REVIEW OF THE LANDSLIDE AT SLOPE NO. 2NE-D/C112 AND THE NATURAL HILLSIDE ABOVE NEAR TAK YUET LAU LO WU

GEO REPORT No. 280

Halcrow China Limited

GEOTECHNICAL ENGINEERING OFFICE

CIVIL ENGINEERING AND DEVELOPMENT DEPARTMENT

THE GOVERNMENT OF THE HONG KONG

SPECIAL ADMINISTRATIVE REGION

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This report is largely based on GEO Landslide Study Report No. LSR 10/2009 produced in November 2009

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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. The GEO Reports can be downloaded from the website of the Civil Engineering and Development Department (http://www.cedd.gov.hk) on the Internet. Printed copies are also available for some GEO Reports. For printed copies, a charge is made to cover the cost of printing.

The Geotechnical Engineering Office also produces documents specifically for publication in print. These include guidance documents and results of comprehensive reviews. They can also be downloaded from the above website.

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H.N. Wong
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May 2013

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FOREWORD

This report presents the findings of a review of a landslide (Incident No. 2006/01/0570) at slope No. 2NE-D/C112 and the natural terrain immediately above, near Tak Yuet Lau, Lo Wu, which occurred in August 2005. The landslide involved a failure volume of about 550 m^3 and the majority of the debris remained within the landslide scar, whilst some debris came to rest within a 500 mm wide trench adjoining a footpath at the toe of the slope. The landslide was not reported until 2006. No casualties were reported as a result of the incident.

The key objectives of this review were to document the facts about the incident and to present relevant background information and pertinent site observations made under this review. The scope of the review does not include any ground investigation or detailed diagnosis of the causes of the incident. Recommendations for follow-up actions are presented separately.

The report was prepared as part of the Landslide Investigation Consultancy for landslides occurring in Kowloon and the New Territories, for the Geotechnical Engineering Office, Civil Engineering and Development Department, under Agreement No. CE 53/2006 (GE). This is one of a series of reports produced during the consultancy by Halcrow China Limited.

Gerry Daughton
Project Director
Halcrow China Limited

Agreement No. CE 53/2006 (GE)
Study of Landslides Occurring in Kowloon and the New Territories in 2007 – Feasibility Study

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1. INTRODUCTION

A major landslide (Incident No. 2006/01/0570), which occurred at slope No. 2NE-D/C112 and the natural terrain above, near Tak Yuet Lau, Lo Wu (Figure 1 and Plate 1), was reported by the District Office (DO) on 19 January 2006. According to the GEO Incident Report, the failure occurred in August 2005 but the exact date and time of failure was unknown. The landslide involved a failure volume of about 550 m^3. The majority of the debris remained within the landslide area, and some debris came to rest within a 500 mm wide trench adjoining a footpath at the toe of the slope. No casualties or closure of the footpath were reported as a result of the incident.

Following the incident, Halcrow China Limited (HCL), the Landslide Investigation Consultants for Kowloon and the New Territories, carried out a review of the failure for the Geotechnical Engineering Office (GEO) of the Civil Engineering and Development Department (CEDD) under Agreement No. CE 53/2006 (GE).

This review report documents the facts about the incident, and presents relevant background information and pertinent observations made by HCL. The scope of the review does not include any ground investigation or detailed diagnosis of the causes of the incident.

2. THE SITE

2.1 Site Description

The landslide occurred at the east-facing, vegetated cut slope No. 2NE-D/C112 and the natural hillside above. Slope No. 2NE-D/C112 is approximately 95 m long and 3.5 m high, and comprises one batter formed at a maximum angle of about 40°. The slope is covered with dense vegetation including trees and shrubs. There are no surface drainage provisions at the slope.

At the toe of the slope are a 500 mm wide trench and an about 1.2 m wide footpath. On the opposite side of and below the footpath are a small vegetated slope and a level field. Above the crest of slope No. 2NE-D/C112 is a heavily vegetated natural hillside with an average slope angle of about 25°.

A streamcourse trending in a northeast direction is situated about 80 m to the northwest of the subject slope while another streamcourse trending in a southeast direction is located about 20 m to the south of the subject slope (Figure 1).

A site layout plan showing the location of the August 2005 landslide is presented in Figure 2. General views of the slope are shown in Plates 2 and 3.

2.2 Geological Setting

According to the Hong Kong Geological Survey (HKGS) 1:20 000 scale map series HGM20, Sheet No. 2 (GCO, 1986), the subject slope is underlain by metasandstone with metaconglomerate and phyllite of the Tai Shek Mo Member (Figure 3). A number of conglomerate layers are recorded about 200 m to the west of the subject area. The Geological

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Map also indicates the presence of foliation in vicinity of the study area which is oblique to the subject cut slope and dipping 28° to the northwest.

The subject slope is located at the foothill of the meta-sedimentary terrain in close proximity to the Ng Tung River. A layer of superficial deposits comprising unsorted sand, gravel, cobbles and boulders with a clay/silt matrix belonging to the Pleistocene debris flow deposits is present immediately to the east of the slope. Further downhill to the east, the debris flow deposits are covered by younger Holocene alluvium deposits.

2.3 Maintenance Responsibility

According to the Slope Maintenance Responsibility Information System (SMRIS) of the LandsD, slope No. 2NE-D/C112 is under the maintenance responsibility of the LandsD.

2.4 Water-carrying Services

Based on the information provided by various utilities undertakings including utility companies and services departments, there were no water-carrying services affecting the slope.

3. SITE HISTORY AND PAST SLOPE INSTABILITIES

3.1 Site History

The development history of the site has been established from a review of aerial photographs and inspection of available relevant documentary records. A detailed account of the aerial photograph interpretation (API) is presented in Appendix A. Salient aspects of the key observations are summarised below.

The earliest available aerial photographs, taken in 1924, show that the August 2005 landslide site was located at the toe of an east-facing natural hillside to the west of Ng Tung River. It appeared that slope No. 2NE-D/C112 had been formed in association with an adjacent footpath at its toe. The area below the subject slope was cultivated land adjacent to the Ng Tung River. Above the subject slope was a sparsely vegetated hillside with occasional graves. A northeast-southwest trending ridge line was present to the west of the 2005 landslide site. Two natural drainage lines were observed to the north and south of the landslide site, respectively. Spur lines were also evident below the ridge line. A number of relict landslides and gully erosions were noted on the natural hillside above the subject slope.

In 1964 aerial photographs, a subtle convex break-in-slope possibly related to a degraded relict landslide scar could be observed on the subject cut slope at similar position as the August 2005 Landslide.

Based on the 1973 aerial photographs, the cultivated land below the subject slope was modified to form a pond. Minor modifications to the hillside were noted about 10 m and 100 m south of the subject slope.

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By 1975, Ng Tung River was re-aligned with the section south of the subject feature abandoned and a new straightened alignment formed to the east.

According to the 1976 aerial photographs, the fields along the re-aligned section of Ng Tung River noted in the 1975 photographs had been modified to form a pond. From a low altitude aerial photograph, sub-horizontal lines along contour were observed on the hillside above the subject feature, which appeared to be abandoned terraces.

No significant change to the subject slope and its surrounds was observed in aerial photographs since 1976.

3.2 Past Slope Instabilities

Aerial Photograph Interpretation was carried out to identify past instabilities at the subject slope and within the catchment above. However, due to the lack of available low altitude aerial photographs for the subject area prior to 1994, detailed examination of the photogeology and geomorphology is not possible.

In the 1964 aerial photographs, a number of relict landslides scars (Figure 4 - R1 to R6) were seen within the subject catchment. These relict landslides scars were degraded features evidenced by subtle convex break-in-slope and probably existed prior to 1924. Relict landslide scars R1 to R4 were located at the foothill of the catchment, where more recent colluvium is expected to be accumulated. The other two landslide scars R5 and R6 were located at mid catchment and were close to the head of two preferential drainage paths.

It appears that the location of relict landslide scar R1 was approximately at the same location as the subsequent landslide in August 2005. However, it was noted that the scar was no longer observable in later aerial photographs due to vegetation growth. This may suggest that the landslide scar was relatively shallow. A subtle concave break-in-slope could be observed at the toe of the subject slope, which could be traced further down to the footpath and may represent the downhill limit of movement associated with the relict landslide R1.

Another three relict landslide scars (Figure 4 - R7 to R9) were identified in the 1973 and 1975 aerial photographs. R7 was a larger depression lying within a stream valley adjacent to the catchment above the subject slope. Relict landslide scars R8 and R9 were small locallised depressions located above, and about 50 m to the west of, the subject slope.

In 1993, a landslide was observed to have occurred within R7 and could be due to the reactivation of old debris or a progressive failure.

In 1995, a curvilinear shadow in the tree canopy was observed at the subject slope, extending 10-20 m above the slope crest (Plate 4). This shadow may be associated with the tilting of trees, steps on the ground created by distress or could be the presence of a footpath. Two patches of bare soil were visible on the slope below the access path immediately in front of the subject slope, which may be associated with erosion or instabilities.

In 1997, additional patches of bare soil surface, possibly caused by erosion or instability, were visible at the subject slope surface and on the slope below the access path.

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No significant sign of erosion or instability were visible since 1997 except that in 2001 the curvilinear shadow in the tree canopy, as previously observed in 1995, was again visible but with an additional linear shadow extending further to the south (Plate 5).

No relevant landslide data in the vicinity of the 20 August 2005 failure are shown in the GEO's Enhanced Natural Terrain landslide Inventory (ENTLI) or the Large Landslide Database.

4. PREVIOUS ASSESSMENTS AND SLOPE WORKS

4.1 SIFT and SIRST Studies

In April 1997, under the study entitled "Systematic Inspection of Features in the Territory" (SIFT) initiated by the GEO, the subject slope was designated as SIFT Class 'C1' (i.e. cut slopes that have been formed or substantially modified before 30 June 1978 or have been illegally formed after 30 June 1978).

In October 1997, the subject slope was inspected as part of the study entitled "Systematic Identification and Registration of Slopes in the Territory" (SIRST). According to the inspection records, the surface condition of the slope was poor and signs of distress were noted near the crest, mid-portion and toe of the slope. The consequence category of the subject slope was classified as "Negligible".

4.2 Stage 1 Study by GEO

In October 1997, a Stage 1 Study of the subject slope was carried out by the Mainland West Division of GEO and recommended that an Engineer Inspection (EI) be carried out. No emergency action was required.

4.3 Engineer Inspections and Routine Maintenance Inspections

In October 2001, Maunsell Fugro Joint Venture (MFJV) carried out an EI for cut slope No. 2NE-D/C112 for LandsD. The EI did not cover the natural hillside above the cut slope. According to the EI report, the classification of overall state of slope maintenance was assessed as being "Fair". No recent seepage, erosion, tension cracks at the slope crest or signs of distress were noted at the time of inspection. No recommendation on routine maintenance works or preventive maintenance works (PMW) were made in the 2001 EI report. It was also noted in the EI report that "In view of the mature vegetated slope surface and low consequence-to-life of the slope in the event of failure, the existing slope condition is considered to be acceptable and no PMW are recommended".

Based on LandsD's records, Ove Arup and Partners Hong Kong Limited (OAP) carried out a Routine Maintenance Inspection (RMI) for slope No. 2NE-D/C112 in May 2006. According to the RMI report, no routine maintenance works were recommended. No other RMI records could be located in the LandsD.

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4.4 Stage 3 Study by Fugro (Hong Kong) Limited

According to GEO's files, the slope No. 2NE-D/C112 was injected into Landslip Preventive Measures (LPM) Programme for Stage 3 Study after the occurrence of the landslide in August 2005. The Stage 3 Study was completed by Fugro (Hong Kong) Limited (FHK) under Agreement No. CE 24/2004 (GE) in August 2007 (FHK, 2007). LPM works commenced, under Contract No. GE/2005/43, in September 2007 and were completed in March 2008.

As part of the Stage 3 Study, site-specific ground investigation (GI) works including three drillholes, eleven trial pits, three trial trenches and six surface strips together with eleven GCO probe tests were carried out at the subject slope (Figure 5). The GI results revealed that the cut slope comprised colluvium, maximum 2.7 m thick, overlying completely decomposed meta-siltstone. Residual soil of about 0.7 m thick was encountered beneath the colluvium at the southern portion of the subject slope. The colluvium was described as firm, moist, light brown and greyish brown, slightly silty gravely SAND with some angular to subrounded fine to coarse gravel and occasional cobbles. Completely decomposed meta-siltstone (CDM) was described as extremely weak, light brown and purplish brown, sandy clayey SILT with occasional angular fine to coarse gravel. No adverse geological features were identified in the vicinity of the landslide area.

Groundwater monitoring records, taken from November 2006 to June 2007, revealed that the highest groundwater level was recorded at about the level of slope toe. No perched water table in the colluvium layer was recorded during the monitoring period.

The Stage 3 Report noted that, considering the relative permeability of the colluvium and CDM beneath and the presence of soil pipes within the layer of colluvium in the landslide scar (see Section 5.2 below), the 2005 landslide might be caused by the build-up of a perched water table in the colluvium layer. A sensitivity analysis showed that the factor of safety against failure is less than one when a 1.5 m of groundwater is perched on the top of the CDM within the colluvium layer. The report concluded that the landslide occurred mainly in the colluvium layer.

The proposed LPM works for the slope comprised minor trimming of the steep slope surface, re-grading of the distressed slope surface, installation of soil nails and prescriptive raking drains, hydroseeding with erosion control mat and steel wire mesh, construction of mass concrete toe wall, and provision of drainage channels.

5. THE AUGUST 2005 INCIDENT AND POST-FAILURE OBSERVATIONS

5.1 Description of the Incident

According to the incident report prepared by the GEO, the failure was reported by the DO on 19 January 2006 and probably occurred in August 2005. However, the exact date and time of failure were not known. The landslide (about 10 m high by 46 m long by 2 m deep) involved slope No. 2NE-D/C112 and the natural hillside above, with a failure volume of about 550 m^3. Most of the landslide debris was deposited within the source area and some debris came to rest within a trench at the toe of the slope. No casualties or closure of footpath were reported as a result of the incident.

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5.2 Post-failure Observations of the Incident Site

The first inspection was carried out by Maunsell Geotechnical Services Limited (MGSL), the Landslide Investigation Consultants for Kowloon and the New Territories, under Agreement No. CE 15/2004 (GE) on 26 January 2006.

According to the information provided by MGSL, the failure scar was about 10 m high by 46 m long by 2 m deep with a failure volume of about 550 m^3. MGSL noted that about 90% of the detached materials remained within the source area and some debris appeared to have fallen into a 0.5 m wide trench at the toe of the subject slope. The debris that was not particularly mobile and had travelled only up to 1.5 m horizontally.

A number of tension cracks were noted within the detached materials. They were 100 mm to 200 mm wide, 8 m to 25 m long with a maximum depth of about 0.5 m. The tension cracks were subsequently sealed up by the Highways Department during the remedial works in January 2006. No tension cracks were noted above the main scarp.

Based on MGSL's inspection record, the main scarp was about 2 m high where mainly colluvium was exposed (Plate 6). The central and southern portions of the main scarp comprised mainly dense, yellowish brown slightly silty fine to coarse sand with some gravels and cobbles, whereas many cobble sized rock fragments were exposed at the northern main scarp. The central portion of the upper part of the main scarp (Figure 6) possibly is the location of relict landslide scar R1 observed in 1964 aerial photographs.

Two soil pipes were identified at the main scarp (50 mm in diameter by 200 mm deep) and within the colluvium layer (Plate 7).

MGSL noted that no signs of seepage were observed at the main scarp at the time of inspection in January 2006, some six months after the landslide.

Slope No. 2NE-D/C112 was densely vegetated with shrubs and mature trees at the time of inspection. Below the footpath was a densely vegetated slope, which was about 3 m high with an angle of about 35° to the horizontal.

Apart from the main failure, a small-scale failure (landslide volume of about 4 m^3) was also noted at the northern end of the subject slope.

The paved footpath located at the toe of slope No. 2NE-D/C112 showed no sign of distress and the footpath was unaffected by the incident.

During the subsequent Stage 3 Study, site inspections were conducted by FHK in June 2006 and February 2007. Their observations were similar to those made by MGSL. The detached material at the main scarp was identified as colluvium, inclining at about 25° with a travel angle of about 25°, which is similar to the average gradient of the natural hillside above the failure.

HCL inspected the landslide site on 5 November 2007. At the time of inspection, slope upgrading works were being carried out by the LPM Contractor. Trimming back of landslide scars and re-profiling of the slope had been carried out. Evidence of the failure

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scars, i.e. the tension cracks and the break in slope, had already been removed and the slope surface was generally covered with a thin veneer of loosened soil. At the crest of the newly trimmed slope, a small ditch had been excavated for the construction of a crest channel. Inspection of the temporary cut face alongside this ditch revealed the presence of colluvial soil. A soil pipe was observed in the cut face, which was 100 mm in diameter with a measured depth of 470 mm (Plate 8). This soil pipe appeared similar to the other soil pipes recorded in MGSL's inspection record. An exposure of in-situ material, comprising moderately weak to weak, light yellowish brown, slightly metamorphosed siltstone (metasiltstone), was observed in the cut face of the ditch. Extremely closely spaced jointing appeared to run parallel to the foliation of the in-situ material and was measured as having an orientation of 347º/17º (Plate 9).

No GI works were carried out for the present landslide study. Nevertheless, site-specific GI works were carried out as part of the Stage 3 Study, as noted in Section 4.4 above. A geological model based on the available information was prepared in this study as shown in Figure 6.

Laboratory tests on the soil samples retrieved during the site-specific GI works were carried out in the Stage 3 Study. The tests included determination of moisture content, Atterberg Limits, particle size distribution and triaxial compression. The test results are summarised in Table 1. The results indicate that the fines content of the CDM was higher than that of the colluvium, suggesting that the colluvium is probably more permeable than the CDM. The difference in permeability is favourable to developing a perched water table within the colluvium under heavy rainfall.

The shear strength parameters of the CDM and colluvium were based on single-staged and multi-staged consolidated undrained triaxial tests with pore water pressure measurement. As the landslide mainly occurred within the colluvium layer, the test results for the colluvium were reviewed in this study and presented in the form of p'-q plot in Figure 7. The approximate shear strength parameters, c' and ϕ' for the colluvium determined from the least squares method are 2.5 kPa and 37° respectively. The corresponding lower bound values of c' and ϕ' are 0 kPa and 33° respectively.

5.3 Review of Ground Investigation Samples

Since no GI was carried out for this study, soil samples remaining from the previous GI for the Stage 3 Study were examined to identify any adverse geological features. A total of 10 Mazier samples taken within the CDM at depths between 5.3 m and 20.4 m and five block samples within the CDM and colluvium at depths of 0.7 m to 2.7 m were thoroughly examined (Table 2). No obvious slip plane was observed. However, foliation fabric and sub-vertical relict joints were noted in the block samples of the decomposed metasiltstone.

The foliation appeared to be low-persistence relict discontinuities with an orientation of 320°/15° (Plate 10). Sub-vertical and slightly inclined joints commonly infilled with firm silt were also observed in the decomposed metasiltstone. The dip direction and dip angle of the sub-vertical relict joints was typically about 125º/80º. None of the discontinuities were adversely orientated.

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6. ANALYSIS OF RAINFALL RECORDS

Rainfall data were obtained from the nearest GEO automatic raingauge No. N34, which is located at Sheung Shui Water Treatment Plant, Fu Tei Au Road, about 1200 m to the southeast of the subject slope (Figure 1). This raingauge records and transmits rainfall data at 5-minute intervals via a telephone line to the Hong Kong Observatory and GEO. According to the landslide incident report prepared by GEO, the exact time and date for the landslide incident are not known, but it probably occurred in August 2005 during heavy rainfall on 19 and 20 August 2005, the only significant rainfall at that time (see Figure 8). For the purposes of the rainfall analysis, it has been assumed that the failure occurred at about 9:00 a.m. on 20 August 2005, immediately after the maximum hourly rainfall had occurred.

The daily rainfall recorded by raingauge No. N34 over the month preceding the assumed timing of the landslide, together with the hourly rainfall readings for the period of 19 to 20 August 2005, are presented in Figure 8. The record of the daily rainfall shows that 102 mm, 239.5 mm and 18 mm of rainfall was recorded on 19, 20 and 21 August 2005, respectively. The maximum 24-hour and 48-hour rolling rainfall before the incident were 154.5 mm and 222.5 mm, respectively. The maximum 1-hour rolling rainfall was recorded as 34 mm between 8:00 a.m. and 9:00 a.m. on 20 August 2005 (see Table 3).

The return period for the rainfall recorded at raingauge No. N34 preceding the assumed timing of the landslide was estimated based on historical rainfall data at the Hong Kong Observatory (Lam & Leung, 1994). The maximum rolling rainfall for various durations was derived and is given in Table 3. The results show that the return periods of the rainfall were very short, generally less than 2 years.

The return periods were also assessed based on the statistical parameters derived by Evans & Yu (2001) for rainfall data recorded by raingauge No. N34. The return periods estimated using data of Lam & Leung and Evans & Yu are very similar to those estimated by historical rainfall data at the Hong Kong Observatory for both short and long durations.

A comparison of the maximum rolling rainfall of the 20 August 2005 rainstorm with those of the past major rainstorms between 2000 and 2005 recorded by raingauge No. N34 is presented in Figure 9. It is noted that the rainfall on 20 August 2005 is less severe than the previous major rainstorm.

7. THEORETICAL STABILITY ANALYSES

Theoretical stability analyses were carried out to assist the diagnosis of the mechanism and causes of the landslide. The analyses were aimed to determine the likely range of shear strength parameters mobilised along the most probable failure surface for various groundwater levels.

Information obtained from the ground investigations, laboratory testing, and topographical survey in Stage 3 Study report together with site observations and measurements was used in the analyses. A representative cross-section of the landslide site and the geotechnical parameters adopted in the analyses are shown in Figure 10. Parametric

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stability analyses were undertaken for the failed section using different perched water levels above the assumed slip surface and various combinations of strength parameters of colluvium.

The results of the back analyses are summarised in Figure 11. The results indicate that with the “best fit” shear strength parameters derived from the triaxial tests (i.e. c' = 2.5 kPa and ϕ' = 37°) for the colluvium, together with a perched water level of 1.7 m above the slip surface (close to ground surface), failure could occur. However, if the shear strength parameters of the colluvium are reduced to the lower bound value of c' = 0 kPa and ϕ' = 33°, which are close to the shear strength parameters of the remoulded samples (c' = 0 kPa and ϕ' = 32°) taken from the distressed material (FHK, 2007), a perched water table of 0.8 m (i.e. about 0.9 m below the ground surface) would be sufficient to initiate failure.

8. DISCUSSION

The landslide comprised an open hillslope failure on a gentle sloping natural hillside (an average angle of about 25°) with a 3.5 m high cut slope (No. 2NE-D/C112) at the toe. The landslide was spatially extensive (about 46 m long) and relatively shallow (about 2 m deep), with a failure volume of about 550 m^3. Most of the detached material remained on the hillside with limited runout. The landslide is not a typical type in Hong Kong.

The landslide probably occurred in August 2005, but the exact date and time of the failure are unknown. There were several rainstorms recorded in August 2005 in the area so the landslide was likely rain-induced.

The geology of the landslide site comprises a thin mantle of colluvium of up to 2.7 m in thickness overlying CDM. This setting is favourable for the development of a perched water table within the colluvium. In addition, possible subsurface seepage from the hillside above through preferential flow paths, as evidenced by the presence of two soil pipes observed at the scar, may result in fast build-up of transient groundwater pressure locally within the colluvium. The site has a history of instabilities as evidenced by the presence of many relict landslides in the vicinity of the August 2005 landslide location. The groundmass in this area may have been subject to progressive deterioration and deformation, which may have resulted in development of tension cracks in the near surface groundmass. This would promote water ingress, make the hillside more susceptible to rain-induced failure and it could be the reason why the August 2005 landslide may have been triggered by a rainstorm that was less severe than others previously recorded.

The hillside has a history of failures and as such pre-existing slip planes may have been present in the near surface groundmass, which could have been reactivated under heavy rainfall. This possibility could not be ruled out, although the limited GI data did not reveal any pre-existing slip surface in the colluvium and CDM.

The cut slope at the toe would have influenced the stability of the hillside, which is "meta-stable" as reflected from the histories of relict landslides. The repeated failures subsequent to the cutting are not unexpected. As to why the hillside was subject to progressive deterioration in the first instance, it may be related to the material properties of the metasiltstone (high fines content with foliations) or the colluvium. However, this cannot be ascertained given the limited scope of the present study.

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Table 1 – Summary of Laboratory Tests

Soil Type	No. of Test	Particle Size Distribution				Fines Contents (%)	Average Fines Content (%)	Average Liquid Limit (%)	Average Plastic Index (%)
		Clay (%)	Silt (%)	Sand (%)	Gravel (%)				
Colluvium	15	5 – 21	20 – 70	11 – 39	1 – 57	25 – 88	60	45.3	22.8
CDM	22	15 – 23	36 – 72	11 – 43	0 – 17	56 – 89	74.2	53	26.7

Notes: (1) Eleven out of 15 Colluvium samples were reported as non-plastic.
(2) Nineteen out of 22 CDM samples were reported as non-plastic.

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Table 2 – Summary of Soil Samples Examined

GI Station No.	Sample No.	Sample Depth	Type of Sample	Soil Type
C112-DH2	21	9.00 m – 10.00 m	Mazier	CDM
	25	10.60 m – 11.60 m	Mazier	CDM
	29	12.20 m – 13.20 m	Mazier	CDM
	33	13.80 m – 14.80 m	Mazier	CDM
	37	15.40 m – 16.40 m	Mazier	CDM
	41	17.80 m – 18.80 m	Mazier	CDM
	45	19.40 m – 20.40 m	Mazier	CDM
C112-DH3	9	5.30 m – 6.30 m	Mazier	CDM
	13	6.90 m – 7.90 m	Mazier	CDM
	17	8.50 m – 9.50 m	Mazier	CDM
C112-TP2	8	2.70 m – 3.00 m	Block	HDM
C112-TP5	2	0.70 m – 1.00 m	Block	Colluvium and CDM
	5	1.70 m – 2.00 m	Block	CDM
	8	2.70 m – 3.00 m	Block	CDM
C112-TP9	10	2.50 m – 2.80 m	Block	Colluvium

Notes:
(1) Refer to Figure 5 for location of GI stations.
(2) Soil Samples were taken by Vibro (HK) Ltd. between November 2006 and January 2007 under the supervision of Fugro (HK) Ltd, as part of the LPM Stage 3 Study for Slope 2NE-D/C112 (Agreement No. 24/2004(GE)).
(3) Splitting of soil samples were carried out by PWCL between 22 February and 29 February 2008.
(4) CDM: Completely Decomposed Meta-siltstone,
HDM: Highly Decomposed Meta-siltstone.

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Table 3 – Maximum Rolling Rainfall at GEO Raingauge No. N34 for Selected Durations Preceding the Landslide on 20 August 2005 and Estimated Return Periods

Duration	Maximum Rolling Rainfall (mm)	End of Period (Hours) (see Note 4)	Estimated Return Period (Years) (see Note 3)	
			A	B
5 minutes	5.5	8:55 hours on 20 August 2005	1	< 2
15 minutes	14.5	9:00 hours on 20 August 2005	1	< 2
1 hour	34	09:00 hours on 20 August 2005	< 2	< 2
2 hours	48	09:00 hours on 20 August 2005	< 2	< 2
4 hours	65	09:00 hours on 20 August 2005	< 2	< 2
12 hours	103.5	09:00 hours on 20 August 2005	< 2	< 2
24 hours	154.5	09:00 hours on 20 August 2005	< 2	< 2
2 days	222.5	09:00 hours on 20 August 2005	< 2	< 2
4 days	272.5	09:00 hours on 20 August 2005	< 2	< 2
7 days	376.5	09:00 hours on 20 August 2005	2	2
15 days	438.5	09:00 hours on 20 August 2005	< 2	< 2
31 days	715.5	09:00 hours on 20 August 2005	3	2

Notes:
(1) Maximum rolling rainfall was calculated from 5-minute rainfall data.
(2) The nearest GEO raingauge to the landslide site is Raingauge No. N34 located at Sheung Shui Water Treatment Plant, Fu Tei Au Road at about 1200 m to the southeast of the landslide site.
(3) Return periods were derived from Table 3 of Lam & Leung (1994) (Column A refers) and using data of Raingauge No. N34 from Evans & Yu (2001) (Column B refers). The return periods obtained by data of Lam & Leung (1994) and Evans & Yu (2001) do not show a significant difference.
(4) The exact date and time of the landslide were not known. The landslide was assumed to occur at about 09:00 hour on 20 August 2005.

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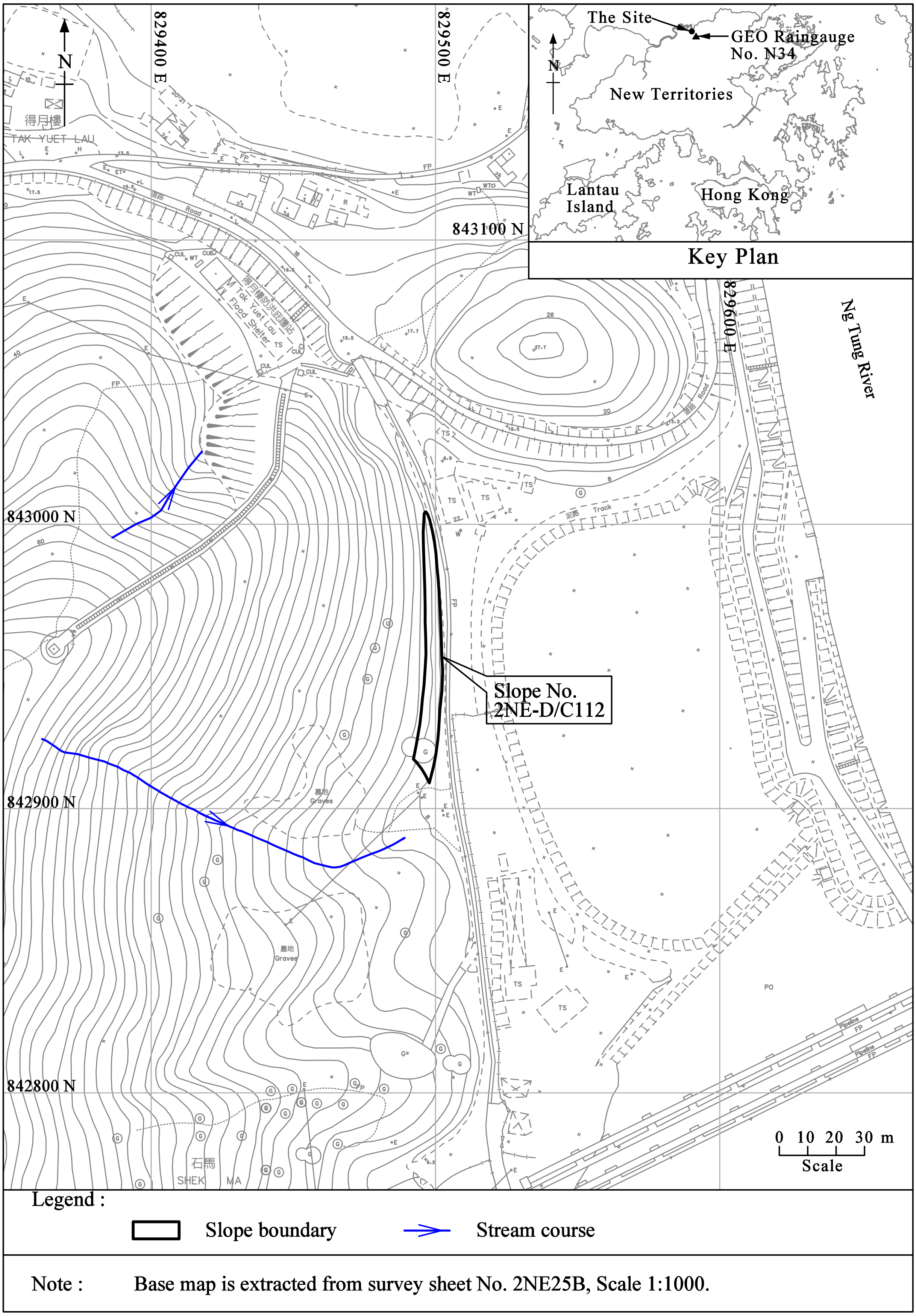

Figure 1 - Location Plan

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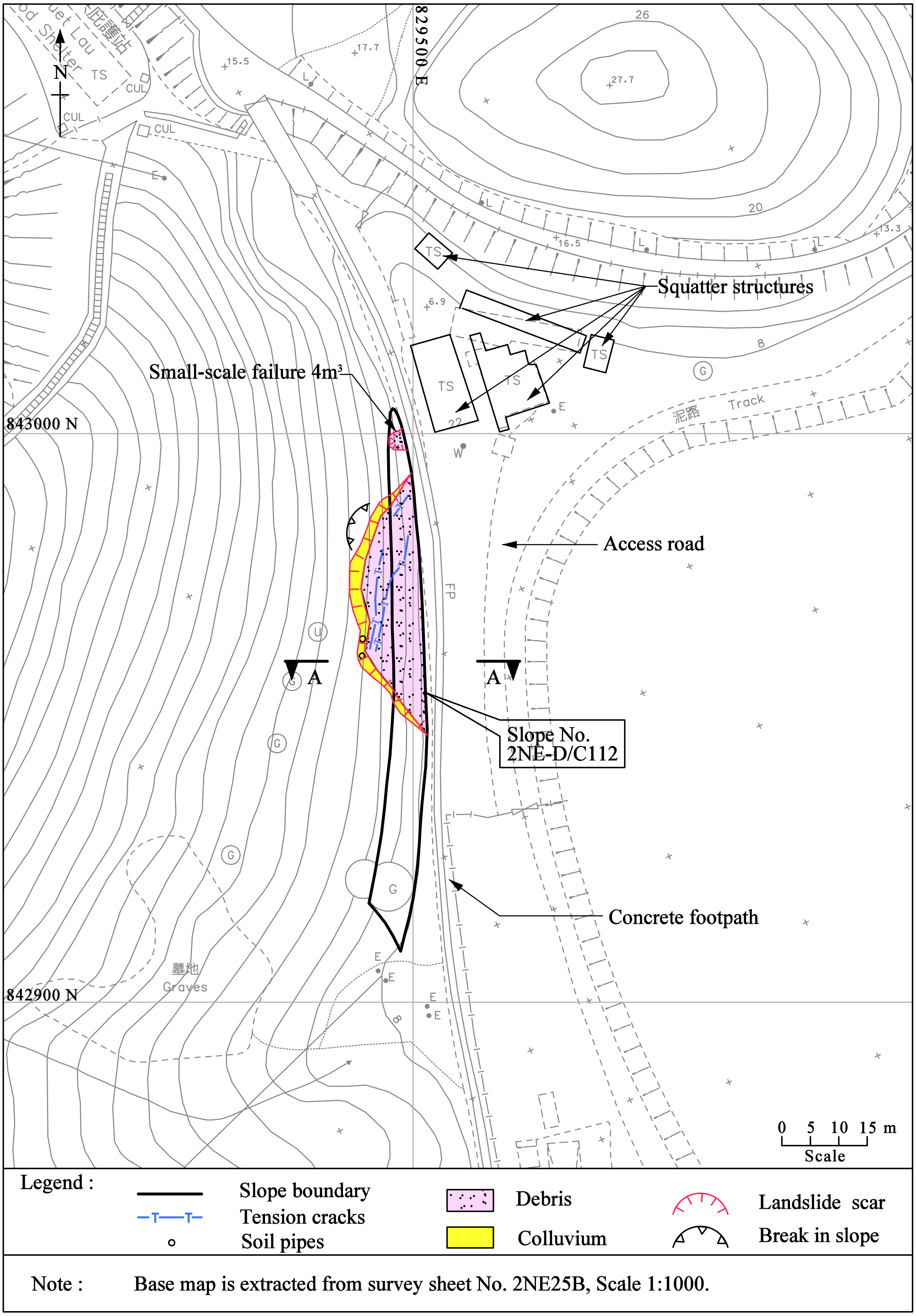

Figure 2 - Site Layout Plan

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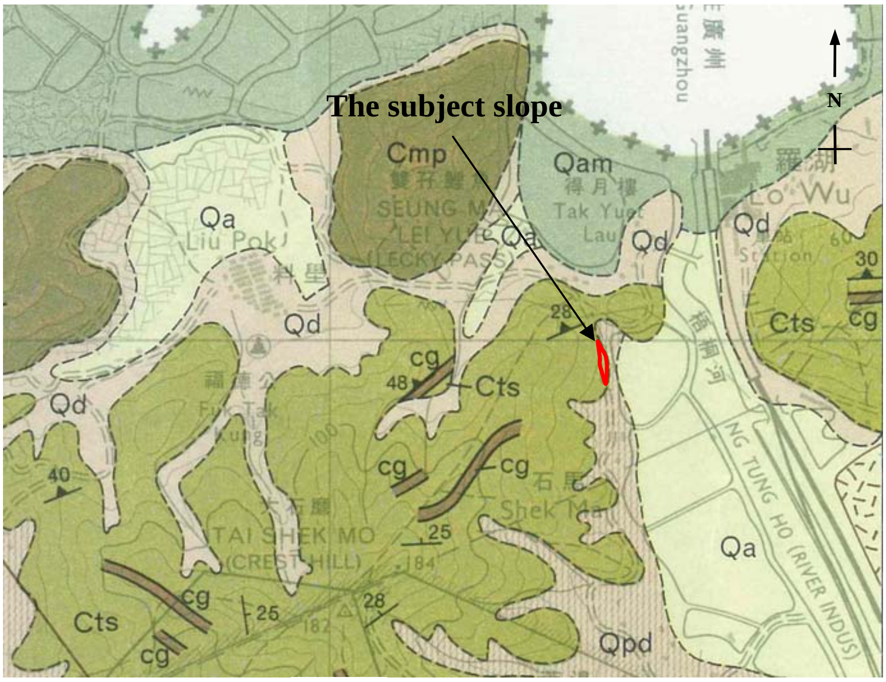

0 m 1000m

Scale

LEGEND:

SUPERFICIAL DEPOSITS

Fill	Fill	Qam	Estuarine deposits
Qa	Alluvium	Qpd	Debris flow deposits (Pleistocene)
Qd	Debris flow deposits (Holocene)		

SOLID GEOLOGY

(San Tin Group)

Cts	Metasandstone with metaconglomerate and phyllite (Tai Shek Mo Member)	cg	Metaconglomerate
Cmp	Phyllite, metasiltstone with metasandstone and graphite schist (Mai Po Member)		

GEOLOGICAL LINES

Geological boundary, superficial deposit

1982 Fill boundary, with limit of reclamation at date shown

* Geological boundary, solid rock (* Broken line denote uncertainty)

STRUCTURAL SYMBOLS

25 Bedding

40 Foliation

Note : Extracted from Hong Kong Geological Survey Map Series HGM20, Sheet No. 2, 1:20,000 scale (GCO, 1989).

Figure 3 – Regional Geology

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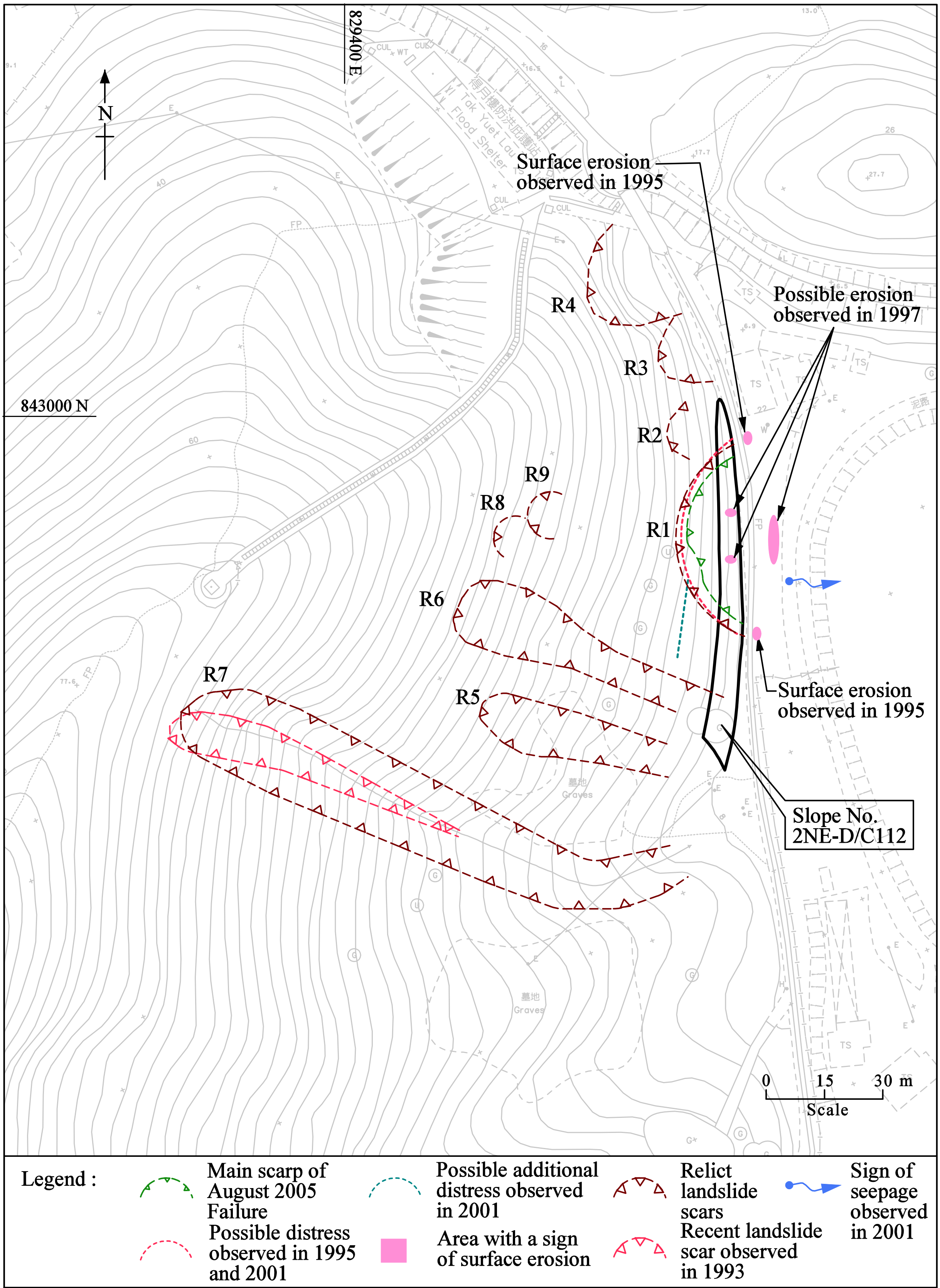

Note : Base map is extracted from survey sheet No. 2NE-25B, Scale 1:1000.

Figure 4 - Past Instabilities

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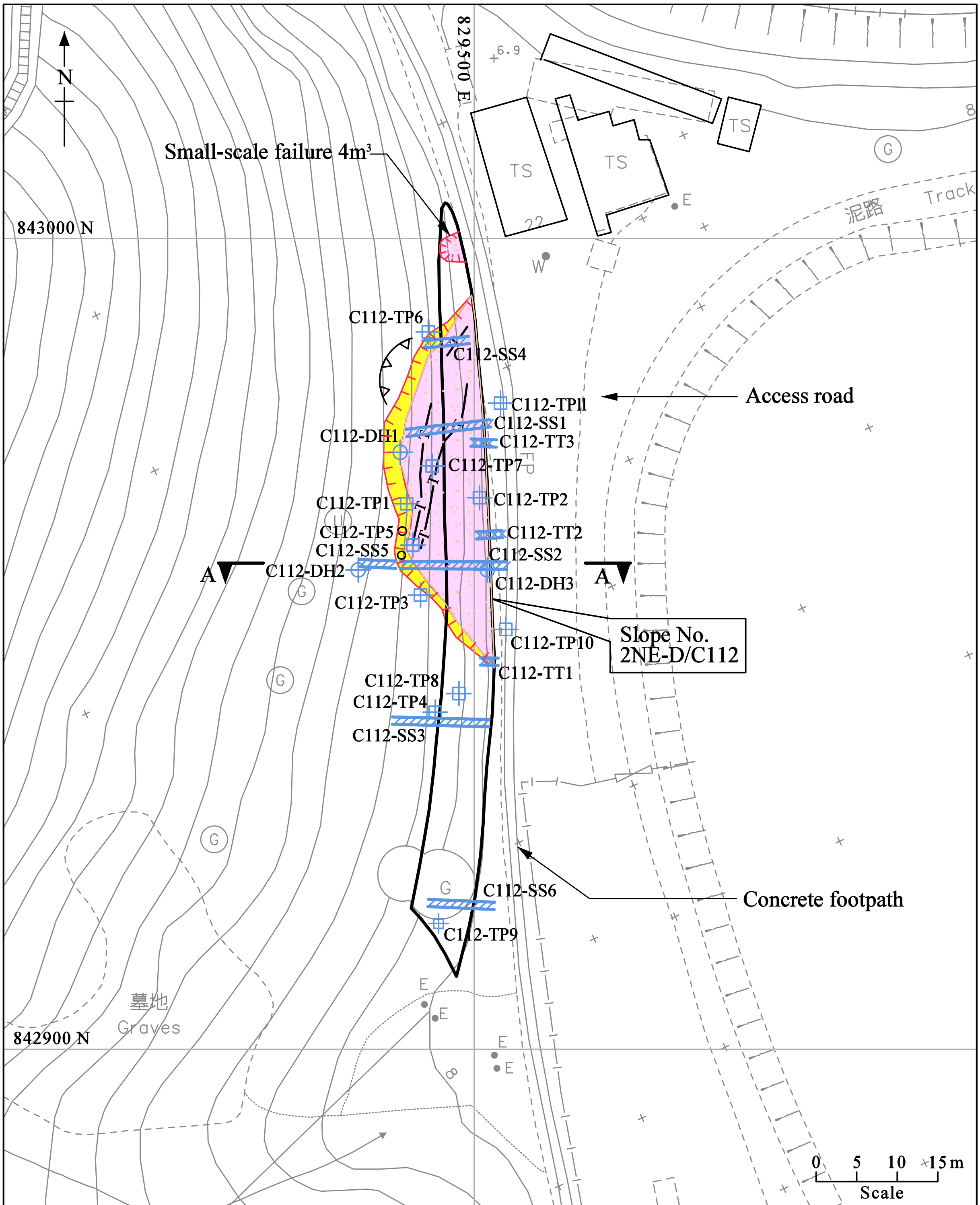

Legend : Slope boundary; Tension cracks; Colluvium exposed on landslide; Soil pipes; Landslide scar; Break in slope; C112-DH1 Drillhole with piezometers; C112-TP1 Trial pit; C112-TT1 Trial trench; C112-SS1 Slope stripping

Note : Base map is extracted from survey sheet No. 2NE25B, Scale 1:1000.

Figure 5 - Ground Investigation Layout Plan during Stage 3 Study

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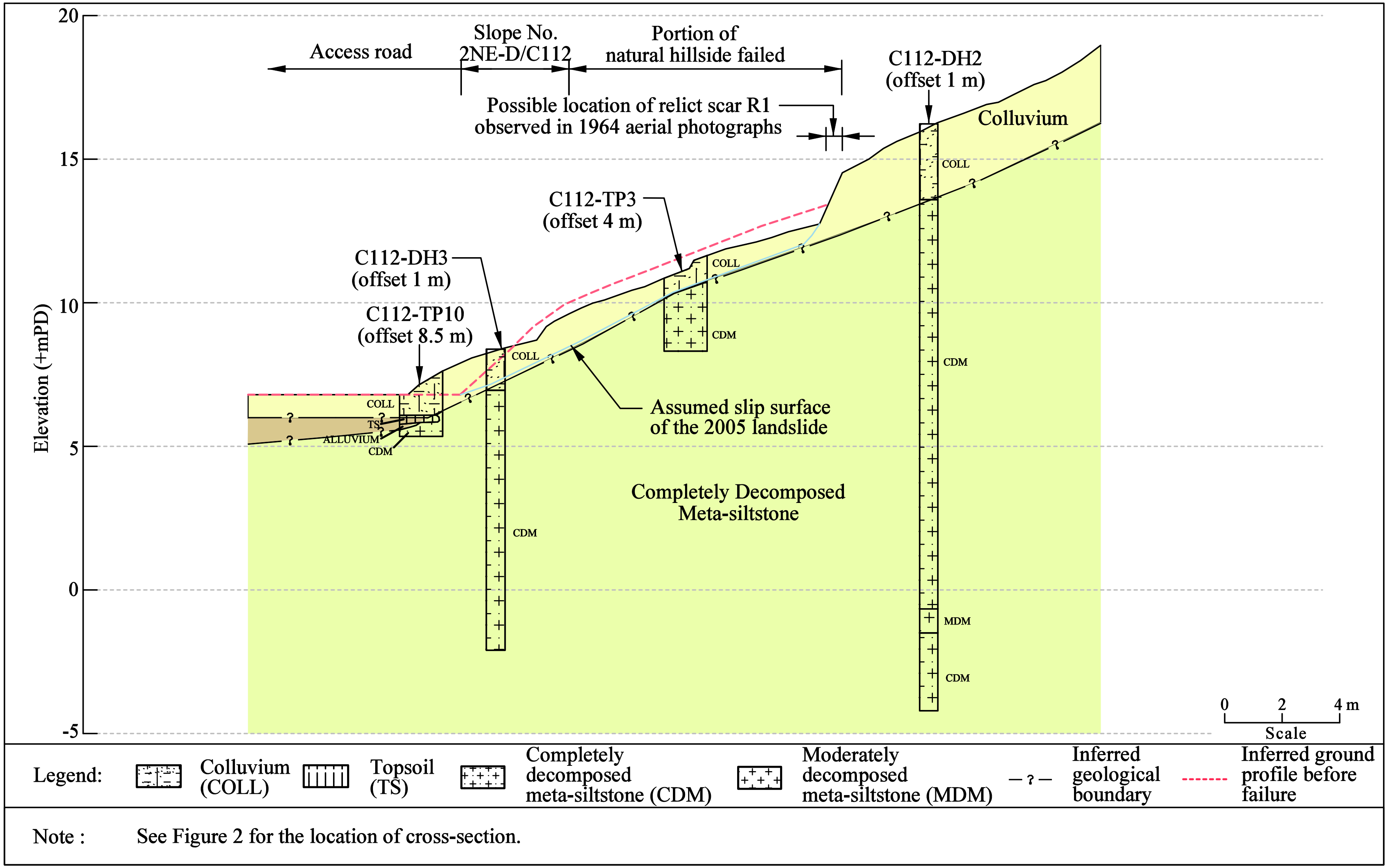

Figure 6 - Section A-A through the 2005 Landslide

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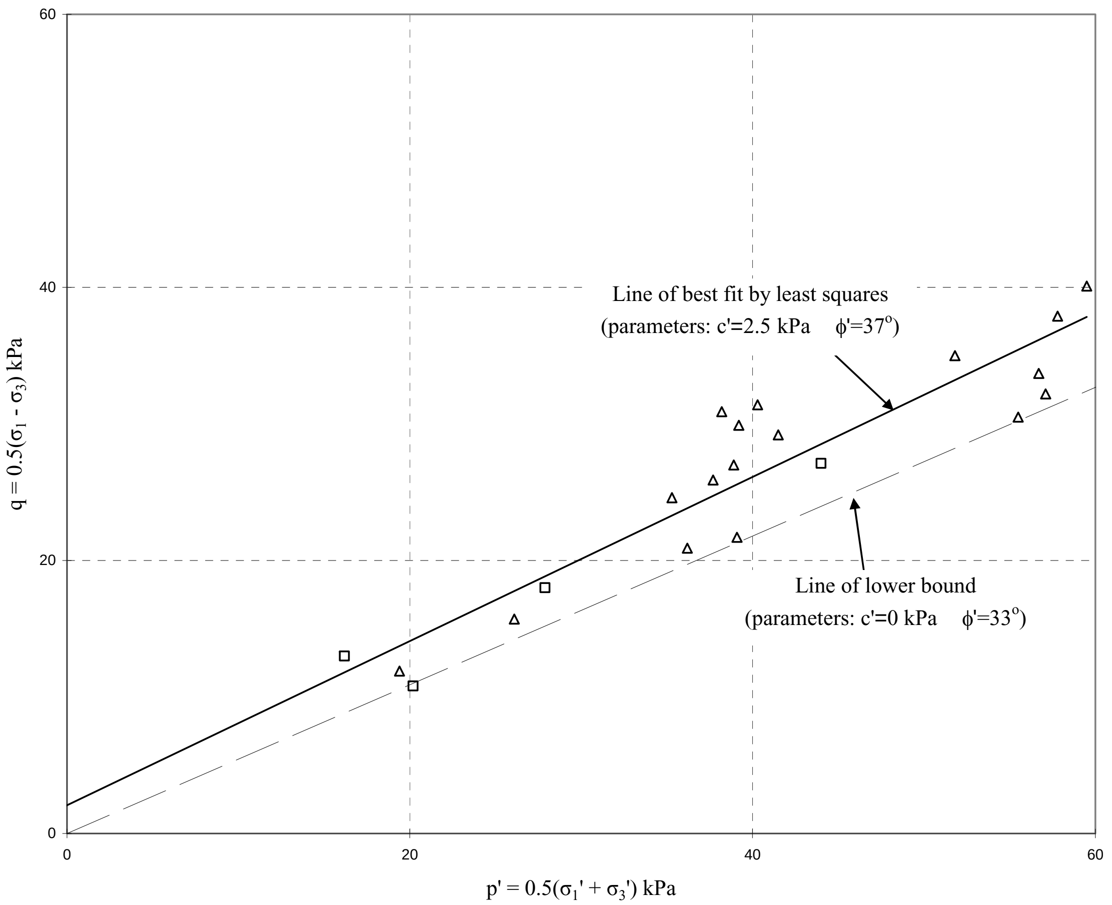

Legends:	□ Single-staged test	σ_1'	Major principal effective stress	c'	Cohesion
	△ Multi-staged test	σ_3'	Minor principal effective stress	ϕ'	Angle of shearing resistance

Notes: Triaxial compression test results correspond to those at the point of maximum deviator stress, σ_1'-σ_3' for single-staged test and maximum effective principal stress ratio, σ_1'/σ_3' for multi-staged test.

Figure 7 – Triaxial Compression Test Results for Colluvium

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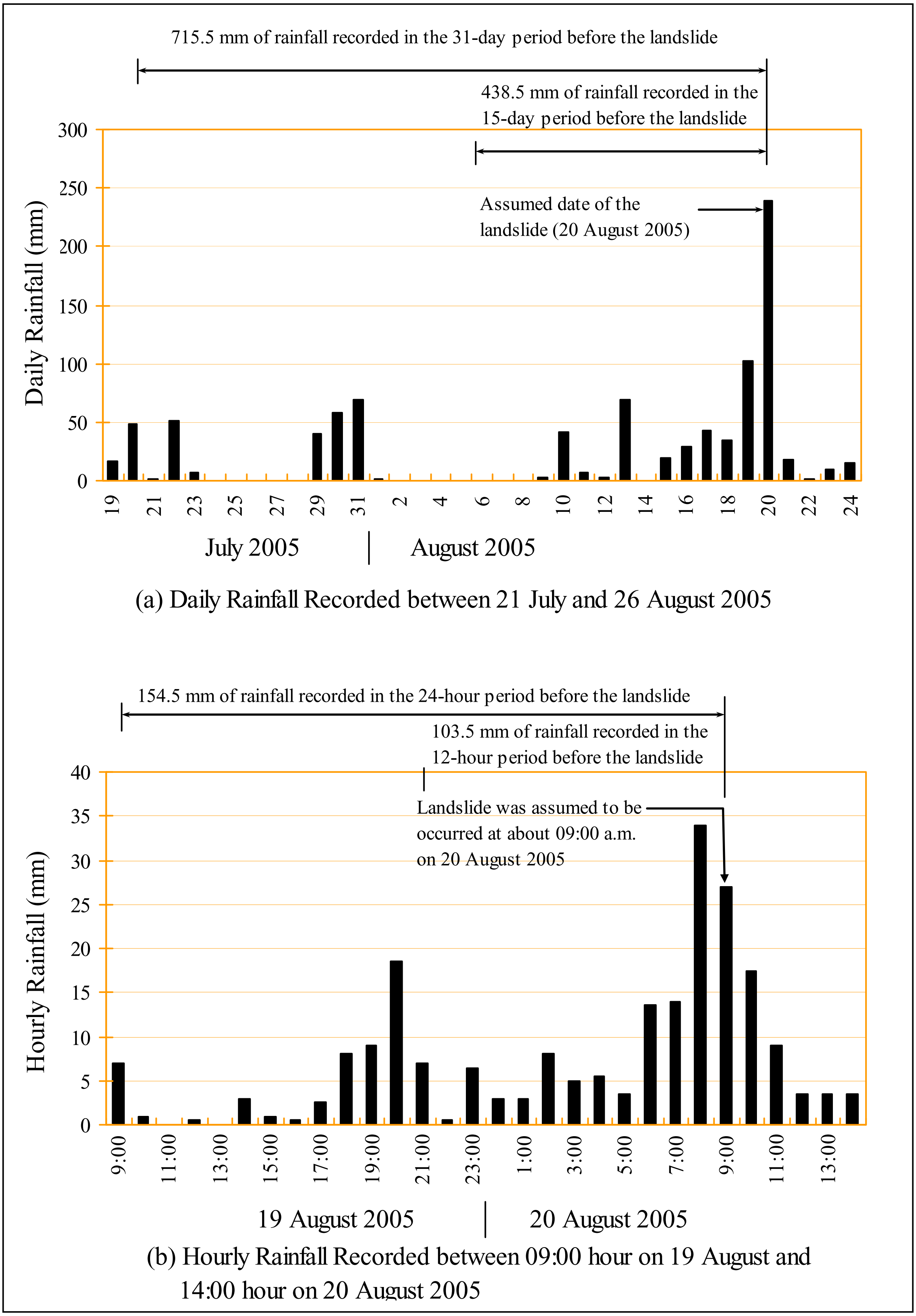

Figure 8 – Daily and Hourly Rainfall Recorded at GEO Raingauge No. N34

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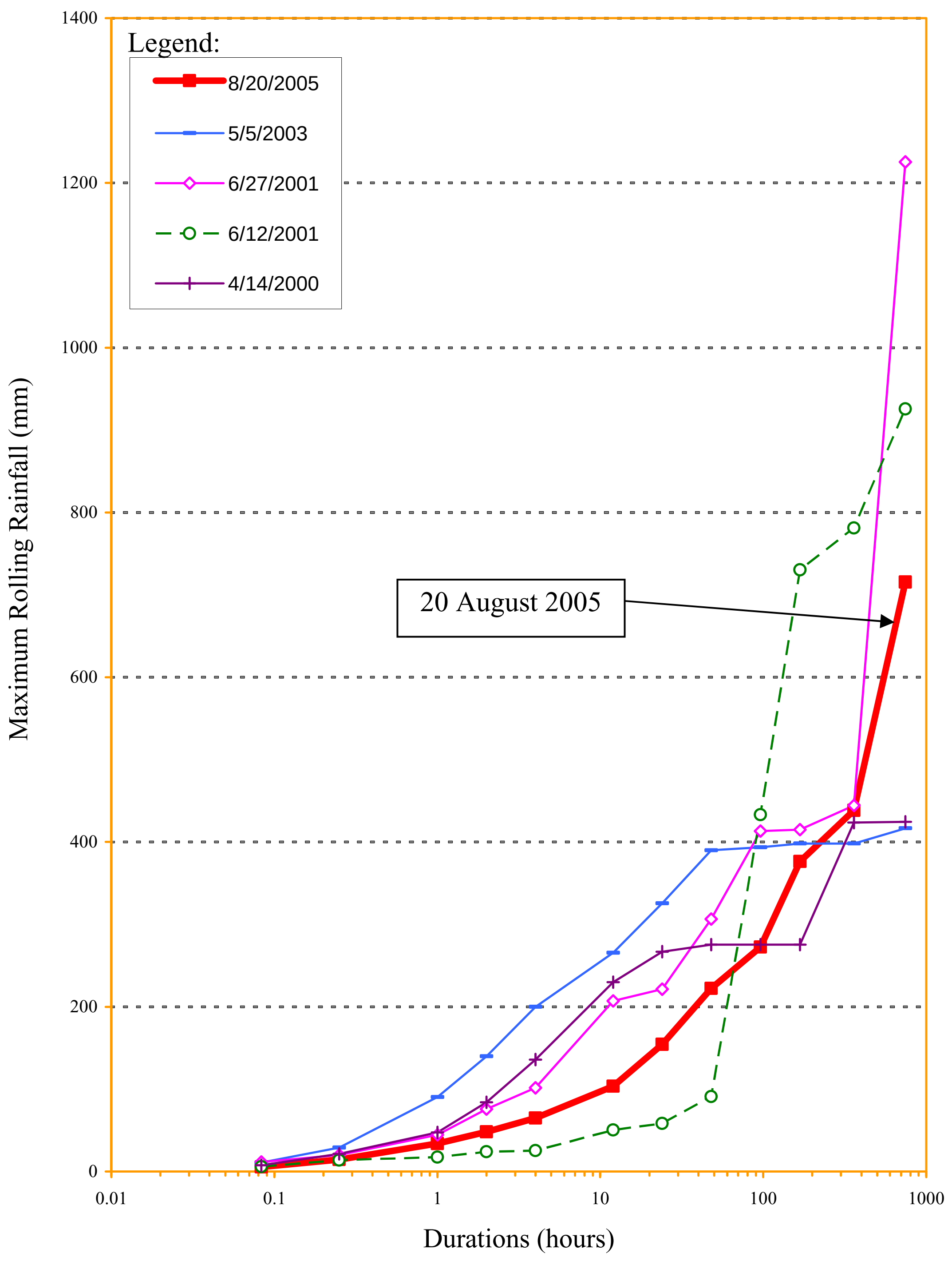

Note: Rainfall data are 5-minute statistics from GEO Raingauge No. N34.

Figure 9 – Maximum Rolling Rainfall for Previous Major Rainstorms at GEO Raingauge No. N34 between 2000 and 2005

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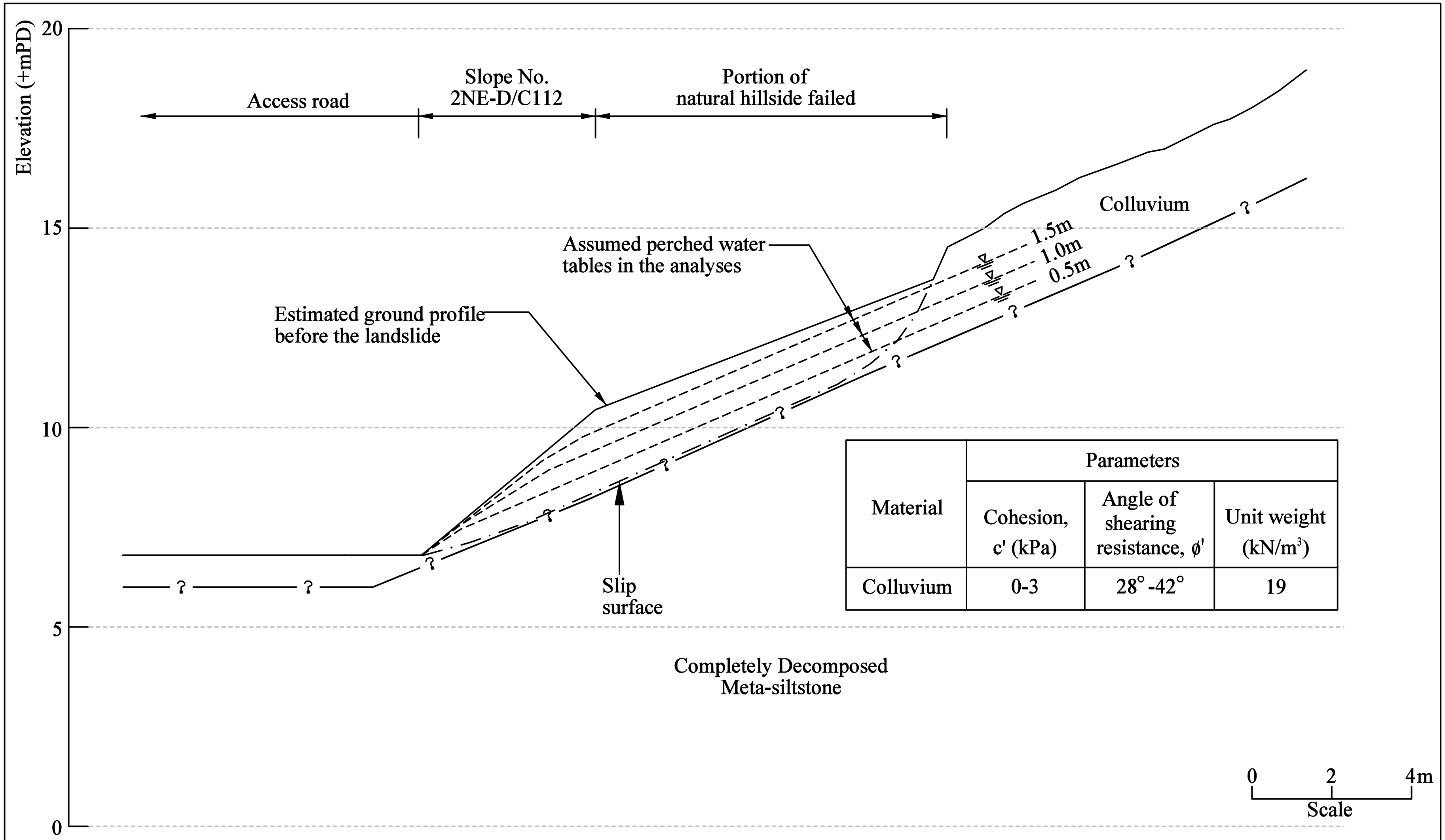

Material	Parameters		
	Cohesion, c' (kPa)	Angle of shearing resistance, ϕ'	Unit weight (kN/m^3)
Colluvium	0-3	28° -42°	19

Note : See Figure 2 for the location of cross-section.

Figure 10 - Representative Cross-section of the Landslide for Theoretical Stability Analyses

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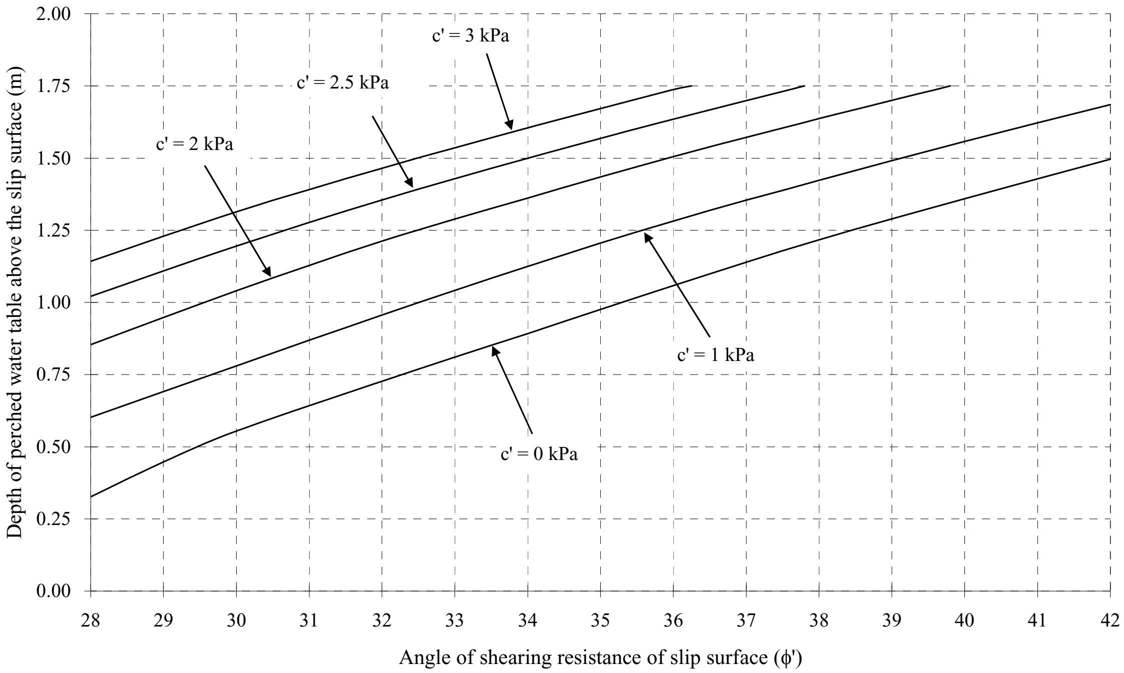

Legend:

——— Factor of safety equal to unity

Note: See Figure 2 for location of cross-section line.

Figure 11 - Results of Theoretical Stability Analyses

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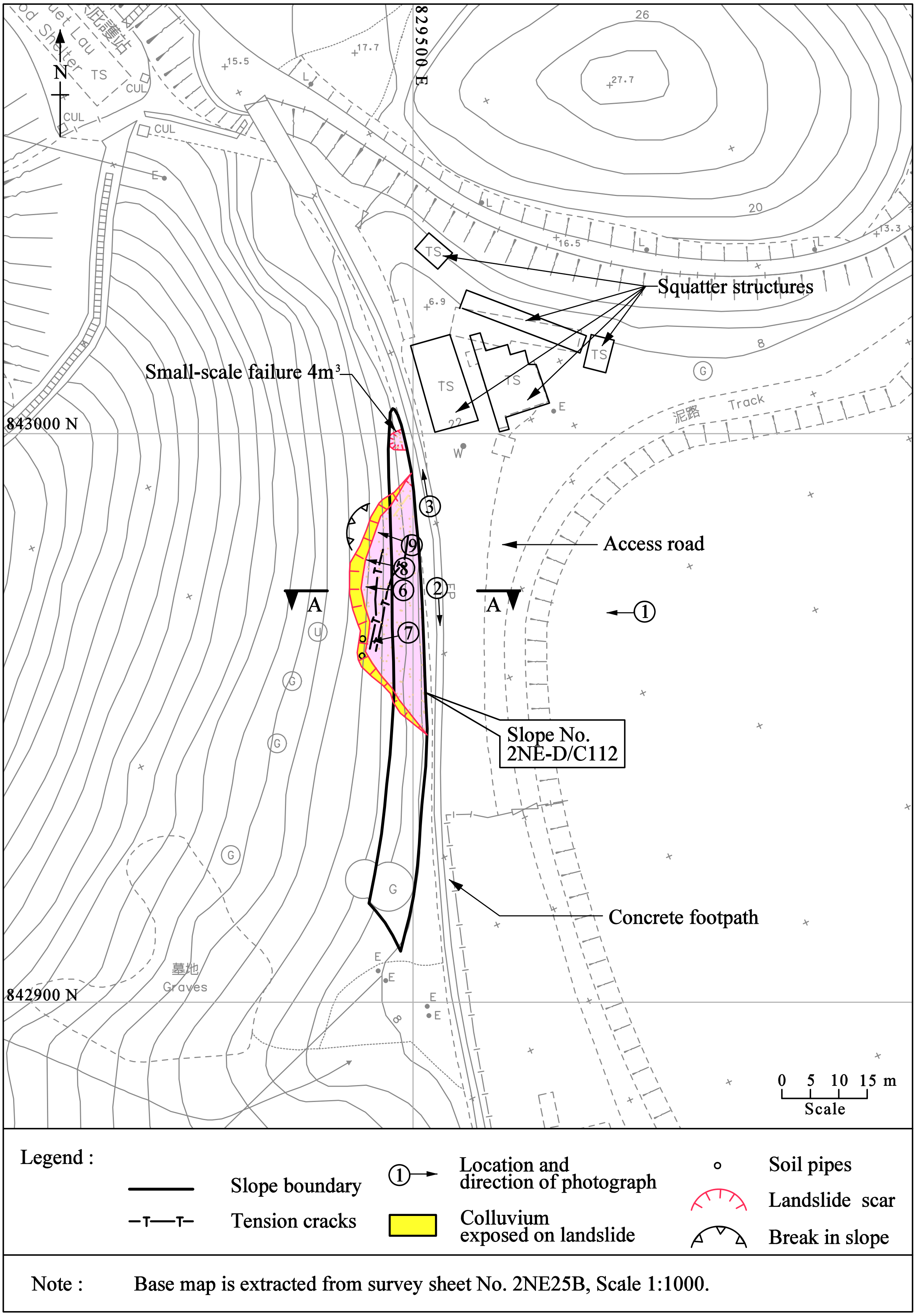

Figure 12 - Locations and Directions of Photographs Taken

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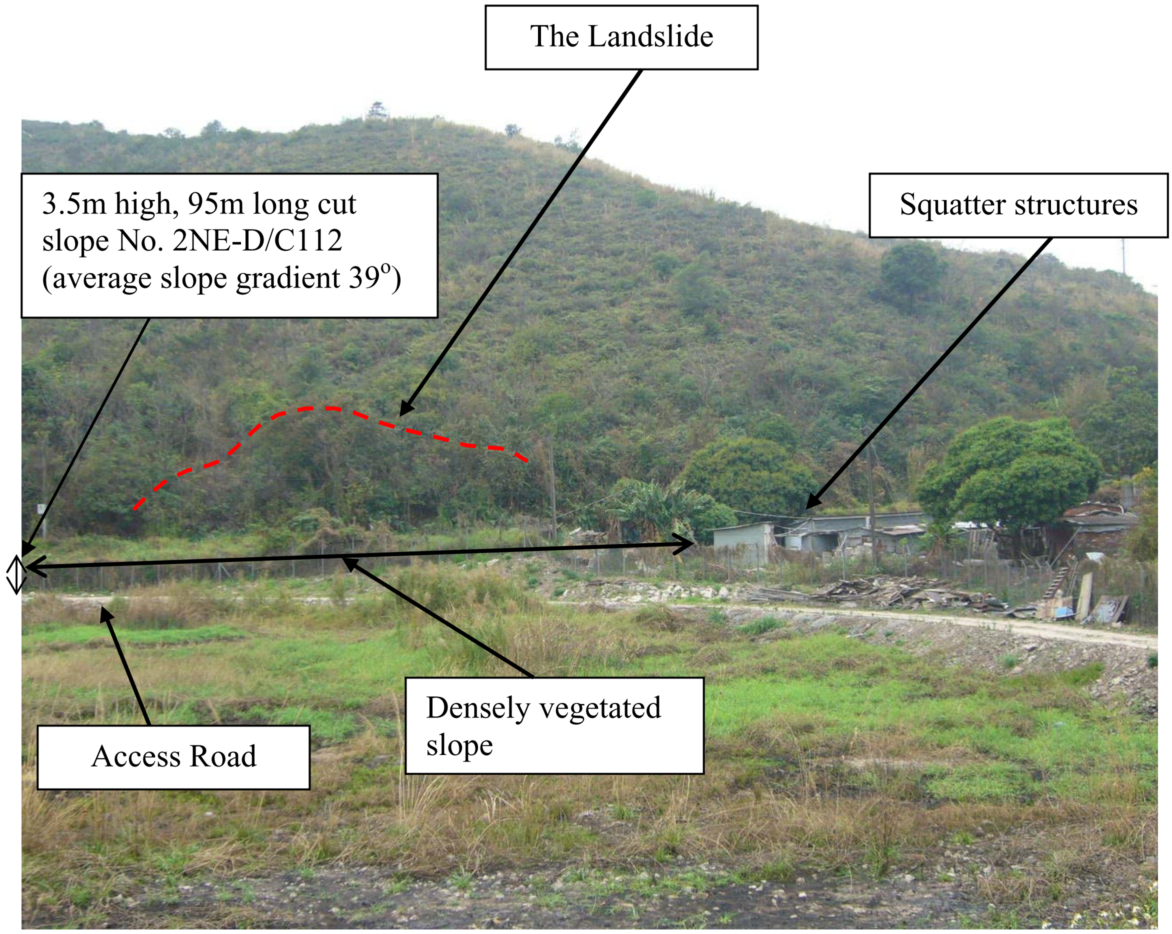

Plate 1 – General View of the Landslide Site

Note : See Figure 12 for Locations and Directions of Photographs Taken.

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Plate 2 – General View of the Slope No. 2NE-D/C112 (Looking South)

Note : See Figure 12 for Locations and Directions of Photographs Taken.

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Plate 3 – General View of Slope No. 2NE-D/C112 (Looking North)

Note : See Figure 12 for Locations and Directions of Photographs Taken.

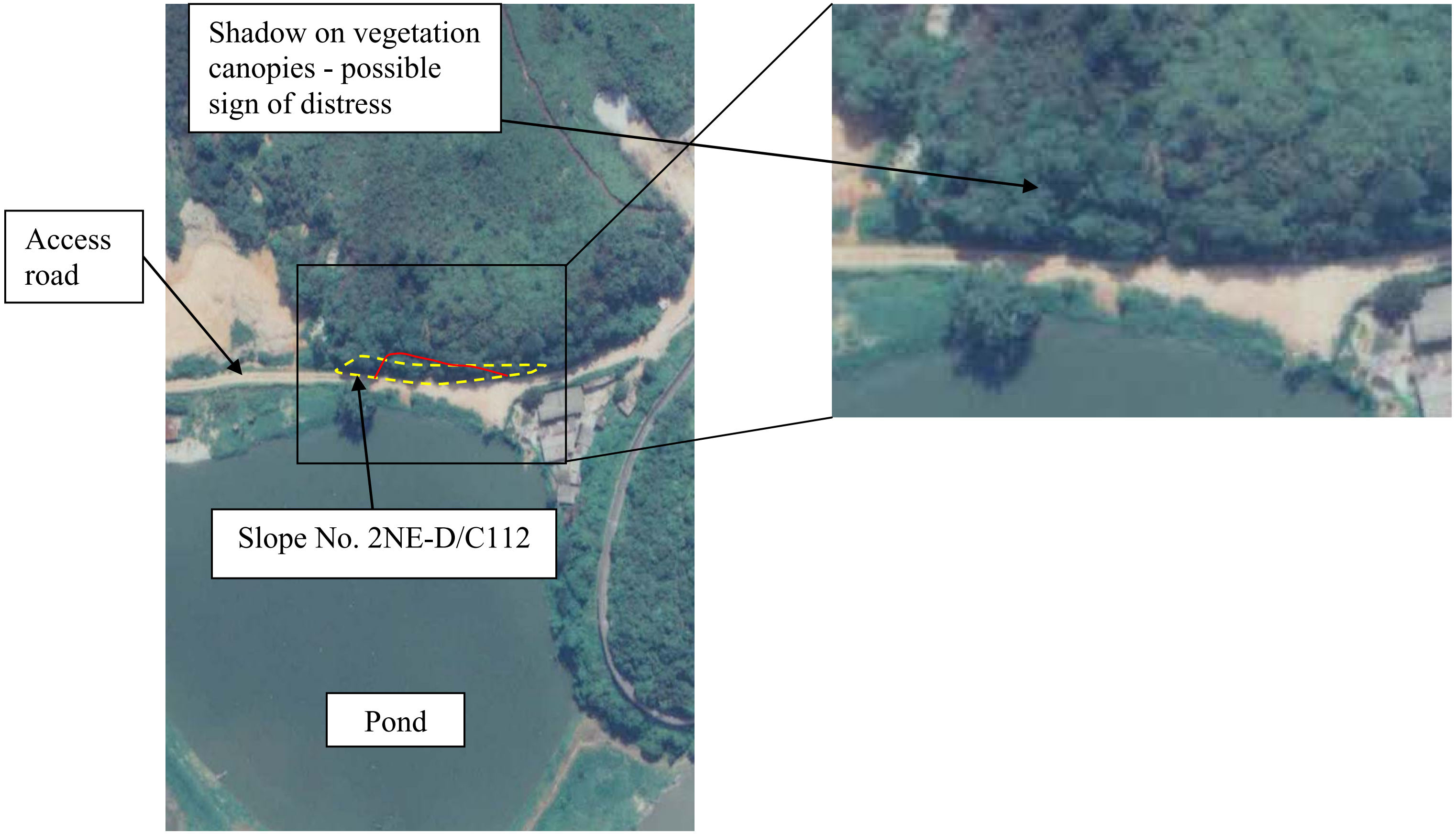

Plate 4 – Distress Observed in 1995 Aerial Photograph

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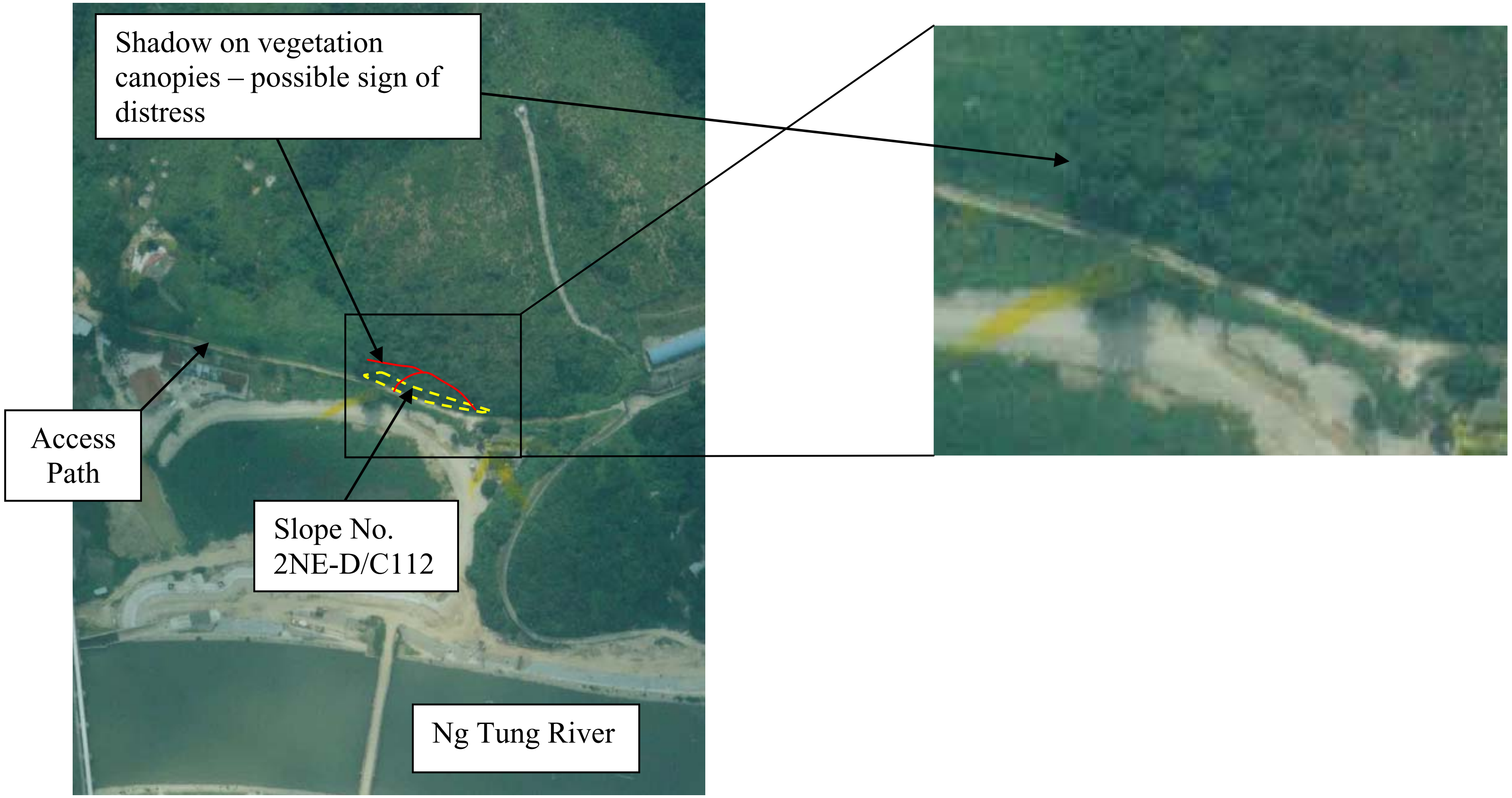

Plate 5 – Distress Observed in 2001 Aerial Photograph

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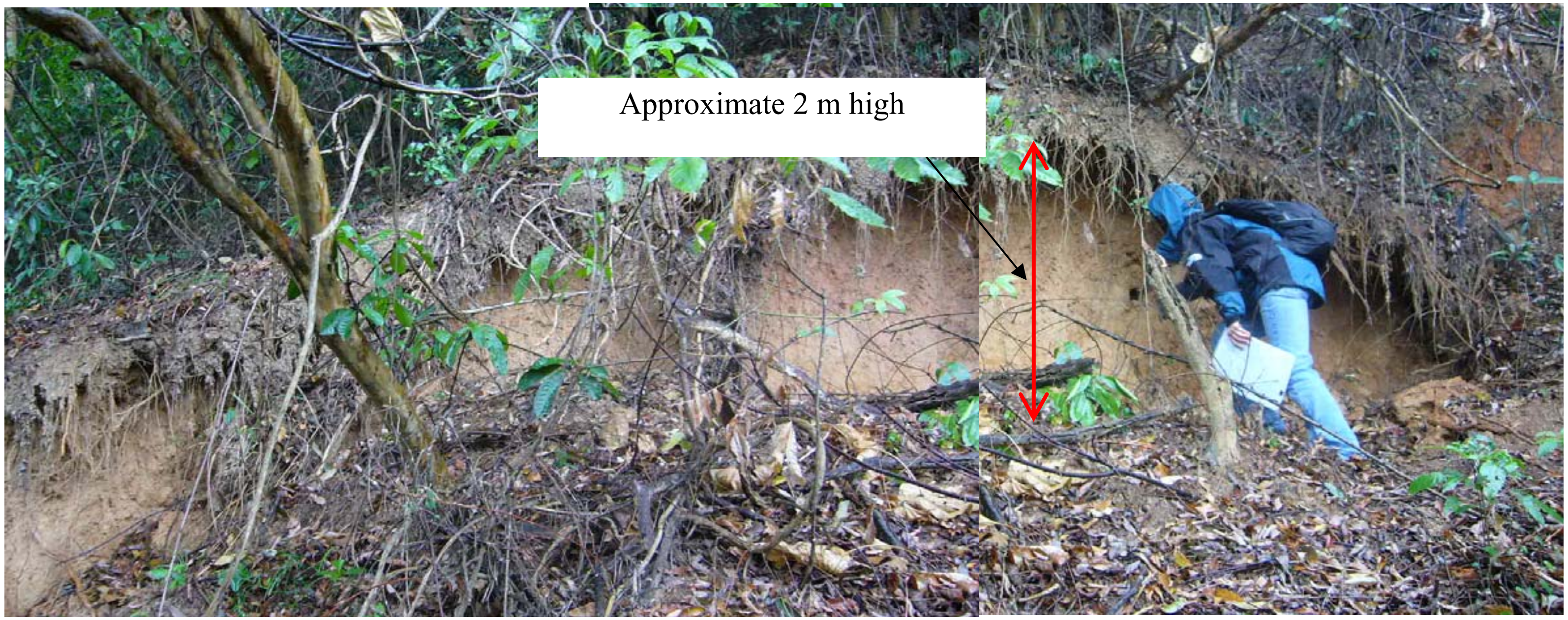

Plate 6 – View of the Soil Portion at the Main Scarp

Note : See Figure 12 for Locations and Directions of Photographs Taken.

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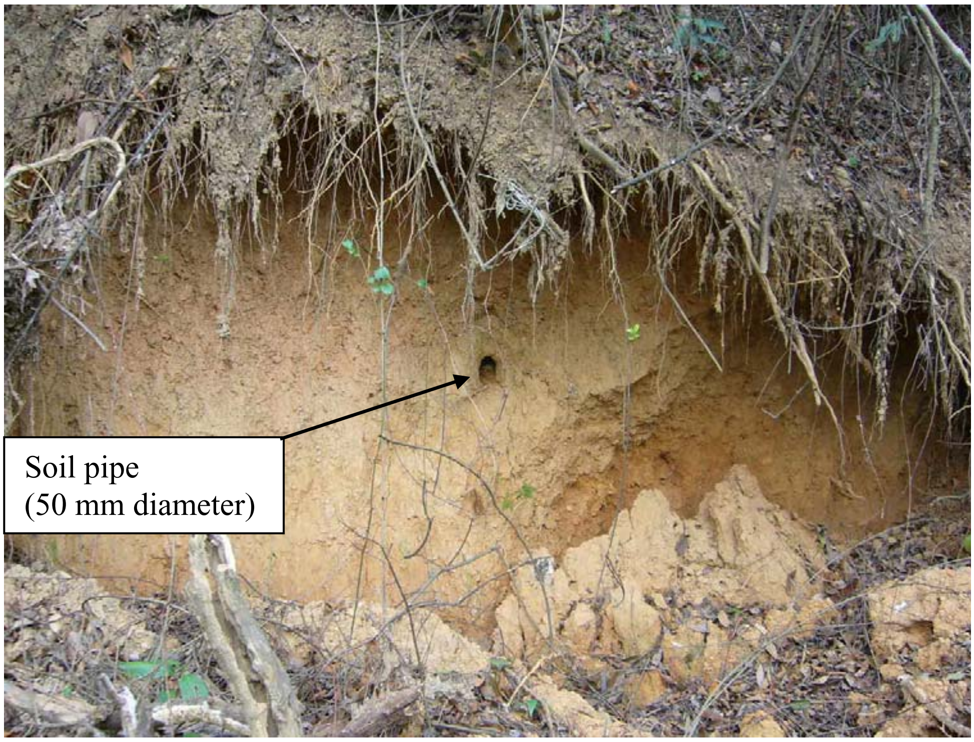

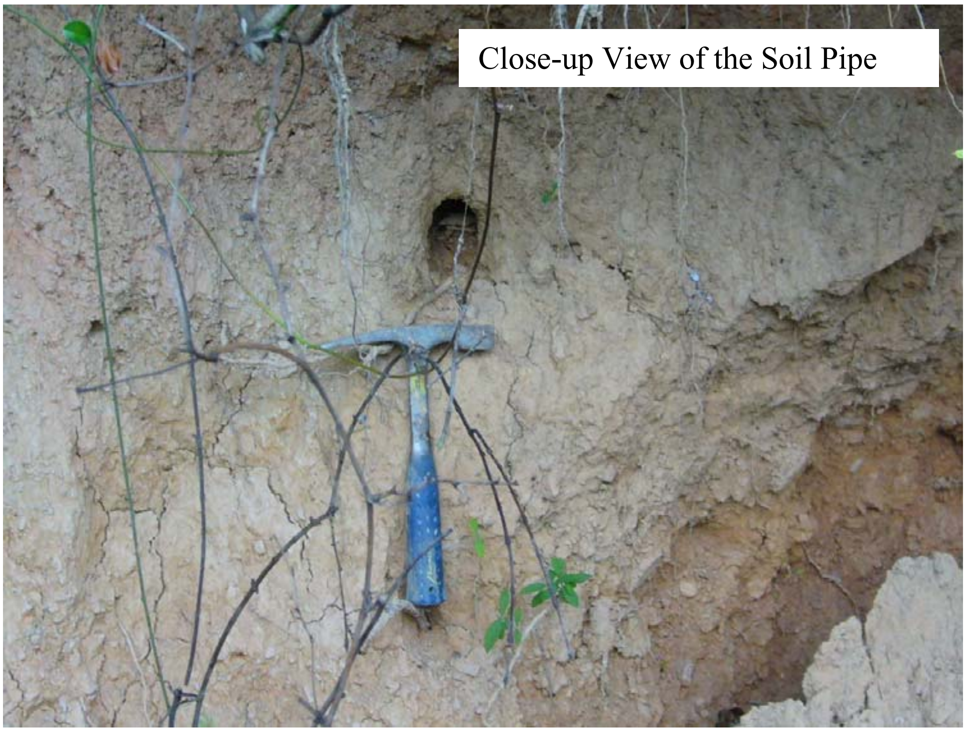

Plate 7 – View of Soil Pipe in Scarp within Colluvium

Note : See Figure 12 for Locations and Directions of Photographs Taken.

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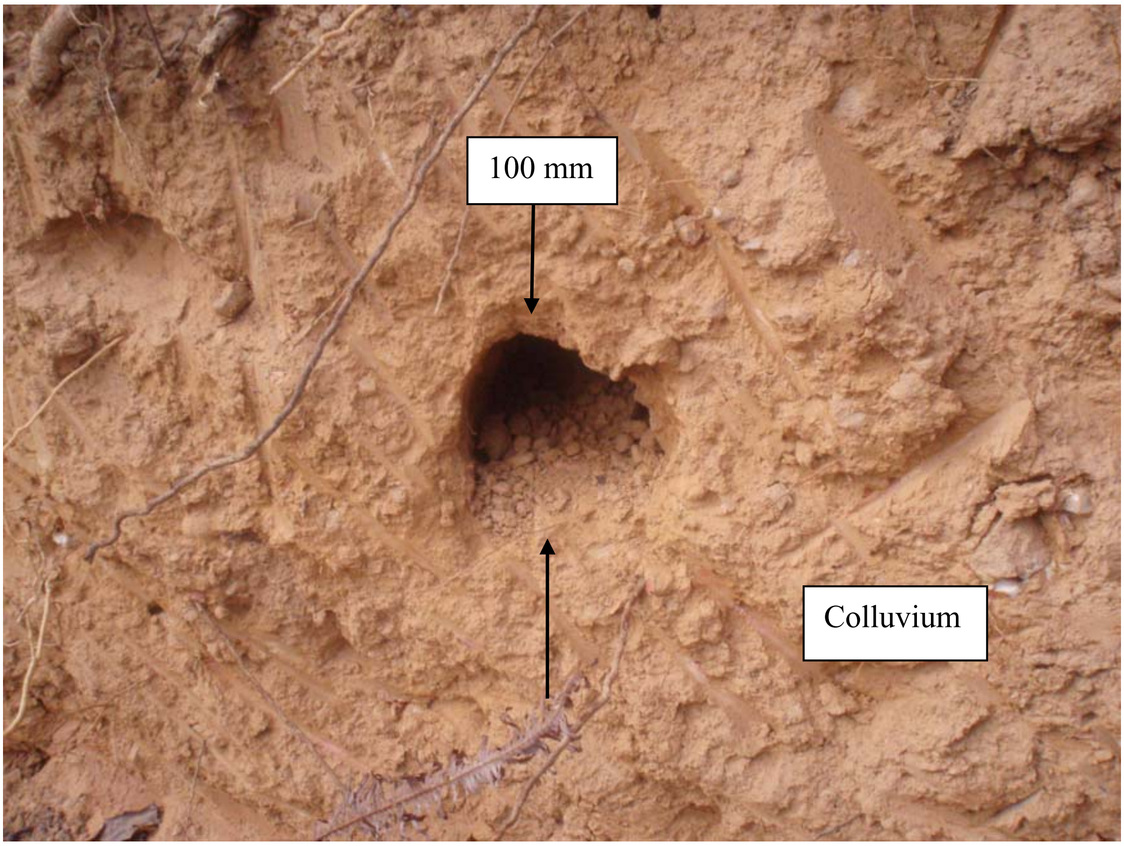

Plate 8 – Soil Pipe Observed in the Excavated Face of the Crest Channel during the LPM Works

Note : See Figure 12 for Locations and Directions of Photographs Taken.

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Plate 9 – Schistosity Observed at Slope Crest during Site Visit on 7 November 2007

Note : See Figure 12 for Locations and Directions of Photographs Taken.

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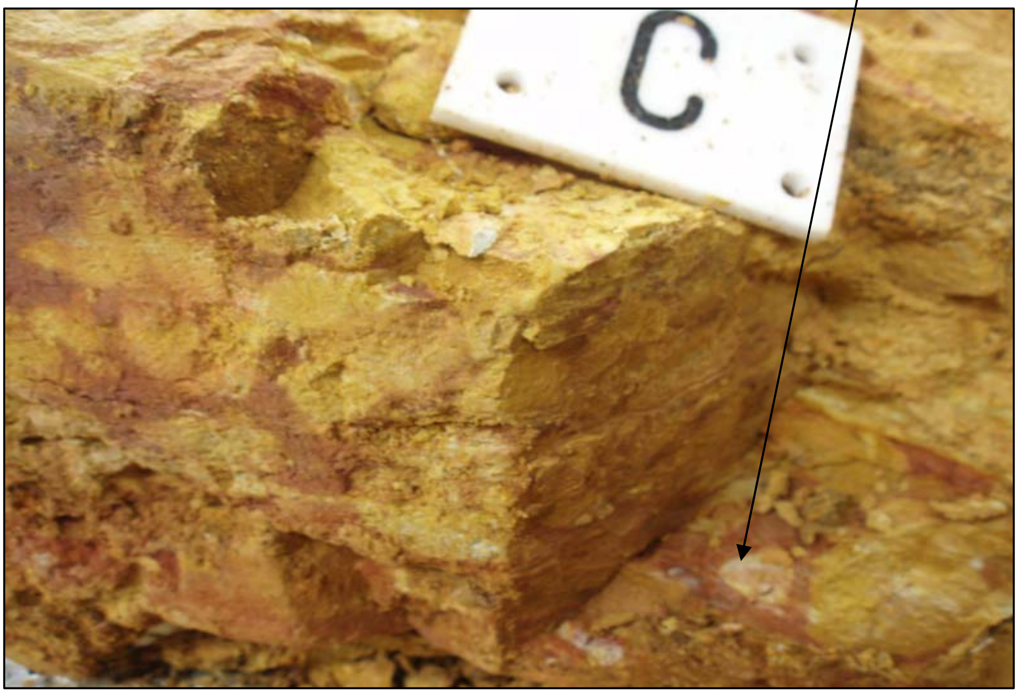
Schistosity dipping at 320º/15º



(Photographs taken on 7 Nov 2007)

Plate 10 - Schistosity Identified in Block Sample Taken in TP2 at Depth 2.7 m to 3.0 m (Sample Taken by Vibro (HK) Ltd. during LPM Study in 2006)

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APPENDIX A

AERIAL PHOTOGRAPH INTERPRETATION

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CONTENTS

A1. DETAILED OBSERVATIONS

The following report comprises the detailed observations made from the examination of aerial photographs taken between 1924 and 2006. A list of aerial photographs examined in this study is presented in Table A1 and the main observations of the API are shown in Figure A1 and Figure A2.

YEAR	**OBSERVATIONS**
1924	High altitude, single photograph of poor resolution. Slope No. 2NE-D/C112 appeared to be formed. The subject slope is located at toe of an east-facing hillside to the west of Ng Tung River. The subject slope is a cut feature possibly formed in association with the creation of the footpath. Surface of the slope could not be observed in detail but is believed to be covered by vegetation evidenced by its dark tones. The area below the subject slope is comprised of fields adjacent to the N-S meandering Ng Tung River. Above the subject slope is a sparsely vegetated hillside with occasional graves. An NE-SW trending ridge line is present west of the subject slope. A series of E-W trending drainage concentrations and spur lines are observed below the ridge line. A number of relict landslides and gully erosions are noticed on the hillside.
1964	High altitude and fair resolution. The subject area could not be observed in detail due to the high altitude photograph and possibly due to the steep slope angle. The access path located in front of the subject slope appeared to be traversing the toe of the hillside adjacent to an agricultural land. Degraded relict scars evidenced by subtle convex break-in-slope were observed on the hillside immediately above the subject slope. One of these scars is located on the subject cut slope at the same position as the August 2005 landslide. A section of the access path adjacent to this concave break-in-slope appeared to bend outward towards the river following the topography. Numerous stripes of paler tones running parallel to the contours are observed on the hillside above the subject slope. These could be due to the presence of footpaths or the remains of old terraces. No stereo coverage is available on the hillside to the south-west of the subject slope. Two hollows and linear depression evidenced by shadow could be observed in this area, which may be related to old landslides and/or drainage paths.

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YEAR	**OBSERVATIONS**
	The fields below the subject slope were partially abandoned.
1973	High altitude and high resolution. Photos not on the same flight line but managed to give stereoview on the area.
	No observable significant change to the subject slope. The two hollows observed in 1964 and another larger hollow further to the southwest could be observed clearly in these photos. The hollows appeared to be trending southeast-northwest and may be associated with structural weakness.
	A small high reflective spot could be observed on the hillside above the subject cut slope and is believed to be some kind of man-made structure, possibly a grave.
	The hillside below the small high reflectant appeared to have more tree growth. This may be related to the different geology, hydrology or possible effects of the presence of old terraces.
	The degraded relict scar located immediately above the subject cut slope observed in 1964 was not apparent, possibly due to the denser vegetation cover. The other three relict landslide scars further to the north were still evident, as seen by the arc-shaped convex break-in-slopes.
	To the south of the subject cut slope adjacent to the path, excavation work could be observed.
	The fields below the subject slope were modified to form a pond with a dike constructed around the pond. It was not certain whether dredging work had been carried out at bottom of pond. The portion of side slope of the pond below the subject slope may have been subjected to minor trimming.
1974	High altitude stereo pairs.
	No significant changes apart from denser grass on the hillside above the subject cut slope. Isolated small trees could also be observed close to the main access path at the toe of the hillside.
	Two graves could be observed at the southern end of the subject slope.
	The three hollows could still be visible on the hillside above the subject slope but with denser grass inside the hollows.
1975	High altitude and high resolution.
	No observable significant change to the subject slope.

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YEAR	**OBSERVATIONS**
	Two small bowl-shaped depressions, possibly evidence of degraded relict landslide scars could be observed on the hillside above the subject slope.
	A small area of pale tone could be observed on the hillside which is thought to be a man-made structure. A curvilinear feature with pale tone is observed above the small structure which is more likely to be a man-made feature.
	Ng Tung River was re-aligned; the section south of the subject feature was abandoned and a new straightened alignment formed to the east.
1976	High altitude and high resolution stereo pairs. Low altitude and high resolution, single photograph.
	No observable significant change to the subject slope
	A newly created footpath running parallel to contour could be observed above the subject cut slope. Linear shadows are apparent on the vegetated hillside above the main access path. The locations of these shadows appeared to be similar to the possible footpath/old terraces observed in 1964.
	The fields along the re-aligned section of Ng Tung River in 1975 were modified to a pond.
	Remnant of old footpath or old terraces is still evident on the hillside above the subject slope.
1978	High altitude and high resolution, single photographs.
	No observable significant change to the subject slope.
	A bund had been formed on the pond, about 250 m south of the subject slope. To the north, excavation and filling work was evident.
1981	High altitude and high resolution stereo pairs.
	No observable significant change to the subject slope and its surrounds apart from denser vegetation on the hillside. Cottages have been built on the area under excavation in 1978.
1982	High altitude and high resolution stereo pairs.
	No observable significant change to the subject slope and its surrounds. A fill platform was being created adjacent to the pond.

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YEAR	**OBSERVATIONS**
1983	High altitude and high resolution, stereo pairs and single photograph. No observable significant change to the subject slope. A pipeline had been constructed across the pond and Ng Tung River, about 150 m south of the subject slope.
1985	High altitude and high resolution, stereo pairs and single photograph. No observable significant change to the subject slope and its surrounds.
1986	High altitude and high resolution stereo pairs. No observable significant change to the subject slope. A bund had been formed on the pond, about 400 m south of the subject slope.
1987	High altitude and high resolution, single photographs. No observable significant change to the subject slope and its surrounds.
1988	High altitude and high resolution stereo pairs. No observable significant change to the subject slope and its surrounds.
1989	High altitude and high resolution, stereo pairs and single photograph. No observable significant change to the subject slope and its surrounds.
1990	High altitude and high resolution, single photograph. No observable significant change to the subject slope and its surrounds.
1991	High altitude and high resolution, single photographs. No observable significant change to the subject slope.
1992	High altitude stereo pairs and single photographs. No observable significant change to the subject slope and its surrounds.
1993	High altitude stereo pairs and single photographs. A landslide scar with a partially detached block was visible on a relict landslide scar near to the ridge line of the hillside above the subject slope. Tension crack could be observed behind the partially detached block.

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YEAR	OBSERVATIONS
	The hillside within about 50m from the subject slope appeared to be densely vegetated with trees.
	A pipeline was being constructed parallel to the existing pipeline identified in the 1983 aerial photographs.
1994	Low altitude stereo pairs. High altitude single photograph.
	No observable significant change to the subject slope.
	A landslide had occurred near the ridge line of the hillside northeast of the subject slope during the wet season of 1994. A partially detached block could be observed below the scar.
	The pipeline construction works observed in the 1993 aerial photographs was complete.
1995	Low altitude and high resolution stereo pairs.
	A curvilinear shadow on the tree canopies could be observed on the subject slope extending about 10-20 m above the slope crest. This curvilinear shadow may be associated with tilting of the trees, steps on the ground created by distress or could be the presence of a footpath.
	Two patches of bare soil are visible on the slope below the access path immediately in front of the subject slope, which may be associated with erosion or instabilities.
	A path had been constructed along the ridge line above the subject slope. Site formation of the area adjacent to the southern end of the slope was observed.
	A hillfire had occurred on the hillside southwest of the subject slope, with an estimated area of 30 km^2 affected. The landslide scar seen in the 1994 aerial photographs was exposed by the hillfire. Further movement of the partially detached block was noted.
1996	High altitude stereo pairs. Low altitude, single photographs.
	No observable significant change to the subject slope and its surrounds. The curvilinear feature observed in the tree canopy was not visible.
1997	High altitude stereo pairs.
	Patches of bare soil surface possibly caused by erosion or instability were visible on the subject slope surface and on the slope below the access path. The area affected by the 1995 hillfire was re-vegetated.

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YEAR	**OBSERVATIONS**
2000	Low altitude single photograph. No observable significant change to the subject slope. Decreased vegetation (mainly grass) density evident on the hillside, from the hilltop to about 50m west of the subject slope. The extent of the pond below the subject slope had been modified to its current shape. The Ng Tung River itself was outside the extent of the aerial photographs, but based on the observations from 2001 aerial photographs (described below), it is believed that the section of the Ng Tung River below the subject feature was being re-aligned. The two landslide scars observed in the 1993 and 1994 aerial photographs were covered by vegetation.
2001	High altitude and low altitude stereo pairs. The curvilinear shadow in the tree canopy observed in 1995 was visible again, with an additional linear shadow extending further south. This additional linear shadow may be evidence of further distress occurred on the hillside. Fill had been placed along the dike around the pond, possibly associated with improvement works for the Ng Tung River. Evidence of seepage was visible on the new fill slope below the access path immediately below the subject slope. The Ng Tung River had been re-aligned to its current shape. Temporary access was observed across the re-aligned river A hillfire had occurred between late September 2001 and mid-November 2001 at the hillside southwest of the feature. The scale and extent of the hillfire was similar to the 1995 hillfire. Relict landslide scars identified in the 1924 and 1964 aerial photographs within the affected area were visible in the aerial photographs.
2002	Low altitude stereo pairs and single photograph. No observable significant change to the subject slope. The possible failure observed at the subject slope in 2001 was still evident, as seen by the curvilinear shadow. Decrease in density of trees was noted between May and August 2002. The tension crack observed in the 1993 aerial photographs was clearly visible within the area affected by the 2001 hillfire, the tension crack was covered by sparse vegetation.

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YEAR	OBSERVATIONS
	The temporary access across Rover Indus observed in the 2001 aerial photographs had been removed.
2003	High altitude stereo pairs.
	No observable significant change to the subject slope and its surrounds since 2001.
2004	Low altitude and high resolution stereo pairs.
	No observable significant change to the subject slope.
2005	Low altitude and infra-red stereo pairs.
	No observable significant change to the subject slope and its surrounds since 2001.
2006	Low altitude and fair resolution stereo pairs.
	No observable significant change to the subject slope.
	Area affected by the 2001 hillfire was re-vegetated.

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Table A1 - List of Aerial Photographs

Date of photos taken	Altitude (ft)	Photograph Number
1924	12,500	Y00167
13 December1964	12,500	Y13114
14 December1964	12,500	Y13067
20 December 1973	12,500	7843(R), 7857, 7867
25 November 1974	12,500	10016 – 10017
24 December 1975	12,500	11872, 11876, 11904 – 11905
23 November 1976	12,500	16332 – 16333
24 November 1976	2,500	16687
15 December 1978	12,500	24461, 24490
27 October 1981	10,000	39333 – 39334
10 October 1982	10,000	44763 – 44764
24 January 1983	20,000	47013 – 47014
22 December 1983	10,000	52328 R
7 July 1985	10,000	A01864
4 October 1985	15,000	A02826 – A02828
21 December 1986	10,000	A07942 R – A07943 R
5 January 1987	20,000	A08486 R, A08521 R
6 March 1988	20,000	A13285 – A18286
3 November 1988	10,000	A14963, A14991 – A14992
13 November 1989	10,000	A19106
30 November 1989	20,000	A19822 – A19823
4 December 1990	20,000	A24475 R
19 October 1991	10,000	A28205 R, A28258 R
13 December 1991	20,000	A29601 R
11 November 1992	10,000	A33017 R
17 December 1992	20,000	A33660 R, A33667 R – A33668 R
4 October 1993	20,000	CN4501 R
6 December 1993	10,000	CN5504 R, CN5445 R – CN5446 R

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Date of photos taken	Altitude (ft)	Photograph Number
24 March 1994	10,000	CN6240 R
7 November 1994	4,000	CN8897 R – CN8898 R
20 July 1995	3,000	CN10465 R – CN10466 R
17 September 1996	5,000	CN15025 R
29 October 1996	3,500	A43357 R
9 November 1996	10,000	CN16002 R – CN16003 R
30 July 1997	Unknown	CN17784 R – CN17785 R
9 August 2000	3,000	CN27666
24 September 2001	4,000	CW34108 R – CW34109 R
19 November 2001	8,000	CW35153 R – CW35154 R
15 August 2002	4,000	CW42670 R
25 September 2003	8,000	CW49436 R – CW49437 R
17 December 2004	4,000	CW63075 R
6 March 2005	6,000	RW05560 R – RW05561 R
10 February 2006	4,000	CW71004 R – CW71005 R
Note: All aerial photographs are in black and white except for those prefixed with CN, CW or RW.		

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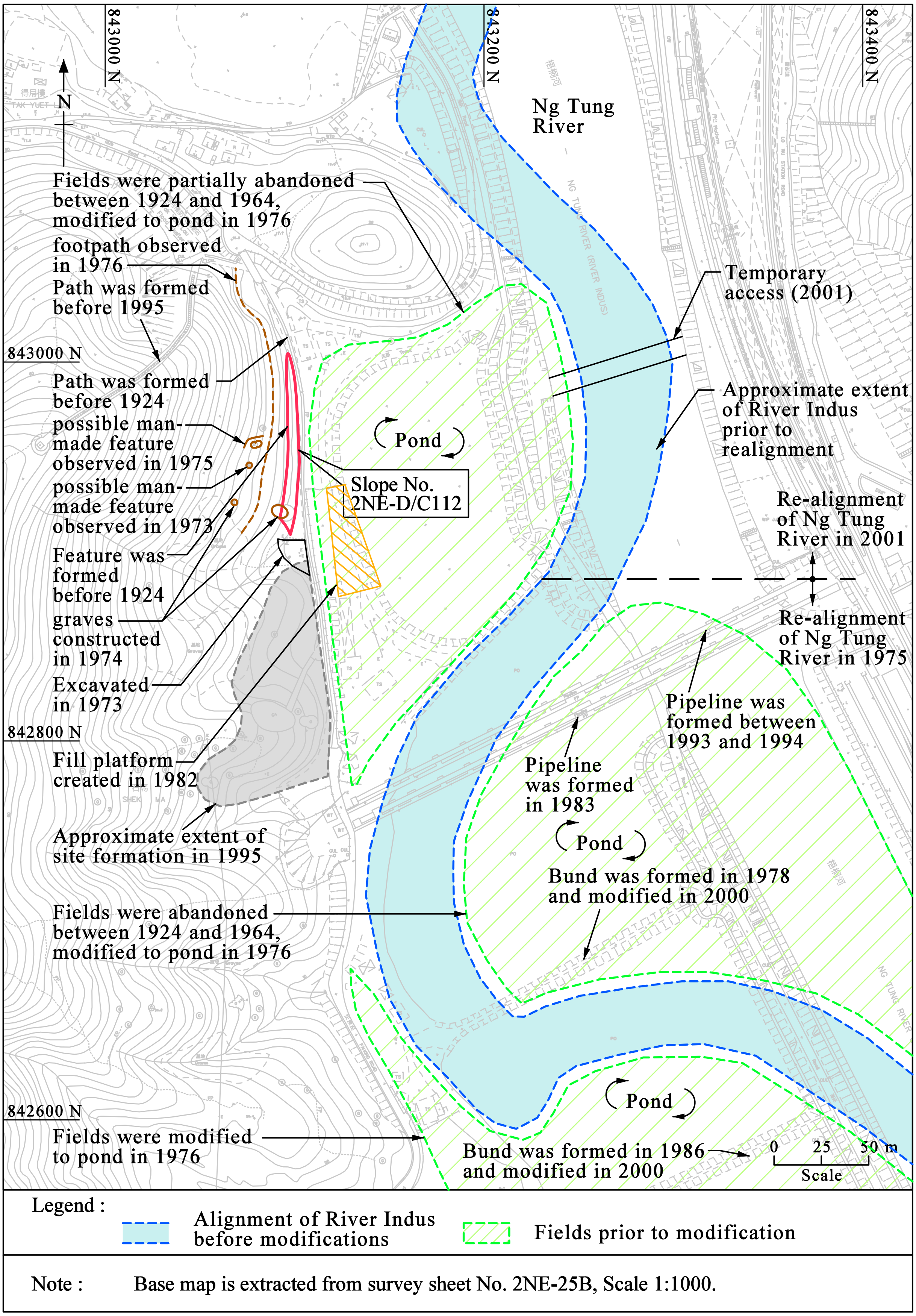

Figure A1 - Site Development History

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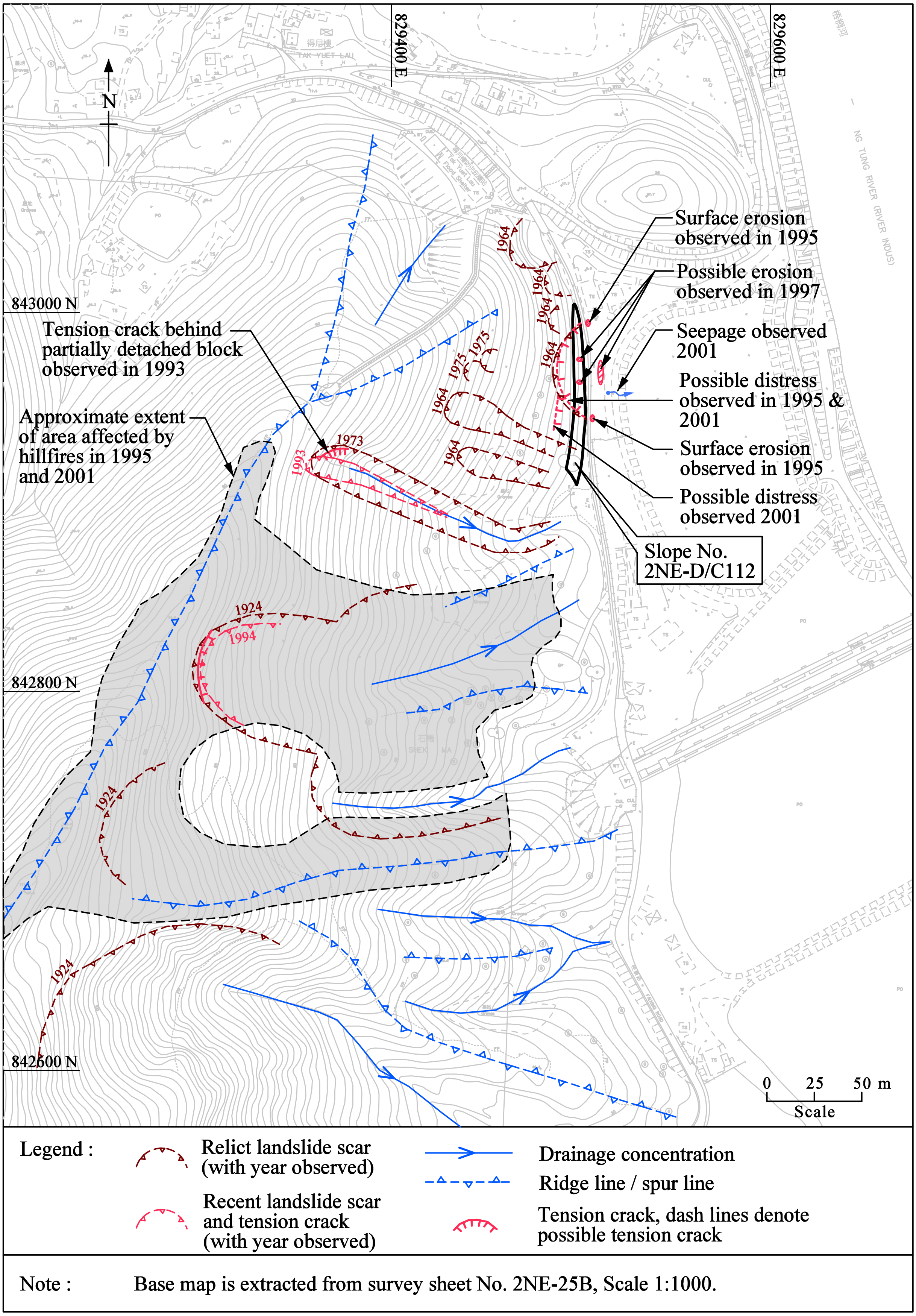

Figure A2 - API Findings

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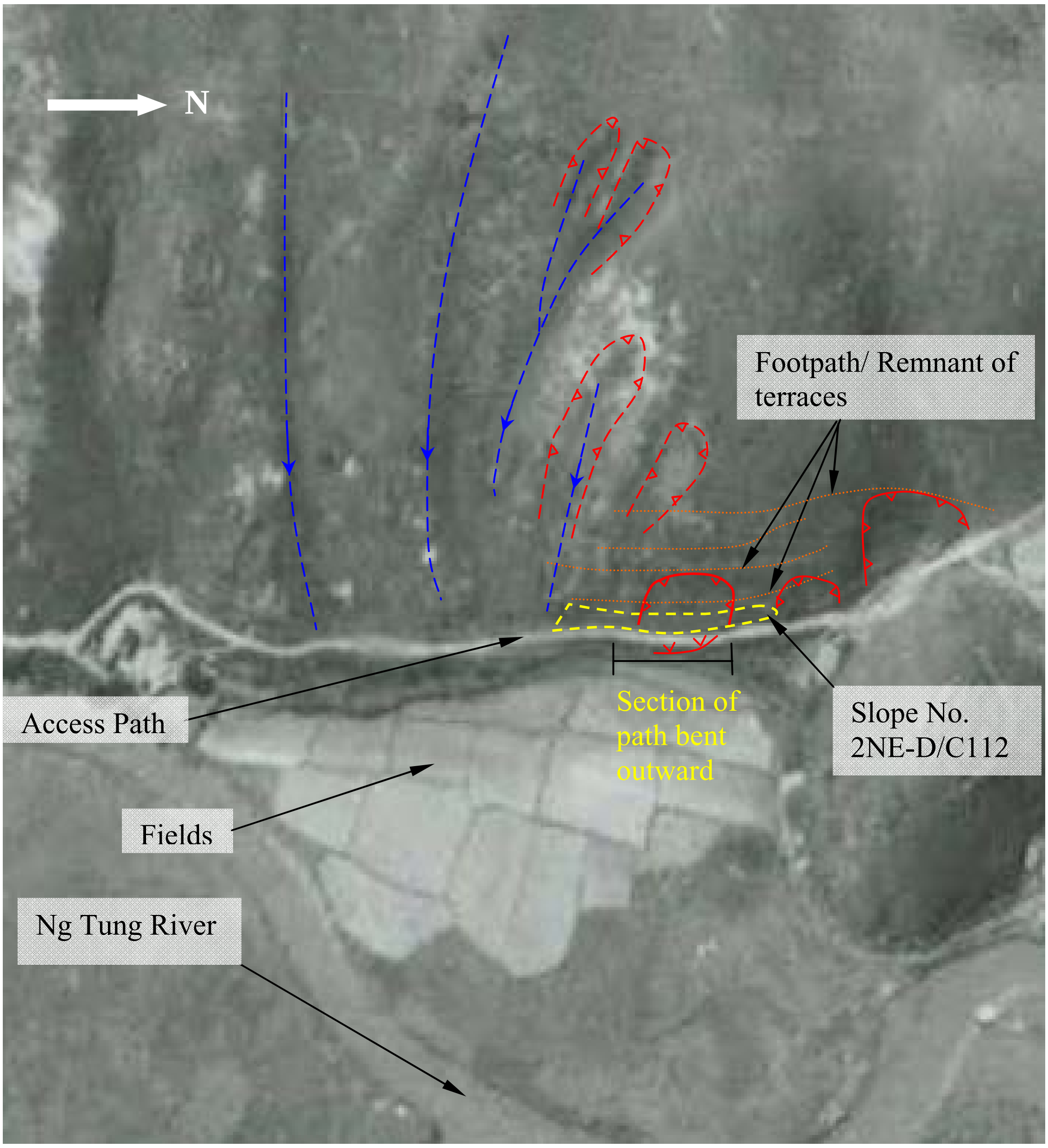

(Photograph Y13067 taken in 1964)

Legend:

Possible drainage concentration

Relict landslide scar

Possible relict scar (no stereo coverage)

Concave break-in-slope

Plate A1 – Interpretation of 1964 Aerial Photograph

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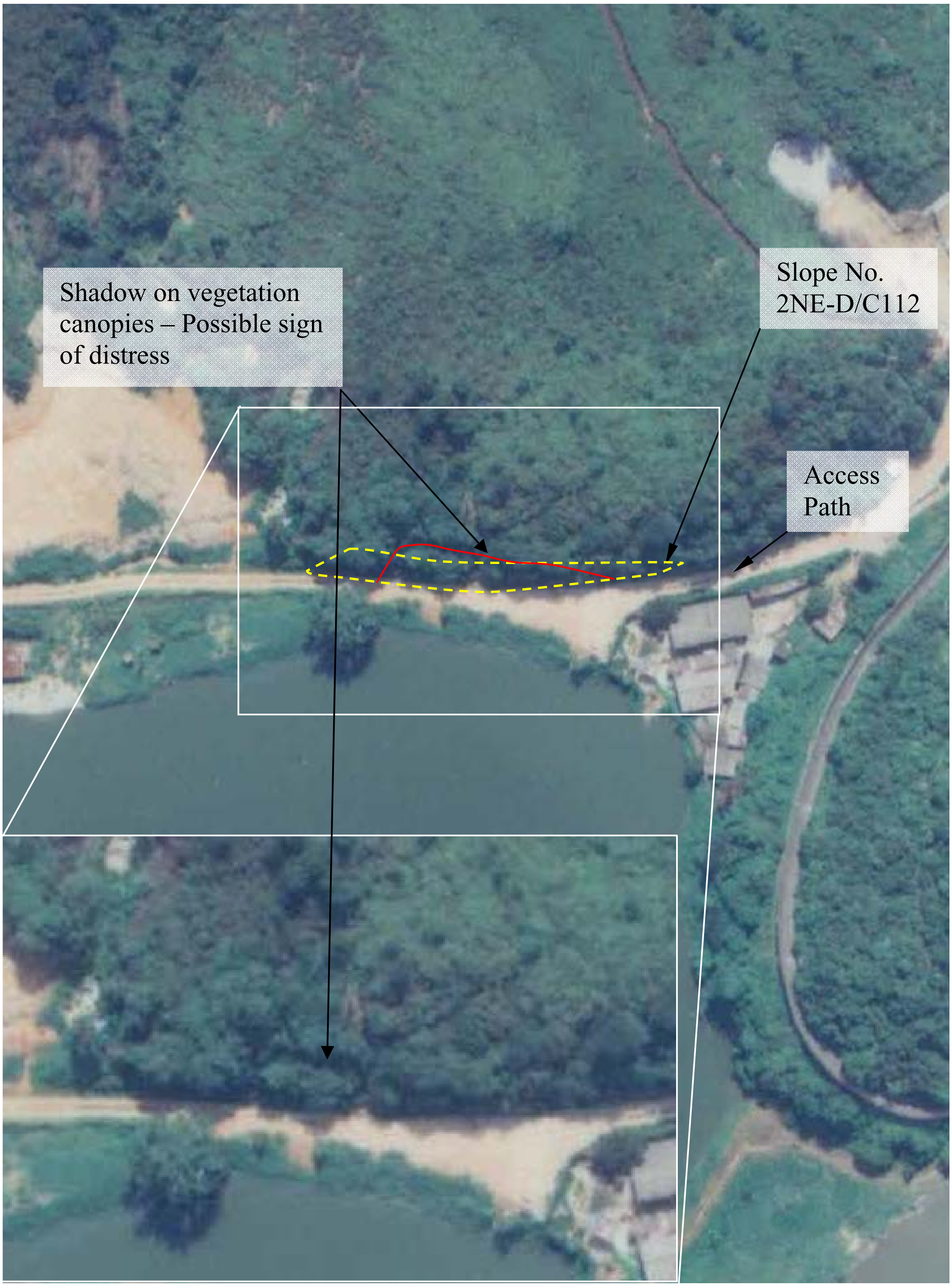
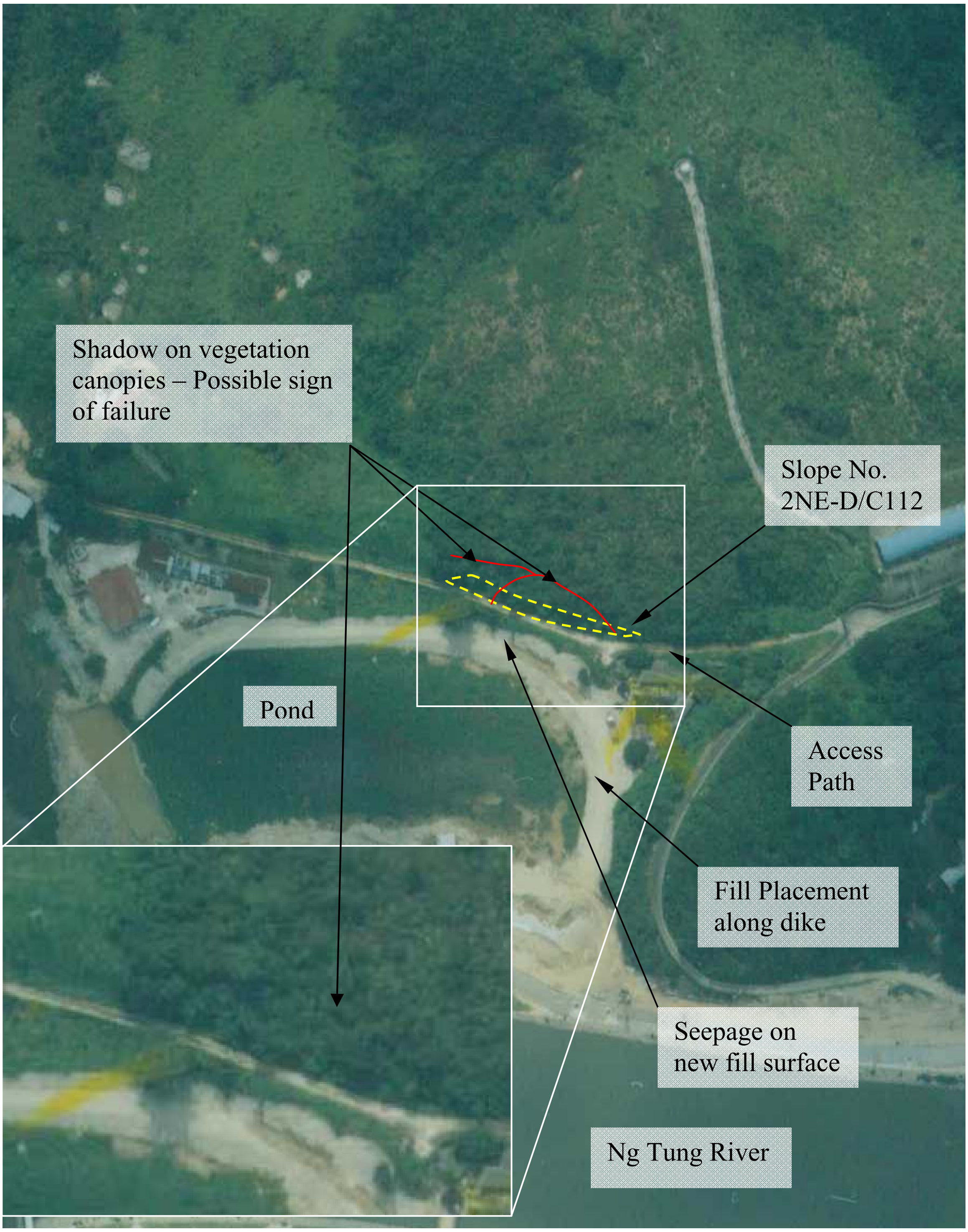


(Photograph CN10465R taken on 20 July 1995)

Plate A2 - Interpretation of 1995 Aerial Photograph



(Photograph CW34108R taken on 24 September 2001)

Plate A3 - Interpretation of 2001 Aerial Photograph

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土力工程處刊物及訂購資料

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

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

GEOTECHNICAL MANUALS

Geotechnical Manual for Slopes, 2nd Edition (1984), 302 p. (English Version), (Reprinted, 2011).

斜坡岩土工程手冊(1998)，308頁(1984年英文版的中文譯本)。

Highway Slope Manual (2000), 114 p.

GEOGUIDES

Geoguide 1	Guide to Retaining Wall Design, 2nd Edition (1993), 258 p. (Reprinted, 2007).
Geoguide 2	Guide to Site Investigation (1987), 359 p. (Reprinted, 2000).
Geoguide 3	Guide to Rock and Soil Descriptions (1988), 186 p. (Reprinted, 2000).
Geoguide 4	Guide to Cavern Engineering (1992), 148 p. (Reprinted, 1998).
Geoguide 5	Guide to Slope Maintenance, 3rd Edition (2003), 132 p. (English Version).
岩土指南第五冊	斜坡維修指南，第三版(2003)，120頁(中文版)。
Geoguide 6	Guide to Reinforced Fill Structure and Slope Design (2002), 236 p.
Geoguide 7	Guide to Soil Nail Design and Construction (2008), 97 p.

GEOSPECS

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

GEO PUBLICATIONS

GCO Publication No. 1/90	Review of Design Methods for Excavations (1990), 187 p. (Reprinted, 2002).
GEO Publication No. 1/93	Review of Granular and Geotextile Filters (1993), 141 p.
GEO Publication No. 1/2006	Foundation Design and Construction (2006), 376 p.
GEO Publication No. 1/2007	Engineering Geological Practice in Hong Kong (2007), 278 p.
GEO Publication No. 1/2009	Prescriptive Measures for Man-Made Slopes and Retaining Walls (2009), 76 p.
GEO Publication No. 1/2011	Technical Guidelines on Landscape Treatment for Slopes (2011), 217 p.

GEOLOGICAL PUBLICATIONS

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

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

TECHNICAL GUIDANCE NOTES

TGN 1	Technical Guidance Documents