五年八月三十日，由跨部門的防止山泥傾瀉計劃委員會(LPMC)選入防止山泥傾瀉計劃內。 該斜坡的第三階段調查研究， 是由土力工程處委聘的防止山泥傾瀉計劃顧問工程師，在一九九六年年初開始的。 調查研究包括：背景資料檢討、場地勘察、實驗室土壤試驗、評估斜坡既有穩定性分析，以及在需要時按照現行工程標準進行勘察、設計及加固工程。 在一九九七年山泥傾瀉之前，顧問工程師完成了場地勘察工作和初步的斜坡整治設計。

防止山泥傾瀉鄰選計劃，提名斜坡調查報告，土力工程處
一九九五年五月

A.3.4 (寮屋)非發展清拆

從八十年代中期起，香港境內有大約 72 000 名住在陡斜山邊的寮屋居民因清拆而獲得安置，這是因為其容易遭到山泥傾瀉的威脅的原因(通稱(寮屋)非發展清拆，NDC)。 這些需要清除的寮屋，是由土力工程處調查研究後鑒定的，政府土地上的寮屋的清拆和安置是由地政總署（在一九九三年以前稱為屋宇地政處）和房屋署(HD)根據許可的資源的情況完成的。

在"(寮屋)非發展清拆"計劃下，土力工程處在一九八九年一月至二月，勘察了這九華徑上村及泵房上村。 26 號寮屋位於"(寮屋)非發展清拆"計劃之泵房上村被調查的範圍內。 土力工程處在一九八九年三月向房屋署建議清拆的寮屋中，沒有該寮屋。 屋宇地政署準備了兩份清除計劃，亦即是關於泵房上村編號 KT4/89 的清拆計劃和一九九一年十一月關於九華徑上村編號KT5/89 的清拆計劃。 在編號 KT5/89 的清拆計劃中，在一九九二年十月已完成清拆了 64 座寮屋。 然而，編號 KT4/89 的清拆計劃中選定被清拆的 29 座寮屋沒有被清拆。

土力工程處內部備忘錄(CGE/MW給CGE/LI)，參考GCMW2/E2/97-4，一九九八年一月二十三日

屋宇地政署圖則編號KTCP31B，土力工程處
文件
GCMd/2/E1/RA4(W)

屋宇地政署圖則編號KTCP32C，土力工程處文件
GCMd/2/E1/RA4(W)

在一九九三年一月至二月期間，土力工程處再次對這兩個寮屋村進行了視察，以檢查過往的建議是否令人滿意地執行了，並且提出進一步清拆的建議。 由於 26 號的寮屋位於遠離上述兩村莊的主要範圍內，所以沒被包括在這次重新調查範圍內。 土力工程處在一九九三年一月和三月向房屋署建議，對這兩寮屋村進行(寮屋)非開發清拆。 地政總署為此作了兩份進一步的清拆計劃，亦即是一九九四年六月關於九華徑上村編號為 KT2/94 的清拆計劃和一九九五年三月關於泵房上村編號為 KT4/95 的清拆計劃。 編號為 KT4/95 的清除計劃還包括了編號 KT4/89 清拆計劃中沒有完成的工作。 編號 KT2/94 和 KT4/95 的清拆計劃的清拆工作，在一九九七年山泥傾瀉發生前還沒有履行，原來擬定於一九九七年六月進行的。

土力工程處文件
GCMd/4/13/RA11
內的記錄

同上

同上

地政總署圖則編號KTCP77，土力工程處文件
GCMd/4/13/RA11

地政總署圖則編號KTCP82，土力工程處文件
GCMd/4/13/RA11

土力工程處文件
GCMd/4/E1/RA4(W)
內的記錄

A.4 過往的山泥傾瀉

根據土力工程處和路政署的記錄，在一九九七年山泥傾瀉的事發地點，以往沒有報告過有山泥傾瀉發生。 在土力工程處的天然地形崩塌目錄裏，也沒有天然地形崩塌在該地區的發生記錄。 作為這次山泥傾瀉調查的一部分，由老的航空照片的判釋發現，在一九五四年至一九六三年之間，可能有四次小規模滑坡發生在這次山泥傾瀉地區的附近（圖3）。 兩個滑坡影響了一九九七年山泥傾瀉地區上方的山坡，其餘的兩個滑坡影響了編號 11NW－A/C415 和11NW－A/C416 削土坡的頂部。

參考一九九八年三月二日合樂發給房屋署傳真 (RC/IPSS/23.1/829)

第一及二期天然地形崩塌研究報告內的天然地形崩塌目錄圖則，土力工程處，特別項目報告SPR5/97

A.5 參考書目

土力工程處(一九九五) Phase 2 SIFT Study. 圖則報告， 1:1000 圖則編號 11NW-7B。

工務局(一九五三) 圖號 RK425/2B 。

香港房屋委員會(一九九五) 一九九七年七月二十二日發給合樂顧問公司的信件編號 SCTW 4/16/70(438)。

輝固、蒂碩、高鋒組合（一九九五） Roadside Slope Inventory and Inspection 編號 11NW-A/C64 斜坡，斜坡/擋土牆記錄(6頁)和工程師檢查(10頁)。

Evans, N.C., Huang, S.W. & King, J.P.（一九九七） The Natural Terrain Landslide Study Phase I and II，香港土力工程處，119 頁(特別項目報告，編號 SPR 5/97)。