DETAILED STUDY OF THE 15 SEPTEMBER 2006 DISTRESS ABOVE SLOPE NO. 6NE-B/C44 AT 33A2 SHEK TONG TSUEN, TA SHEK WU, PAT HEUNG

GEO REPORT No. 293

AECOM Asia Company 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 13/2009 produced in September 2010

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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.

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H.N. Wong
Head, Geotechnical Engineering Office
January 2014

FOREWORD

This report presents the findings of a detailed study of the signs of distress above (Incident No. 2006/09/0738) the crest of slope No. 6NE-B/C44 at 33A2 Shek Tong Tsuen, Ta Shek Wu, Pat Heung. The incident was reported in the morning of 15 September 2006 following the heavy rainfall on 13 September 2006. The incident involved two distressed areas of about 9 m to 10 m in width which exhibited slope movements. No casualties were reported as a result of the incident.

The key objectives of the study were to document the facts about the incident, present relevant background information and establish the probable causes of the distress. The scope of the study comprised site reconnaissance, desk study, ground investigation and rainfall analysis. Recommendations for follow-up actions are reported separately.

The report was prepared as part of the Landslide Investigation Consultancy for landslides occurring in Kowloon and the New Territories in 2006, for the Geotechnical Engineering Office, Civil Engineering and Development Department, under Agreement No. CE 50/2005 (GE). This is one of a series of reports produced during the consultancy by AECOM Asia Company Limited.

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Agreement No. CE 50/2005 (GE)
Study of Landslides Occurring in Kowloon and the New Territories in 2006 - Feasibility Study

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1. INTRODUCTION

After the heavy rainfall on 13 September 2006, signs of distress above the crest of slope No. 6NE-B/C44 were observed on 15 September 2006 (Incident No. 2006/09/0738). These involved cracking on the drainage channels at the slope crest and two areas of ground movement above the cut slope. The slope is situated behind 33A2 Shek Tong Tsuen, Ta Shek Wu, Pat Heung (Figure 1). No casualties were reported as a result of the incident.

Following the incident, the former Maunsell Geotechnical Services Limited (MGSL) (renamed as AECOM Asia Company Limited (AECOM) in 2010), the Landslide Investigation Consultants for Kowloon and the New Territories, carried out a detailed study of the incident for the Geotechnical Engineering Office (GEO), Civil Engineering and Development Department (CEDD), under Agreement No. CE 50/2005 (GE).

2. THE SITE

2.1 Site Description

The distress occurred at the crest of slope No. 6NE-B/C44 and the hillside above. A site location plan is shown in Figure 1.

Slope No. 6NE-B/C44 is approximately 50 m long, with a maximum height of about 5 m (Figure 2). The eastern slope portion, about 30 m long, is inclined at about 40° to 55° (Figures 2 and 3), with a sprayed concrete cover. Below the eastern portion are a 2-storey residential structure and an abandoned pigsty (Plate 1), which is now used for storage. Surface drainage provisions on the eastern portion include a 300 mm wide U-channel along the slope crest and a 225 mm wide U-channel at the toe. Another 300 mm wide U-channel with an upstand (referred to as the upper 300 mm U-channel in this report) is located about 5 m to 10 m above, and to the south of the crest of the eastern portion (Figure 2). A chain-link fence is located on the uphill side of this U-channel. The area between the crest of slope No. 6NE-B/C44 and the chain-link fence is mostly vegetated and inclined at about 25° to 40° (Plate 2). The area above the chain-link fence is inclined at about 25° to 27° and planted with fruit trees (Figure 3 and Plate 3). Above the tree planting area is densely vegetated natural terrain, which extends about 170 m to the ridgeline.

The western portion of slope No. 6NE-B/C44 is about 20 m long and is inclined at about 40° to 50°. An area of natural terrain extends about 45 m above the crest of the western slope portion. This portion does not have any surface protection or surface drainage provisions. The slope profile is irregular and covered by vegetation. Squatter structures were previously located at the slope toe, which had been cleared.

2.2 Regional Geology

According to the Hong Kong Geological Survey 1:20,000 Solid and Superficial Geology Map Sheet 6 – Yuen Long (GCO, 1986), slope No. 6NE-B/C44 is underlain by coarse ash crystal tuff. The coarse ash crystal tuff in the region is metamorphosed in places. There is an area of debris flow deposits to the southeast of the slope (Figure 4).

2.3 Maintenance Responsibility and Land Status

According to the Slope Maintenance Responsibility Information System (SMRIS) of the Lands Department (LandsD), LandsD is responsible for the maintenance of slope No. 6NE-B/C44. The crest area of slope No. 6NE-B/C44, where the distress was located, is unallocated government land. The 2-storey residential structure and abandoned pigsty are within licensed land Lot No. DD108.

2.4 Utilities

Telephone lines and cables for power and public lighting run along the footpath at about 10 m to the north of slope No. 6NE-B/C44.

No water-carrying services in the vicinity of the slope were documented. However, exposed water pipes were identified on and above the slope during the post-failure investigation (Section 6).

3. SITE HISTORY AND PAST INSTABILITY

3.1 Site History

The history of site development has been determined from an interpretation of the available aerial photographs, together with a review of the relevant documentary information including old topographical survey maps and site observations. Detailed observations from aerial photograph interpretation (API) are summarized in Appendix A.

In the 1949 aerial photograph, a small plot of agricultural terraces is present at about 30 m to the north of slope No. 6NE-B/C44 (Figure 5). The slope and a structure at its toe were formed between 1949 and 1964. In the 1979 aerial photographs, the structure at the toe appeared to have been demolished and the present-day 2-storey structure and abandoned pigsty below the eastern portion were constructed. It appears that a narrow footpath or some surface drainage channels were constructed along the crest of slope No. 6NE-B/C44 at that time. At about the same time, a few squatter structures were erected at the toe of the western portion of the slope. Two of these structures were recommended for clearance under the Non-Development Clearance 1994-95 Inspection Programme. These structures were subsequently cleared in 2001.

An old landslide scar was identified in 2000 on slope No. 6NE-B/C44 during a site inspection. Local trimming and filling of the scar by no-fines concrete were carried out by May 2001. During the same period, slope maintenance works involving the replacement of existing chunam cover by shotcrete, and provision of surface drains were also carried out (Figure 7). Between December 2004 and April 2005, slope No. 6NE-B/C44 was upgraded using soil nails under the GEO's Landslip Preventive Measures (LPM) Programme (Section 4.3).

The area above the crest of slope No. 6NE-B/C44, where the distress was identified in September 2006, appears to have been disturbed by cultivation and tree-planting activities sometime between 1973 and 1997 (Figure 5). However, based on the present API, there was

no major cutting in this area. Following the September 2006 incident, the area immediately above the crest of slope No. 6NE-B/C44, including the distressed areas, was registered as slope No. 6NE-B/C94 (Figure 5), which was subsequently included in the LPM Programme for study. The upgrading works were scheduled to commence in late 2010.

3.2 Past Instability

3.2.1 Natural Terrain Landslide Inventory

The Enhanced Natural Terrain Landslide Inventory (ENTLI) database records a number of landslides in the hillside above and adjacent to slope No. 6NE-B/C44 (Figure 5), including two landslides (tags Nos. 06NEB2087E and 06NEB0093E) at about 80 m to the south of the slope. The natural terrain above the slope was designated as Historical Landslide Catchment No. 06NEB_O12.

3.2.2 Aerial Photograph Interpretation

The aerial photographic record of the site indicates that previous instability has occurred at the natural terrain above slope No. 6NE-B/C44 (Figure A1). However, none of these instabilities was located at the two September 2006 distressed areas.

The API did not identify any new landslide scars in addition to those recorded in the ENTLI. The hillside to the south of slope No. 6NE-B/C44 and a local area around the upper spurline to the southeast appeared to have been affected by hillfire between 1988 and 1992 (Figure A1).

3.2.3 GEO's Landslide Database

According to the GEO's landslide database, no landslides have been reported on or in the immediate vicinity of slope No. 6NE-B/C44.

4. PREVIOUS ASSESSMENTS AND SLOPE WORKS

4.1 SIFT, SIRST and Stage 1 Studies

In 1997, slope No. 6NE-B/C44 was classified as SIFT Class 'C1', i.e. a slope that had "been formed or substantially modified before 30.6.78". The slope was inspected by the SIRST consultants, Binnie Consultants Limited, in May 1997. Signs of minor distress were observed near the crest, mid-portion and toe of the cut slope. Seepage signs were also noted.

In June 2000, MGSL carried out the New Priority Classification System (NPCS) data updating exercise for slope No. 6NE-B/C44 under Agreement No. CE 3/2000. During the inspection by MGSL, a large portion of the chunam surface behind the 2-storey residential structure was found to be broken or missing (Figure 5).

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4.2 Maintenance Inspections

Engineering Inspections (EI) of slope No. 6NE-B/C44 were undertaken by consultants engaged by LandsD in July 1999 and June 2004 respectively. The 1999 EI noted that the chunam surface behind the 2-storey structure was severely broken with extensive erosion on the exposed soil. Apart from this, no other signs of distress or seepage were noted. Also, no sign of distress or seepage was observed in the subsequent EI in 2004. The salient observations made are summarized in Appendix B.

Routine Maintenance Inspections (RMI) of slope No. 6NE-B/C44 were undertaken by LandsD's consultants in 2002, 2003, 2005 and 2006. No sign of distress or seepage was observed, except that during the RMI of January 2006, cracking was noted at the top edge of the upper 300 mm U-channel (Plate 4, Figures 6 and 10). The salient observations made are summarized in Appendix B. The cracked channel was repaired in February 2006. This section of the channel was located at the lower edge of the eastern distressed area and was identified to have subsequently cracked and deformed in September 2006 (Plate 12, Figures 6 and 10).

Previous assessments and maintenance inspections did not cover the hillside above slope No. 6NE-B/C44.

4.3 LPM Works

The eastern portion of the slope (i.e. Portion "B") was upgraded by the GEO under the LPM Programme between December 2004 and April 2005 by Type 3 prescriptive measures (i.e. soil nails). The upgrading works comprised 54 nos. 4 m to 8 m long soil nails, replacement of existing drainage channel, construction of a concrete berm and shotcreting over the existing hard surface, as recommended in the Stage 3 study report (GEO, 2004). Apart from these, the Stage 3 study report also recommended the installation of raking drains. However, the as-built drawing No. GED 51307/02A indicates that no raking drains were installed.

As recorded in the Maintenance Manual (GEO, 2005), no seepage was observed during the construction stage between December 2004 and April 2005.

In September 2005, about five months after the completion of the upgrading works, cracks were observed on the aprons of the 300 U-channel at the slope crest. The cracked section of the apron was reconstructed by mid-October 2005 (Plates 5 and 6). The location of the cracks coincides with the eastern distressed area observed in September 2006.

No upgrading works were proposed for the western portion in the Stage 3 study report, which affected solely squatter structures. Under the prevailing policy at that time, this portion of the slope would be dealt with by clearance of the squatters instead of undertaking slope upgrading works.

5. THE SEPTEMBER 2006 DISTRESS

According to Mr Wong, an eye-witness who lives in the 2-storey structure at the toe of slope No. 6NE-B/C44, he observed cracking of the U-channels located at and above the slope crest in the morning of 15 September 2006.

6. POST-FAILURE OBSERVATIONS

AECOM first inspected the site on 26 September 2006, following the report of the distress. The U-channel above and at the crest of the eastern portion of slope No. 6NE-B/C44 had deformed and cracked at three locations, above a pigsty and a 2-storey residential structure. Tension cracks were also observed on the hillside above, after clearance of the vegetation. No signs of distress were observed on the cut slope portion upgraded in 2005 under the LPM Programme. The locations of the signs of distress are shown in Figure 6. Details are summarized below.

Near the abandoned pigsty, an approximately 9 m long section of the 300 mm wide and 300 mm deep U-channel at the crest of the cut slope had deformed. The apron and uphill side of the channel had cracked and displaced by up to 200 mm (Plate 7). The U-channel was clear of any blockage at the time of the inspection. A 4 m long section of the upper 300 mm wide U-channel was also observed to have deformed and shifted outward in the downslope direction by some 300 mm (Plate 8). Based on a photograph taken in the 2003 RMI (Plate 9), the alignment of this section of the U-channel was straight at that time. This U-channel was also clear of any blockage at the time of inspection.

Cracks on the surface of the sloping ground in the vicinity of the above cracked U-channel sections were also observed (Figure 6) during the inspection in September 2006. These cracks appeared to be recent and were running in directions approximately parallel or normal to the crest line of the slope. Plate 10 shows one of the tension cracks which was about 40 mm wide located at the downslope side of the upper 300 mm U-channel. The deformations of the two sections of U-channel, together with the cracks on the slope surface, suggest the presence of a wider distressed area extending into the hillside above the cut slope. The distressed area was estimated to be about 9 m wide. Part of the area further above the hillside was later cleared (Section 7.2), and a 300 mm wide and 600 mm deep tension crack was observed at about 20 m south of the upper 300 mm U-channel in November 2007 (Figure 6 and Plate 11). This tension crack was within the colluvium and the material was partly discoloured, suggesting the material might have been exposed for some time.

On the hillside behind the 2-storey residential structure (Figure 6) to the southwest of the pigsty was another section of the upper 300 mm U-channel that was cracked and deformed by up to about 200 mm (Plate 12). The affected section of the channel was about 10 m long. The U-channel was clear of any blockage at the time of inspection. The distressed area was estimated to be about 10 m wide. A 300 mm wide and 450 mm deep tension crack was observed about 22 m above the upper U-channel in the November 2007 inspection (Figure 6 and Plate 13). Partly discoloured material was also observed in this tension crack.

No signs of distress were observed on slope No. 6NE-B/C44. A network of water pipes was found in the area above and on the slope surface (Figure 6). No major seepage was

observed although a damp patch was visible on the shotcrete surface (Figure 6 and Plate 14). Some discolouring of the shotcrete surface was also observed, which might be associated with previous seepages (Plate 15).

The western portion of slope No. 6NE-B/C44, which was not upgraded under the LPM Programme, was inspected although access was limited owing to the presence of dense vegetation cover and refuse (Figure 6, Plates 16 and 17). The slope is up to 5 m high, with a slope angle of about 40° to 50°. The slope profile is relatively irregular, with a masonry wall of about 1 m high present on the slope. An old landslide scar measured about 2 m wide, 2 m long and 0.5 m deep was also observed (Figure 6 and Plate 17). An abandoned structure was observed at the toe of this portion of the slope (Plate 18).

7. GROUND CONDITIONS

7.1 General

The geological conditions of the September 2006 distressed site were inferred from the ground investigation, API and field mapping.

7.2 Ground Investigation

Three 13 m to 25 m deep drillholes (Nos. BH1 to BH3) and four trial pits (Nos. TP1, TP2, TP3 and TP4) of 2.5 m to 3.3 m depth were sunk by Driltech Ground Engineering Limited between September and November 2007, as part of this landslide study. Vegetation clearance in strips was also carried out. The locations of the ground investigation stations are shown in Figure 2. There was no record of previous ground investigation carried out in the vicinity of the subject cut slope.

The main focus of the ground investigation was to examine the thickness of the colluvium and identify the upper limits of the distressed areas. Mazier samples were recovered from BH1 and BH2 at 2 m intervals and continuously at BH3. Block samples, U76 and U100 samples were recovered from the trial pits.

An inclinometer access tube was installed at BH3 in November 2007 for ground movement monitoring. The inclinometer monitoring was carried out by the Survey Division of CEDD between November 2007 and April 2010. The results fluctuated between - 3 to + 6 mm, without indicating any trend of increasing movement (Appendix C). The results are within the range of error ($\pm$ 6.3 mm) of the instrument.

7.3 Geology and Geomorphology

Based on the Hong Kong Geological Survey 1:20,000 Solid and Superficial Geology Map Sheet 6 – Yuen Long (GCO, 1986), several metamorphosed tuff bands are indicated within the study area, with one band traversing the upper part of the ground immediately above the subject cut slope (Figure 4). The metamorphism is probably represented by foliation although there is no indication of the orientation in the immediate vicinity.

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Pleistocene debris flow deposits are shown in the valley immediately below (to the northwest) the cut slope (Figure 4), on which the larger cultivation terraces have been formed as identified from API (Figure 5). Most of these deposits are likely to have been sourced from the larger hills across the valley to the northeast. The colluvium present at or near the cut slope is possibly 'older' Pleistocene colluvium and some relatively thin recent Holocene colluvium derived locally from relict instability within the catchment.

From the 1949 aerial photographs, the geomorphology of the natural terrain above the site comprises a broad depression, which is flanked by relatively sharp northwest and northeast trending spurlines on its western and eastern sides respectively. The site is characterized by possible unconfined colluvial deposits which increase in thickness near the toe of the study area.

The ground investigation indicates that Slope No. 6NE-B/C44 and the area above comprises 1 m to 2.2 m of colluvium overlying residual soil of about 0.5 m to 2.2 m thick. Completely decomposed tuff was encountered below the residual soil. The weathered profile was deep (~20 m) in the vicinity of the study area, with a steeply inclined rockhead. The inferred geological section is shown in Figure 3. The colluvium is generally described as firm, moist, yellowish red slightly sandy silty CLAY with angular to subangular gravel and cobbles. The residual soil is generally described as stiff, reddish brown sandy silty CLAY with occasional fine gravel of quartz. The completely decomposed tuff is generally described as extremely week, reddish brown mottled black SILT with manganese stained and clayey infilled relict joints. The completely decomposed tuff has SPT values in the range of 20 to 54.

No tension cracks, slip surfaces or soil pipes were observed in the drillholes or trial pits, which were located within or near the distressed areas.

7.4 Groundwater Conditions

The hillside above slope No. 6NE-B/C44 has a relatively small catchment area of about 2,600 m^2. No signs of seepage on the surface of the toe cutting were recorded in the previous inspections. However, a local damp patch was identified on the cut slope in the post-failure observations for the September 2006 distress.

Figure 3 shows the groundwater monitoring records in BH1 and BH2. Groundwater levels were recorded on a daily basis for about a week in December 2007 at drillholes Nos. BH1 and BH2, which were sunk as part of the ground investigation for this study. In BH1, a piezometer and a standpipe with buckets were installed at 2.9 m (within the CDT) and 12.6 m depths (within the weathered rock) respectively. Piezometers were installed at 2.0 m and 12.1 m depths in BH2 respectively. All the piezometers and standpipe remained dry during the monitoring period between 16 October and 27 October 2007, except for the lower piezometer at BH2, which recorded a groundwater level of about 11.2 to 11.3 m below ground.

These piezometers and standpipe were subsequently monitored by the Survey Division of CEDD between 18 February and 3 June 2010 on a biweekly to monthly basis. From the piezometer at BH1, a maximum groundwater level of about 0.61 m below ground (0.5 m above the colluviums/residual soil interface) was recorded by the buckets between 5 June and

16 July 2008, during which a Black Rainstorm Warning was issued on 7 June 2008. The same piezometer also recorded a groundwater level of 0.61 m below ground between 19 May and 4 June 2009, during which a Red Rainstorm Warning was issued on 4 June 2009. The monitoring results indicated the presence of a perched groundwater table within the colluvium. The buckets of the lower standpipe at BH1 recorded a maximum groundwater level of 4.5 m below ground between 16 September and 17 October 2008. Maximum groundwater levels of 1.1 m and 10.7 m below ground were recorded by the upper and lower piezometers at BH2 respectively, between 8 and 16 July 2008 (Figure 3).

According to the file record of LandsD dated February 2001, concentrated surface runoff above the eastern portion of the cut slope during heavy rainfalls was reported by a local villager. This observation agrees with presence of the ephemeral drainage line above the eastern portion of the cut slope as identified from the API (Figure A2), which is located along the flanks of a topographic depression.

8. ANALYSIS OF RAINFALL RECORDS

Rainfall data were obtained from the nearest GEO automatic raingauge No. N36, which is located about 3.4 km to the southeast of the September 2006 distressed areas, at Kadoorie Agricultural Research Centre, Lam Kam Road, Shek Kong (Figure 1). The raingauge records and transmits rainfall data at 5-minute intervals to the GEO and the Hong Kong Observatory (HKO). The daily rainfall recorded by raingauge No. N36 over the month preceding the observation of the slope distress, together with the hourly rainfall readings for the period between 12 September and 15 September 2006, are presented in Figure 8. Records from another nearby GEO automatic raingauge No. N05, which is about 4.5 km to the east of the September 2006 distress, were also examined. The pattern of rainfall recorded at this raingauge was broadly similar to that recorded at raingauge No. N36.

The rainstorm preceding the distress commenced in the morning of 13 September 2006 and continued until the early morning of 14 September 2006. Amber Rainstorm Warnings were issued on three occasions on 13 September 2006 from 7:50 a.m. to 9:30 a.m., from 12:15 p.m. to 1:45 p.m. and from 5:40 p.m. to 11:15 p.m. A Red Rainstorm Warning was issued from 9:30 a.m. to 12:15 p.m. on 13 September 2006. According to the eyewitness account, the distress was first observed on the morning of 15 September 2006. The maximum rolling 12-hour and 24-hour rainfall before the report of the distress was 253.5 mm and 361.5 mm respectively. The maximum 1-hour rolling rainfall was recorded as 45 mm between 6:00 p.m. and 7:00 p.m. on 13 September 2006 (Table 1).

An analysis of the return periods for various durations of maximum rolling rainfall recorded at raingauge No. N36, with reference to the historical rainfall data at the HKO at Tsim Sha Tsui where records began in 1884 (Lam & Leung, 1994), shows that a rainfall duration of 24 hours was the most severe, with a corresponding return period of 9 years (Table 1).

The return periods were also assessed based on the statistical parameters derived by Evans & Yu (2001) from rainfall data recorded by local raingauge No. N05 between 1984 and 1997. The return period of the 24-hour rainfall at raingauge No. N05 was the most severe, with a return period of 8 years (Table 1).

The maximum rolling rainfall for the 13 September 2006 rainstorm has been compared with the past significant rainstorms recorded by raingauge No. N05 between 1986 and 2005 (Figure 9a), and by raingauge No. N36 between 2000 and 2005 (Figure 9b). Although the 13 September 2006 rainstorm was not the most severe when compared with the previous major rainstorms, the long-duration intensity of the rainfall was on the high side.

9. DISCUSSION

Signs of distress comprising displaced and deformed surface drainage channels were reported in September 2006 on a gently sloping hillside (with a gradient of about 27°) as well as at the crest of a toe cut slope (No. 6NE-B/C44) below. No signs of distress were observed on the cut slope itself, which was about 5 m high. The slope was upgraded in April 2005 under the LPM Programme using Type 3 prescriptive measures (i.e. soil nails).

The geology of the site comprises a thin mantle of colluviums up to 2.2 m thick, overlying residual soil and CDT. The broad depression on the natural hillside above the cut slope may have resulted in convergent surface runoff and subsurface seepage during periods of heavy rainfall. Two ephemeral drainage lines are present in the close vicinity. This setting is favourable to the development of a perched water table in the near surface groundmass above the colluviums/residual soil interface during heavy rainfall. Results of the groundwater monitoring carried out in June 2008 and June 2010 also confirmed the presence of a perched water table in the surficial colluvium. The development of the perched water table could have led to loss of soil suction and hence soil shear strength, initiating deformation in the near-surface colluvium mantle. The observation that the soil-nailed slope No. 6NE-B/C44 and the ground in front of the slope toe did not exhibit any signs of deformation also suggests that the slope movement was likely confined to be near-surface ground mass.

The site may have been subject to deterioration given the presence of recent and relict landslides as well as tension cracks in the hillside above. The tension cracks were probably pre-existing as evidenced by the partly discoloured infill material observed. Presence of such tension cracks would have increased infiltration and water ingress into the near-surface ground mass during heavy rainfall, further destabilising the ground.

Formation of the 5 m high unsupported cut slope at the toe of the hillside may have an adverse effect on the hillside stability. There is record indicating sign of distress observed at the cut slope after its formation (e.g. broken chunam surface in 1999 EI, Section 4.2). The presence of an old landslide scar at the cut slope possibly indicates instability problem. In addition, possible disturbance due to previous cultivation activities in the area could have contributed to the hillside deterioration.

10. CONCLUSION

Signs of distress were reported on 15 September 2006 on the hillside above a 5 m high cut slope, which was upgraded under the LPM Programme in 2005. No sign of distress was observed at the cut slope itself. There is no evidence to suggest that the signs of distress on the hillside were related to the LPM works. It is probable that the hillside was undergoing deterioration and intermittent deformation, resulting in development of tension cracks. The movement seems to confine to the colluvium layer. This could have been initiated by build-up of transient perched groundwater table in the near surface colluvium in heavy rainfall. It is not known when the tension cracks first occurred.

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Table 1 - Maximum Rolling Rainfall at GEO Raingauge No. N36 for Selected Durations Preceding the September 2006 Distress and the Estimated Return Periods

Duration	Maximum Rolling Rainfall (mm)	End of Period	Estimated Return Period (Years)	
			Based on Lam & Leung (1994)	Based on data of N05 from Evans & Yu (2001)
5 Minutes	8.0	4:35 p.m. on 13 September 2006	< 2	< 2
15 Minutes	22.0	4:40 p.m. on 13 September 2006	< 2	< 2
1 Hour	45.0	7:00 p.m. on 13 September 2006	< 2	< 2
2 Hours	71.0	6:15 p.m. on 13 September 2006	< 2	< 2
4 Hours	118.5	8:15 p.m. on 13 September 2006	2	3
12 Hours	253.5	9:10 p.m. on 13 September 2006	6	8
24 Hours	361.5	11:55 p.m. on 13 September 2006	9	8
48 Hours	387.0	11:55 p.m. on 13 September 2006	6	6
4 Days	396.0	11:55 p.m. on 13 September 2006	4	3
7 Days	512.5	11:50 p.m. on 13 September 2006	6	6
15 Days	537.5	11:55 p.m. on 13 September 2006	3	3
31 Days	699.0	11:55 p.m. on 13 September 2006	2	2

Notes : (1) Maximum rolling rainfall was calculated from 5-minute rainfall data.

(2) Return periods were derived from Table 3 of Lam & Leung (1994) and using rainfall data of raingauge no. N05 from Evans & Yu (2001).

(3) According to the incident records, the distress was first observed on 15 September 2006.

(4) The nearest GEO raingauge to the site is raingauge No. N36 situated at about 3.4 km to the southeast of the distress. GEO raingauge No. N05 situated at about 5.4 km to the northeast of the distress.

LIST OF FIGURES

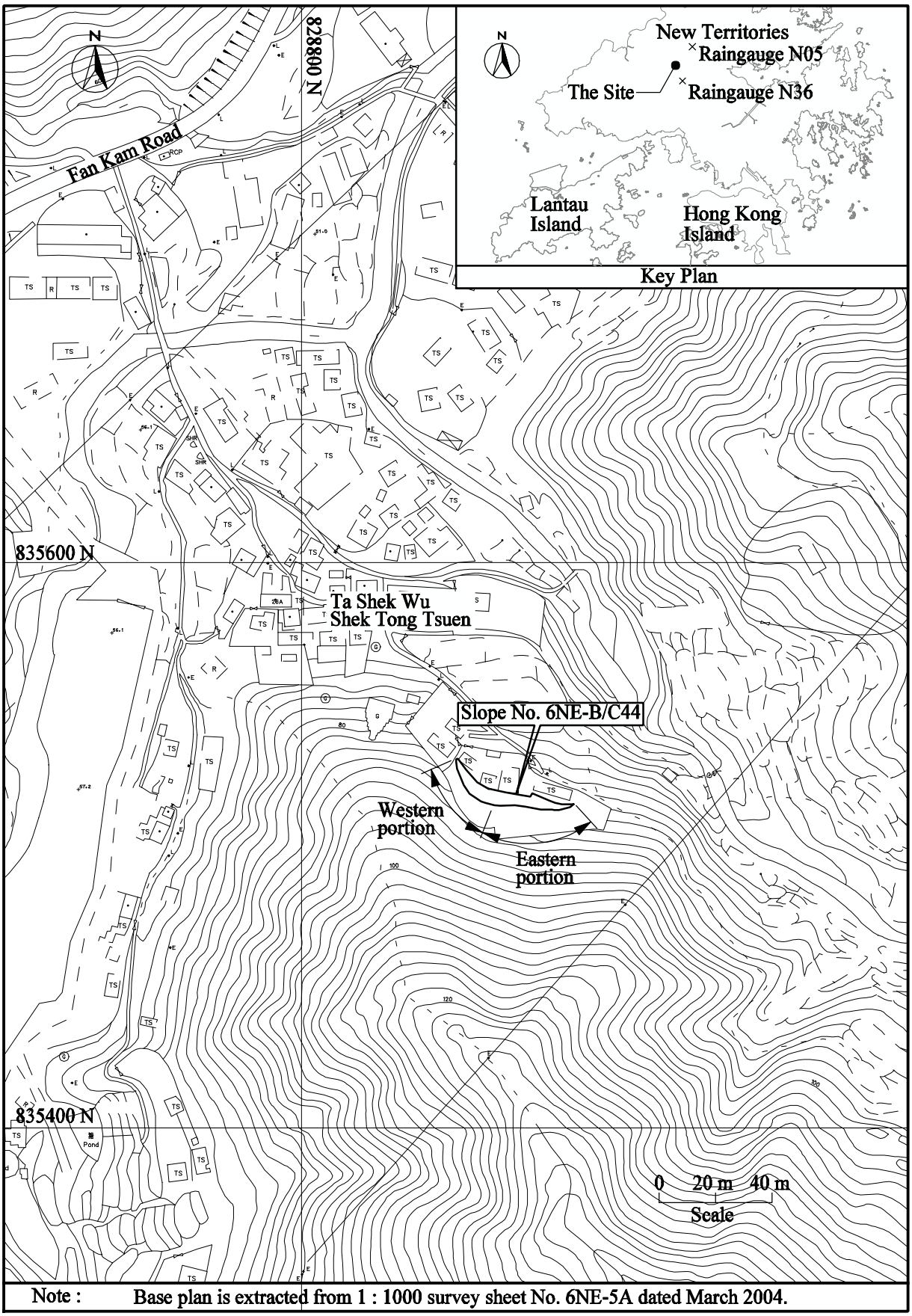


Figure 1 - Location Plan

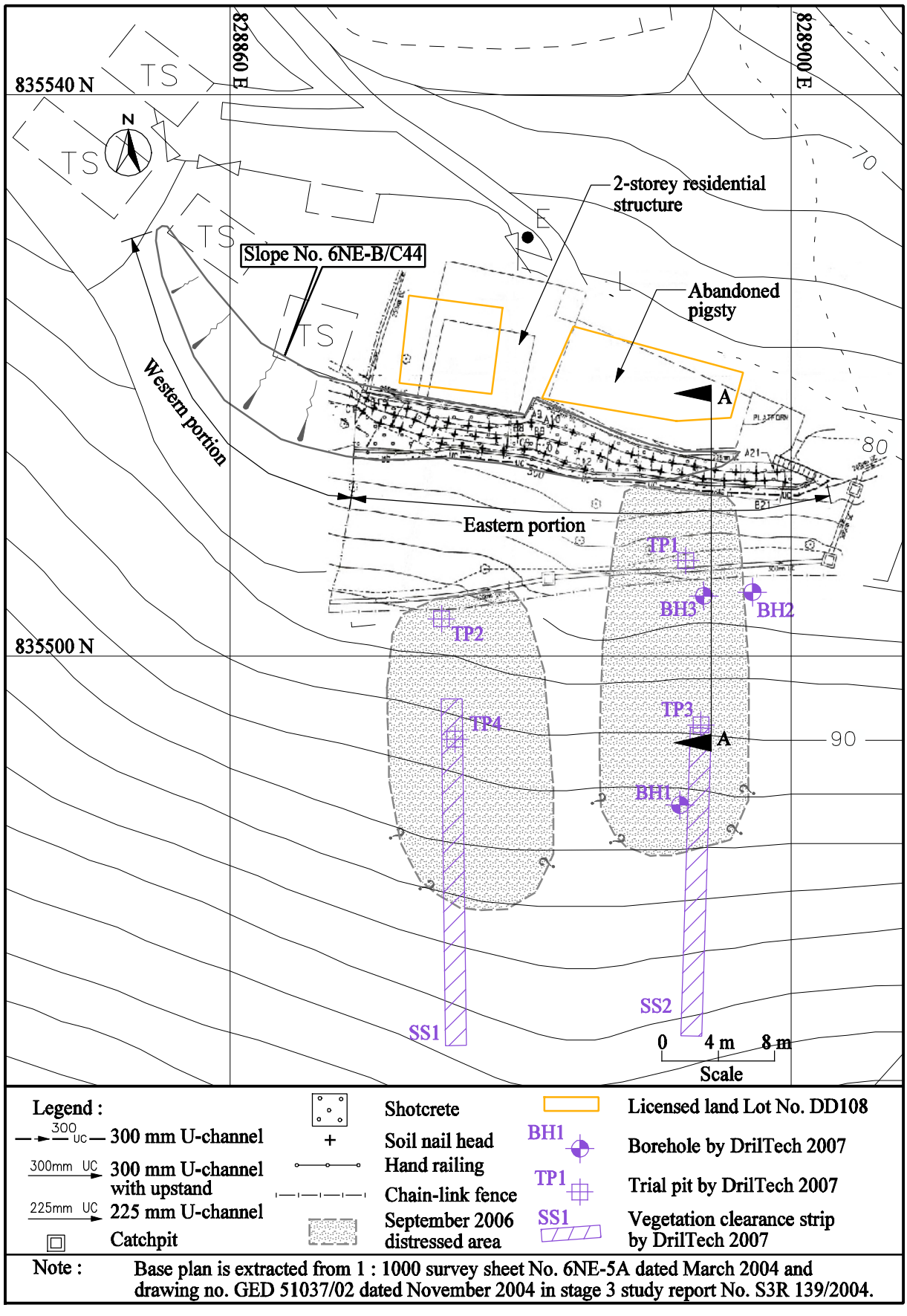
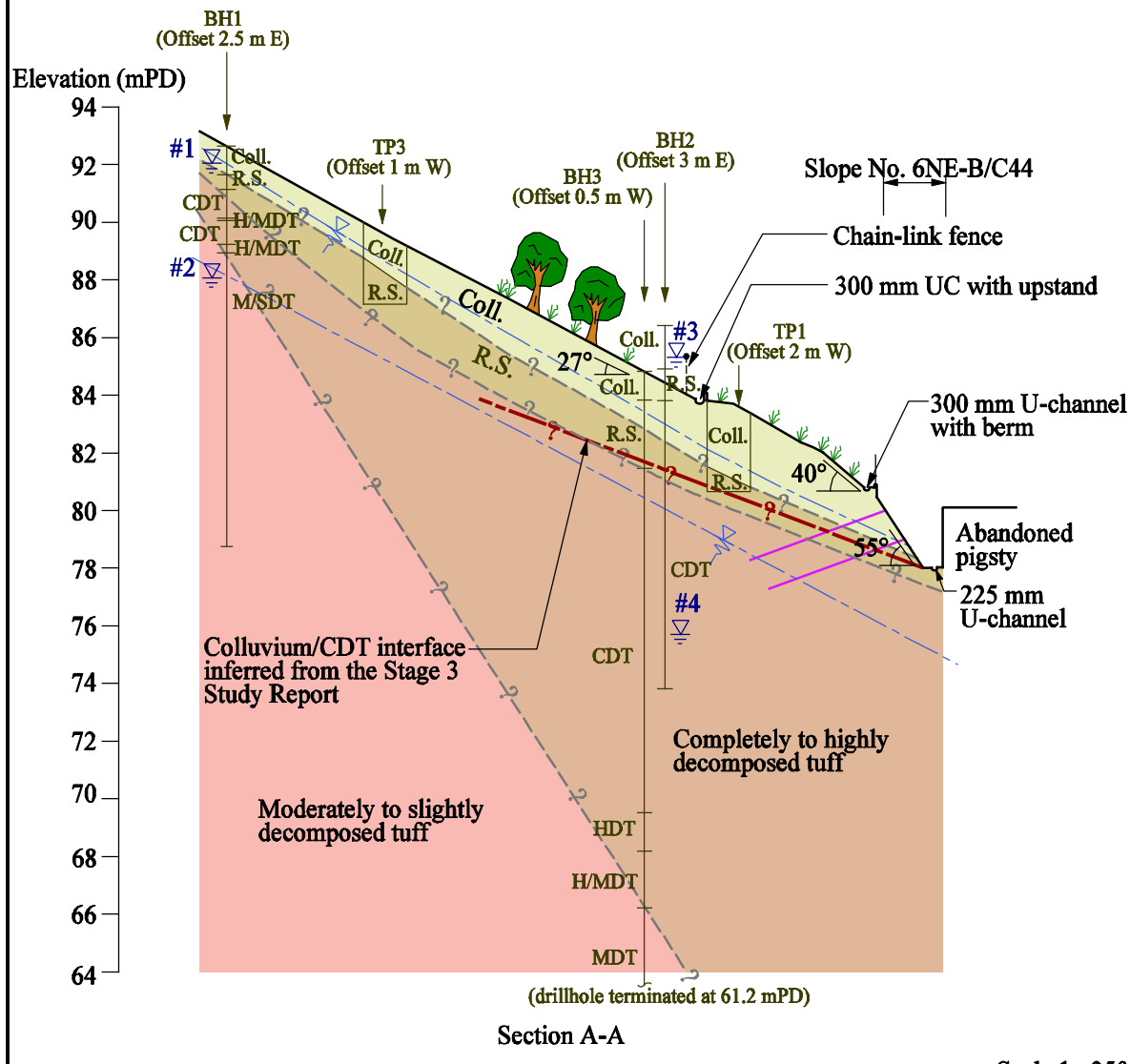


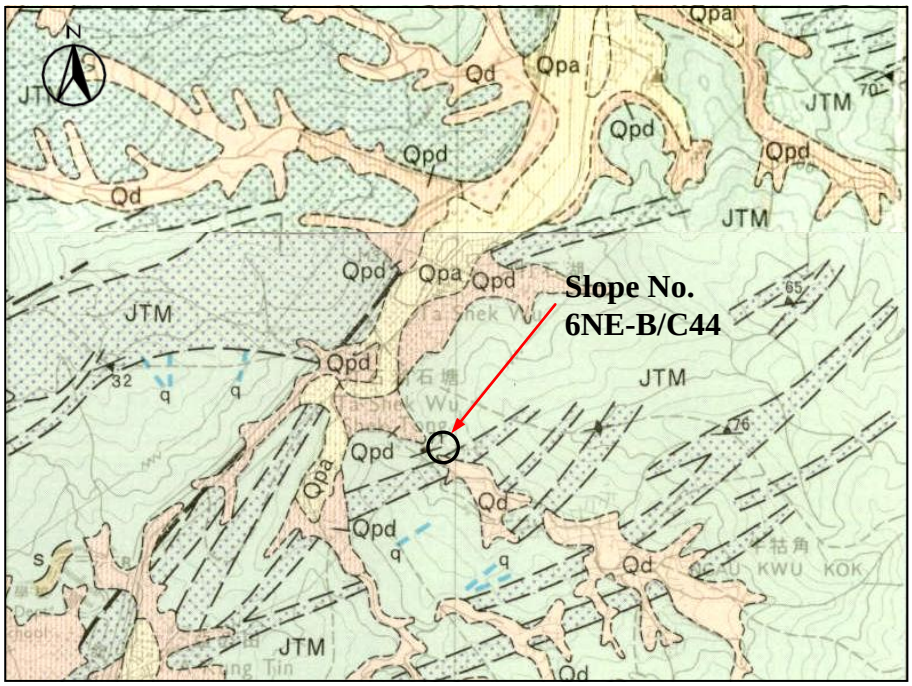
Figure 2 - Site Layout Plan



Legend :	Coll.	Colluvium	#1 92.08 mPD (5/6/08 - 16/7/08, 19/5/09 - 4/6/09)
	R.S.	Residual soil	#2 88.07 mPD (16/9/08 - 17/10/08)
		5 m long soil nails at 1.5 m horizontal spacing (20° inclination)	#3 85.31 mPD (8/7/08 - 16/7/08)
	#2 88.07 mPD (16/9/08 - 17/10/08)	Highest groundwater level / Record date	#4 75.71 mPD (8/7/08 - 16/7/08)

Note : The cross-sections are based on 1 : 1000 survey sheet No. 6NE-5A dated March 2004 and drawings Nos. GCS 3089/1 dated August 2004 and GED 51037/2 dated November 2004 in Stage 3 Study Report No. S3R 139/2004.

Figure 3 - Cross-Section A-A



0 m 1000 m

Scale

LEGEND:

SUPERFICIAL DEPOSITS

Qpd	Silt/sand, gravelly, clayey with cobbles and boulders; unsorted	Qd	Unsorted sand, gravel, cobbles and boulders; clay/silt matrix (Debris flow deposits)
Qpa	Clay/silt, gravelly sandy, well-sorted to semi-sorted		

SOLID GEOLOGY

JTM	Coarse ash crystal tuff		Metamorphosed
s	Sandstone		

GEOLOGICAL LINES

- Geological boundary, superficial deposits
- Geological boundary, solid rock
- Fault (crossmark indicates downthrow side)
- Mineral vein

STRUCTURAL SYMBOLS

- 40 Foliation
- 50 Jointing
- Jointing for vertical

MINERAL AND MISCELLANEOUS SYMBOLS

q Quartz

Note: Extracted from Hong Kong Geological Survey, Map Series HGM20, Sheets Nos. 2 and 6 1:20 000 scale (GCO, 1988).

Figure 4 - Regional Geology

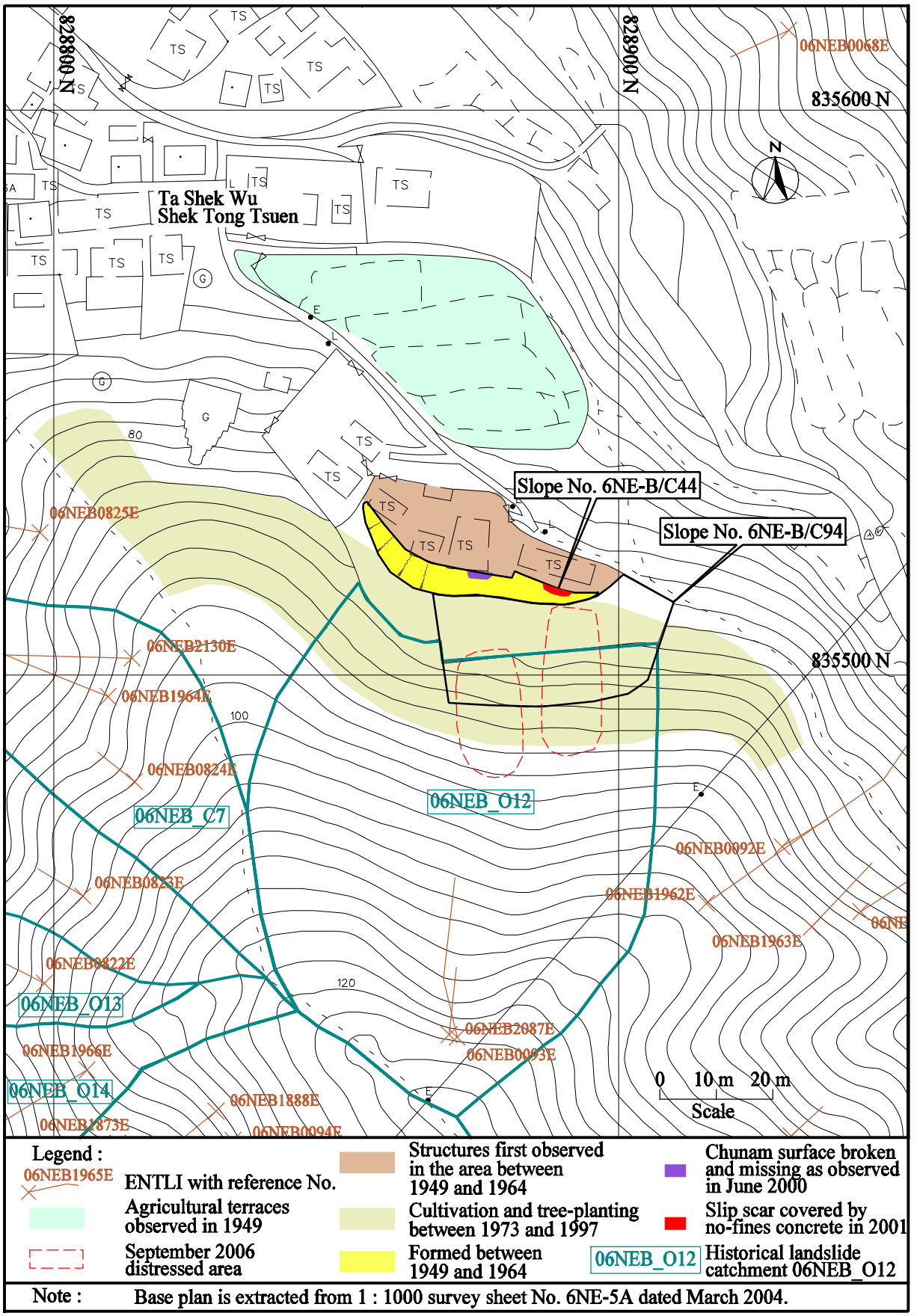


Figure 5 - Site History and Past Instabilities

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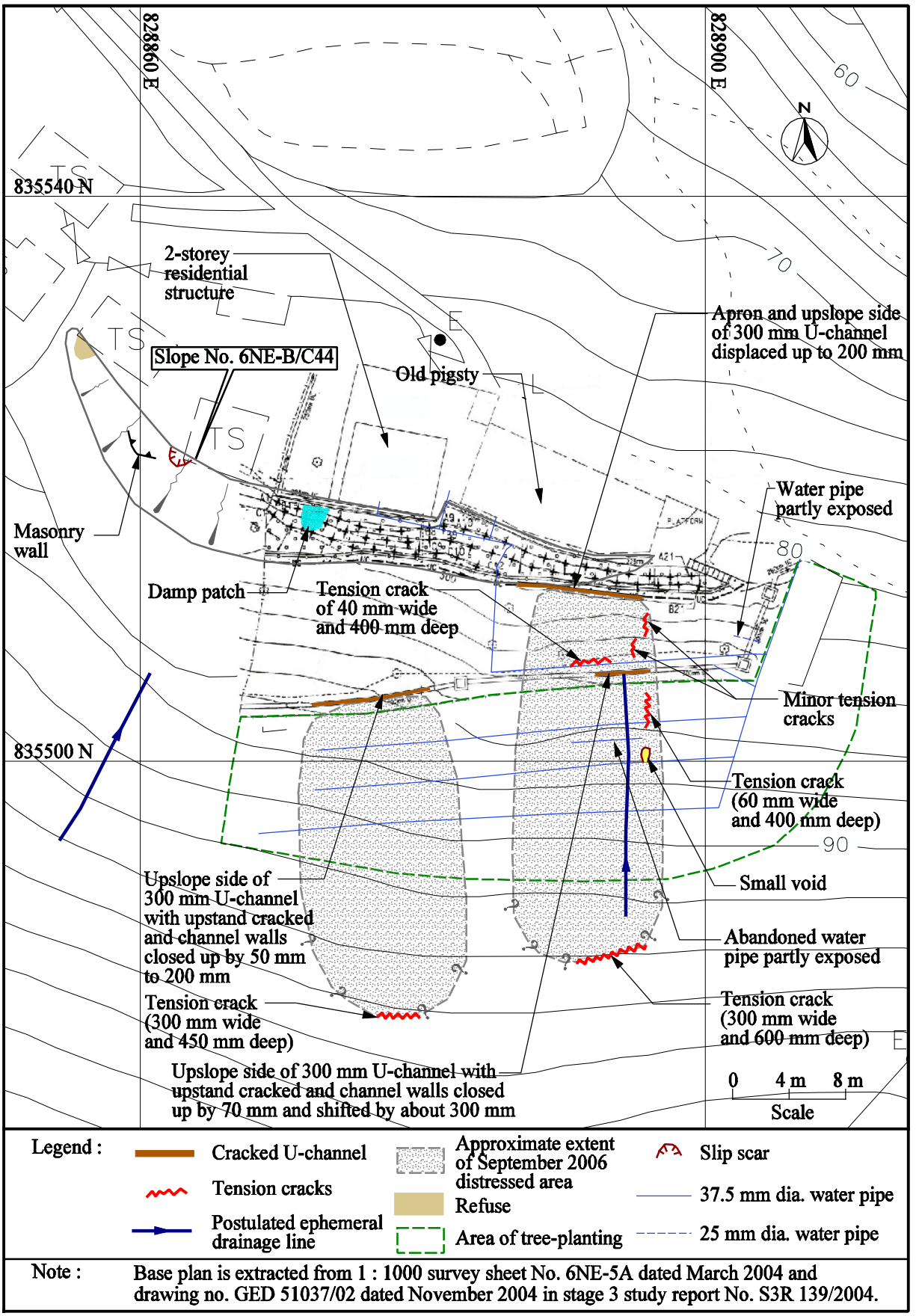

Figure 6 - Post-failure Observations by AECOM in September 2006

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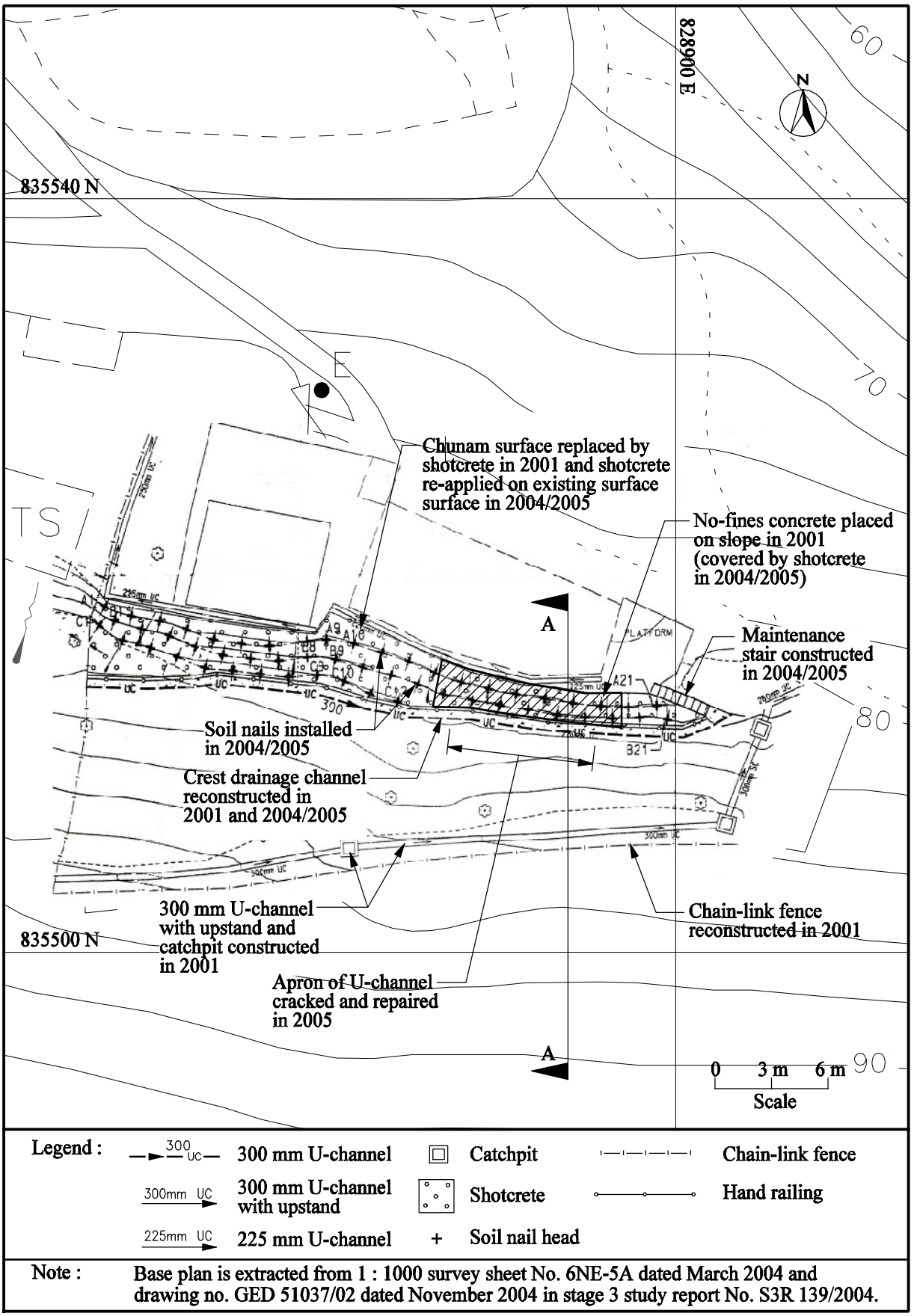

Figure 7 - Previous Maintenance and Slope Upgrading Works (Eastern Portion)

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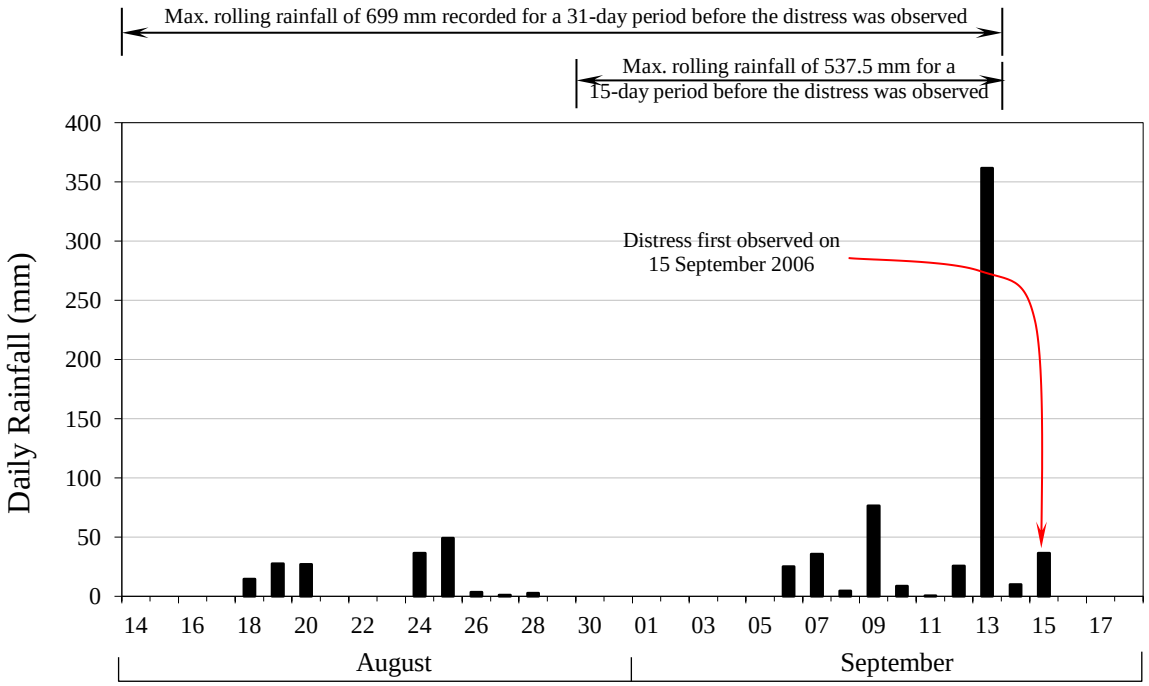
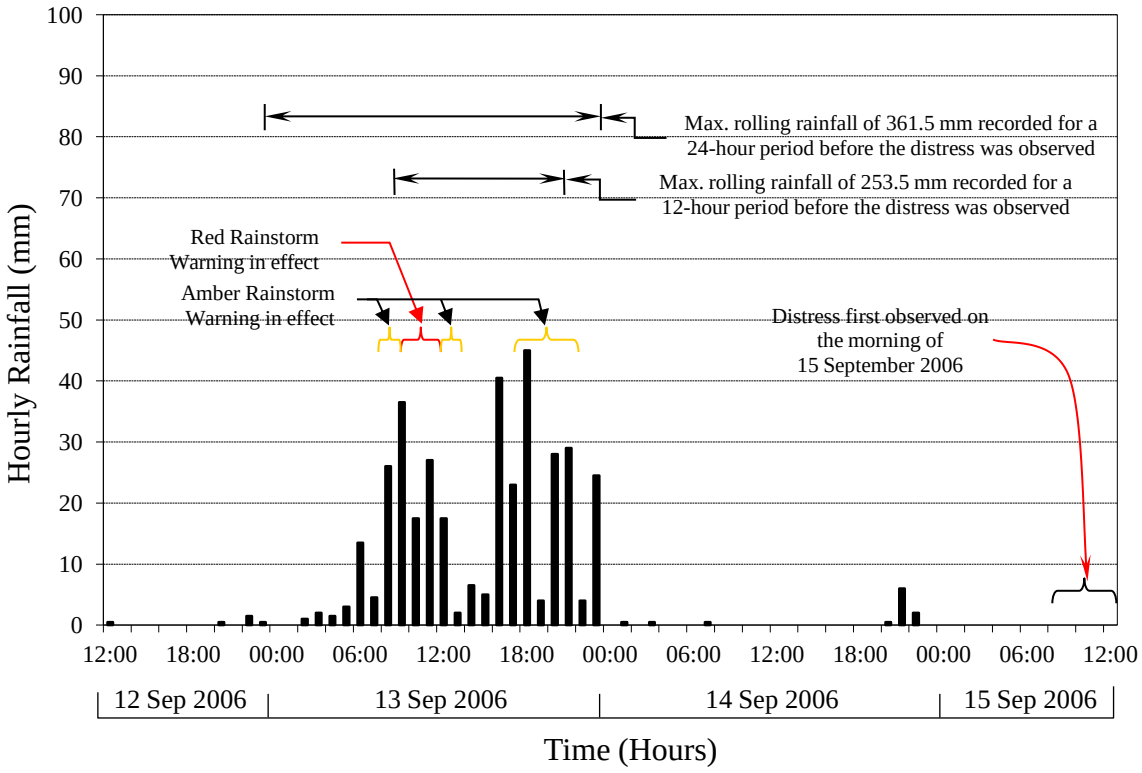


(a) Daily rainfall recorded at GEO Raingauge No. N36 between 14 August 2006 and 18 September 2006



(b) Hourly rainfall recorded at GEO Raingauge No. N36 between 12 September 2006 and 15 September 2006

Figure 8 - Daily and Hourly Rainfall Recorded at GEO Raingauge No. N36

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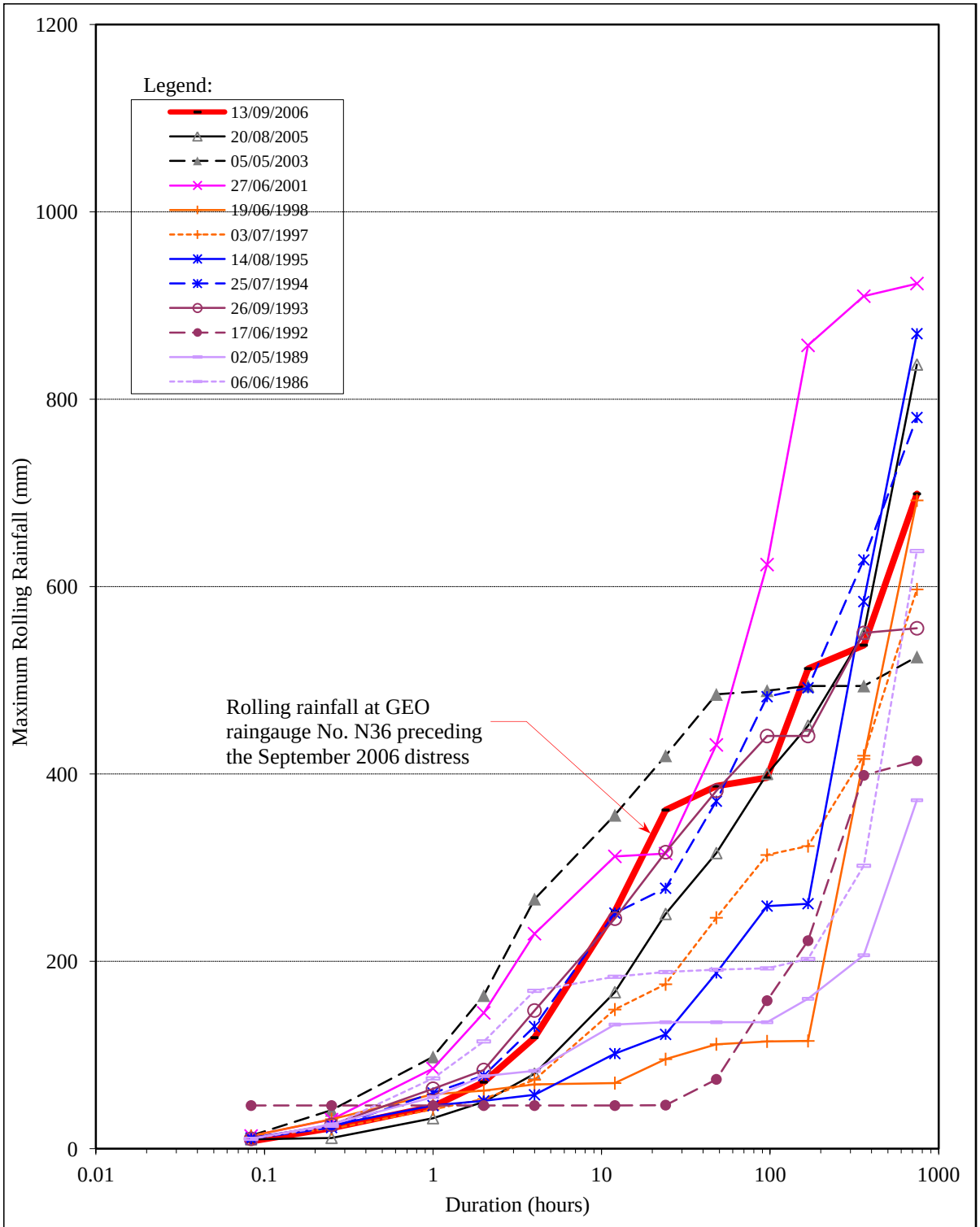

Notes: (1) Rainfall data evaluated from 5-minute readings from GEO raingauge No. N36 (about 3.4 km to the southeast of the site) and GEO raingauge No. N05 (about 5.4 km to the northeast).
(2) Rolling rainfall of previous rainstorms calculated at GEO raingauge No. N05 since March 1983 when the raingauges became operational.

Figure 9a - Maximum Rolling Rainfall for Previous Major Rainstorms at GEO Raingauge No. N05

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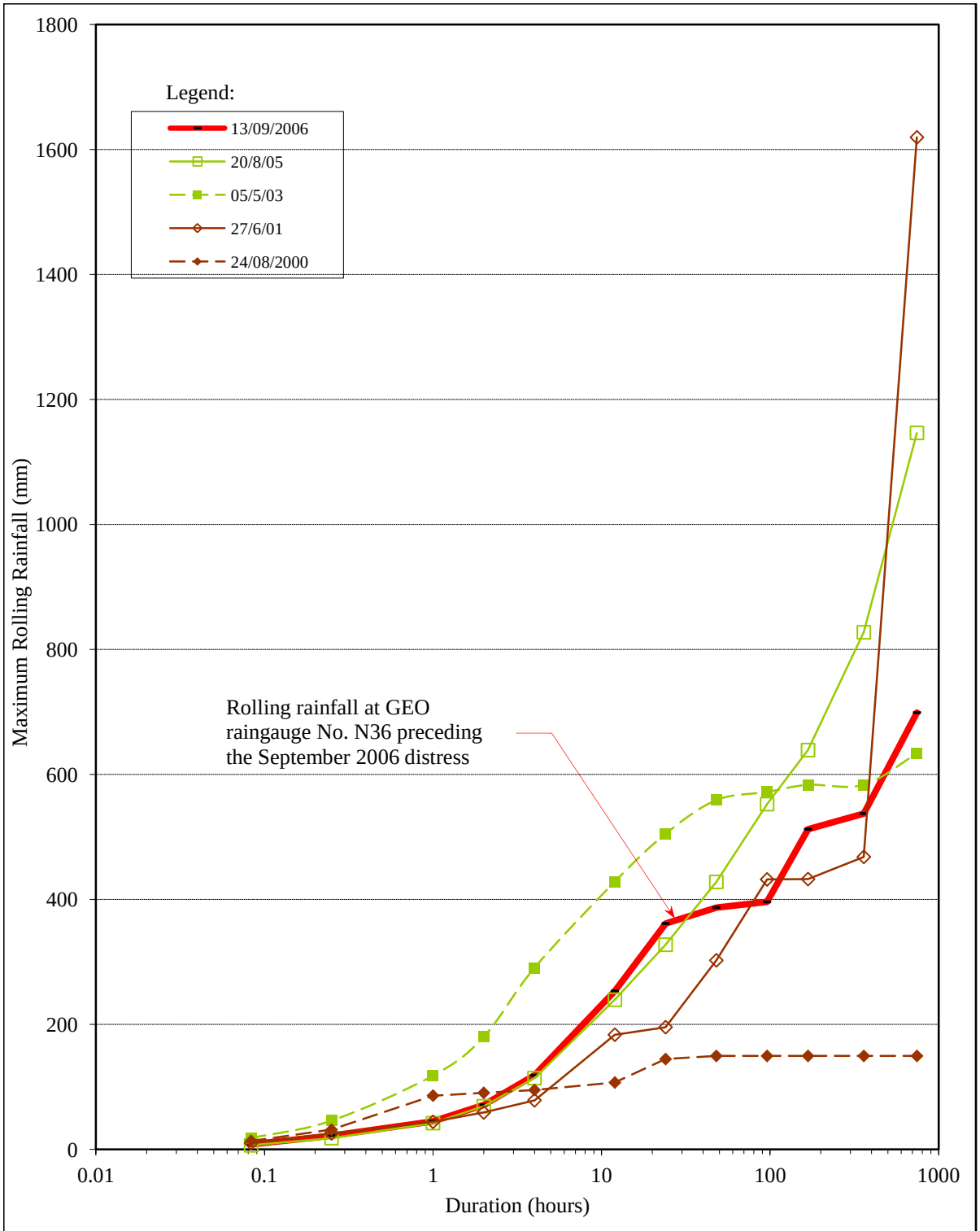

Notes: (1) Rainfall data evaluated from 5-minute readings from GEO raingauge No. N36 (about 3.4 km to the southeast of the site).
(2) Rolling rainfall of previous rainstorms calculated at GEO raingauge No. N36 since November 1999 when the raingauges became operational.

Figure 9b - Maximum Rolling Rainfall for Previous Major Rainstorms at GEO Raingauge No. N36

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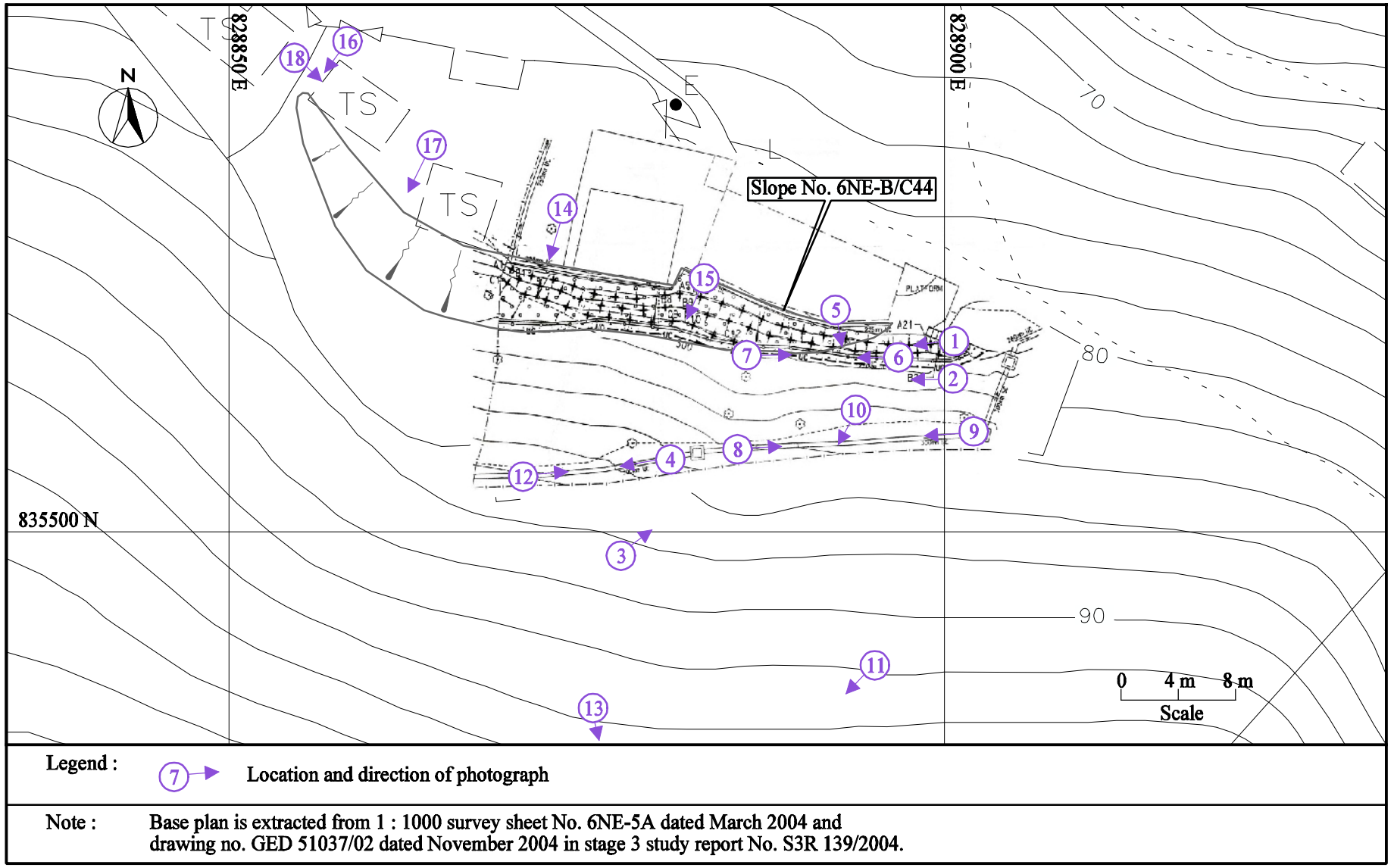

Figure 10 - Locations and Directions of Photographs Taken

LIST OF PLATES

Plate 1 - General View of Eastern Portion of Slope No. 6NE-B/C44 Looking West
(Photograph taken on 26 September 2006)

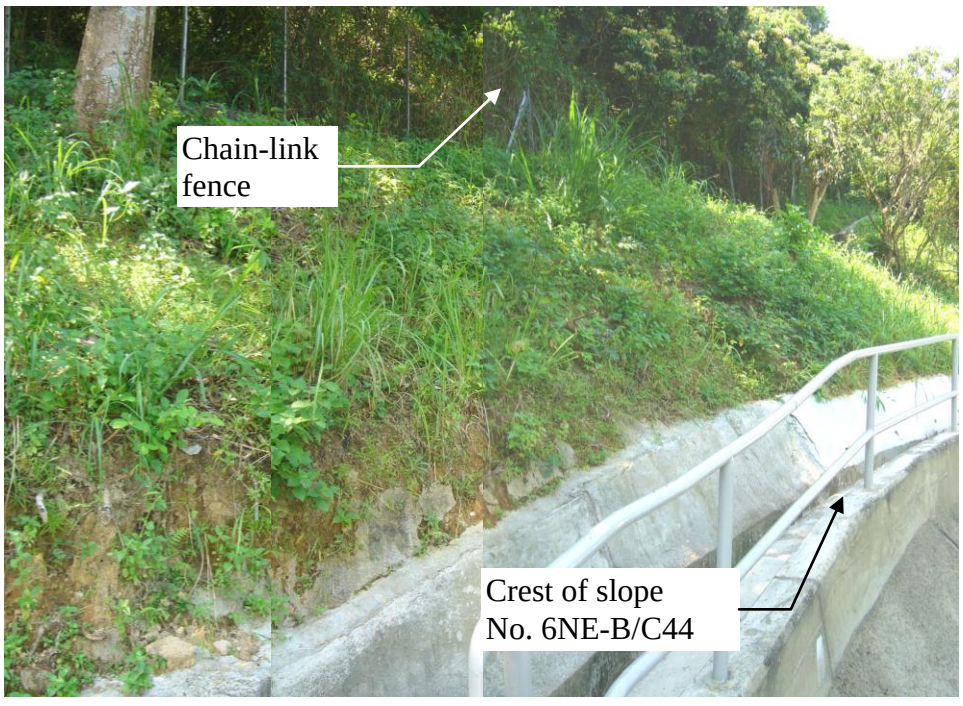

Plate 2 - General View of Area above Eastern Portion of Slope No. 6NE-B/C44 Looking West
(Photograph taken on 26 September 2006)

Note : See Figure 10 for locations and directions of photographs.

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Plate 3 - General View of Area above Eastern Portion of Slope No. 6NE-B/C44 Looking Northeast (Photograph taken on 26 September 2006)

Plate 4 - Cracked Upper 300 mm U-channel of Slope No. 6NE-B/C44 (Photograph taken by OAP on 21 February 2006)

Note : See Figure 10 for locations and directions of photographs.

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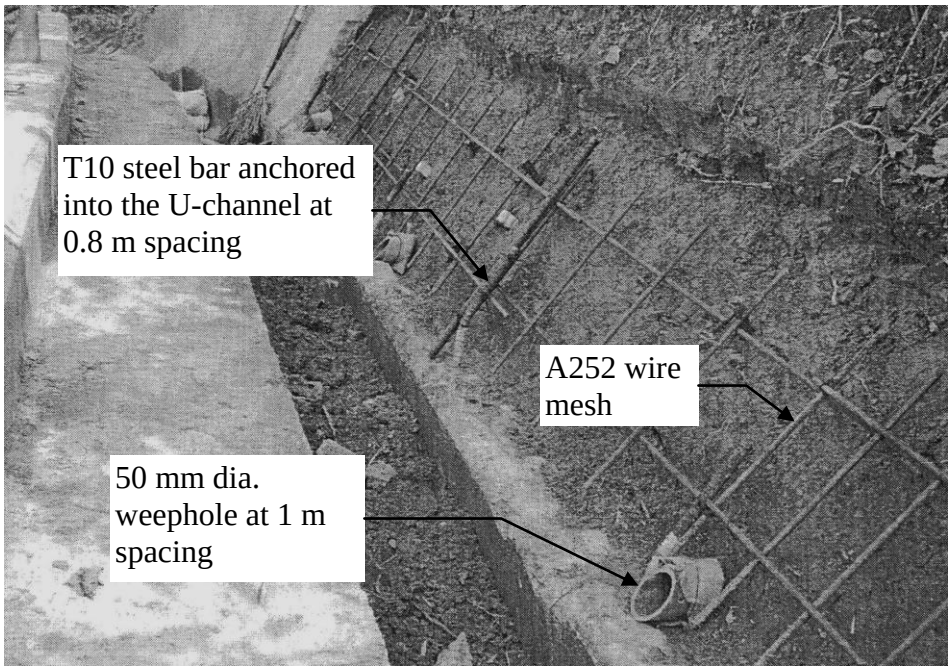

Plate 5 - Repair of Cracked U-channel along the Crest of Slope No. 6NE-B/C44 Looking Southeast (Photograph taken by LandsD on 3 October 2005)

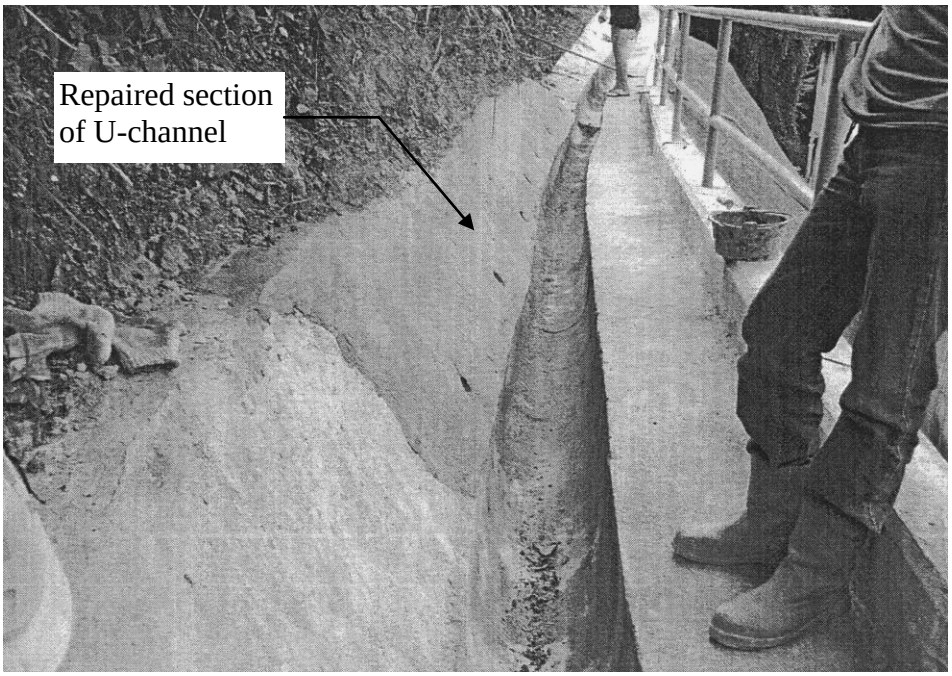

Plate 6 - Repair of Cracked U-channel along the Crest of Slope No. 6NE-B/C44 Looking West (Photograph taken by LandsD on 3 October 2005)

Note : See Figure 10 for locations and directions of photographs.

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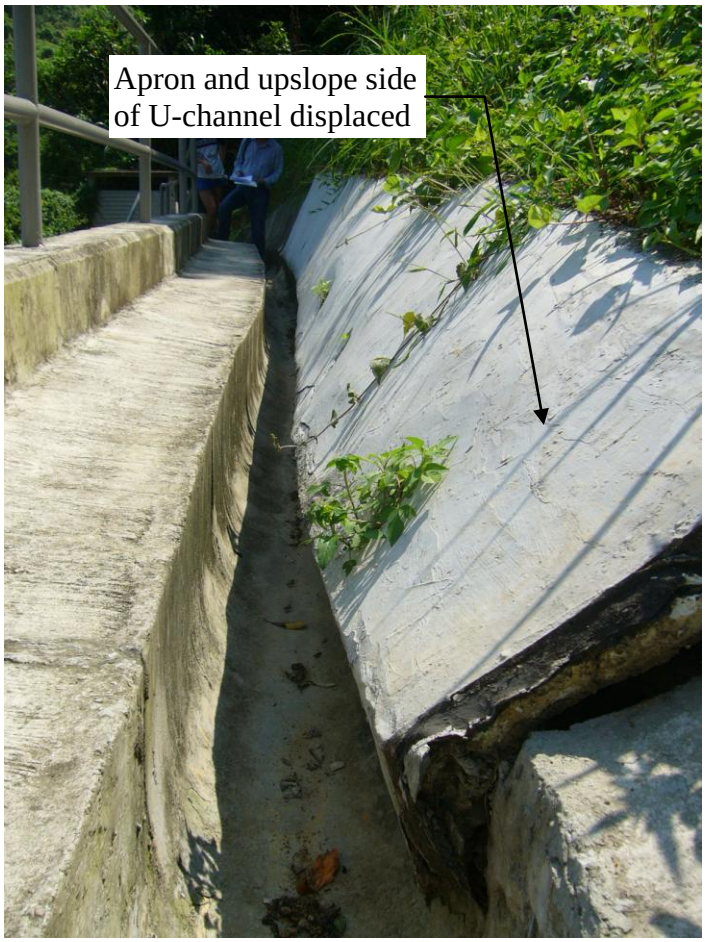

Plate 7 - View of the Displaced 300 mm U-channel along the Crest of Slope No. 6NE-B/C44 (Photograph taken on 26 September 2006)

Note : See Figure 10 for locations and directions of photographs.

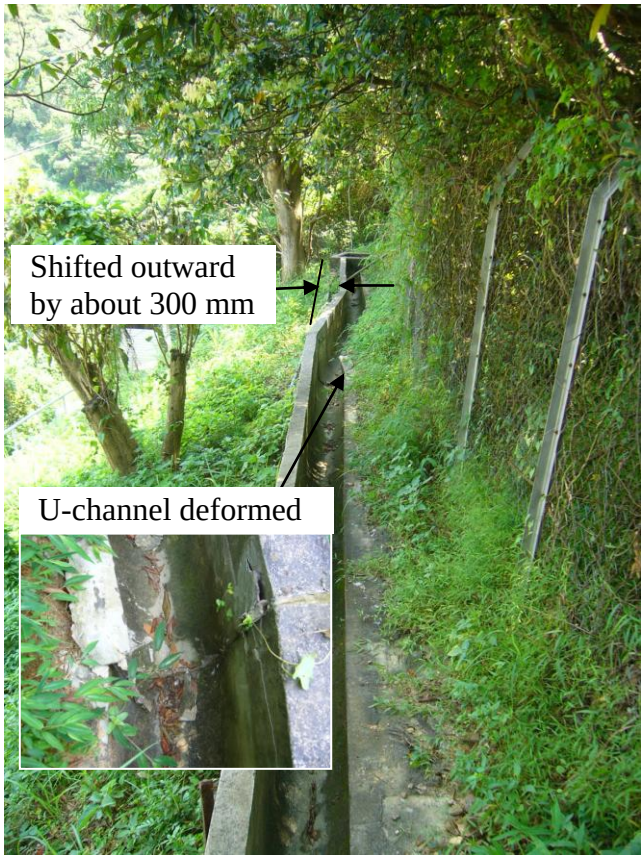

Plate 8 - Deformed Upper 300 mm U-channel near the Eastern End of Slope No. 6NE-B/C44 Looking East (Photograph taken on 26 September 2006)

Note : See Figure 10 for locations and directions of photographs.

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Plate 9 - Upper 300 mm U-channel near the Eastern End of Slope No. 6NE-B/C44 Looking West Showing Its Straight Alignment in 2003
(Photograph taken by OAP on 22 November 2003)

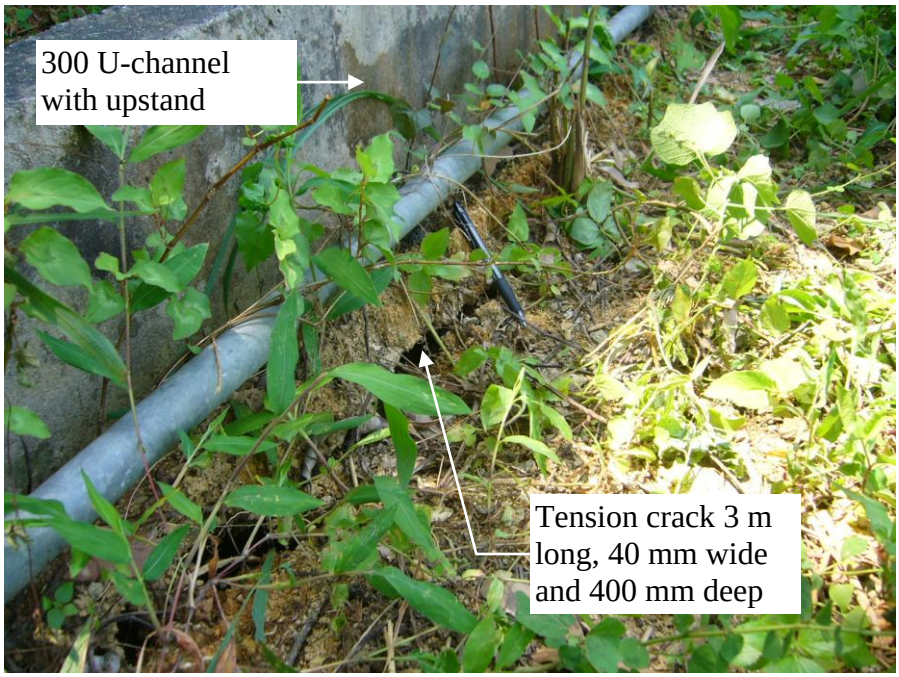

Plate 10 - Tension Crack on Downslope Side of the Upper 300 mm U-channel
(Photograph taken on 26 September 2006)

Note : See Figure 10 for locations and directions of photographs.

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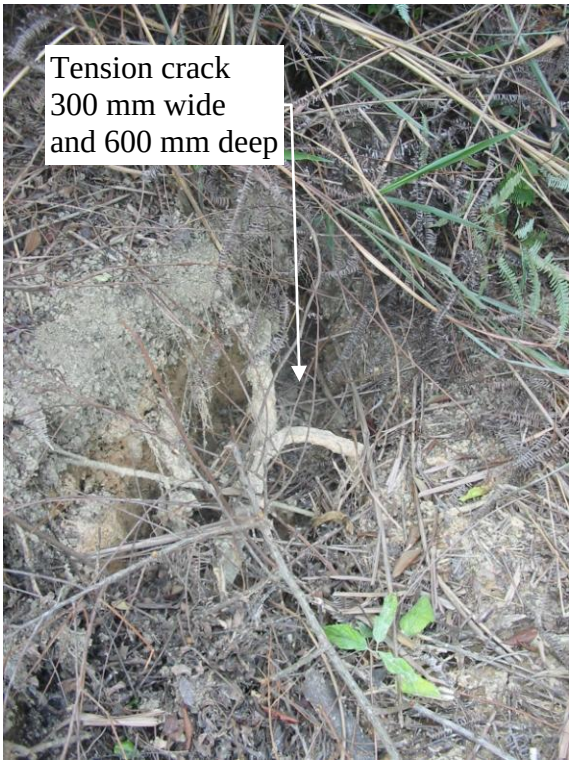

Plate 11 - Tension Crack on Area above Slope No. 6NE-B/C44
(Photograph taken on 19 November 2007)

Plate 12 - Deformed Upper 300 mm U-channel
(Photograph taken on 26 September 2006)

Note : See Figure 10 for locations and directions of photographs.

Plate 13 - Tension Crack on Area above Slope No. 6NE-B/C44
(Photograph taken on 19 November 2007)

Plate 14 - Damp Patch on Shotcrete Surface
(Photograph taken on 26 September 2006)

Note : See Figure 10 for location and direction of photograph.

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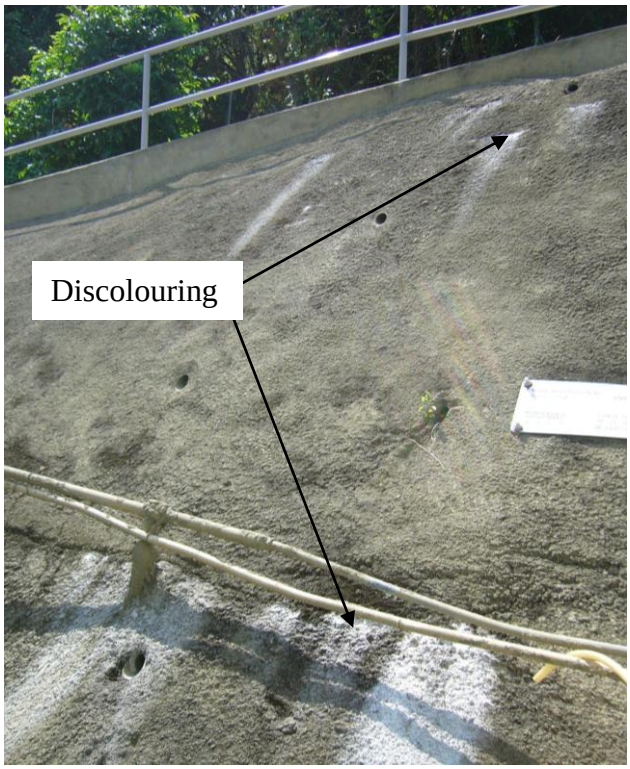

Plate 15 - Discolouring on Shotcrete Surface
(Photograph taken on 26 September 2006)

Plate 16 - View of the Western End of Slope No. 6NE-B/C44 Looking Southwest (Photograph taken on 9 May 2007)

Note : See Figure 10 for location and direction of photograph.

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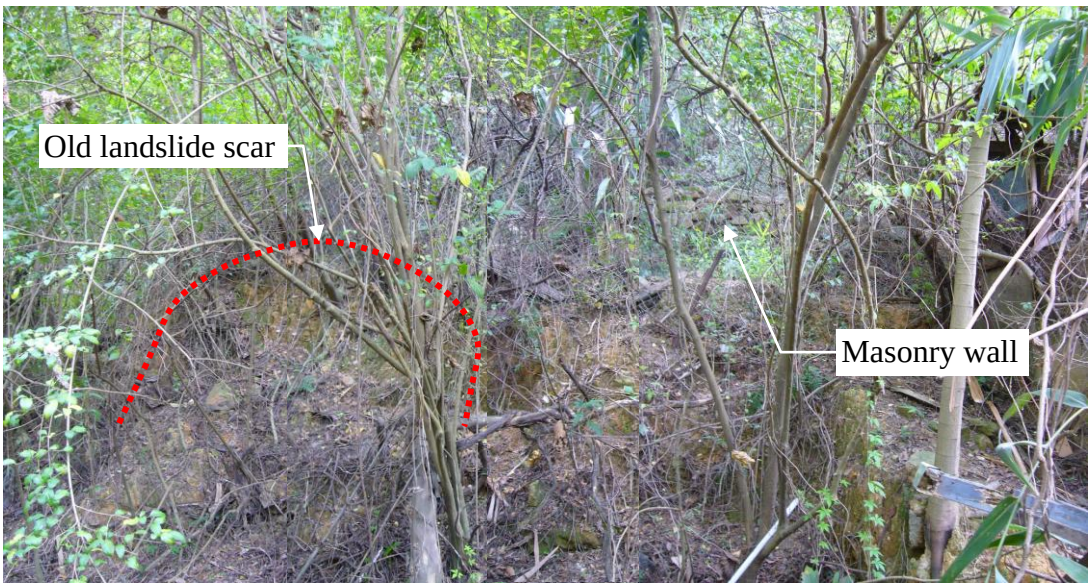

Plate 17 - General View of the Western Portion of Slope No. 6NE-B/C44 Looking Southwest (Photograph taken on 9 May 2007)

Plate 18 - Ruin at Toe of Western Portion of Slope No. 6NE-B/C44 (Photograph taken on 9 May 2007)

Note : See Figure 10 for location and direction of photograph.

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APPENDIX A

AERIAL PHOTOGRAPH INTERPRETATION

CONTENTS

A1. DETAILED OBSERVATIONS

Detailed observations from examining the available aerial photographs taken between 1949 and 2006 are presented below. A list of the reviewed aerial photographs is presented in Table A1. The major site development history is shown on Figure A1 and the general geomorphology and hydrology of the site area are presented on Figure A2, both attached to this Appendix.

YEAR OBSERVATIONS

1949 High flight, fair resolution single aerial photograph.

The study feature, which consists of a cut slope behind some minor village structures, has not yet been formed. The general area under concern consists of the lower slope of a thinly vegetated, north-facing natural hillside.

The natural hillside in general consists of a broadly concave terrain, which is flanked by relatively sharp northwest and northeast trending spurlines on its western and eastern sides respectively (Figure A2). A well-defined northwest-trending ridgeline is present at the crest of the hillside. The natural hillside is drained by ephemeral streamcourse channels along some relatively gentle topographic depressions. A major southeast-northwest trending river channel meanders along lower-lying area, at the toe of the natural hillsides. There is no evidence of any boulder or rock outcrop occurring within the natural hillside under study.

A relatively small plot of agricultural terraces (M1) is observed near the foot slope, immediately below the study area. There is evidence of some disturbance to the hillside in the general vicinity of the study feature, although the extent of which cannot be clearly delineated from the high level single aerial photograph. Three graves (M2) are visible within the lower hillside to the northwest of the study area. A minor footpath (M3) traversing the lower slope of the natural hillside is evident. The toe area of the natural hillside is occupied by extensive agricultural terraces (M4), adjacent to the main river channel. An area of erosion (E1) is visible on the upper spurline to the southeast of the study area.

YEAR OBSERVATIONS

1964 High flight aerial photographs.

The study feature has been formed, which consists of a relatively steep cut slope situated immediately behind a minor village structure within the lower slope of the natural hillside. The minor village structure is erected on a platform (M5), which has probably been formed by cutting into the natural hillside; the study cut slope has been formed in conjunction with the development.

Cultivation activities are apparent within the agricultural terraces (M1) previously identified on the downhill side of the study feature, directly below the minor village structure at M5. Another village structure is also identified on a platform (M5a) immediately below M5. Clusters of village structures have been erected within the extensive agricultural terraces M4, at the toe of the hillside.

A relict landslide feature is observed within the upper slope of the natural hillside. The relict landslide scar (R1), which corresponds to the relict landslide (No. 06NEB0146) recorded under the NTLI, is clearly evident and is laterally defined by rounded convex breaks-in-slope. No evidence of associated downslope debris can be observed.

1973 There is evidence of disturbance (M6) to the natural hillside immediately above the study cut slope, which is probably related to some cultivation/tree-planting activities as mentioned in previous year. Localised cutting is probably involved but any major filling is not apparent. A horizontal, linear feature, probably a footpath, is observed within M6.

The extensive agricultural terraces (M4), previously identified at the toe area further downslope of the study feature, have mostly been cleared and the general area is occupied by a big cluster of village houses.

1974 Single aerial photograph.

The plot of agricultural terraces at M1 has extended further upslope (M1a), below the village structure at M5. It appears that some planting activities are underway within M6 on the upslope of the study feature.

1976 The study feature and its immediate vicinity are covered with dense vegetation growth. The graves (M2) on the downhill side, to the northwest of the study area, are also obscured by dense vegetation.

Planting activities are apparent within the western portion of M6. An electricity post (M7) is observed on the eastern spur further upslope, to the southeast of the study feature.

YEAR OBSERVATIONS

1978 Single aerial photograph.

No changes of significance are observed.

1979 Some patterned tree planning is observed within M6, directly upslope of the study feature. It appears that the previous village structures at M5 have been demolished and replaced by two new structures that are generally in line with the present-day layout. In conjunction with the development, it appears that some works have been carried out to the study cut slope. A linear feature is evident along the crest of the slope, which may possibly be a narrow footpath or some surface drainage channel.

1981 Planting activities remain evident within M6. On the downhill side, cultivation activities are underway within M1, whereas the field terraces at M1a is overgrown with dense vegetation and appears abandoned.

1982 The area of M6 generally shows a long tabular shape with some micro-terracing along the hillside, which extends from the western spur to the eastern spur, on the upslope of the study feature. There is evidence of small local areas of disturbance within the upper slope of the natural hillside (M8). The general hillside remains thinly vegetated.

1987 Planting activities are evident within the eastern portion of M6, which is immediately above the study cut slope. Whilst, the western portion is overgrown with dense vegetation, and cultivation activities are not apparent. Some horizontal access paths are identified within the eastern portion of M6.

A large portion of the agricultural terraces at M1 are covered with dense vegetation growth. Another electricity post (M7a) is observed at the ridgecrest, further upslope, to the south of the study area.

1988 Planting activities remain active within eastern M6, directly above the study feature. The planting area at M6 is traversed by a series of horizontal paths, which are probably associated with access and/or drainage purposes. A relatively sharp vertical linear feature (M9) is evident within the mid portion of M6, which may also be associated with some drainage facility.

The area on the downhill side of the minor village structures (M5) are overgrown with dense vegetation and agricultural activities within M1 are not apparent. Few village structures are observed at platform M5a, further downslope to the northwest of the study feature. The natural hillside above M6 remains covered with light vegetation growth.

It appears that the footpath (M3) originally identified within the lower slope of the natural hillside, has been widened, which passes below the minor village structures at M5. The natural hillside to the southwest of the study feature has

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YEAR OBSERVATIONS

probably been affected by hillfire with a large portion of the vegetation removed.

1992 Cultivation activities have re-activated within the agricultural terraces at M1. A trail (M10) is observed along the spurline to the southeast of the study feature. Some landslide scars are observed on the hillside to the southeast of the study area.

It appears that a major hillfire has affected a large area of the hillside to the south of the study area as well as a local area around the upper spurline to the southeast.

1993 A scar (L1), which relates to a previous landslide, is evident within the upper slope of the natural hillside, to the south of the study feature. The general hillside is covered with light vegetation; the associated debris trail has possibly re-vegetated.

Planted vegetation is still evident within M6 directly above the study feature. Dense vegetation cover is observed within the agricultural terraces M1 on the downhill side of the feature. Another trail (M11) is visible along the western spurline to the southwest of the study feature.

The scars (L2 and L3) of the two previous landslides, which correspond to the landslide features (No. 06NEB0488 and 06NEB0489) recorded under the NTLI, are evident on the hillside to the southeast of the study area. For landslide L2, the associated debris trail is observed; whereas for L3, the associated trail is not evident.

1994 No changes of significance are observed.

1995 The access paths, which divide the planting area of the eastern M6 into three even layers, are clearly observed. These access paths are probably those observed in the 1987 photographs. The agricultural terraces at M1 appear less apparent, as the area is generally covered with dense vegetation. The scars (L1 to L3) are still visible.

1997 No changes of significance are observed, the general study area becomes overgrown with dense vegetation. It is uncertain whether cultivation activities are still underway within M1 and M6.

1998 The general study area and the natural hillside on the upper slope continue to be covered with moderate to dense vegetation growth.

1999 No changes of significance are observed, except that the scar L1 has fully re-vegetated.

2000 The study feature and its general vicinity are overgrown with dense vegetation. The scar of L2 is still visible; the area has not fully re-vegetated; whereas for L3,

YEAR	OBSERVATIONS
	the landslide scar is not evident.
2001	It appears that some hard surface cover has been applied to the face of the eastern portion of the study feature. Small-scale cultivation activities are evident within the lower portion of M1.
2003	No changes of significance are observed.
2004	The study feature and its general vicinity are obscured by dense vegetation growth. Further cultivation activities within M6 appear unlikely.
2005	The slope face and the access path along the slope crest are both visible. It is uncertain whether further slope works has been carried out to the study feature since 2001. The upslope side of the study feature remains covered with dense vegetation growth.
2006	Only single aerial photograph is available. No changes of significance are observed.

LIST OF TABLES

Table A1 - List of Aerial Photographs

Date Taken	Altitude (ft)	Photograph Number
8 May 1949	-	Y1852
13 December 1964	12500	Y13039-40
20 December 1973	12500	7913-14
21 November 1974	12500	9868
23 November 1976	12500	16448-49
15 December 1978	12500	24534
7 November 1979 29 November 1979 30 November 1979	10000	27801 28274-76 28479/28481
13 January 1981 19 May 1981 27 October 1981	10000	35610-12 37993-95 39269
27 July 1982	4000	42927-28
16 December 1987	4000	A11246-47
2 June 1988	4000	A13044-45
28 April 1992	4000	A30650-51
2 November 1993	3000	CN5124-25
6 May 1994	4000	A38205-06
19 July 1995	3200	CN10126-27
23 July 1997	3300	CN17725-26
10 July 1998	3000	CN19945-46
9 February 1999	3500	CN22473-74
1 June 2000	3500	CN26534-35
20 September 2001	4000	CW32985-86
27 November 2003	3500	CW53955-56
11 June 2004	2500	CW57771-72
26 October 2005	4000	CW66702-03
22 December 2006	6000	CS3366
Note: Aerial photographs are in black and white except for those prefixed with CN or CW.		

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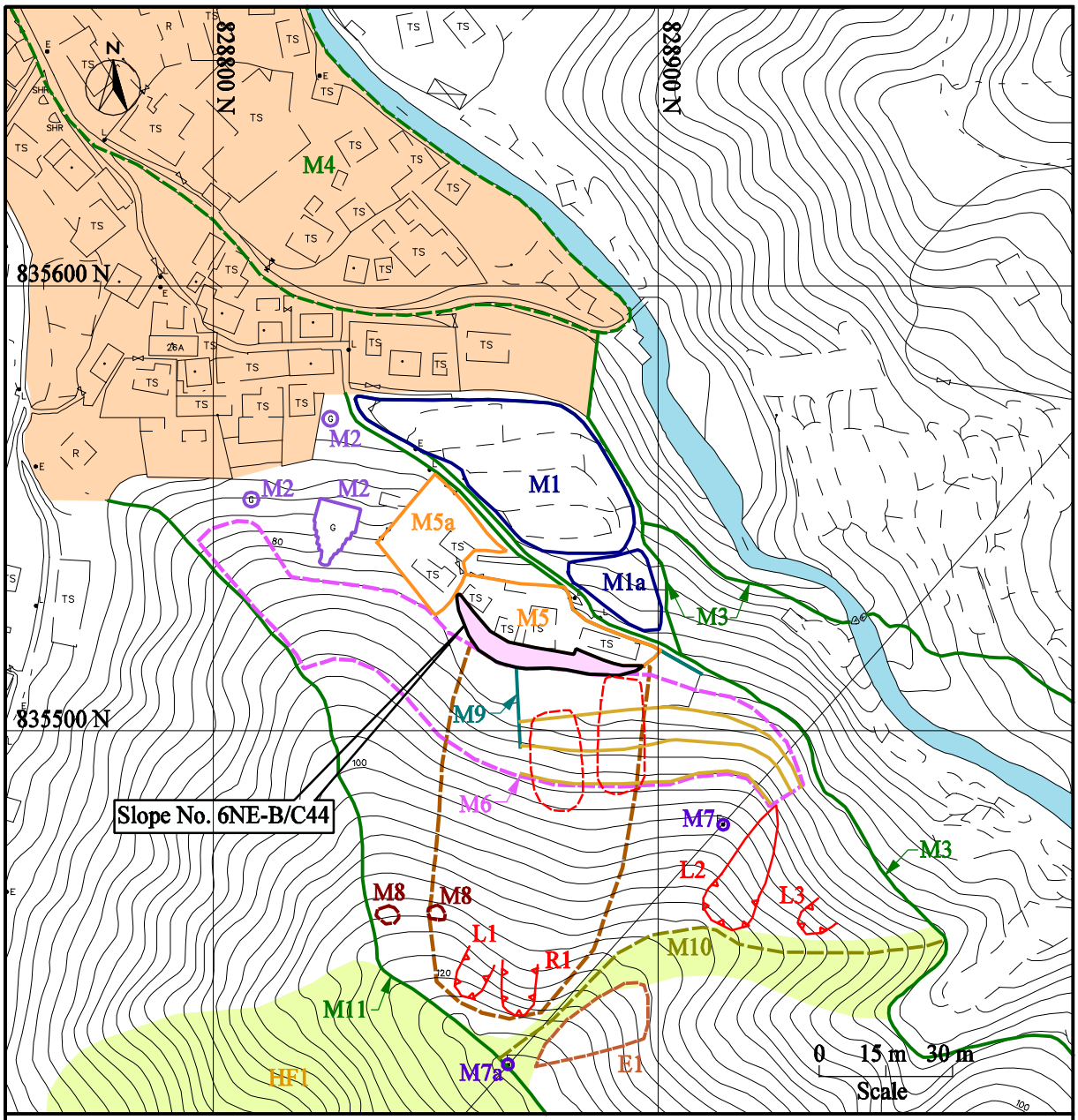

Legend :

- M7 — Man-made feature / disturbance with reference No. M7
- L1 — Landslide scar from 1993 photos
- L2 — Landslide scar from 1993 photos
- L3 — Landslide scar from 1993 photos
- R1 — Relict landslide scar from 1964 photos
- HF1 — Area affected by hillfire from 1992 photos
- Cluster of village structures
- E1 — Erosion feature
- Horizontal path observed within eastern M6
- A major southeast-northwest trending river
- September 2006 distressed area
- M1/M1a — Small plot of agricultural terraces
- M2 — Graves
- M3 — Minor footpath along hillside
- M4 — Extensive agricultural terraces
- M5/M5a — Minor village structure
- M6 — Evidence of disturbance (related to cultivation / tree planting activities)
- M7/M7a — An electricity post
- M8 — Local areas of disturbance
- M9 — Drainage facility
- M10 — Trail along spurline
- Depression

Note : Base plan is extracted from 1 : 1000 survey sheet No. 6NE-5A dated March 2004.

Figure A1 - Site Development History

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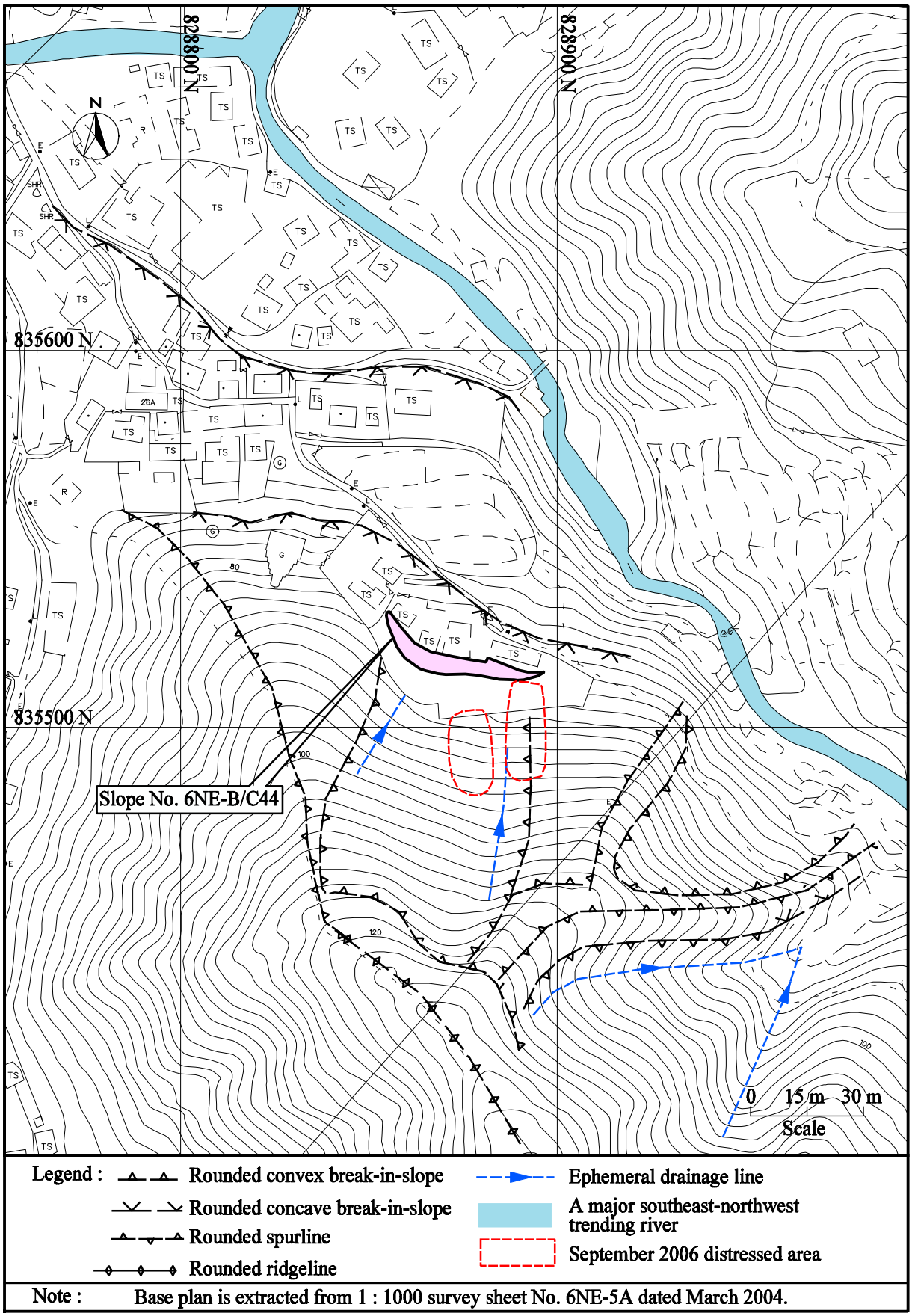

Figure A2 - Site Geomorphology and Hydrology

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APPENDIX B

SUMMARY OF MAINTENANCE INSPECTIONS

LIST OF TABLES

Table B1 – Summary of Maintenance Inspections for Slope No. 6NE-B/C44

Month/ Year	Responsible Party	EI/RMI	Observations/ Remarks	Maintenance Works Recommended
7/99	HAP	EI	The overall state of maintenance was assessed as "Poor". The chunam surface was severely broken. The surface drainage channels at the slope crest were partly blocked with moderate cracking.	Routine maintenance works, including replacement of the chunam surface, clearance of blocked drainage channels and repair of cracked drainage channels, were recommended. The report also recommended preventive maintenance works, comprising shotcreting, provision of a stepped channel and catchpit in the centre of the slope, and regrading of the slope. However, there are no records that these recommended works have been carried out.
2/02	MGSL	RMI		Minor maintenance works including clearance of drainage channels, repair of cracked drainage channels and slope surface cover at the slope crest behind the 2-storey residential structure and pigsty respectively, removal of surface debris and vegetation that had caused cracking, and clearance of blocked weepholes, were recommended by MGSL. Similar maintenance works were recommended by the LandsD. The works recommended by MGSL and LandsD were completed by November 2002 and April 2002 respectively.
3/02	LandsD	RMI		
2/03	LandsD	RMI		No maintenance works were recommended.
10/03	OAP	RMI		Minor maintenance works including clearance of drainage channels and removal of surface debris and vegetation that had caused cracking, were recommended and completed by November 2003.
6/04	OAP	EI	The overall state of maintenance was assessed as satisfactory in general (Class 1). The condition of the shotcrete surface was assessed as "Good". No signs of seepage or distress were noted.	No routine maintenance works were recommended. The report however recommended soil nailing as preventive maintenance works for the entire slope.
4/05	OAP	RMI		Minor maintenance works including the repair of the drainage channels and replacement of surface protection (both at the eastern end of the slope), and provision of drainage channel cover, were recommended and completed in May 2005.
1/06	OAP	RMI		Cracking at the top edge of the upper 300 mm U-channel was observed. Minor maintenance works including clearance of drainage channels, repair of cracked drainage channels, removal of surface debris and vegetation that had caused cracking, and trimming overgrown vegetation on slope surface, were recommended and these were completed in February 2006.

HAP – Halcrow Asia Partnership
MGSL – Maunsell Geotechnical Services Limited
OAP – Ove Arup & Partners Hong Kong Limited

APPENDIX C

INCLINOMETER RESULTS

LIST OF FIGURES

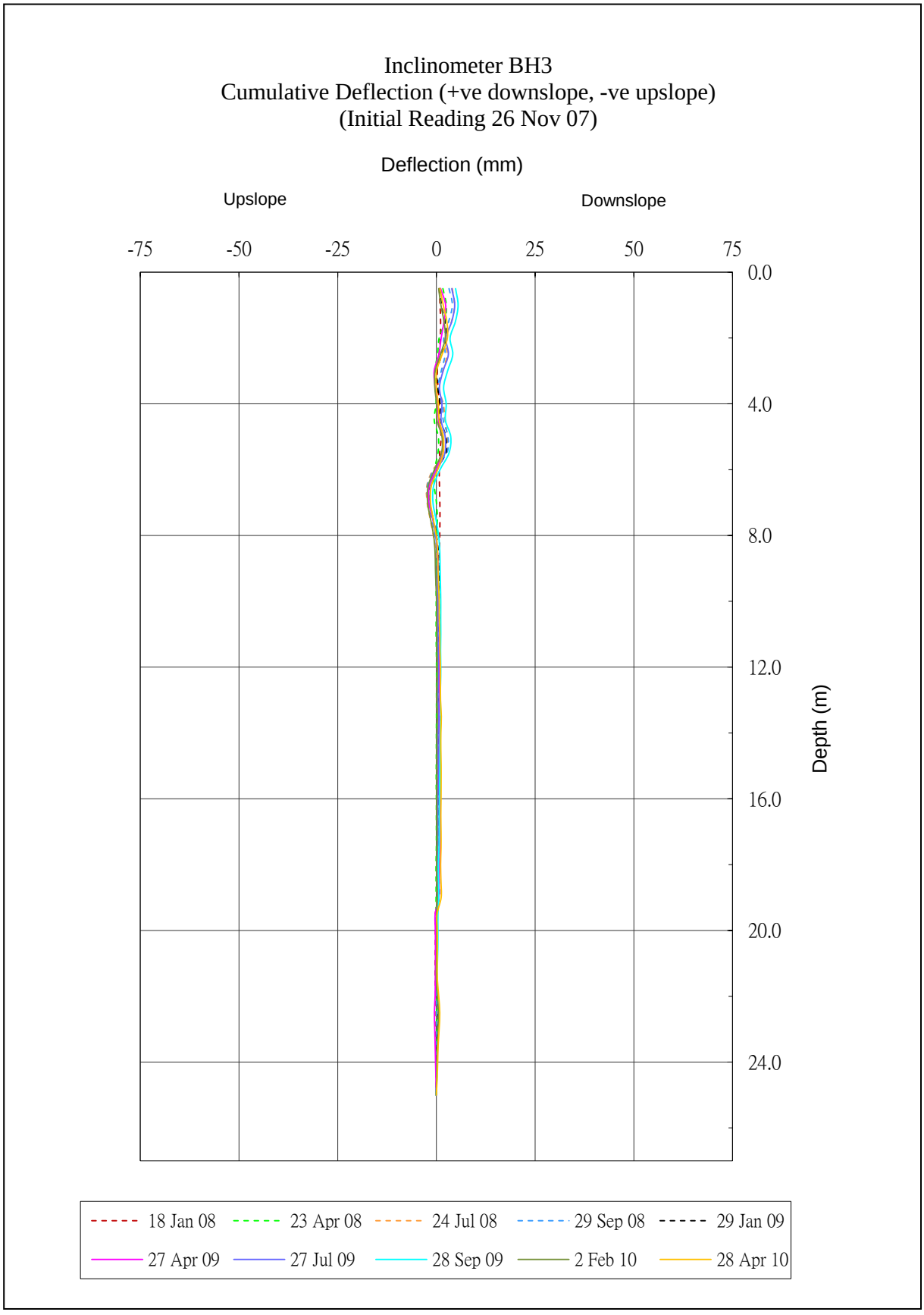

Figure C1 – Summary of Monitoring Records of Inclinometer No. BH3 between January 2008 and April 2010

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

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

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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

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