REVIEW OF THE 21 AUGUST 2005 LANDSLIDE ON SLOPES NOS. 7SE-B/C195 AND 7SE-B/C131 AND THE DISTRESSED HILLSIDE ABOVE SLOPE NO. 7SE-B/C122 AT MA ON SHAN UPPER VILLAGE

GEO REPORT No. 216

Maunsell Geotechnical Services Limited

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

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PREFACE

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

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

R.K.S. Chan
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December 2007

FOREWORD

This report presents the findings of a review of a landslide (Incident No. 2005/08/0384) that occurred on 21 August 2005 at Ma On Shan Upper Village. The landslide occurred on cut slopes Nos. 7SE-B/C195 and 7SE-B/C131, which were separated by a large drainage ditch. The detached debris (with a volume of about 1,000 m^3) severely damaged three registered squatter structures and partly buried another registered squatter structure and resulted in the permanent evacuation and clearance of a number of other adjacent registered squatter structures. No casualties were reported as a result of the incident.

An adjacent area on and above slope No. 7SE-B/C122 was observed to have significant signs of distress in the form of numerous tension cracks and a recent toe slump failure (with a total volume of about 5000 m^3). The observed distress and the toe slumping were noted to be recent and were probably concurrent with the landslide in August 2005. The total detached and displaced volume of the August 2005 landslide and the adjacent distressed hillside was about 6,000 m^3.

The key objectives of the review were to document the facts about the landslide and the adjacent distressed hillside, present relevant background information and establish the probable causes of the failure. The scope of the review comprised desk study, site reconnaissance and analysis of the information obtained.

The report was prepared as part of the Landslide Investigation Consultancy for landslides occurring in Kowloon and the New Territories in 2005, for the Geotechnical Engineering Office, Civil Engineering and Development Department, under Agreement No. CE 15/2004 (GE). This is one of a series of reports produced during the consultancy by Maunsell Geotechnical Services Limited.

L J Endicott

Dr. L.J. Endicott
Project Director
Maunsell Geotechnical Services Limited

Agreement No. CE 15/2004 (GE)
Study of Landslides Occurring in Kowloon and the New Territories in 2005 - Feasibility Study

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1. INTRODUCTION

At about 7:00 a.m. on 21 August 2005 when the Landslip Warning had been in effect for more than 35 hours and the Amber Rainstorm Warning had been in effect for more than 13 hours on 20 August 2005, a landslide (Incident No. 2005/08/0384) occurred on cut slope Nos. 7SE-B/C195 and 7SE-B/C131, which are situated to the south of, and directly above, Ma On Shan Upper Village (Figure 1 and Plate 1). The detached debris (with a volume of about 1,000 m^3) severely damaged three unoccupied, registered squatter structures and partly buried one occupied, registered squatter structure. Four occupants of other registered squatter structures at the toe of the landslide were temporarily evacuated following the landslide. No casualties were reported as a result of the incident.

Slope No. 7SE-B/C122 and the hillside above the slope, which abuts the eastern flank of the landslide, showed significant signs of distress in the form of numerous tension cracks, ground mass displacement, tilted trees and a toe failure (with a total volume of about 5000 m^3). The total detached and displaced volume of the August 2005 landslide and the adjacent distressed hillside was about 6,000 m^3.

Following the incident, Maunsell Geotechnical Services Limited (MGSL), the 2005 Landslide Investigation Consultant for Kowloon and the New Territories, with the support of their sub-consultant Ove Arup and Partners Hong Kong Ltd (Arup), carried out a review of the landslide for the Geotechnical Engineering Office (GEO), Civil Engineering and Development Department (CEDD), under Agreement No. CE 15/2004 (GE).

This report documents the facts about the landslide and the adjacent distressed hillside, as well as the findings of a file search and pertinent site observations made by MGSL and Arup. The scope of the review does not include any ground investigation or detailed analysis of the failure.

2. THE SITE

2.1 Site Description

The landslide, which affected two cut slopes Nos. 7SE-B/C195 and 7SE-B/C131, occurred within a local depression between two minor spurs on a north-facing hillside above Ma On Shan Upper Village. Slope No. 7SE-B/C195, which comprises a series of minor abandoned agricultural terraces (each approximately 1.0 m to 1.5 m high) inclined at an overall angle of about 35°, is some 95 m wide with a maximum height of about 14 m. It lies within the lower portion of the failed area. Slope No. 7SE-B/C131, which appears to be a small cut into a minor spur, is about 35 m wide, with a maximum height of about 3 m. It comprises one slope batter inclined at an angle of about 34° and is situated at the crest of the landslide scar. The two slopes are covered with vegetation and separated by a drainage ditch (see Section 2.2 and Figure 2). Slope No. 7SE-B/C122, which is also a single batter slope inclined at an angle of about 50°, is situated to the east of slope No. 7SE-B/C195 and is about 63 m wide with a maximum height of about 12 m. The slope surface was partly vegetated and partly covered by shotcrete prior to the landslide.

There are many abandoned agricultural terraces on the hillside above and adjacent to the landslide. The hillside above the landslide is inclined at an angle of about 35° and is

covered by a mixture of immature trees and scrub vegetation (Plate 1). The hillside between slope No. 7SE-B/C122 and the drainage ditch is inclined at an angle of about 26° to 32° and is also densely vegetated. There are no major natural streamcourses in the vicinity of the landslide but several ephemeral streamcourses are present nearby (Figure 3).

Ma On Shan Upper Village is situated at the toe of the hillside and consists of a collection of one- or two-storey squatter structures and outbuildings (e.g. kitchen, toilet or storage shed) that are connected by footpaths. The squatter structures encroach on the natural hillside and form a series of irregular building platforms with associated gardens and small agricultural terraces. Some vacant platforms are present between the structures. The damaged squatter structures and some other affected squatter structures at the toe of the August 2005 landslide include single-storey brick and concrete structures as well as several flimsy structures built using sheets of corrugated iron/steel. Lutheran Grace Youth Camp (Youth Camp), which comprises a church, a few dormitories, a playground and a toilet/shower structure, is situated at the toe of the August 2005 landslide and slope No. 7SE-B/C122.

2.2 Drainage Ditch

On the 1:1000 survey maps, the drainage ditch that runs between slopes Nos. 7SE-B/C195 and 7SE-B/C131 was marked as a “catchwater”. This drainage ditch is approximately 1.0 m to 1.2 m deep and 1.0 m to 1.2 m wide (Plate 2). The drainage ditch starts from the east of Ma On Shan Upper Village (i.e. about 400 m to the east of the landslide) where it intersects a streamcourse and falls in a westerly direction across the hillside near the August 2005 landslide, and then it discharges into a tributary of a river, which flows through Tai Shui Hang. The ditch crosses several ephemeral streams to the south of the distressed hillside (Figure 2) and flows from these streams appear to have been intercepted by the ditch.

The drainage ditch is partly unlined, with some portions of the sidewalls covered by chunam and stone facing on the downhill side. The drainage ditch is generally cut into the hillside with the upper face comprising exposed soil and the invert lined with rock rubble (Plate 2). At some locations, a mortared-rubble retaining structure has been constructed on the downhill side to support the drainage ditch. No weirs or spillways are present along the drainage ditch. During inspection, several rock blocks and other debris were observed in the drainage ditch indicating the absence of regular maintenance. However, limited vegetation was growing in the drainage ditch, which suggests that some water has flowed along the ditch on a regular basis. At several locations in the vicinity of the ditch, there are some old landslides. It is not clear if any of the old landslides would have affected the function of the ditch in conveying runoff from the uphill area.

2.3 Water-Carrying Services and Other Utilities

A search was made of the relevant Government Department records, including Water Supplies Department (WSD) and Drainage Services Department (DSD), as well as the records of various utility companies and service providers in Hong Kong. No records of any water-carrying services or other utilities within the landslide area or immediately above the landslide were found.

A water tank about 6 m in diameter is present approximately 6 m above and 15 m to the southeast of the August 2005 landslide. A 300 mm drainage U-channel collects surface runoff from the adjacent hillside and feeds into the water tank via a catchpit (Figure 2). The tank contained a small amount of water (<300 mm deep) and showed no signs of leakage at the time of inspection. Staining on the side of the tank suggests that the water level in it had been at a higher level in the past. Heavily rusted, disused pipes, some of which were completely disconnected, appeared to have formerly served the lower squatter structures and agricultural areas. The water supply at the toilet/shower structure was disconnected for some time.

2.4 Maintenance Responsibility and Land Status

According to the Slope Maintenance Responsibility Information System (SMRIS) of the Lands Department (Lands D), Lands D is responsible for the maintenance of slopes Nos. 7SE-B/C195 and 7SE-B/C131. The tenants of short-term tenancy No. STT 721 are responsible for the maintenance of slope No. 7SE-B/C122.

A Land Status plan obtained from Lands D indicates that the Lutheran Grace Youth Camp is covered by the short-term tenancy No. STT 721 held by The Evangelical Lutheran Church of Hong Kong (Lutheran Church). The area above the drainage ditch falls within the Ma On Shan Country Park area. The Lands D records indicate that the tenancy No. STT 721 is renewable on a quarterly basis. A letter from the Lutheran Church to District Land Office/Sha Tin (DLO/ST) in August 2003 indicated that they had ceased using the Youth Camp at the time. The Youth Camp was also unoccupied at the time of failure in August 2005.

Enquiries of the relevant Government Department records (including those of WSD, DSD, Lands D, District Office/Shatin (DO/ST) of Home Affairs Department (HAD) and Agriculture, Fisheries and Conservation Department (AFCD)) regarding the maintenance of the drainage ditch were made. The responses from these departments indicate that the drainage ditch is not under the maintenance responsibility of these Departments.

2.5 Regional Geology

According to the Hong Kong Geological Survey 1:20,000 Solid and Superficial Geology Map Sheet 7 - Sha Tin (GCO, 1986), the landslide site is underlain by fine-grained granite. Two areas of debris flow deposits overlying the fine-grained granite are present on the hillsides immediately to the west and further to the east of the landslide site (Figure 4). Two faults are noted on the geology map and these lie about 300 m to the north (an inferred fault) and 300 m to the southeast of the landslide respectively. These faults form the contacts with the coarse ash crystal tuff to the southeast and partly with the sandstone and siltstone to the northeast. An intrusion of quartz monzonite and slivers of sandstone is along the faulted boundary to the southeast.

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 relevant documentary information and site observations. Detailed observations from the aerial photograph interpretation (API) are summarised in Appendix A.

Based on the earliest available aerial photographs taken in 1945 and 1949, the hillside above the landslide area forms a north-facing slope that has rounded spurs normal to the toe of the hillside. Several minor ephemeral streams, which discharge into an active streamcourse within the village to the north and northeast of the landslide, are present near the toe of the hillside. Much of the hillside has been disturbed by agricultural and human activity over a long period of time (Figure 3).

The August 2005 landslide and the distressed hillside was at the edge and within a rounded hillspur. The August 2005 landslide lay within a slight topographic depression on the western side of the spurlines while the majority of the distressed hillside lay within the apex of the rounded hillspur (Figure 3).

Construction of the drainage ditch to the south and above Ma On Shan Upper Village was carried out some time between 1949 and 1954, and construction of the associated slopes on the uphill side of the drainage ditch, including slope No. 7SE-B/C131, was probably completed at the same time. The mining and village activities in Ma On Shan suggests that the drainage ditch may have been formed to divert surface water away from the mining activities and supply water to the various communities downstream.

Slope No. 7SE-B/C195 and the area above, which was affected by the landslide, was being used for agricultural purposes between 1954 and 1963. The extent of the agricultural terraces is clearly visible on the 1963 aerial photographs (Figure A3). The agricultural terraces above the drainage ditch were abandoned by the early 1980s whereas most of the agricultural terraces below the drainage ditch were abandoned in the 1990s. The August 2005 landslide occurred within these abandoned agricultural terraces and the registered slope features. The water tank above the drainage ditch and the connecting channel were constructed between 1949 and 1954.

The church, the Youth Camp and their associated building platforms were constructed between 1954 and 1963. Some minor extensions of the church and the Youth Camp were built between the early and late 1980s. Slope No. 7SE-B/C122 was formed, by cutting into the round hillspur, some time before 1963 in association with the building platform construction. A landslide occurred on this slope between 1963 and 1973 (Figure 3). In 1994, a large landslide occurred at the same location of slope No. 7SE-B/C122. The landslide debris associated with this landslide was not removed and has remained on the building platform until the present day.

Squatter structures below the August 2005 landslide were constructed between 1949 and 1963. A few of these structures were demolished between 1963 and 1976. Based on API, there has been no significant demolition of these squatter structures since then. Details of the Non-Development Clearance (NDC) Programme for the Ma On Shan Upper Village are

presented in Section 4.6.

A minor natural drainage line passes through the eastern flank of the August 2005 landslide. Based on the 1963 photographs, two possible relict landslides were identified at the natural drainage lines above slope No. 7SE-B/C195 and it is considered that they are pre-1945 features (see Section 3.2).

3.2 Past Instability

3.2.1 Natural Terrain Landslide Inventory (NTLI) and Large Landslides Database

According to the GEO's Natural Terrain Landslide Inventory (NTLI), there are no reported natural terrain landslides within the immediate vicinity of the study area. The nearest NTLI incident occurred about 100 m to the southeast of the landslide (Figure 5). The GEO's Large Landslides Database contains no records of any reported large landslides within or in the vicinity of the study area.

3.2.2 Aerial Photograph Interpretation

Based on API, a landslide occurred on slope No. 7SE-B/C122 between 1963 and 1973 and another was observed in the 1996 high altitude photograph (which occurred in July 1994 according to the file records). Two topographic depressions, which are considered to be relict instability (pre-1945), are located above the drainage ditch about 50 m to the south of the August 2005 landslide (Figure 3). To the southwest of the landslide site, a convex break-in-slope can be seen in the natural terrain above two of the relict landslides (Plate A3).

No past instability was identified at slopes Nos. 7SE-B/C195 and 7SE-B/C131. No major signs of movement can be observed on the aerial photographs at the distressed hillside adjacent to the August 2005 landslide.

3.2.3 GEO's Landslide Database

According to the landslide database and file records, four previous landslide incidents occurred on slope No. 7SE-B/C122 (Figure 5). No past instability record could be found for slopes Nos. 7SE-B/C195 and 7SE-B/C131.

On 21 June 1992, two minor landslides (Incident No. ME92/7/11, with a failure volume at both locations estimated to be about 10 m^3) occurred on slope No. 7SE-B/C122 (see Figure 5 and Plate 3). One of the landslides buried part of the staircase along the slope toe and the other knocked over a lamppost at the slope toe. The Incident Report indicated that the failure material was colluvium and the possible causes of failure were "erosion" and "blockage of drains".

On the morning of 1 May 1993, a minor landslide (Incident No. ME93/5/9, with a failure volume of about 5 m^3) occurred at the eastern portion of slope No. 7SE-B/C122 (Figure 5 and Plate 4). The Incident Report stated that the failure material was "residual soil" and the possible causes of failure included "infiltration", "rupture of water mains/drains"

and “lack of maintenance of the U-channel (referred to as the drainage ditch in this report) along slope crest and surface of slope not properly maintained”.

On 7 July 1995, a landslide with a volume of 200 m³ (Incident No. ME95/7/2, Location A) and a minor landslide (Incident No. ME95/7/2, Location B) were reported to the GEO. It was reported that the slope failed in July 1994. The Incident Report shows that the size of the major landslide was about 25 m wide by 9 m long (Plate 5). The debris spilled onto the basketball court east of the Youth Camp knocking down part of the external wall to dormitory No. 6. The Incident Report indicated that a “bare slope surface” was observed. The material involved in the failure was weathered rock and the possible cause of failure was “infiltration”.

Following a regular review of slopes under the maintenance of STT with Warning Letters issued to the tenants (see Section 4.3), the Mainland East (ME) Division of the GEO visited slope No. 7SE-B/C122 on 4 March 2003 and observed a minor landslide scar at the western end of the slope (Figure 5 and Plate 6). This landslide had not been recorded in the GEO’s landslide database and the exact date of the failure is unknown. Based on the record photographs, the size of the landslide was about 8 m wide by 6 m high and the GEO noted the following: “Signs of wash-out were observed at various locations of the feature”.

4. PREVIOUS ASSESSMENTS AND SLOPE WORKS

4.1 SIFT, SIRST and Stage 1 Studies

The August 2005 landslide affected slopes Nos. 7SE-B/C195 and 7SE-B/C131, while the distressed hillside involved slope No. 7SE-B/C122 and the terrain above.

In 1992, the GEO initiated a project entitled "Systematic Inspection of Features in the Territory" (SIFT). Slopes Nos. 7SE-B/C195, 7SE-B/C131 and 7SE-B/C122 were all classified as SIFT Class “C1” in December 1996/January 1997, i.e. slopes that had “been formed or substantially modified before 30.6.78”. The SIFT record for slope No. 7SE-B/C195 also noted that this feature included “abandoned agricultural terraces”.

In July 1997, the GEO commenced a project entitled “Systematic Identification and Registration of Slopes in the Territory” (SIRST), to update the 1977/78 Slope Catalogue. Slope No. 7SE-B/C195 was inspected by the SIRST consultant, Binnie Consultants Ltd (BCL), on 5 September 1997. The inspection record noted that the slope condition was assessed as “fair”. Some signs of distress were identified near the crest, midpoint and at the toe of the slope. The consequence-to-life category was assessed to be “1”.

Slope No. 7SE-B/C122 was inspected by the SIRST consultant, BCL, on 2 August 1997. The inspection record noted that the slope surface was in fair condition with no signs of seepage. The consequence-to-life category was assessed to be “1”. A photograph taken on 2 September 1997 for the Stage 1 Study is shown in Plate 7.

Slope No. 7SE-B/C131 was inspected by the SIRST consultant, BCL, on 5 September 1997. The consequence-to-life category was assessed to be “3”. The inspection record noted that the slope was heavily vegetated and no detailed observation was made by the SIRST consultant.

4.2 Engineer Inspections and Routine Maintenance by Government

Engineer Inspection (EI) was carried out by Halcrow Asia Partnership Ltd on slope No. 7SE-B/C195 in September 1999 for Lands D. The EI report indicated that there was "recent erosion" and noted "Locally exposed soil surface noted across feature. Slope will continue to deteriorate unless preventive measures are undertaken". No rating under "Overall State of Slope Maintenance" was made in the EI report. The vegetated slope surface was considered as "Fair". The repair of "vegetated areas on slope" was recommended as routine maintenance. Recommendations on preventive maintenance works (PMWs) included "Improve surface drainage by providing surface drainage channels" and "Improve surface drainage by providing a slope crest channel with upstand".

Routine Maintenance Inspections (RMIs) of slope No. 7SE-B/C195 were carried out in May 2001, January 2003 and November 2003. No routine maintenance works were recommended under these RMIs.

Another EI on slope No. 7SE-B/C195 was carried out by Arup in October 2004 for Lands D. According to the EI report (which had not been finalised by September 2006 in Lands D's records), the condition of the vegetated slope surface was considered as "Fair". The overall state of maintenance was classified as "Class 1" and there were no major defects in the surface drainage system. Recommendations on routine maintenance works included "Trim overgrown vegetation on slope". Recommendations on preventive maintenance works included "Provide/reconstruct surface channels/catchpits/downpipes". The EI report remarked that "The last EI was carried out on 27-Sept-1999, PMW such as improve surface drainage by providing surface drainage channels and a slope crest channel with upstand were recommended but no works have been done" and "Since the affected toe facility is only an abandoned cottage, therefore it is recommended to downgrade the feature to category 3".

Both EI identified the "Catchwater" (referred to as a drainage ditch in this report) as shown on the plans in the reports but no comments were made on the condition of the drainage ditch.

An EI was carried out on slope No. 7SE-B/C131 by Maunsell Fugro Joint Venture in May 2002 for the Lands D. No classification of the overall state of slope maintenance was made in the EI report. According to the EI report, the condition of the vegetated slope surface was considered as "Fair". "Nil" was marked under "Recommendations on Routine Maintenance Works" and no recommendation was given on preventive maintenance works.

No RMI records could be found for slope No. 7SE-B/C131.

4.3 Maintenance of Slope No. 7SE-B/C122 and GEO Actions

Following the July 1994 landslide, the Lutheran Church submitted a remedial works proposal to DLO/ST in May 1996 and this was referred to the GEO for comment. The proposed works mainly involved trimming of the failed slope, the application of chunam protection to the slope face and provision of surface drains. GEO considered the proposed works as "temporary remedial measures" and reminded the Lutheran Church to "appoint an

AP/RSE to carry out an investigation and advise on permanent slope works proposal".

The proposed temporary remedial measures were completed in late 1996, including the use of part of the demolished dormitory walls to retain the failed soil debris that had been mostly left in place. The landslide scars were covered with shotcrete and temporary drainage measures were provided along the slope crest and toe. A letter from the Lutheran Church in February 2006 indicated that they had also carried out repair works in 1995 on the "big catch-water ditches" at the crest of the slope but no further detail was provided.

Following a site visit to the above works in January 1997, the ME Division of GEO prepared a Case Report in February 1997 and recommended the Buildings Department (BD) to issue a Dangerous Hillside (DH) Order on the owner concerned. GEO noted "The Church indicated that they had no intention to appoint an AP/RSE to carry out investigation work in the near future" and "The shotcreted slope scars appear to be over-steepened and is likely to fail during heavy rainfall or under high ground water condition". GEO also inspected the drainage ditch outside the STT boundary and noted that the "unlined" drainage ditch "appeared to carry storm drainage from a large catchment area". GEO considered that "some urgent maintenance works are considered necessary and will be carried out by the relevant government departments once the maintenance responsibility is determined by DLO/ST". DLO/ST was subsequently requested to determine the maintenance responsibility of the drainage ditch. No information regarding the related follow-up action could be found in the file record.

The recommendation of serving a DH Order on the tenants of STT No. 721 was made by GEO to BD on 24 February 1997. A reply from BD to DLO/ST on 21 April 1997 pointed out that it would be impracticable to serve a DH Order on the tenants because the "specified time span for the works required under the recommended DH-Order will extend beyond the STT [a quarterly basis]." As subsequently advised by BD on 24 December 2002, DLO/ST informed BD on 31 December 2002 that "Letters have been sent to the tenant of the premises reminding to take all necessary steps to maintain the slope within the tenancy area regularly."

Slope No. 7SE-B/C122 was included in a list of "STT features" in December 2002, for which DH Orders were considered "unenforceable" and as such it should be regularly reviewed by the GEO. The ME Division of the GEO carried out a site inspection on 4 March 2003 and noted that no maintenance works had been carried out on slope No. 7SE-B/C122 since the completion of the temporary remedial works in 1996. GEO also recommended to DLO/ST that "Investigation and slope stabilisation works should be carried out without further delay", and to "fence off the area in danger as an immediate safety precaution" and that "The application for the extension of the STT should not be entertained prior to completion of slope stabilisation works." DLO/ST issued a Warning Letter to the STT tenants on 1 April 2003. A letter from the Lutheran Church in October 2003 noted that the area has been abandoned for a long time and agreed to fence off the area affected by the slope of concern for public safety. In December 2003, the ME Division of the GEO noted that no further GEO action is required "until reuse of the area is considered".

No other EI or RMI records could be found for slope No. 7SE-B/C122.

4.4 Drainage Ditch Maintenance Works

Apart from the repair works allegedly carried out by the Church in 1995 (see Section 4.3), no other records of maintenance works of the drainage ditch could be found. WSD, DSD, Lands D, DO/ST and AFCD are unable to locate any records relating to construction or maintenance works of the drainage ditch, and they confirmed that the drainage ditch were outside their maintenance responsibility.

4.5 Landslip Preventive Measures - Stage 2 Studies

Slope No. 7SE-B/C122 was assigned to the LPM Programme for a Stage 2 Study under Agreement No. CE 13/2002 in 2002. The study was carried out by CM Wong and Associates Limited (CMW) and site inspections were carried out in January and April of 2003. It was noted in a draft report submitted to the GEO on 6 June 2003 that "bare surface washout is evident at the southern [upper] portion". The draft report did not mention the presence of the drainage ditch or observation of any signs of distress on the hillside above the subject cut slope. In their letter to the GEO dated 3 December 2003, CMW suggested deleting the Stage 2 Study for this slope since "DLO/ST issued a Warning Letter to the tenants for feature No. 7SE-B/C122" on 1 April 2003 (see Section 4.3).

4.6 Non-Development Clearances

Under the Non-Development Clearance (NDC) Programme, Ma On Shan Upper Village was inspected by the GEO in 1986, 1993 and 2004 respectively. Clearances of squatter structures, generally located in the valley or in the vicinity of the toe of the hillside to the northwest and north of the August 2005 landslide, were recommended under the 1986 and 1993 NDC Programme. No additional clearance was recommended following the 2004 inspection. Figure 6 summarises the NDC recommendations and the status of the squatter structures within reach of the landslide debris. A visual survey of the squatter structures was carried out immediately after the August 2005 landslide to identify various occupied and habitable structures (Figure 7). The affected structures are discussed in more detail in Section 5.2.2.

Under the three phases of NDC inspections, no squatter structure in the vicinity of the August 2005 incident (i.e. in the vicinity of the Youth Camp and at the toe of the hillside within the reach of the debris of the 2005 landslide) was recommended for clearance. These squatter structures all lie to the west of the STT No. 721 and situated on government land.

Several squatter structures to the west of the August 2005 landslide incident were permanently evacuated following a major landslide (75 m^3) in 1993 (Incident No. ME93/5/7, see Figures 5 and 6).

In September 2005 (i.e. following the August 2005 landslide incident), GEO recommended Category 1 NDC for the squatter structures below the landslide site. The NDC recommendation is shown on Figure 6. The clearances were completed in June 2006 by the Clearance (1) Office Lands D.

5. THE AUGUST 2005 LANDSLIDE AND POST-FAILURE OBSERVATIONS

5.1 The 21 August 2005 Landslide

The landslide (Incident No. 2005/08/0384) occurred at about 7:00 a.m. on 21 August 2005 (Plate 1). The landslide affected cut slopes Nos. 7SE-B/C195 and 7SE-B/C131 and severed a drainage ditch (about 16 m long, 1.0 m deep and 1.2 m wide) that lay between the two cut slopes. The locations of the August 2005 landslide, associated features and distressed hillside are shown on Figure 8.

The landslide occurred from a single source (Plate 8) with a volume estimated to be about 1,000 m³. The overall height of the affected hillside at the landslide source (including the affected slopes) was about 20 m and the average inclination was approximately 35°. Some landslide debris was deposited within the landslide scar and most of the debris ran out onto the open hillside and partly buried some squatter structures in the upper part of the village. The toe of the debris extended into the village (Plate 9).

The landslide debris severely damaged three registered squatter structures, which were not occupied at the time of landslide, and partly buried one occupied, registered squatter structure (see details in Section 5.2.2). Four occupants at the adjacent registered squatter structures at the toe of the landslide were temporarily evacuated following the landslide. No casualties were reported as a result of the incident.

Following the incident, MGSL and Arup carried out site inspections on 23 August 2005 and thereafter.

5.2 Post-failure Observations

5.2.1 Landslide Source Area

The crown of the landslide scar developed mainly within slope No. 7SE-B/C131 and the remainder of the landslide scar affected a large part of slope No. 7SE-B/C195. The main scarp was located about 3 m to 5 m above the drainage ditch when it was first inspected on 23 August 2005 (Plate 10). During subsequent inspections, it was noted that the landslide scarp had retrogressed with further collapses of soil material some time between 23 August and 21 September 2005. The crown of the landslide was at an elevation of approximately 297 mPD but by 21 September 2005 it had migrated to approximately 305 mPD. The width of the main scarp was about 9.5 m and the landslide scar widened to approximately 16 m at the location of the drainage ditch. By September 2005, the maximum vertical height of the extended main scarp was noted to be up to 6.4 m. The overall thickness of the landslide was considered to be about 4 m deep in the middle of the landslide scar. Figure 9 shows the general layout of the features noted within the landslide cross-section.

Both the original and retrogressed main scarp had a dip angle of about 50° to 70°. The exposed material on both main scarps was partially weathered rock of grade PW 50/90 comprising mainly moderately weak to moderately strong granite. Localised impersistent joints, striking sub-parallel to the main scarp, were exposed and minor patches of kaolin infill up to 2 mm thick were noted (Plate 11). Unfavourably orientated relict joints were present in the flanks, striking sub-parallel and normal to the hillside, forming sliding/toppling surfaces

and side-release surfaces. Slickensided, manganese and kaolin infills and coatings up to 4 mm to 5 mm thick were observed on some of these joints (Plate 12). A stereoplot in Figure 10 shows the relationship of the mapped relict joints within the failure scar to the orientation of the slope. These clearly identify the local control that they provided for the development of side release surfaces, toppling joint, tension cracks at the main scarp and the sliding surface.

Release joints on the eastern flank were found to be orientated at 70°/263° (Plate 13). The base portion of the failure surface was located within the corestone layer of the weathered profile, possibly between the PW50/90 layer and the PW90/100 layer (Plate 13). A layer of colluvium up to 3 m thick was present at the western flank (Plate 14). Pockets of fill were noted on the downhill portion of the drainage ditch.

A significant tension crack was noted leading eastwards from the eastern end of the main scarp of the landslide (Plate 15). This tension crack had a vertical displacement up to about 200 mm, a horizontal width of some 150 mm and was open to a depth of approximately 1.4 m. This tension crack and another minor tension crack (Plate 16) led into the distressed hillside to the east of the landslide, which included slope No. 7SE-B/C122 at its toe (see Section 5.2.3). One minor tension crack was noted to the west of the failure area associated with the back of a terrace and the presence of a large tree which had prevented the failure scar from progressing westwards.

Landslide debris within the source area comprised yellowish brown slightly clayey sandy silt with many sub-angular boulders ranging in size from 0.2 m to 0.4 m.

No signs of piping or water features were noted except for a minor ephemeral streamcourse on the eastern side of the landslide scar, just above the drainage ditch. This ephemeral stream could be traced for approximately 9 m back from the landslide scar.

5.2.2 Debris Trail

The landslide debris deposited mostly on the hillside above the highest registered squatter structure No. RMOS/B/95-97 of Ma On Shan Upper Village (Figure 8). Registered squatter structures Nos. RMOS/B/95-97 were completely destroyed and crushed (Plate 17). Registered squatter structures Nos. RMOS/B/93 and RMOS/B/99 were damaged by the debris (Plates 18 and 19). Registered squatter structures Nos. RMOS/B/98, 100-102 were partly buried but remained intact (Plate 18). The landslide debris inundated some open platforms between the above structures (formerly occupied by squatter structures). Debris from the landslide also affected the Youth Camp including localised damage to a perimeter wall (Plate 20), minor inundation of the platform and dislocation of a disused water tank at the Youth Camp, but the buildings were not damaged.

The landslide debris did not appear to be particularly wet during the initial inspection on 23 August 2005, just two days after the landslide. Subsequent inspection in September 2005 revealed that the landslide debris consisted of loose very silty sand with numerous irregular sub-angular to sub-rounded blocks of more intact grade III to grade IV granite up to 1 m^3 in size as well as fragments of the broken drainage ditch. The debris was partly deposited within the failure scar, and extended up to 30 m downhill of the toe of slope

No. 7SE-B/C195. The initial travel distance of the landslide was about 50 m. Subsequent retrogressive failure of the landslide scar caused the landslide crown to move uphill by some 10 m. The initial travel angle was about 23° for the landslide scar observed on 23 August 2005, which was quite mobile. Following the retrogression of the landslide in September 2005, the travel angle increased to about 25° and about 100 m³ of additional material detached from the hillside (i.e. a total detached volume of about 1,100 m³).

Three distinct rafts were observed within the debris and these were up to 6 m long by 3 m wide (Plate 8). Tree roots within each of the rafts probably held the rafts intact.

There did not appear to be any significant entrainment of material from the toe of the landslide scar to the front of the debris lobe.

Following its initial forward surge that crushed squatter structure No. RMOS/B/95-97, the landslide debris appears to have spilled out relatively gently onto the roofs of squatter structures Nos. RMOS/B/98, 100-102 without causing any significant damage.

5.2.3 Adjacent Distressed Hillside

An area with significant distress was noted to the east of the August 2005 landslide within and above slope No. 7SE-B/C122. Two cross-sections (Figures 11 and 12) have been drawn through the distressed hillside showing the mapped features within the hillside and the locations of the downhill facilities. The distress was manifested by numerous tension cracks (Plate 21) and toe failures. The tension cracks extended from the eastern flank of the August 2005 landslide (Plates 15 and 16) to the drainage ditch directly uphill of the eastern end of the platform of the Youth Camp and then northwards almost to the elevation of the platform. The size of the distressed hillside is about 30 m long by about 45 m wide at the toe of slope No. 7SE-B/C122, with an estimated volume of about 5,000 m³, assuming a depth of about 6 m. The distressed hillside has suffered ground displacement without complete detachment of the displaced mass. The total volume of the detached mass from the August 2005 landslide and the displaced mass of the distressed hillside is about 6,000 m³.

A section of the main tension crack at the southeast corner of this area has caused a vertical displacement of the drainage ditch of about 1 m and a horizontal displacement of approximately 0.5 m (Plate 22). Significant scouring of this tension crack occurred due to water being diverted down the displaced section of the drainage ditch onto the lower part of the hillside. Slumping of the ground occurred lower down the hillside and in situ soils comprising PW30/50 mass were exposed in a scoured-out zone on the hillside. Colluvium, with a thickness of about 0.5 m to 1.0 m was also noted at some locations.

An approximately 25 m long persistent tension crack was noted running along the bottom of the drainage ditch with several cross-cutting tension cracks (Plate 23). There was very significant distress of the channel lining (i.e. both the chunam and rubble in this area), and the rubble structure had been rotated through approximately 15° to 20°.

The distressed hillside area has numerous small to medium sized trees that show evidence of recent as well as previous movement or possible ground creep (Plate 24).

Numerous tension cracks were found in the middle of the distressed hillside above the crest of slope No. 7SE-B/C122. These are considered to be the result of the distortions associated with the movement of the entire zone of displaced material on the hillside. Close inspection of the lateral tension crack release surface identified signs of infilled tension cracks within the distressed hillside. Thick roots were seen to run along the cracks (Plate 25), suggesting that progressive movement of the hillside had been taking place for some considerable time, most probably in an intermittent manner associated with previous heavy rainstorms. The observed horizontal and vertical displacements of the main tension cracks are shown in Figures 11 and 12.

The movement directions are mostly orientated between 340° and 350° (except near the boundary of the distressed hillside, i.e. at the crest of slope No. 7SE-B/C122, near the eastern and western end of the distressed hillside, see Figure 13). These orientations are roughly normal to the strike of the steeply-dipping relict joints that were mapped in the scar of the August 2005 landslide (see Figure 10 and Plate 13). This suggests that tension cracks could have developed along the relict joints in both parts of the hillside probably with a similar failure mechanism.

The presence of infilled tension cracks and the past instabilities on slope No. 7SE-B/C122 suggest that the distressed hillside might have had ongoing movements since the 1990's. The lack of signs of scouring at the August 2005 landslide compared to that noted at the distressed hillside, would suggest that significant movement of the distressed hillside occurred either at the same time or shortly prior to the August 2005 landslide. Without any eyewitness records, the exact timing of this significant movement cannot be determined.

There were two recent failures within slope No. 7SE-B/C122 at the base of the distressed hillside area (Plates 26 and 27) in August/September 2005, and the shotcrete and vegetated surface covers of the slope were significantly disturbed (Plate 28). The detached soil mass, which was about 100 m^3 in volume, was deposited onto the platform. Most of the detached debris was deposited on the backyard of the Youth Camp (Plate 26), and some of it was deposited behind the disused toilet/shower structure on the eastern section of the platform (Plate 27). Some tension cracks, at least 500 mm deep, found near the toe of the cut slope may be attributed to the debris slumping in front of the failed raft (Plate 28).

Both old and new subsidence cracks were noted to run through the disused toilet/shower structure (Plate 29) and a gap that was observed beneath the concrete fence foundation opposite the structure indicated possible subsidence and/or washout of soil (Figure 8). A collapsed, brick-lined drain was observed below the platform that appeared to run towards the disused toilet/shower structure on the eastern end of the platform.

During the field mapping between September and October 2005 (in which about 356 mm of rainfall was recorded at GEO raingauge No. N44 in September 2005, with corresponding return periods of less than 2 years for all rainfall durations), continued movement of the distressed hillside was observed. Further opening up of the tension cracks (about 10 mm to 20 mm wide) at the upper portion of the distressed hillside and further rotation and partial collapse of the damaged drainage ditch were observed (see Figure 13).

An existing landslide scar was noted to the west of the August 2005 landslide scar

(Figure 8 and Plate 30). This landslide had caused the collapse of the downhill side of the drainage ditch, which had been replaced with a mortared rubble wall. The size of the tree (with a trunk of about 50 mm diameter) at the base of the landslide (i.e. within the debris lobe) suggests that the landslide is likely to be quite old, i.e. at least several years. The juxtaposition of this landslide scar and the repaired section of the drainage ditch, suggests that the failure may have been caused by seepage of water from the drainage ditch.

5.3 Actions Taken by Various Government Departments Following the Incident

Following the landslide, Lands D carried out emergency works on the August 2005 landslide (slopes Nos. 7SE-B/C195 and 7SE-B/C131), including trimming back the failure scar and providing shotcrete cover and drainage measures and the works were completed in March 2006. Highways Department (HyD) then carried out emergency works to the adjacent distressed hillside and the downhill cut slope No. 7SE-B/C122 to prevent the hillside and the slope from further deterioration. Shotcrete was applied by HyD to the upper part of the distressed hillside, including the washout and lateral tension crack areas, and drainage measures (in the form of shotcreting the scouring channel at, and near, the toe of the distressed hillside, see Plate 31) were provided at the toe of the hillside and platform. The works by HyD were completed in May 2006.

GEO also recommended Category 1 NDC clearance of a number of registered squatter structures (see Figure 6) in the vicinity of the toe of the August 2005 landslide. The clearance was completed in June 2006.

A flooding incident occurred in June 2006 at the squatter structure No. 86 of Ma On Shan Upper Village below the Youth Camp platform. Surface water, some of which likely conveyed from the drainage ditch, discharged onto the platform, which overspilled and flooded the backyard of the above squatter structure. Following this incident, Lands D and HyD placed sand bag barriers at the edge of the platform and at the toe of the distressed hillside near the disused toilet/shower structure to intercept surface water runoff and divert it to the existing natural streamcourse at the eastern end of the platform.

6. ANALYSIS OF RAINFALL RECORDS

Rainfall data were obtained from GEO automatic raingauge No. N44, which is the nearest raingauge to the study area and is located about 2.5 km to the northwest at Kam Ying Court Commercial Complex, Ma On Shan. The raingauge records and transmits rainfall data at 5-minute intervals to the Hong Kong Observatory and the GEO.

According to the Incident Report prepared by the GEO, the landslide occurred at 7:00 a.m. on 21 August 2005. The daily rainfall recorded by raingauge No. N44 over the month preceding the incident, together with the hourly rainfall readings for the period between 19 and 21 August 2005, is presented in Figure 14.

The Amber Rainstorm Warning was issued on the evening of 19 August 2005 and intense rainfall was recorded until the evening of 20 August 2005. The maximum 12-hour and 24-hour rolling rainfall before the incident were 131 mm and 222 mm respectively. The

maximum 1-hour rolling rainfall was recorded as 24.5 mm between 7:30 a.m. and 8:30 a.m. on 19 August 2005 (Table 1).

Table 1 presents the estimated return periods for the maximum rolling rainfall for various durations recorded by raingauge No. N44 with reference to historical rainfall data at the Hong Kong Observatory in Tsim Sha Tsui (Lam & Leung, 1994). The results show that the 12-day rolling rainfall of 627.5 mm before the incident was the most severe, with a corresponding return period of about 7 years, whilst for other rainfall durations of between 24 hours and 31 days, the corresponding return periods range from less than 2 years to about 6 years. Return periods for rainfall durations of less than 12 hours are 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. N09, which is located at the Meteorological Laboratory of the CUHK, between 1984 and 1997. It is noted that the estimated return periods of the August 2005 rainstorm based on rainfall data at raingauge No. N09 are slightly lower than those estimated by the historical rainfall data at Tsim Sha Tsui.

The maximum rolling rainfall for the August 2005 rainstorm has been compared with the past major rainstorms recorded by raingauges Nos. N09 and N44, which came into operation in June 1983 and October 1999 respectively (Figure 15). It is noted that the August 2005 rainstorm was less severe than previous major rainstorms.

7. DISCUSSION

7.1 The 21 August 2005 Landslide

The August 2005 landslide, involving a deep-seated translational landslide, occurred during a moderate rainstorm with a return period of approximately 7 years, for a 12-day maximum rolling rainfall. It is less severe than many past major rainstorms.

A set of impersistent relict joints formed a stepped release surface at the back of the landslide, and another set of joints, which dipped at a high angle across the slope, was partly infilled with minor patches of kaolin. These joints appeared to have some control on the landslide scar and cleft water pressures may have developed along these joints prior to the detachment of the unstable ground mass.

Progressive movements of the hillside could have occurred in the vicinity of the August 2005 landslide, similar to those observed in the distressed hillside immediately to the east (see Section 7.2). The proximity of the August 2005 landslide to the distressed hillside indicates a close relationship between them and tension cracks were observed on the eastern flank of the August 2005 landslide. Although there is no direct evidence to support the presence of these cracks prior to failure, the fact that apparently ductile movements (similar to those evident in the distressed hillside to the east), which occurred over the years, developed into an uncontrolled detachment and a fairly mobile failure with fast-moving debris suggests the possibility of progressive deterioration of the ground mass on the hillside (Wong & Ho, 2000). The progressive movement probably led to the development of local tension cracks that could have facilitated water ingress into the landslide area as well as reduced the operational shear strength along the potential failure surface.

In geomorphological terms, the August 2005 landslide was located within a slight topographical depression between two rounded spurlines, which was part of an ephemeral drainage line that could have locally concentrated and directed surface runoff into the landslide area. The partly lined drainage ditch across the upper hillside between slopes Nos. 7SE-B/C195 and 7SE-B/C131 intercepted various ephemeral streams and showed signs of regular water flows. The bare cut face on the uphill side of the drainage ditch and the largely unsealed cobble-laid invert probably provided paths for direct infiltration into the hillside since its formation in the 1950s, thus probably contributing to the progressive deterioration of the hillside. It would appear that no regular maintenance had been carried out to the drainage ditch. Signs of previous instabilities in the vicinity of the ditch were observed. It is noteworthy that the agricultural terracing activities on slope No. 7SE-B/C195 and the adjacent hillside could also have promoted infiltration of surface runoff into the ground.

Although the presence of the drainage ditch was noted in the previous EI reports for the registered man-made slopes, its condition and potential impact on the overall hillside stability may not have been fully considered.

The travel angle of the initial landslide was 23°, which is relatively low as compared with that for typical cut slope failures, i.e. about 30° to 40° (Wong & Ho, 1996). The significant antecedent rainfall in early August 2005, together with the hydrogeological setting (i.e. open tension cracks and the potential source of concentrated water ingress from the drainage ditch during rainstorms), probably allowed the ground mass on the hillside to lose soil suction and possibly develop high positive groundwater pressures prior to the landslide, which might have led to a higher debris mobility.

7.2 Adjacent Distressed Hillside

The distressed hillside to the east of the August 2005 landslide shows signs of movement prior to August 2005, which is manifested by the presence of deformed trees and tension cracks infilled with organic materials and thick root systems. The formation of slope No. 7SE-B/C122, and the trimming back of the slope associated with the past failures, at the toe of the distressed hillside would have changed the setting of the natural hillside and resulted in progressive deterioration. Progressive movements of this nature would enhance surface water ingress into the open cracks and the building up of cleft water pressure. The poorly lined drainage ditch running through the zone of progressive movement would have provided a source of water ingress during rainfall. The slope had a history of instability in the 1990's, including minor incidents in 1992 and 1993, with a major landslide in July 1994. These incidents may possibly reflect the progressive development of the large-scale instability that became apparent in August 2005.

During the August 2005 rainstorm, reactivation of movements occurred on the distressed hillside and the development of landslide scars at slope No. 7SE-B/C122. The movement of the area could have been initiated by direct infiltration of rainfall into the pre-existing cracks on the distressed hillside. This could have been further exacerbated by water ingress through the dilapidated drainage ditch into the old tension cracks resulting in the build-up of cleft water pressures at the back of the distressed hillside. It is unlikely that leakage from the water tank contributed to the renewed movements.

Movements within the distressed hillside appear to have continued for at least two to three months after the August 2005 rainstorm, when the rainfall was not particularly heavy. The progressive movements may be associated with the re-distribution of stresses within the distressed hillside and movement along local shear surfaces with reduced operational shear strengths following significant slope displacement.

The movement directions of the distressed mass were broadly similar to the orientation of the relict joints observed in August 2005 landslide source area, suggesting that similar mechanisms of hillside deterioration may have developed in both parts of the hillside and an element of structure control in the instability.

The scale of the failure of slope No. 7SE-B/C122 in 1994 may have provided an indication of inherent stability problems of the hillside. The inspection by ME Division of GEO in early 1997 identified the poorly maintained drainage ditch in the upper hillside as a cause for concern and recommended remedial measures to be taken to minimise leakage affecting the stability of the slope below (see Section 4.3). No information regarding the follow-up actions on this matter has been located in this study. The Stage 2 Study and the GEO inspection carried out in 2003 focused on the cut slope of concern. A Warning Letter was issued by DLO/ST to the STT tenants. Following the GEO's recommendations, the tenants fenced off the area affected by the slope of concern for public safety.

8. CONCLUSIONS

The rain-induced landslide that occurred on slopes Nos. 7SE-B/C195 and 7SE-B/C131 above Ma On Shan Upper Village on 21 August 2005 was probably caused by direct infiltration together with concentrated infiltration and surface runoff from a poorly lined drainage ditch. Progressive deterioration of the hillside condition as well as unfavourably orientated clay infilled joints probably contributed to the failure.

The adjacent hillside with significant signs of distress may have also displaced on 21 August 2005 and triggered a small landslide at slope No. 7SE-B/C122. The hillside, as a whole, shows signs of previous ground movements, such as old soil and root infilled tension cracks and deformed trees. These indicate progressive deterioration of the stability condition.

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LIST OF TABLES

Table 1 - Maximum Rolling Rainfall at GEO Raingauge No. N44 for Selected Durations Preceding the Landslide on 21 August 2005 and Estimated Return Periods

Duration	Maximum Rolling Rainfall (mm)	End of Period	Estimated Return Period (Years)	
			By Lam & Leung (1994)	By Data of N09 from Evans & Yu (2001)
5 Minutes	5.5	4:55 a.m. on 21 August 2005	< 2	< 2
15 Minutes	11.0	9:00 a.m. on 19 August 2005	< 2	< 2
1 Hour	24.5	8:30 p.m. on 19 August 2005	< 2	< 2
2 Hours	35.0	8:35 p.m. on 19 August 2005	< 2	< 2
4 Hours	54.5	6:25 p.m. on 20 August 2005	< 2	< 2
12 Hours	131.0	8:10 p.m. on 20 August 2005	< 2	< 2
24 Hours	222.0	6:10 p.m. on 20 August 2005	2	< 2
48 Hours	311.0	9:20 p.m. on 20 August 2005	3	2
4 Days	417.0	6:20 a.m. on 21 August 2005	4	3
7 Days	517.0	6:20 a.m. on 21 August 2005	6	3
10 Days	575.0	6:20 a.m. on 21 August 2005	6	3
12 Days	627.5	6:20 a.m. on 21 August 2005	7	3
15 Days	628.5	6:20 a.m. on 21 August 2005	5	3
31 Days	853.0	9:00 p.m. on 20 August 2005	5	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 data from Evans & Yu (2001).
(3) According to the incident records, the landslide occurred at about 7:00 a.m. on 21 August 2005.
(4) The nearest GEO raingauge to the landslide site is raingauge No. N44 situated at about 2.7 km to the north of the landslide site. GEO raingauge No. N09 situated at about 3.5 km to the west of the landslide site.

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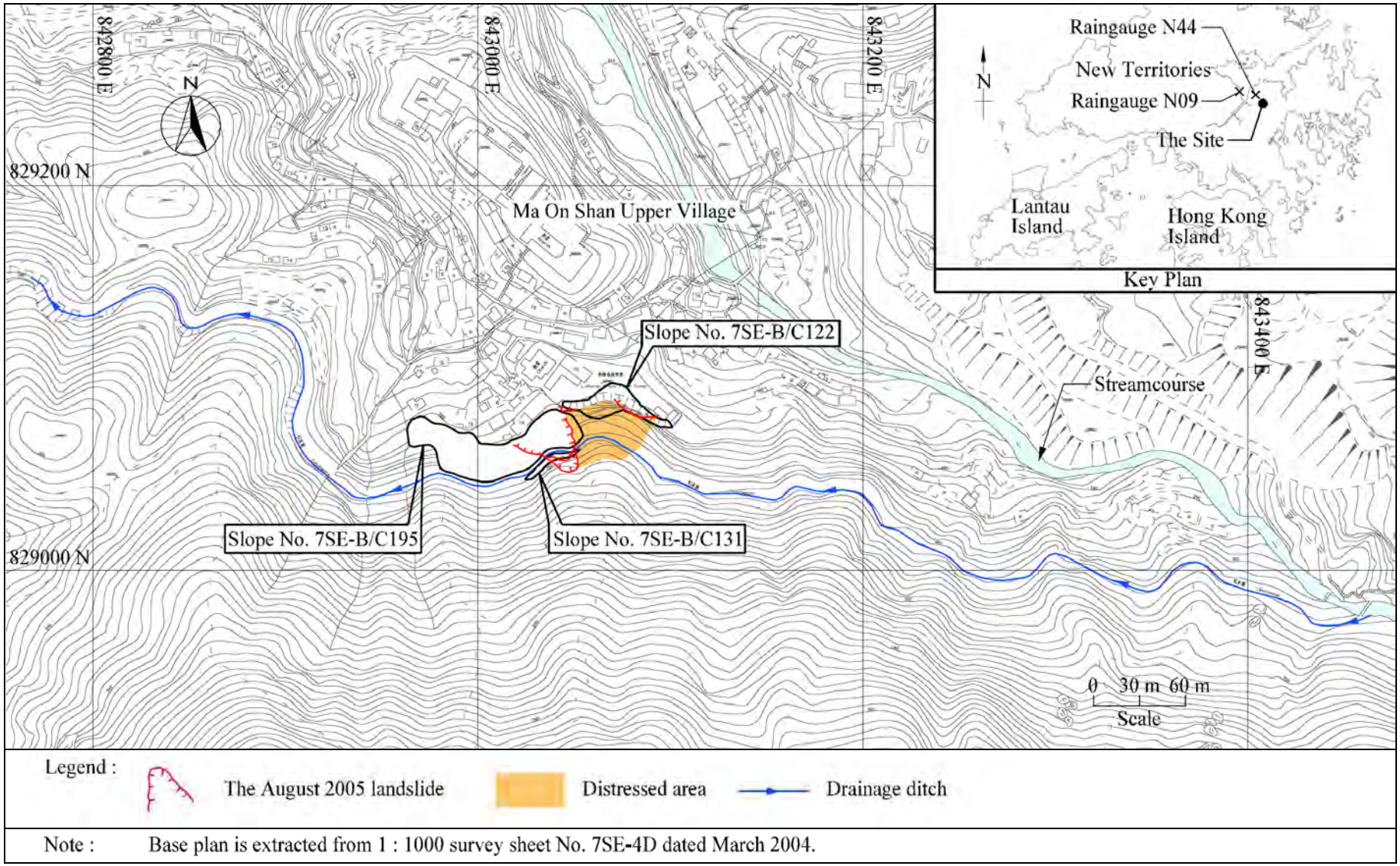

Figure 1 - Location Plan

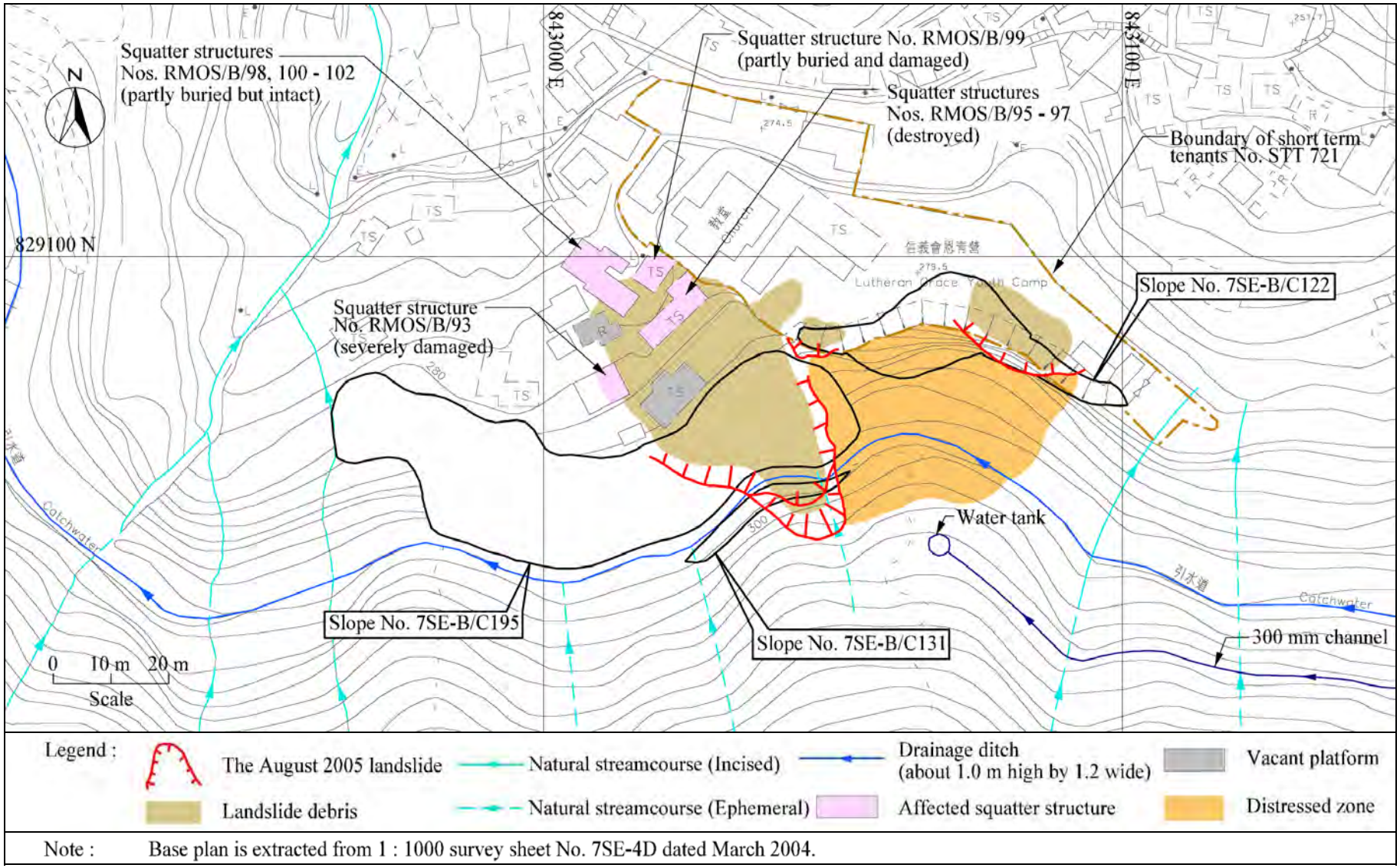

Figure 2 - Site Layout Plan

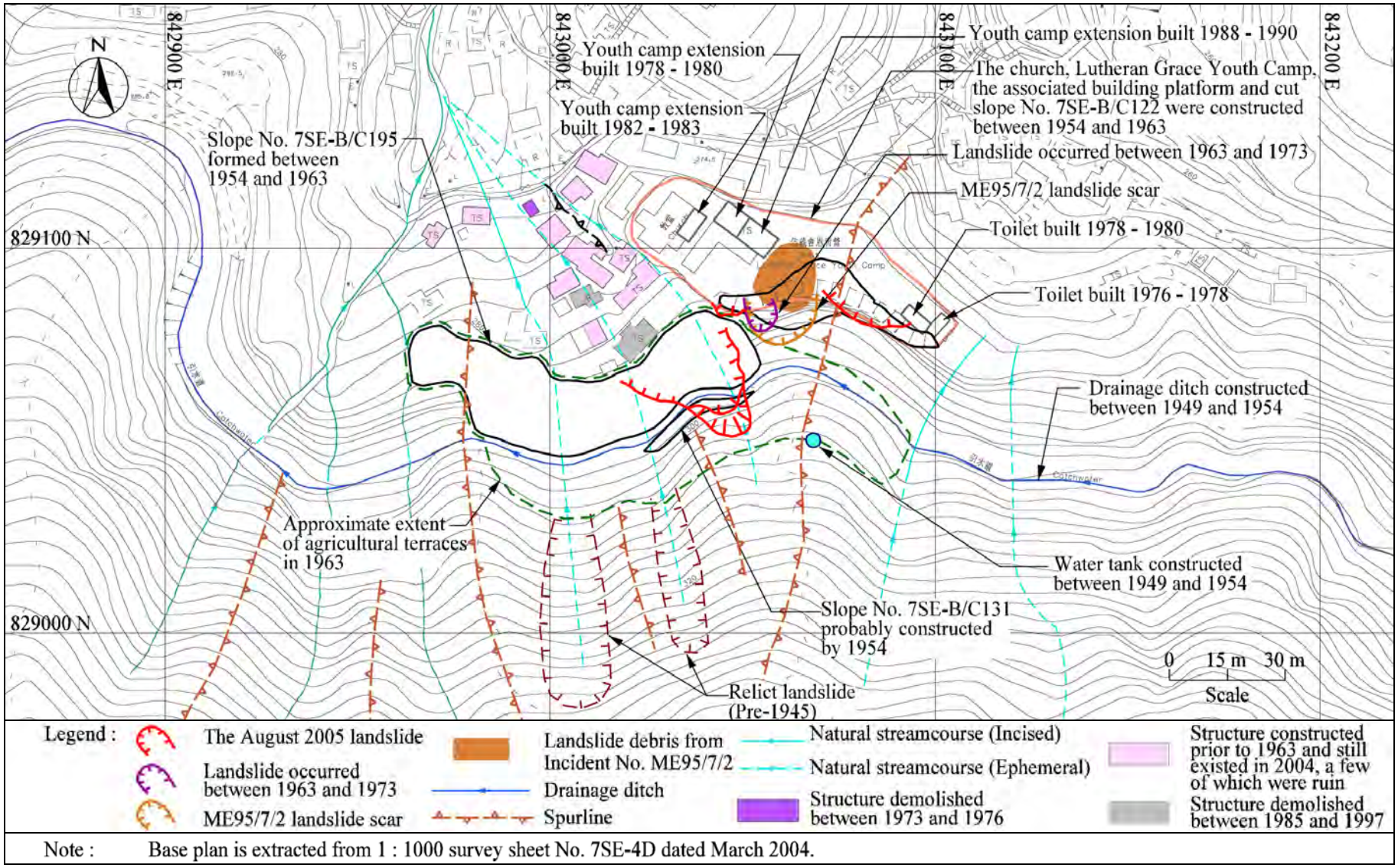

Figure 3 - Site History

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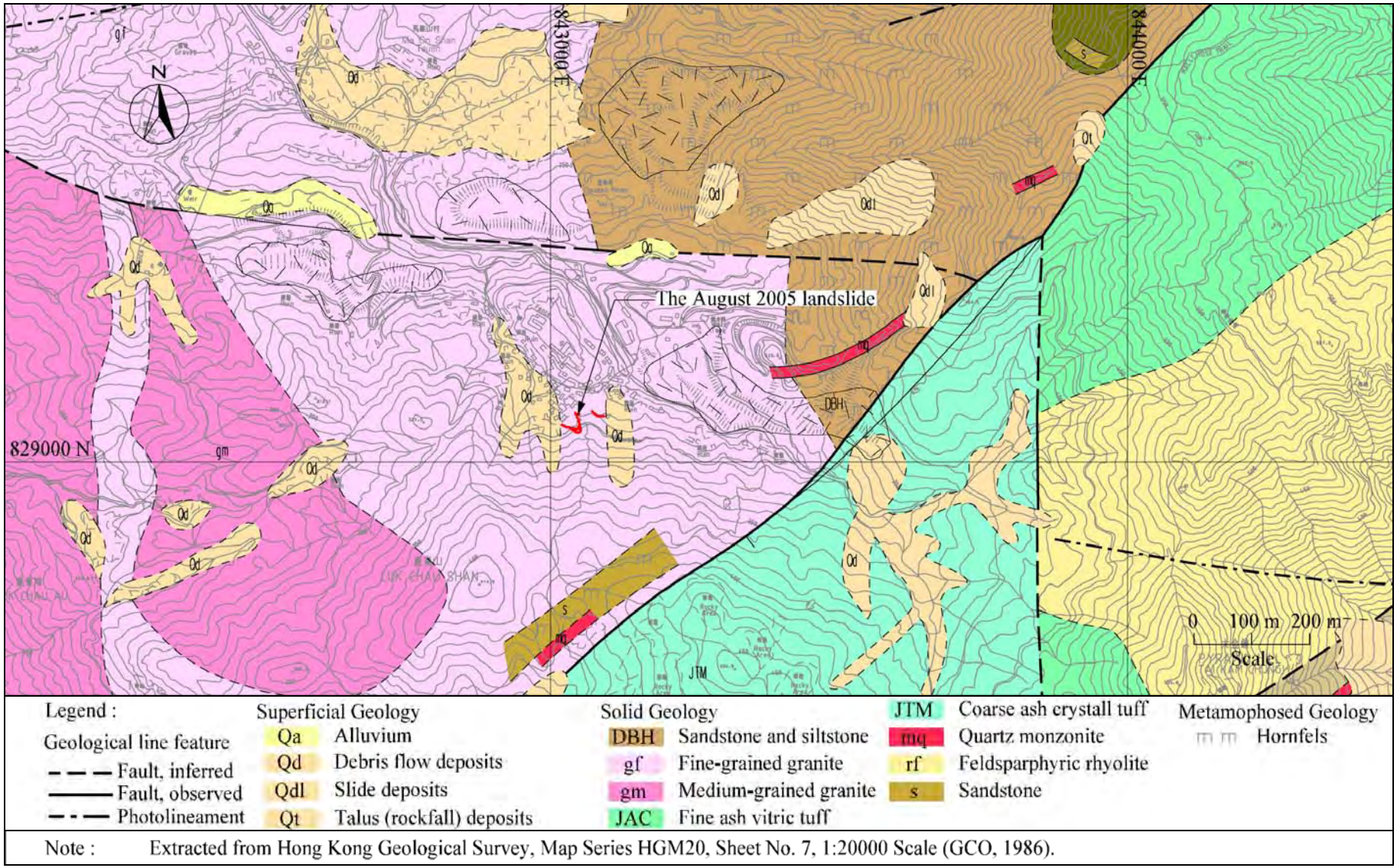

Figure 4 - Regional Geology

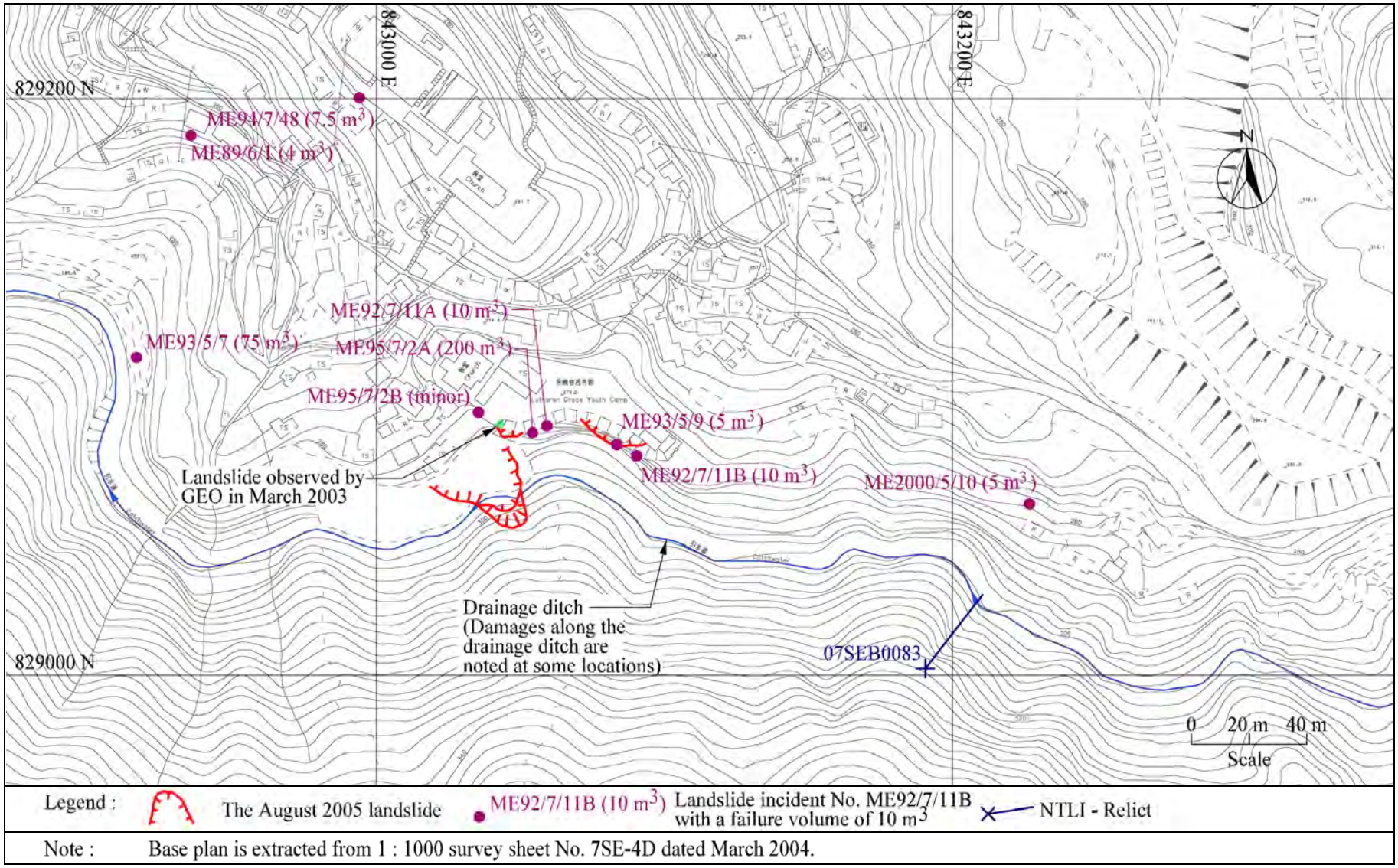

Figure 5 - Past Instability

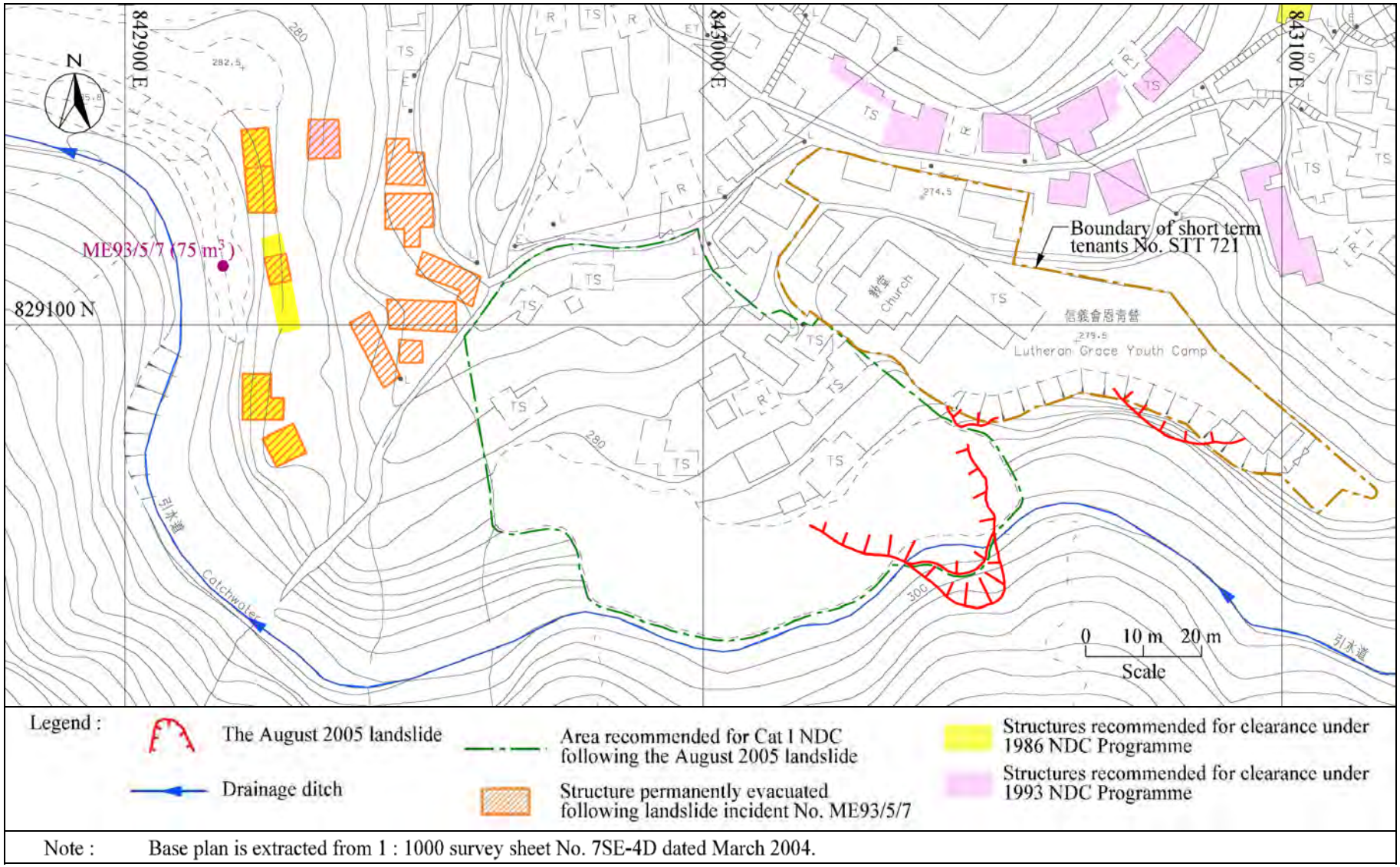

Figure 6 - Recommendation for Non-development Clearance

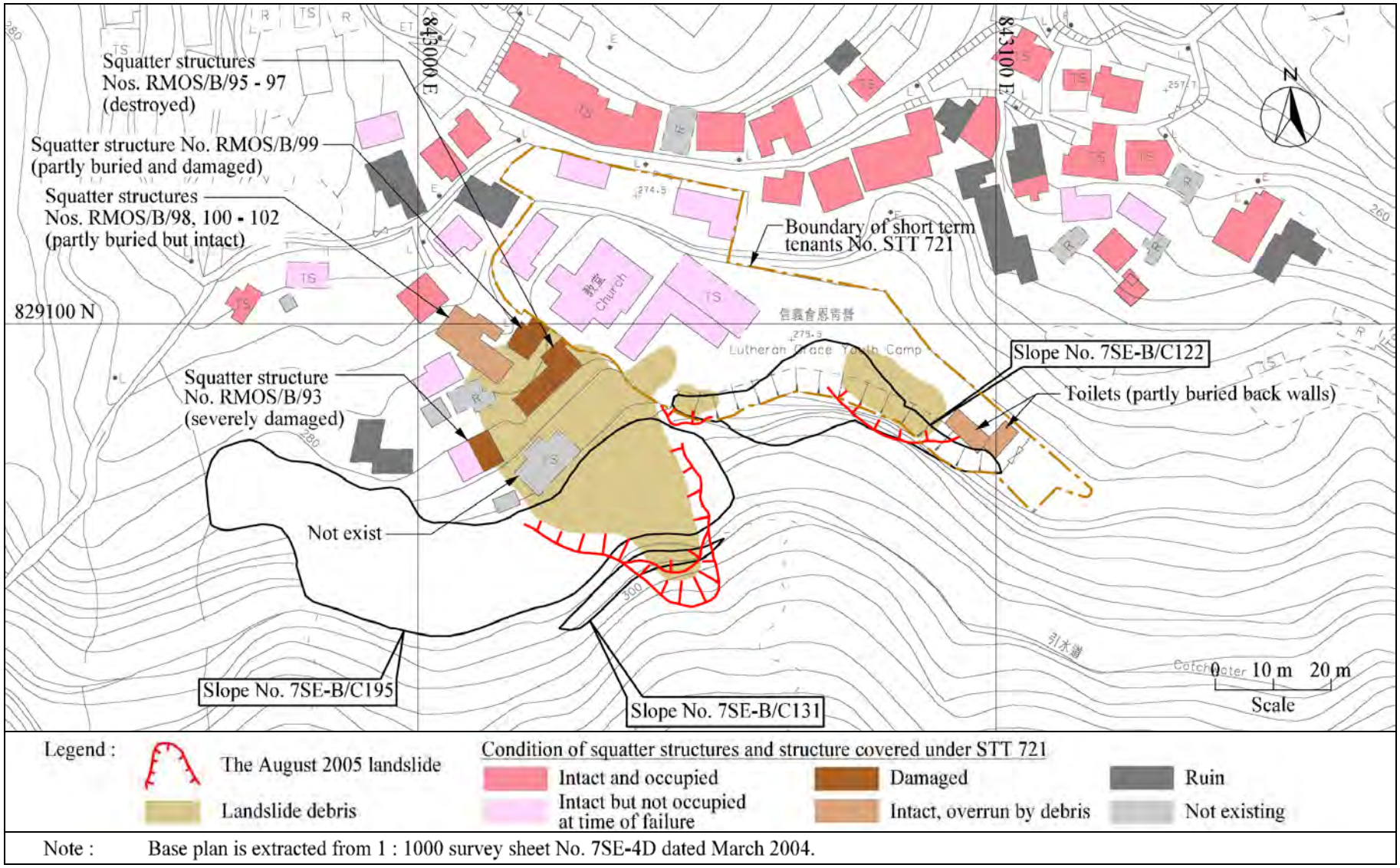

Figure 7 - Facility Survey after the August 2005 Landslide

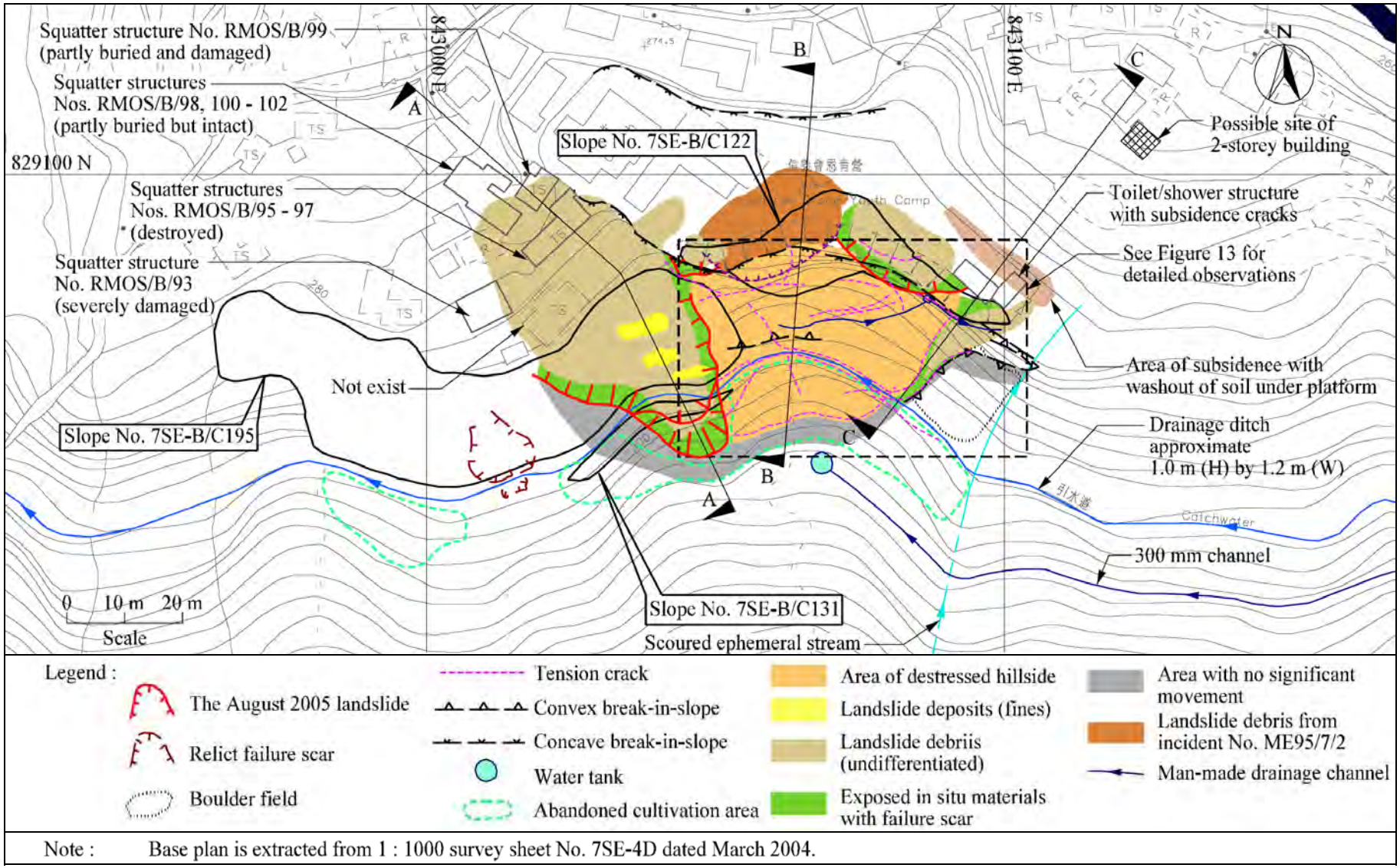

Figure 8 - Field Mapping

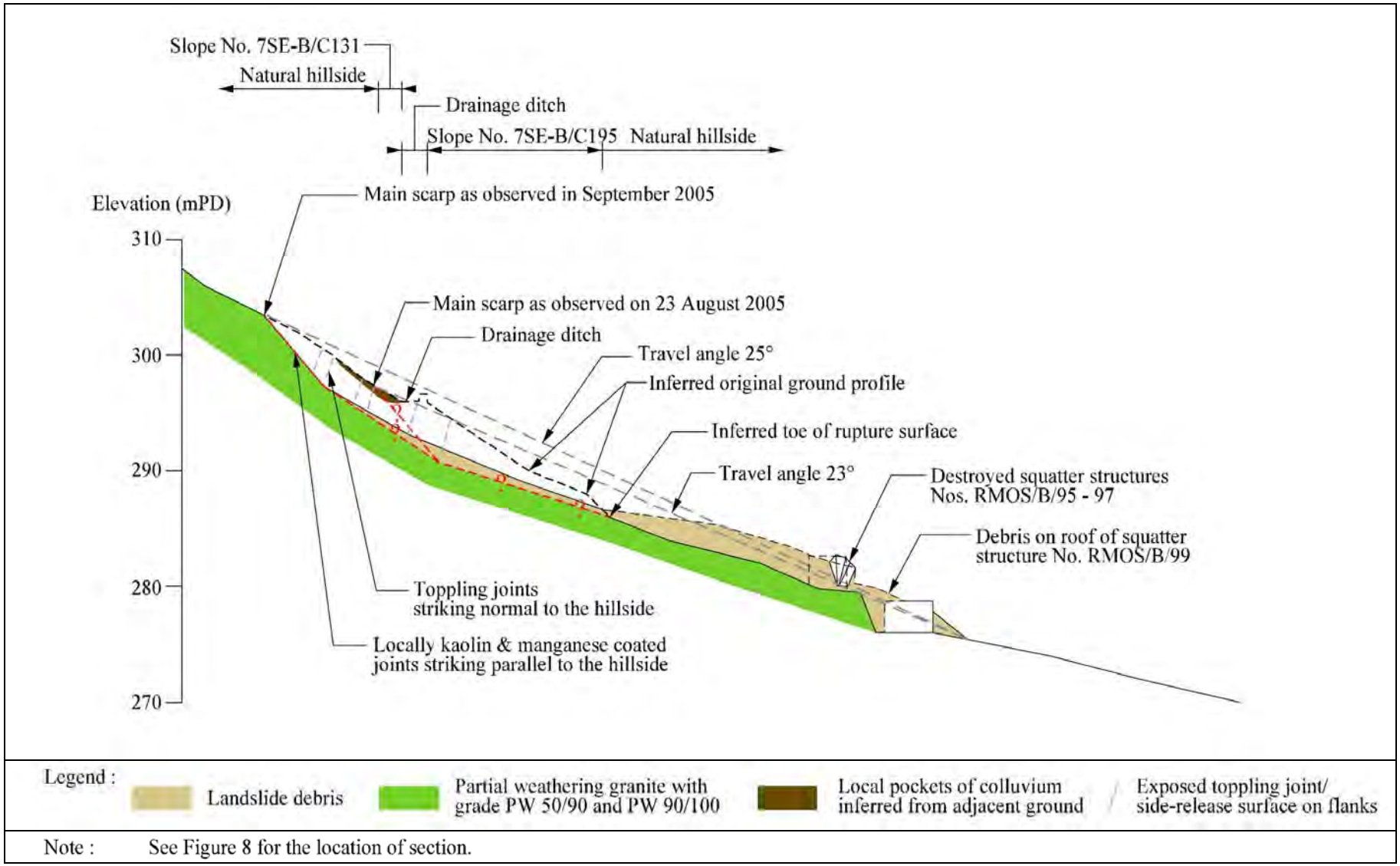

Figure 9 - Cross-Section A-A

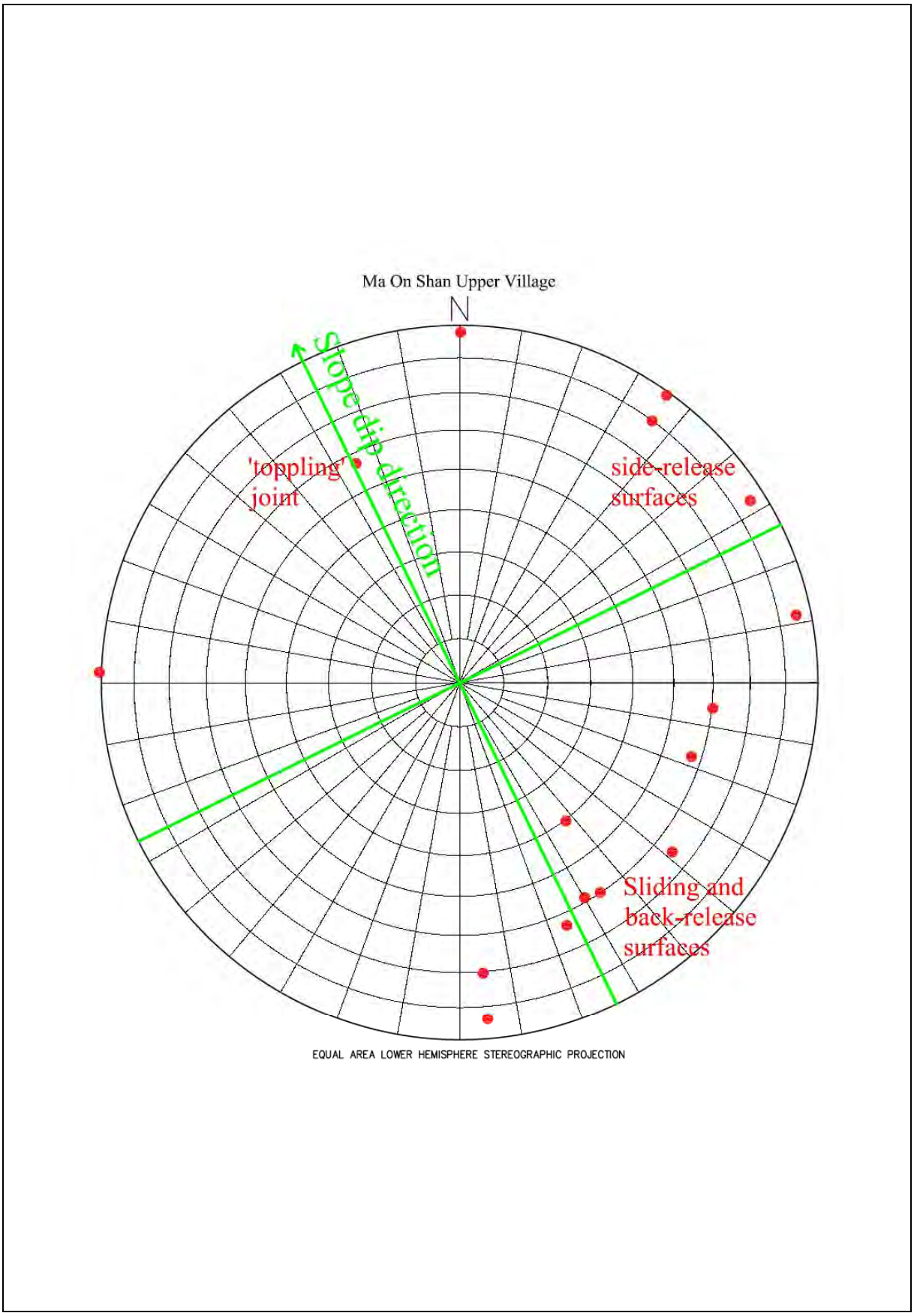

Figure 10 - Poles of Relict Joints Mapped on the 21 August 2005 Landslide

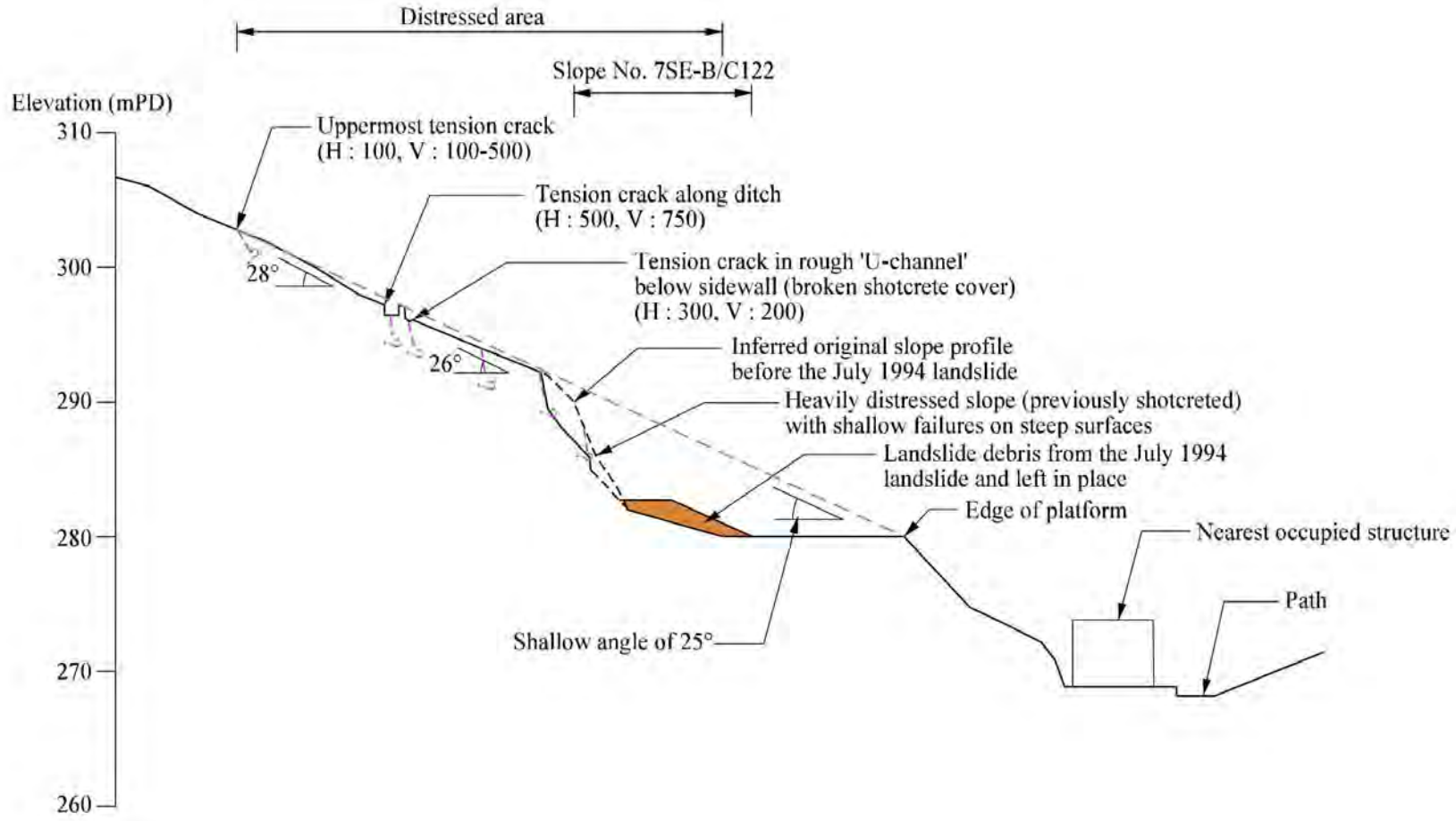

Figure 11 - Cross-Section B-B

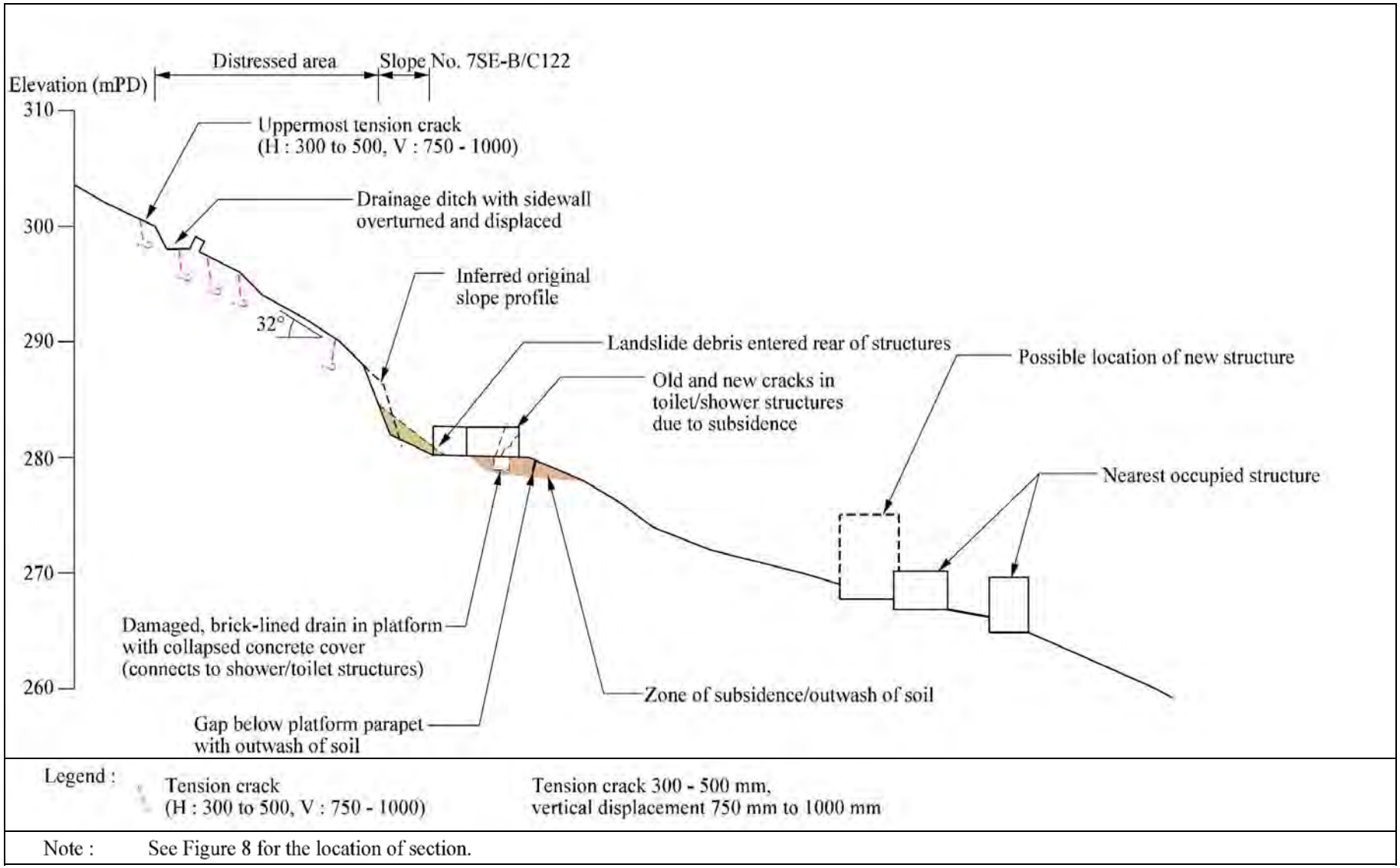

Figure 12 - Cross-Section C-C

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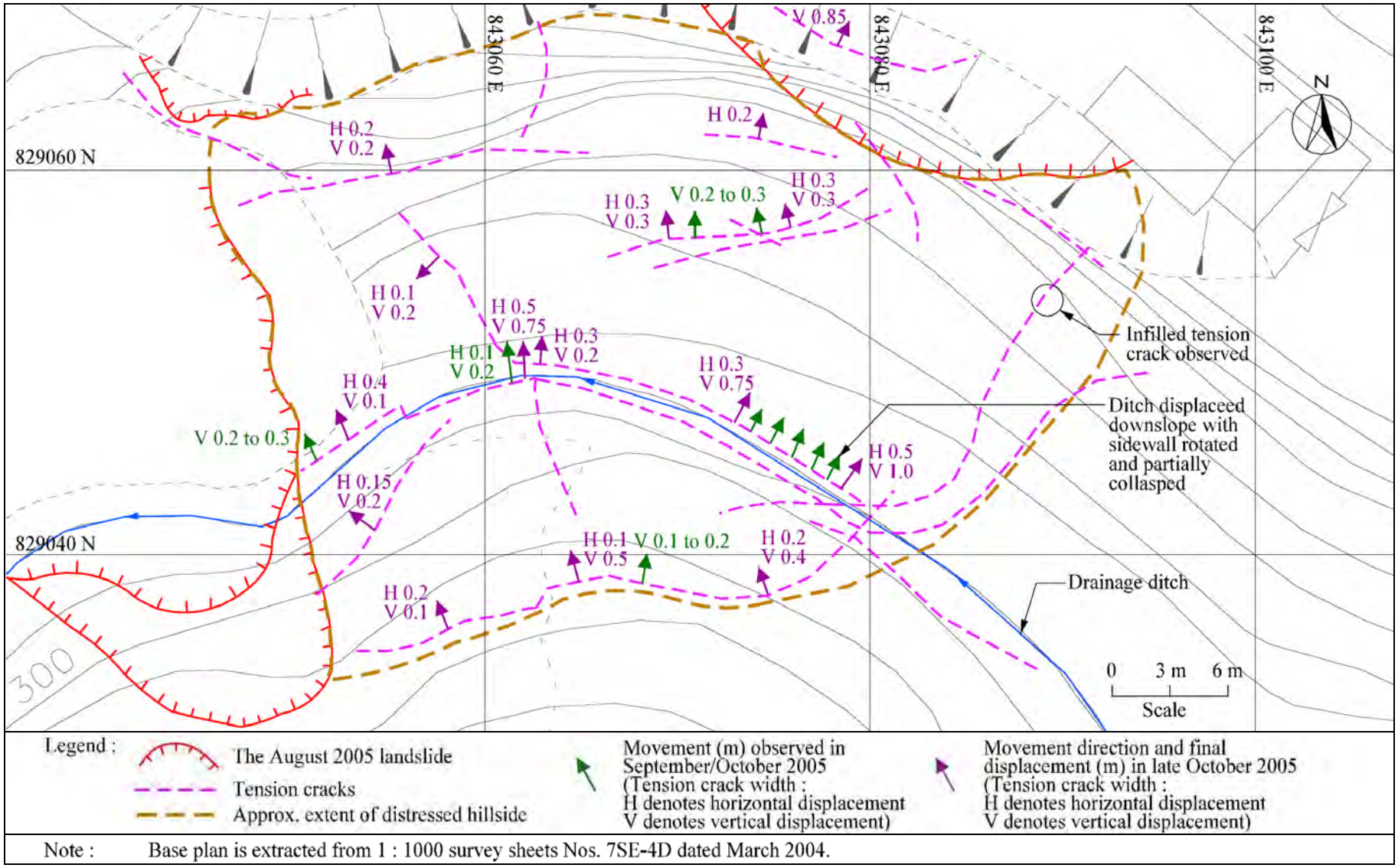


Figure 13 - Movements Observed within the Distressed Hillside

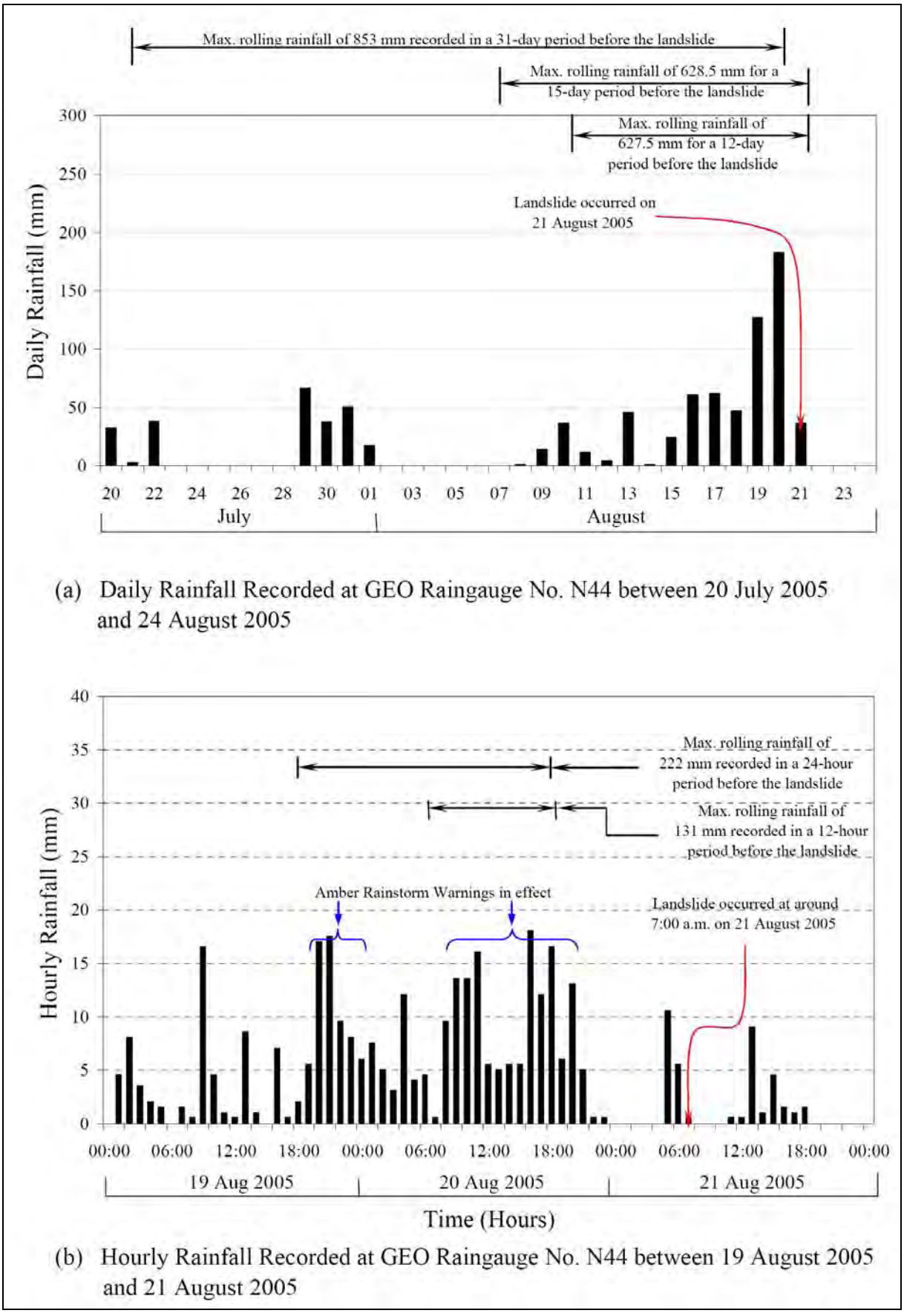
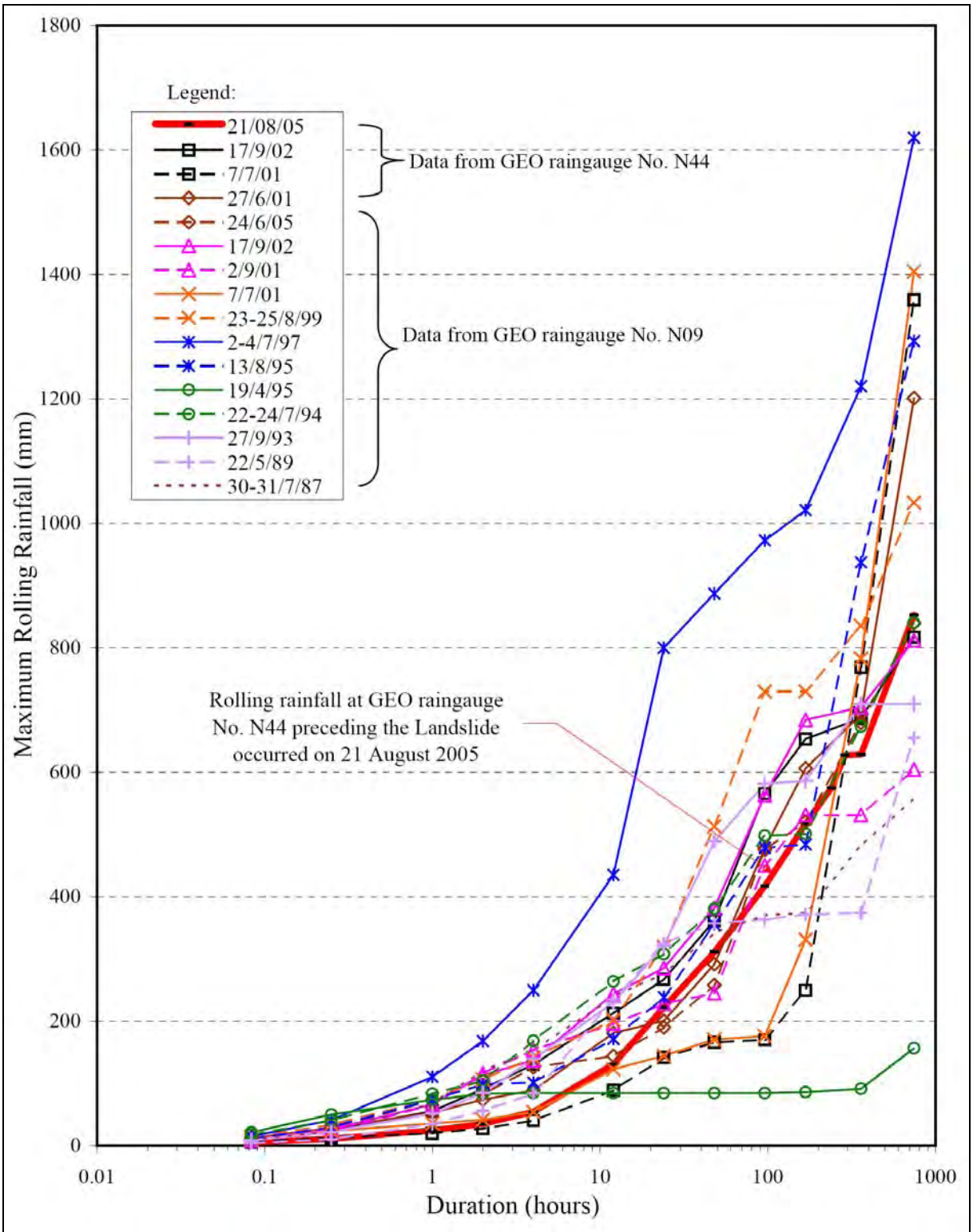


Figure 14 - Daily and Hourly Rainfall Recorded at GEO Raingauge No. N44



Notes: (1) Rainfall data evaluated from 5-minute readings from GEO raingauge No. N44 (about 2.7 km to the north of the site) and GEO raingauge No. N09 (about 3.5 km to the west).

(2) Rolling rainfall of previous rainstorms calculated at GEO raingauge No. N09 since June 1983 and at GEO raingauge No. N44 since October 1999 when the raingauges became operational.

Figure 15 - Maximum Rolling Rainfall for Previous Major Rainstorms at GEO Raingauges Nos. N09 and N44

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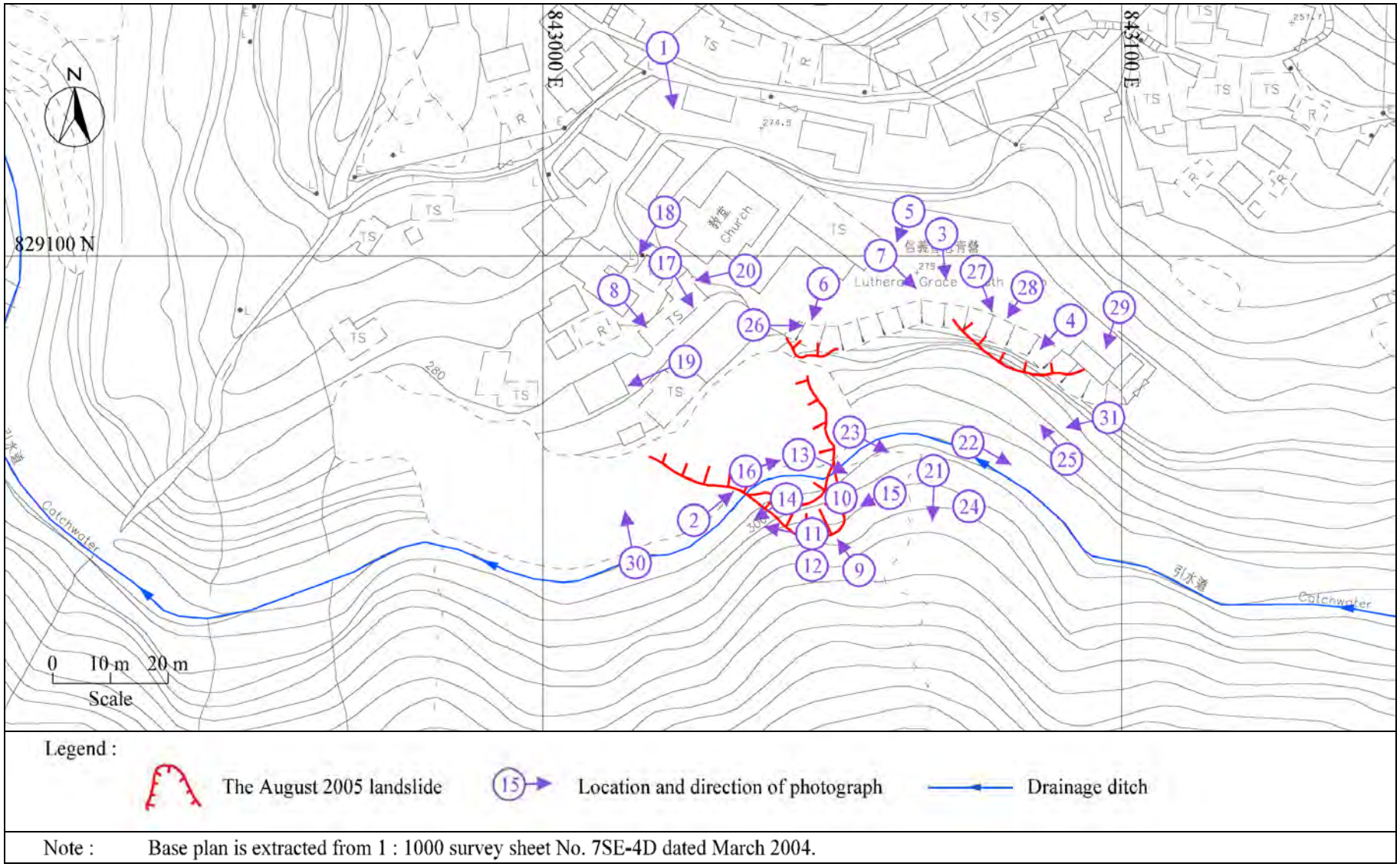

Figure 16 - Locations and Directions of Photographs Taken

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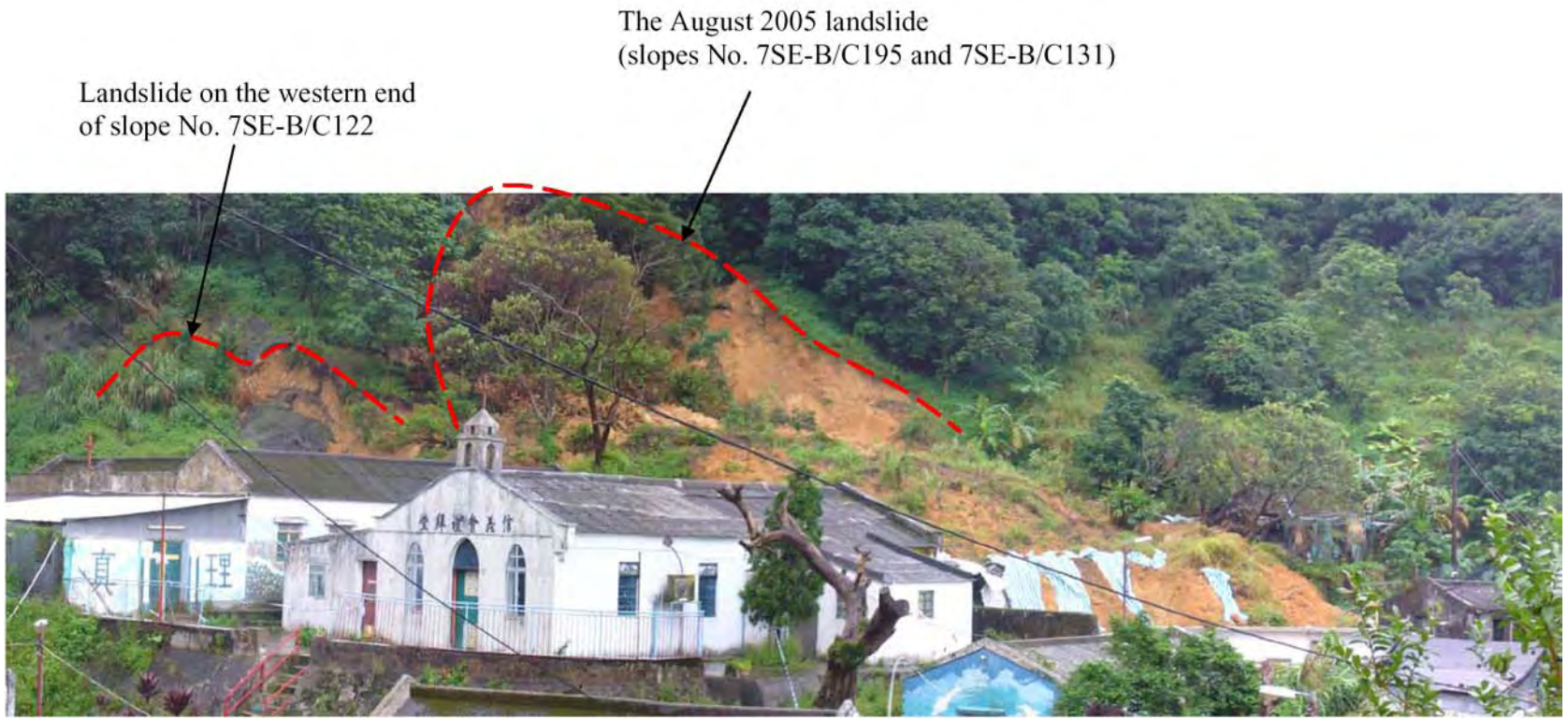

Plate 1 - General View of the August 2005 Landslide (Photograph taken on 21 October 2005)

Note: See Figure 16 for location and direction of photograph.

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Plate 2 - General View of the Drainage Ditch (Photograph taken on 21 September 2005)

Plate 3 - General View of the Landslide Incident No. ME92/7/11 at Slope No. 7SE-B/C122 (Photograph taken on 23 July 1992 as extracted from Incident Report)

Note: See Figure 16 for location and direction of photograph.

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Plate 4 - View of Landslide Incident No. ME93/5/9 at Slope No. 7SE-B/C122 (Photograph taken on 4 May 1993 as extracted from Incident Report)

Plate 5 - View of Landslide Incident No. ME95/7/2 (Location A) at Slope No. 7SE-B/C122 with a Failure Volume of about 200 m^3 (Photograph taken on 10 July 1995 as extracted from Incident Report)

Note: See Figure 16 for location and direction of photograph.

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Plate 6 - View of the Landslide Observed by GEO in March 2003 on the Western Portion of Slope No. 7SE-B/C122 (Photograph taken on 4 March 2003 as extracted from GEO inspection record)

Plate 7 - View of Slope No. 7SE-B/C122 in 1997 after Temporary Remedial Works (Photograph taken on 2 September 1997 as extracted from Stage 1 Report)

Note: See Figure 16 for location and direction of photograph.

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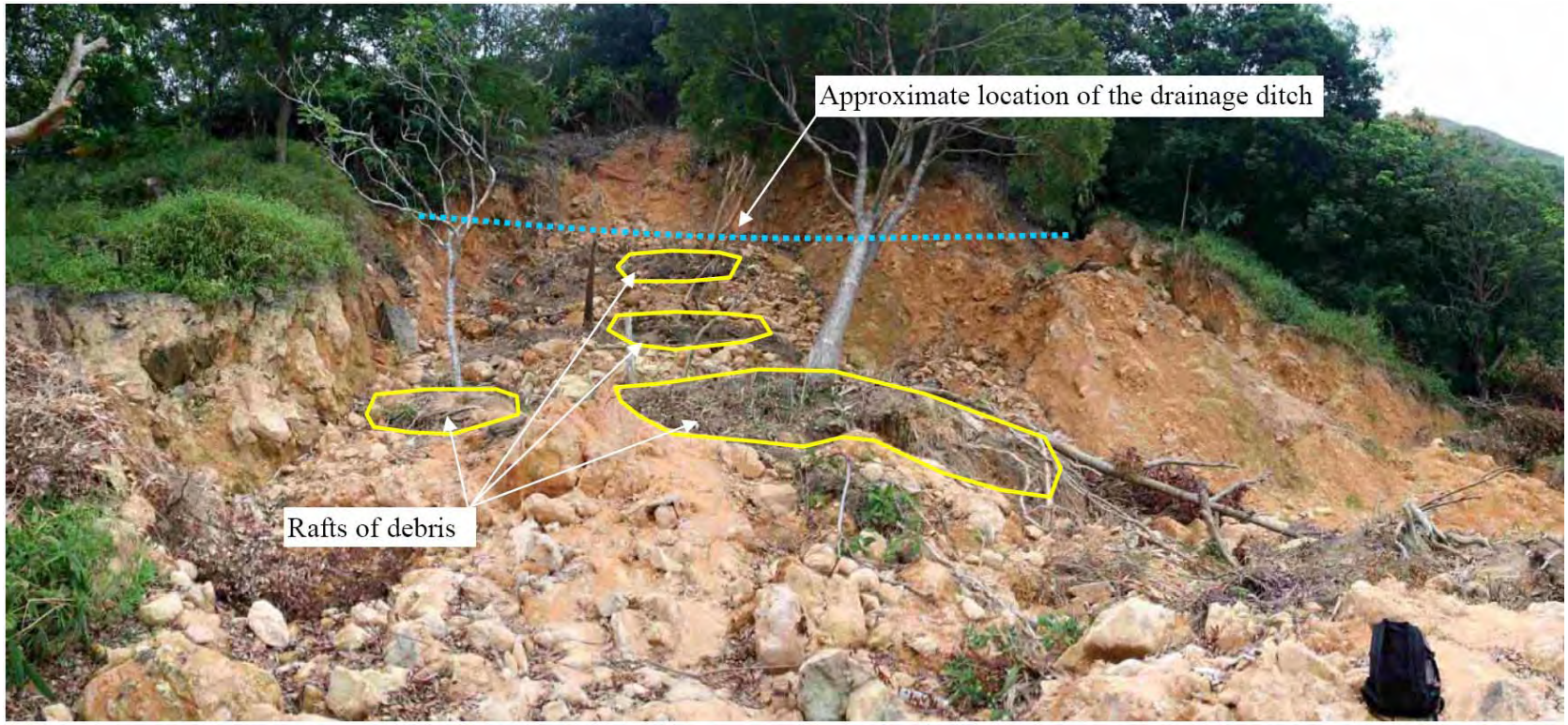

Plate 8 - View of the August 2005 Landslide from Toe Showing Local Rafts of Debris and Approximate Location of the Drainage Ditch (Photograph taken on 21 October 2005)

Note: See Figure 16 for location and direction of photograph.

Plate 9 - View of Debris Lobe from the Crest of the August 2005 Landslide
(Photograph taken on 2 December 2005)

Plate 10 - View of the Main Scarp of the August 2005 Landslide
(Photograph taken on 23 August 2005)

Note: See Figure 16 for location and direction of photograph.

Plate 11 - Localised Kaolin Deposits on the Failure Surface
(Photograph taken on 23 August 2005)

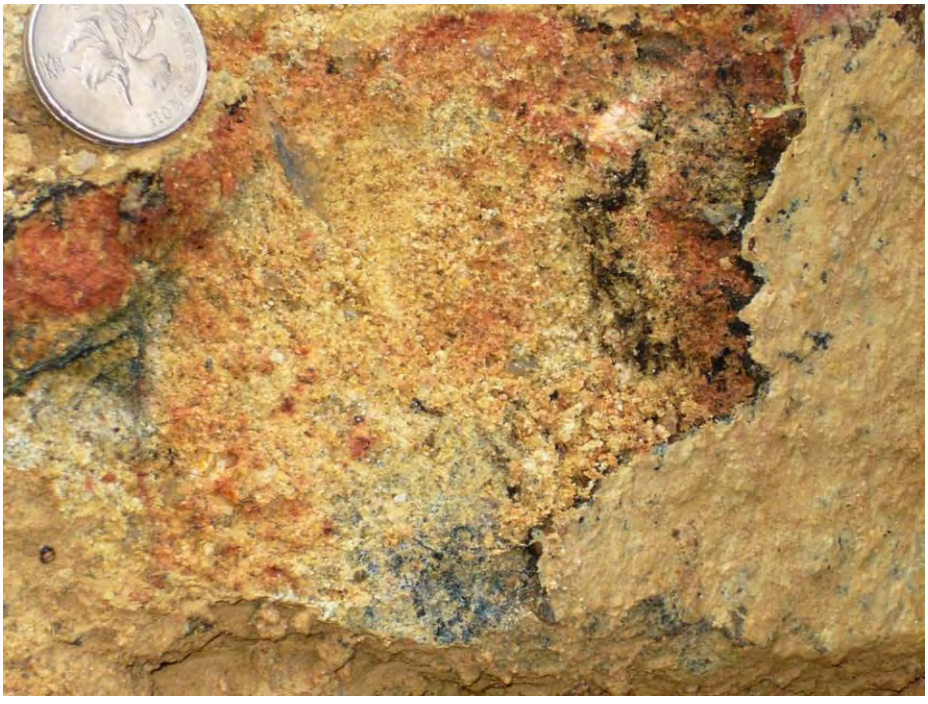

Plate 12 - Close up View of the Kaolin and Manganese Coated Joint
(Photograph taken on 30 September 2005)

Note: See Figure 16 for location and direction of photograph.

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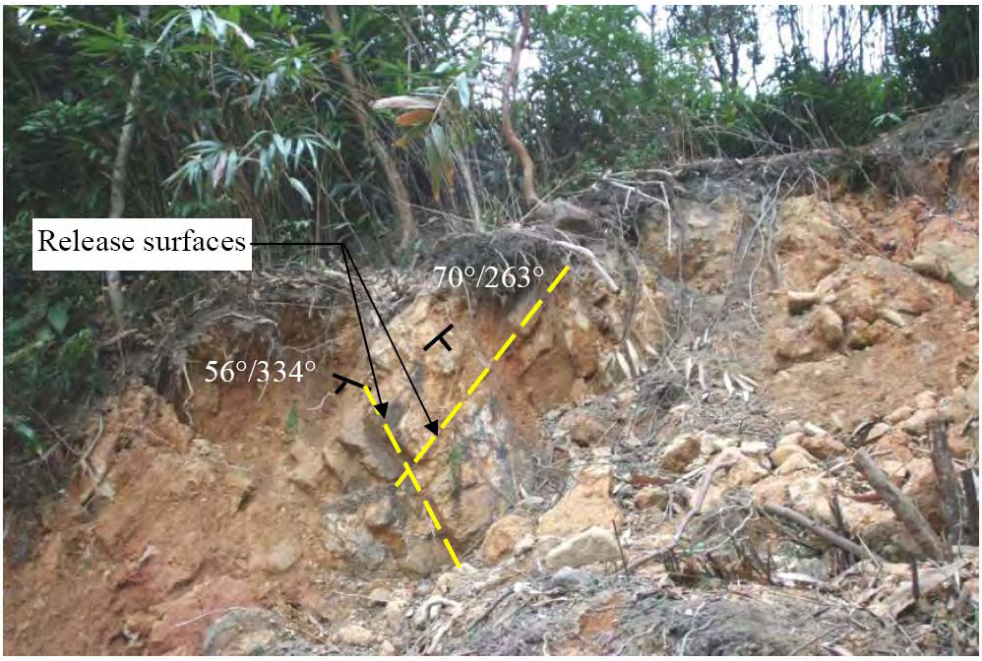

Plate 13 - Release and Unfavourable Joints on Eastern Flank of the Landslide
(Photograph taken on 2 December 2005)

Plate 14 - Western Flank of the August 2005 Landslide
(Photograph taken on 2 December 2005)

Note: See Figure 16 for location and direction of photograph.

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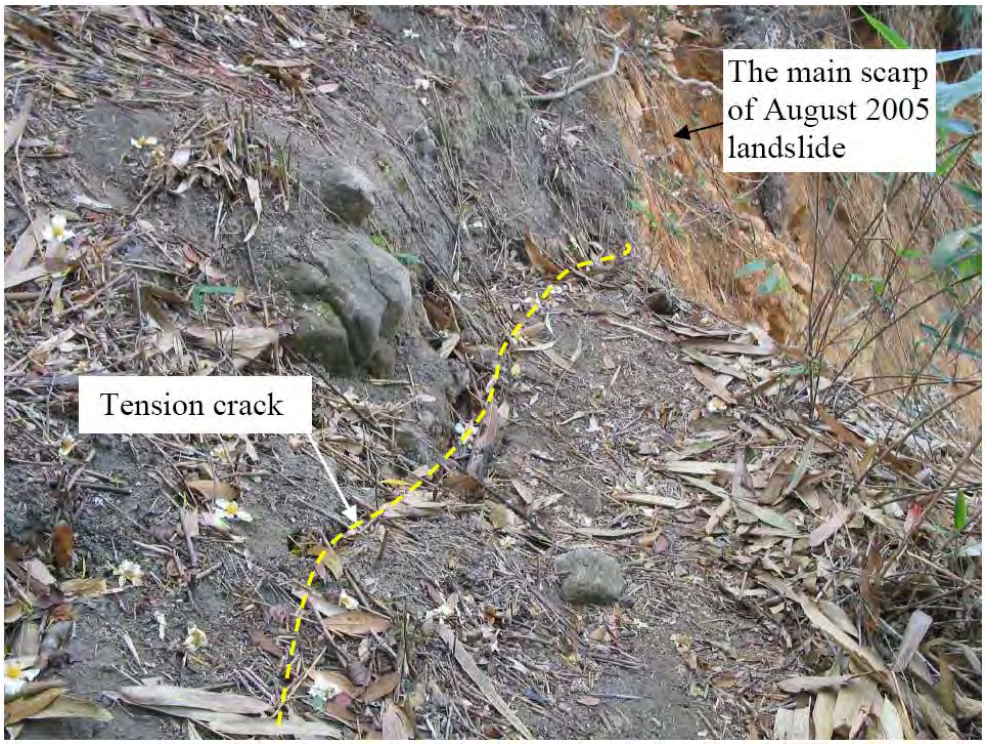

Plate 15 - Tension Crack Extending to the Main Scarp of the August 2005 Landslide from the Distressed Hillside (Photograph taken on 2 December 2005)

Plate 16 - Tension Crack Exposed on the Eastern Flank of the August 2005 Landslide (Photograph taken on 2 December 2005)

Note: See Figure 16 for location and direction of photograph.

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Plate 17 - Destroyed Registered Squatter Structures Nos. RMOS/B/95 97 on Eastern Margin of the Debris Lobe (Photograph taken on 23 August 2005)

Plate 18 - Partly Buried and Damaged Registered Squatter Structures Nos. RMOS/B/98-102 at Northern Margin of the Debris Lobe (Photograph taken on 23 August 2005)

Note: See Figure 16 for location and direction of photograph.

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Plate 19 - Substantially Damaged Registered Squatter Structure No. RMOS/B/93 on Western Margin of the Debris Lobe (Photograph taken on 23 August 2005)

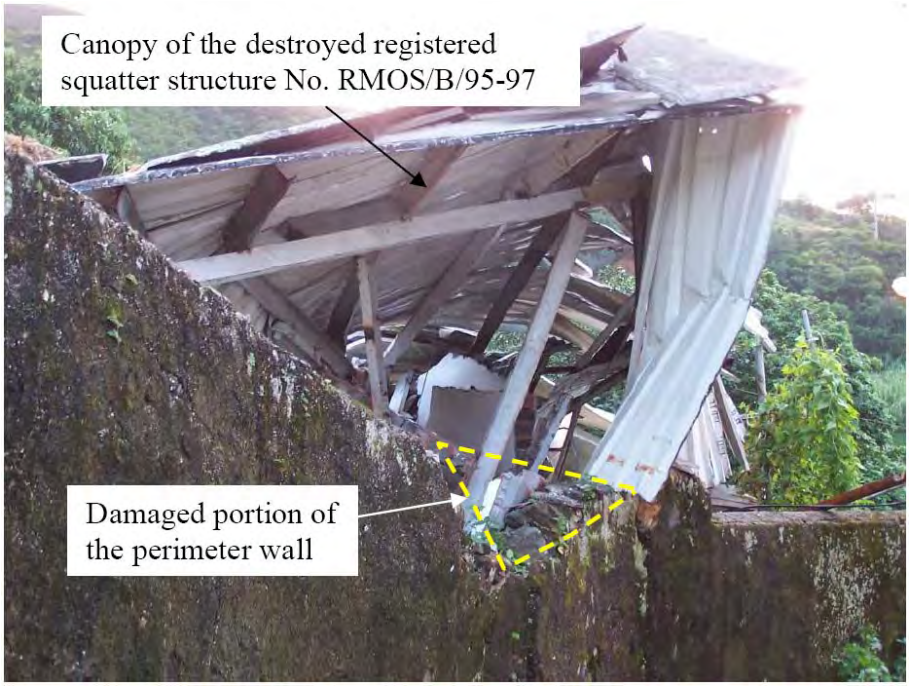

Plate 20 - Partially Damaged Perimeter Wall of the Lutheran Grace Youth Camp (Photograph taken on 23 August 2005)

Note: See Figure 16 for location and direction of photograph.

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Plate 21 - Tension Crack within the Distressed Hillside
(Photograph taken on 2 December 2005)

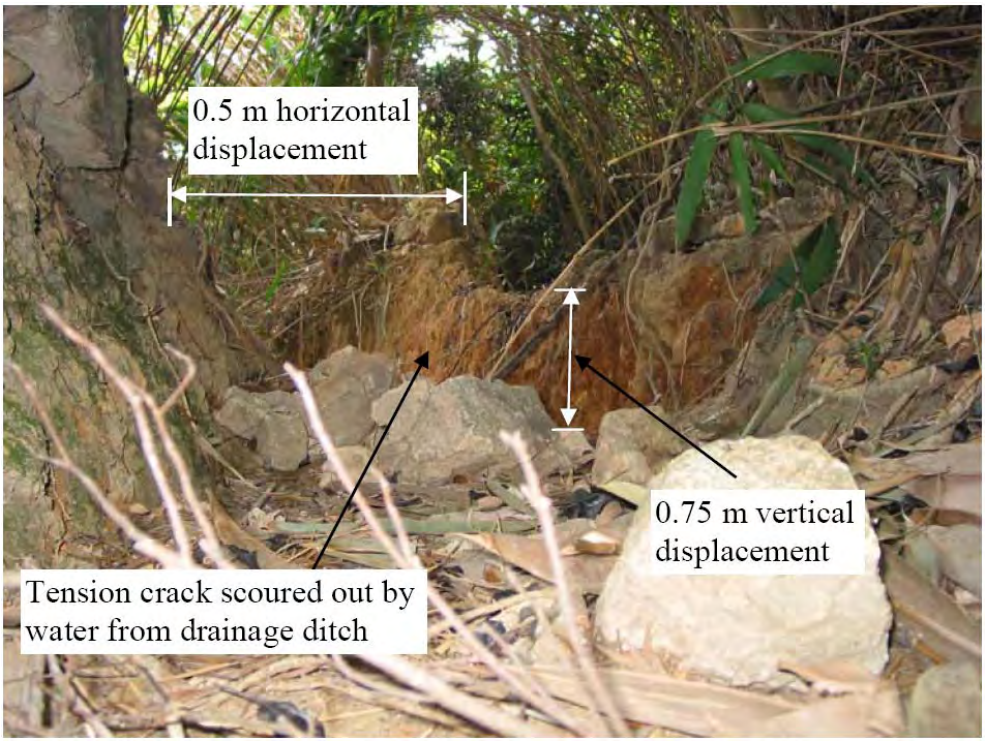

Plate 22 - Displacement of Drainage Ditch across Tension Crack
(Photograph taken on 2 December 2005)

Note: See Figure 16 for location and direction of photograph.

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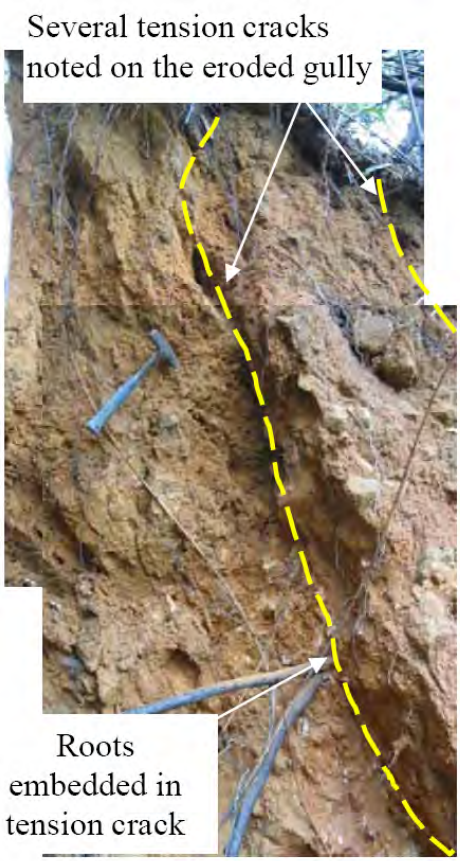
Plate 23 - Tension Crack along Base of the Drainage Ditch and Rotation/Distress of Drainage Ditch Sidewall (Photograph taken on 2 December 2005)

Plate 24 - Deformed Tree within the Distressed Hillside (Photograph taken on 4 June 2006)

Note: See Figure 16 for location and direction of photograph.



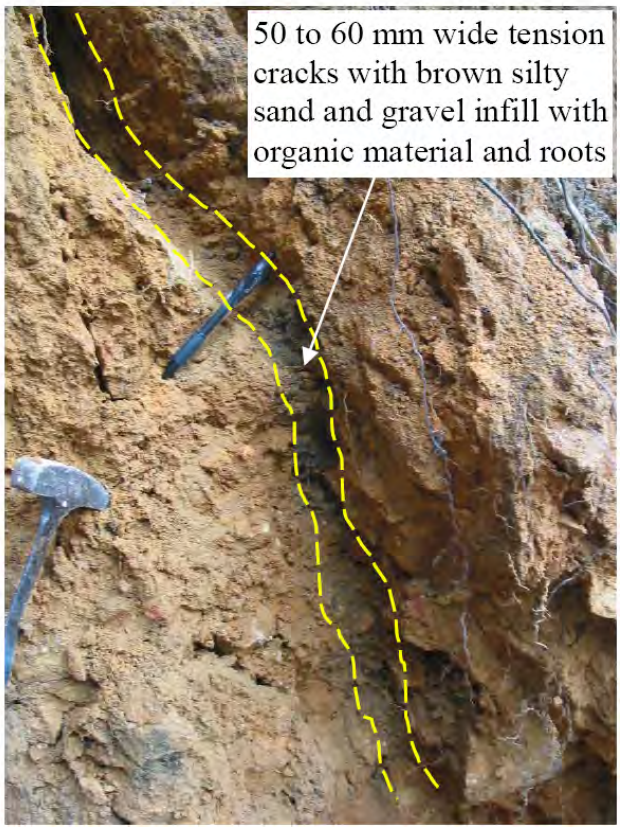


Plate 25 - Pre-existing Tension Cracks in the Washed-out Gully on the Eastern Edge of the Distressed Hillside (Photograph taken on 24 March 2006)

Note: See Figure 16 for location and direction of photograph.

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Plate 26 - View of the August/September 2005 Landslide on the Western Portion of Slope No. 7SE-B/C122 (Photograph taken by GEO on 22 September 2005)

Plate 27 - View of the August/September 2005 Landslide on the Eastern Portion of Slope No. 7SE-B/C122 (Photograph taken by GEO on 22 September 2005)

Note: See Figure 16 for location and direction of photograph.

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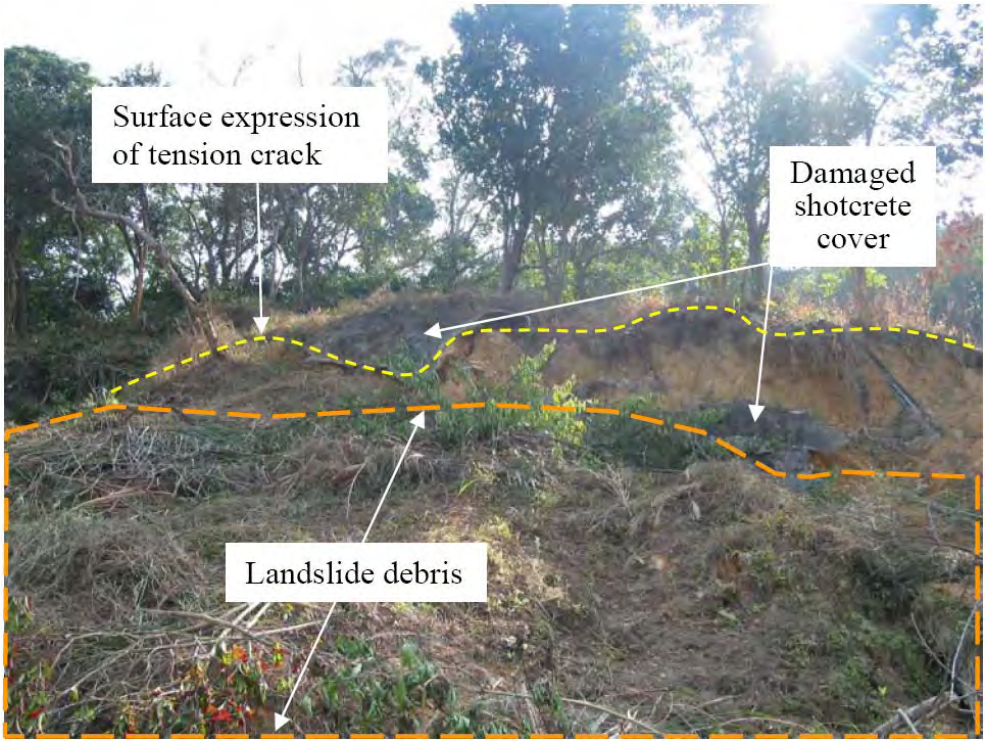

Plate 28 - Tension Cracks and Associated Landslide at the Toe of Slope No. 7SE-BC122 (Photograph taken on 2 December 2005)

Plate 29 - Crack Observed on the Toilet/Shower Structure (Photograph taken on 14 October 2005)

Note: See Figure 16 for location and direction of photograph.

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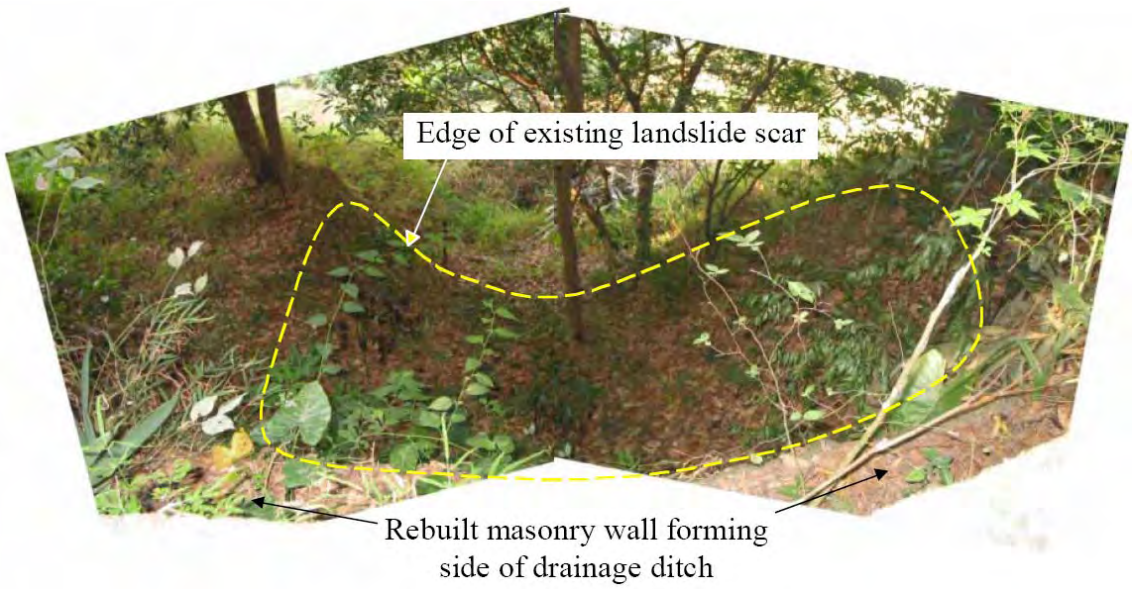

Plate 30 - Existing Landslide Scar to the West of the August 2005 Landslide (Photograph taken on 2 December 2005)

Plate 31 - Urgent Repair Works on the Upper and Eastern Portion of the Distressed Hillside (Photograph taken on 4 June 2006)

Note: See Figure 16 for location and direction of photograph.

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APPENDIX A

AERIAL PHOTOGRAPH INTERPRETATION

CONTENTS

A1. DETAILED OBSERVATIONS

This appendix sets out the detailed observations made from an interpretation of aerial photographs taken between 1945 and 2004. A list of the aerial photographs reviewed is presented in Table A1 and the main observations of API are shown in Plates A1 to A7.

YEAR	KEY OBSERVATIONS
1945	The earliest photograph available with no stereo pair and the photo is blurred. The landslide site was a north facing natural hillside covered by sparse vegetation. Some natural drainage lines were noted on the hillside running from the south to north. No sign of significant human habitation around the landslide site was evident.
1949	First stereo coverage of the landslide site. However the photos are still blurred. No significant change to the site was visible. The 2005 major failure scar is located on a minor ridgeline. The pre-development major drainage lines affecting the landslide site were mapped based on the 1949 photos and are shown on Plate A1. Vegetation clearance was observed to the south and above the landslide site. Some possible mineral exploration trenches were noted on the uphill area. A footpath had been built prior to 1945 along the ridgeline where one of the 2005 failures on slope No. 7SE-B/C122 occurred.
1954	The photos are blurred and details of the landslide site were obscured by shadow. The drainage ditch had been built at some time between 1949 and 1954 (Plate A2). Slope No. 7SE-B/C131 had probably formed in associated with the construction of the drainage ditch. A white patch was visible at the location of the present water tank and it is believed that the water tank has already been constructed by 1954. Some terraces, probably building platforms or agricultural purpose, were constructed at the area within the landslide site and its vicinity. Part of the building platform for the church had been built by 1954 and part of the slope No. 7SE-B/C122 had probably been cut in association with the building platform construction (Plate A2). It appeared that Ma On Shan Upper Village has undergone substantial development between 1949 and 1954. Extensive mining activities were underway in the Ma On Shan Mine to the north-east of the landslide site.

YEAR	KEY OBSERVATIONS
1963	Good quality low altitude aerial photos.
	The Ma On Shan Upper Village has reached its full development by 1963 (Plate A3). All the squatter structures below the August 2005 landslide site appeared to have been constructed by 1963. The church, Lutheran Grace Youth Camp and their associated building platform had been entirely constructed. Slope No. 7SE-B/C122 had been cut by 1963. A footpath/man-made drainage channel had been built along its crest.
	Agricultural terraces were formed in the vicinity of the August 2005 landslide. Slope No. 7SE-B/C195 (a disturbed terrain instead of cut slope) had been formed which was an agricultural terraces and the extent shall be larger than the current slope boundary.
	No evidence of slope failures in the squatter area/agricultural terraces and in the vicinity of the landslide site was apparent. Some possible natural terrain relict landslides on the hillside above the landslide site were identified based on the 1963 photos but all of them should be pre-1945 features.
	A few mineral exploration trenches were noted on the hillside to the south and above the landslide site. A few isolated boulders/rock outcrops were also observed on the hillside to the south and above the August 2005 landslide site.
1973	Some squatter structures below the August 2005 landslide scars were demolished between 1963 and 1973 and the remaining squatter structures in 1973 were highlighted in Plate A4.
	Most of the agricultural terraces above the drainage ditch were found to be abandoned.
	A significant depression, possibly a landslide scar, was noted at the western portion of slope No. 7SE-B/C122. The landslide was estimated to be 8 m wide by 8 m long with depth of about 1 m to 2 m. The slip surface appeared to have been covered by some hard surfacing. A structure of about 1 m high had been formed along the toe of this landslide scar.
1976	Two squatter structures below the August 2005 landslide scar were demolished between 1973 and 1976.
	Some vegetation clearance was noted to the south and above the August 2005 landslide site.
1978	The toilet/shower was built at the eastern end of slope No. 7SE-B/C122.

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YEAR	KEY OBSERVATIONS
1980	More agricultural terraces on slope No. 7SE-B/C195 appeared to be abandoned (Plate A5). An extension to the Lutheran Grace Youth Camp was observed. The toilet/shower was extended some time between 1978 and 1980. Minor cut might have been carried out at the eastern end of slope No. 7SE-B/C122 to accommodate the two structures constructed between 1976 and 1980 but details were obscured by shadow.
1982	No significant changes to the study area are apparent.
1983	An extension of the church was observed.
1985	Slightly more farming activities could be visible at the western portion of slope No. 7SE-B/C195 in mid 1980's (Plate A6). No significant change to the number of squatter structure immediately below the landslide site was apparent.
1988	No significant changes to the study area are apparent.
1990	Only high altitude photo available. An extension of the Lutheran Grace Youth Camp below one of the 2005 landslide scars on slope No. 7SE-B/C122 was observed.
1992	Only high altitude photo available and the recorded landslide incidents could not be visible. The agricultural terraces within slope No. 7SE-B/C195 were abandoned since early 1990's.
1993	Only high altitude photo available and the recorded landslide incident could not be visible. No significant changes to the study area are apparent.
1995	Only high altitude photo available and the recorded landslide incident could not be visible. Photos are blurred. No significant changes to the study area are apparent.

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YEAR	KEY OBSERVATIONS
1996	Only high altitude photo available. A landslide was observed at slope No. 7SE-B/C122 and the landslide scar was barely observed in the 1996 photos. It is believed that this landslide is associated with the 1995 landslide incident ME1995/7/2. A slump of landslide debris appeared to be accumulated at the toe of the scar.
1997	Good quality and low altitude aerial photo. Some surface protection appeared to have been applied on the landslide scar at slope No. 7SE-B/C122 that observed in 1996 and vegetation started to grow on top of the landslide debris at the toe of the slope. A new low rise structure has been constructed to the east of the Church below the 2005 landslide scars on slope No. 7SE-B/C122 (Plate A7). Two squatter structures below the August 2005 landslide scar were demolished between 1980 and 1997. No significant change to other squatter structures was apparent.
1998	Photos are blurred. No significant changes to the study area are apparent.
1999 - 2004	No significant changes to the study area are apparent.

LIST OF TABLES

Table A1 - List of Aerial Photographs Examined

Date Taken	Altitude (ft)	Photograph Number
1945.11.10	20,000	Y00652
1949.04.24	5,800	Y02123-24
1954.11.18	29,200	Y02773-74
1963.01.26	4,100	Y08663-64
1973.12.14	2,500	7281-83
1976.01.30	3,800	13410-12
1978.11.07	4,000	23118-19
1980.09.11	5,000	31727-29
1982.10.10	10,000	44630-32
1983.12.22	10,000	52211-13
1985.12.23	4,000	68165-68
1988.11.04	10,000	A15330-31
1990.12.03	10,000	A24313-14
1992.11.11	10,000	A32866-67
1993.12.06	10,000	CN5606-07
1995.02.12	10,000	CN9744-45
1996.11.09	10,000	CN15869-70
1997.05.27	4,000	CN17379-80
1998.11.11	8,000	CN21476-77
1999.09.03	5,500	A49935-36
1999.10.27	4,000	A50516-17
2000.07.01	4,000	CN26713-14
2000.07.01	4,000	CN26753
2001.03.15	4,300	CN30272
2002.05.27	4,000	CW41735-37
2003.05.31	4,000	CW47846-47
2003.05.31	4,000	CW47903-04
2003.09.27	4,000	CW50500-01
2003.09.27	4,000	CW50211-13
2003.10.16	4,000	CW50846-47
2003.11.25	4,000	CW52846-47
2003.11.29	2,500	RW03495-96
2004.09.11	4,000	CW59056-58

Note: All aerial photographs are in black and white except for those prefixed with CN, CW or RW.

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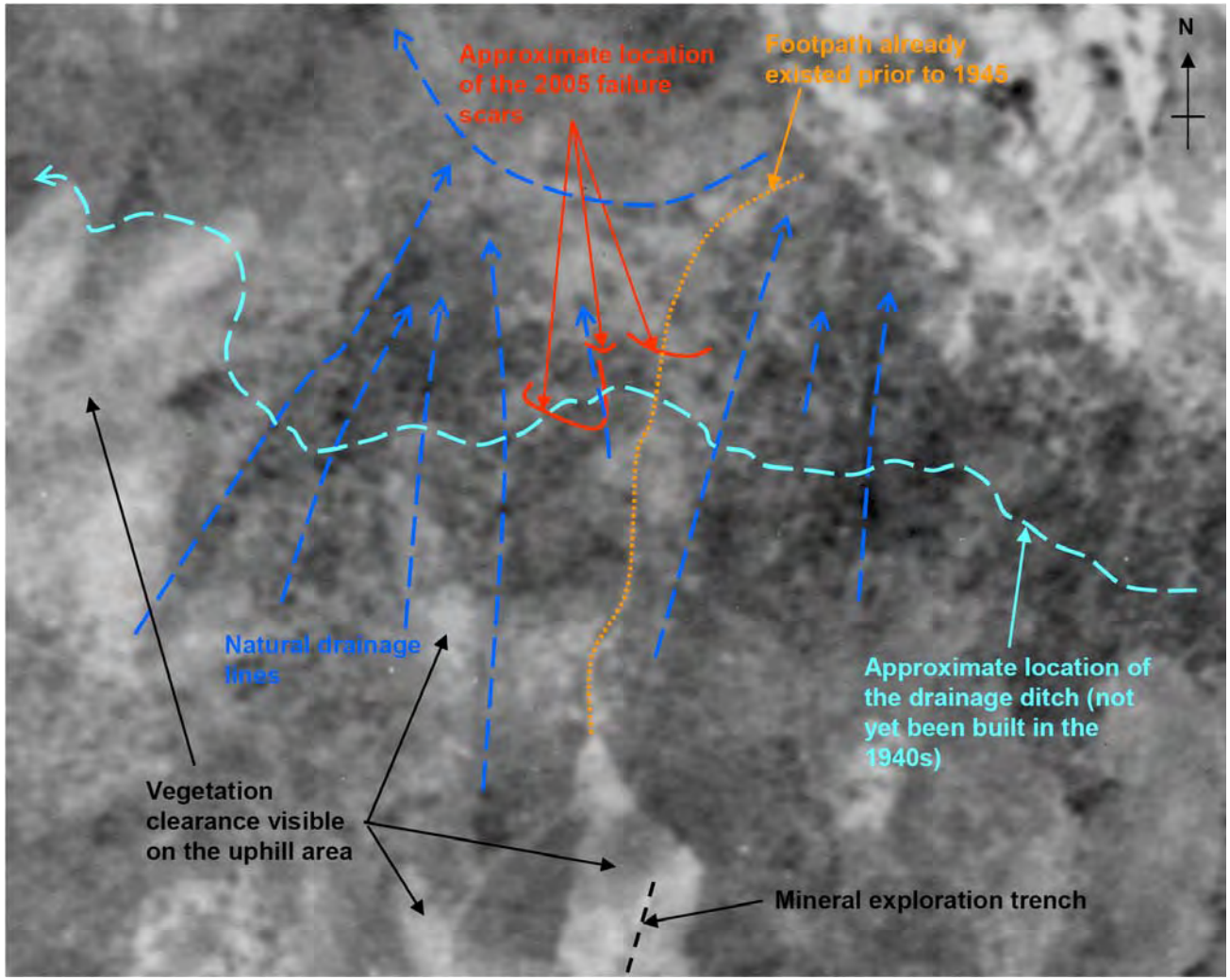

1945-1949

- The landslide site was a natural terrain prior to 1949.
- The hillside was sparsely to moderately vegetated with shrubs and small trees.
- Some vegetation clearance was evident to the south and west of the hillside.
- Major natural drainage lines are identified in the vicinity of the landslide site and they are mainly draining from south to north.
- Some possible mineral exploration trenches were noted on the hillside.
- A footpath had been built prior to 1945 along the ridgeline where one of the 2005 landslide on slope No. 7SE-B/C122 occurred.
- The 2005 failure scar is located on a minor ridgeline.

Plate A1 - Aerial Photograph Interpretation (1949 Photograph)

Note: Interpretation carried out on aerial photographs Nos. Y02123 - Y02124.

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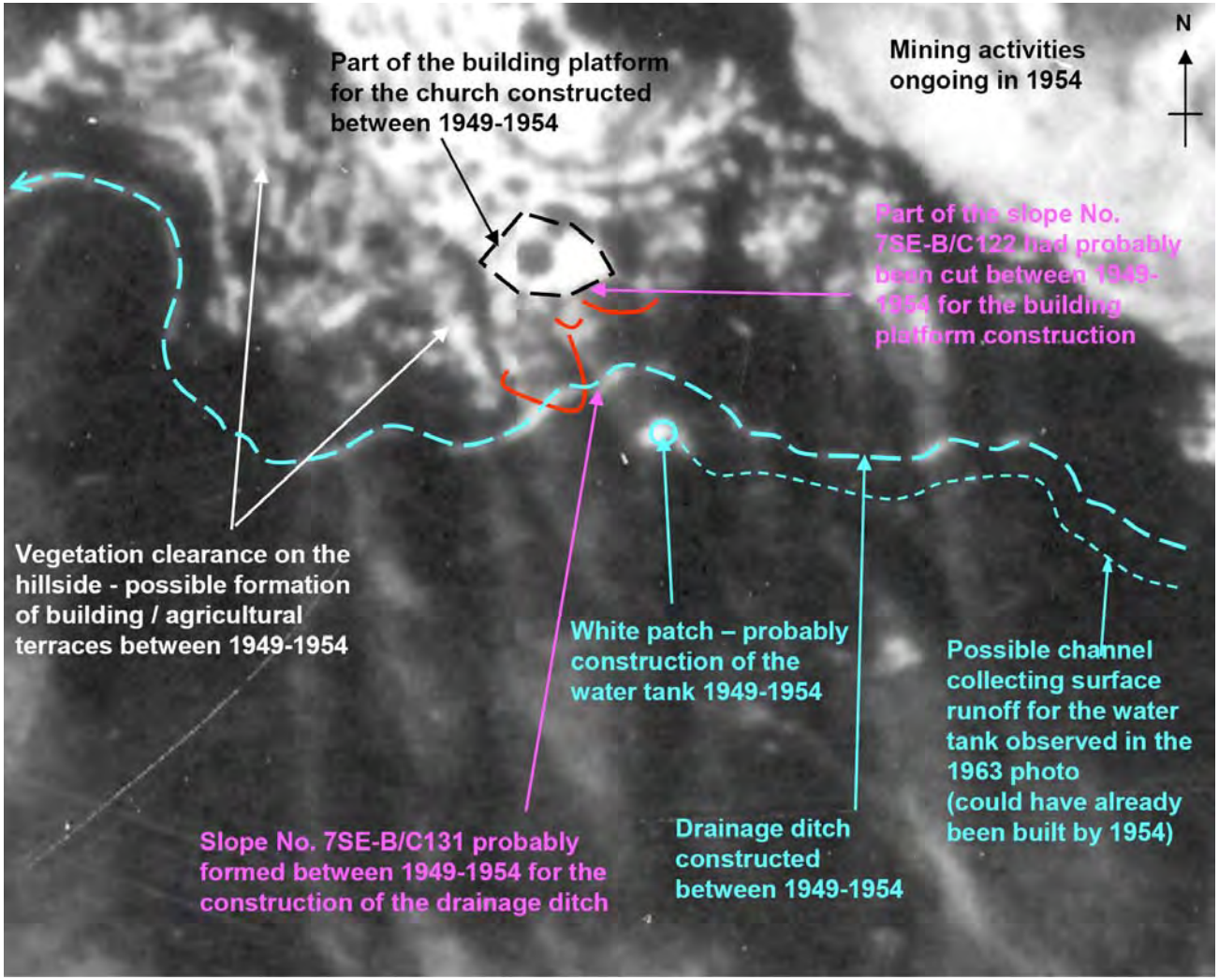
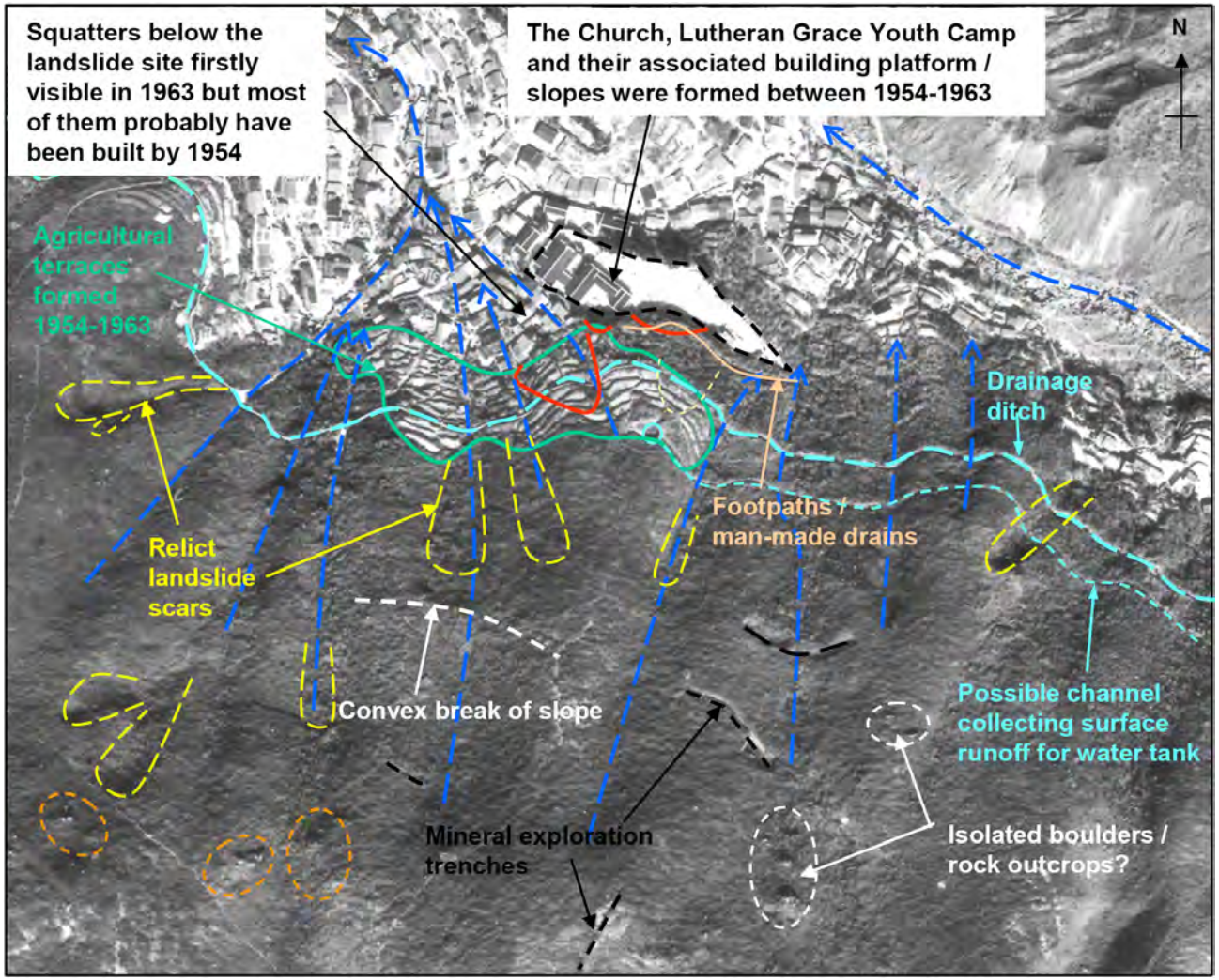


1954

- Photos are blurred and details of the landslide site were not clearly visible.
- The drainage ditch had been built at some time between 1949 and 1954. Slope No. 7SE-B/C131 probably formed in associated with the construction of the drainage ditch.
- A white patch was visible at the present water tank location. A channel appeared to have been constructed to the east of the water tank, collecting surface runoff for the water tank.
- Some terraces, probably building platforms and agricultural terraces, were constructed at the area within the landslide site and its vicinity.
- Part of the building platform for the church had been built by 1954 and part of the slope No. 7SE-B/C122 had probably been cut in association with the building platform construction.
- It appeared that Ma On Shan Upper Village has undergone substantial development between 1949 and 1954.
- Extensive mining activities were underway in the Ma On Shan Mine to the north-east of the landslide site.

Plate A2 - Aerial Photograph Interpretation (1954 Photograph)

Note: Interpretation carried out on aerial photographs Nos. Y02773 - Y02774.



1963

- The Ma On Shan Upper Village has reached its full development.
- All the squatter dwellings below the 2005 landslide site appeared to have been constructed by 1963.
- The church, Lutheran Grace Youth Camp and their associated building platform (part of the platform was constructed by 1954 and the entire building platform built by 1963) had been entirely constructed.
- Slope No. 7SE-B/C122 located at one of the 2005 landslide scars had been cut by 1963. A footpath/man-made drainage channel had been built along its crest.
- Agricultural terraces were formed in the vicinity of the August 2005 landslide scars. Slope 7SE-B/C195 had been formed and the extent shall be larger than the current slope boundary.
- No evidence of landslide in the squatter area/agricultural terraces and in the vicinity of the landslide site was apparent.
- Some possible natural terrain relict landslides on the hillside above the landslide site were identified based on the these photos but all of them should be pre-1945 features.
- A few mineral exploration trenches were noted on the hillside to the south and above the 2005 landslide site.
- A few isolated boulders/rock outcrops were also observed on the hillside to the south and above the 2005 landslide site.

Plate A3 - Aerial Photograph Interpretation (1963 Photograph)

Note: Interpretation carried out on aerial photographs Nos. Y08663 - Y08664.

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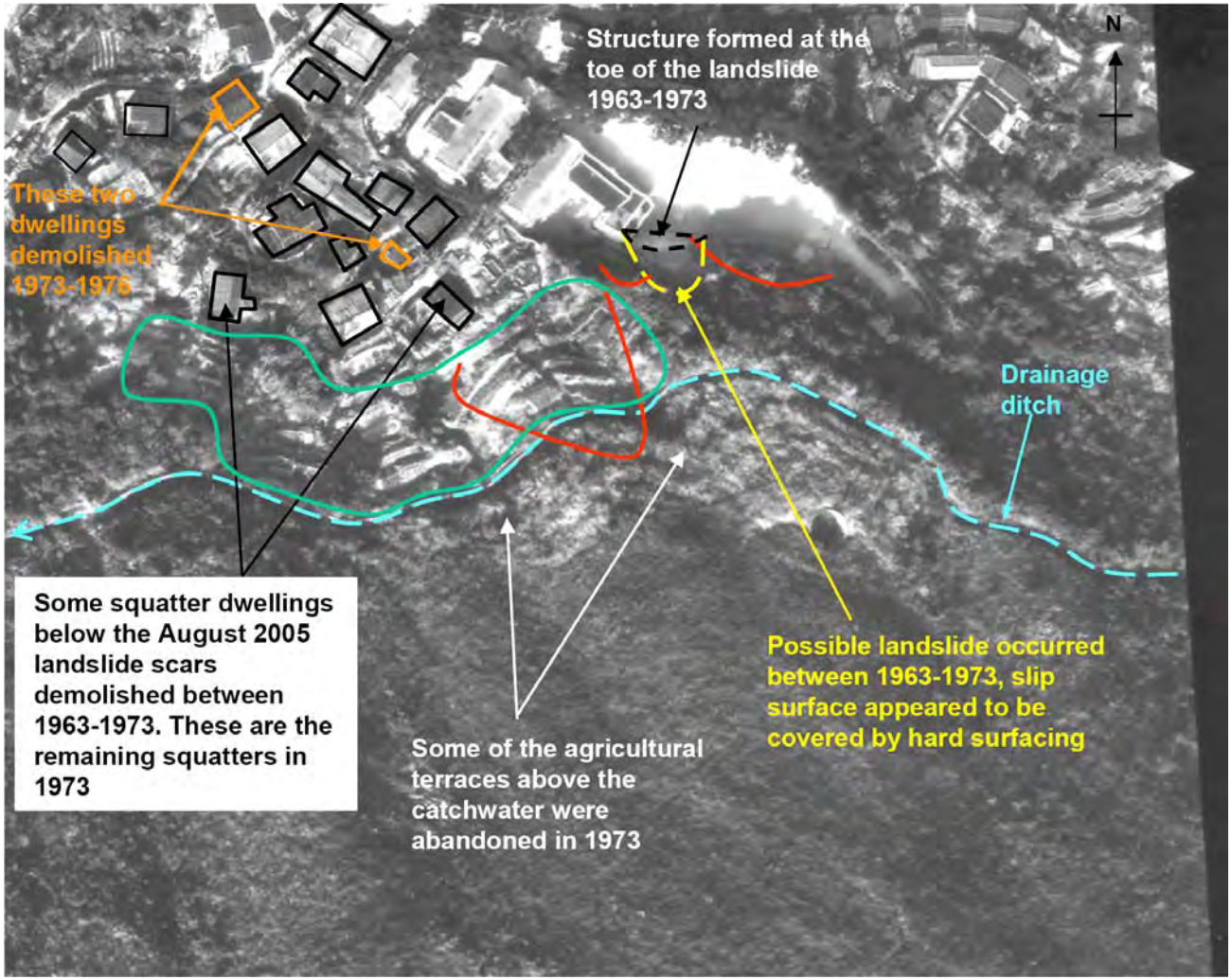

1973-1976

- Some squatter dwellings below the 2005 landslide scars were demolished between 1963 and 1973 and the remaining squatter structures in 1973 were highlighted in the scanned image.
- Two more dwellings below the 2005 main landslide scar were demolished between 1973 and 1976.
- Most of the agricultural terraces above the drainage ditch were found to be abandoned in 1973.
- Some vegetation clearance was noted to the south and above the August 2005 landslide site in the 1976 photos.
- A significant depression, possibly a landslide scar, was noted at the western portion of slope No. 7SE-B/C122. The landslide was estimated to be 8 m wide by 8 m long with 1 m to 2 m deep. The slip surface appeared to have been covered by some hard surfacing.
- A structure of about 1 m high had been formed along the toe of this landslide scar.

Plate A4 - Aerial Photograph Interpretation (1973 Photograph)

Note: Interpretation carried out on aerial photographs Nos. 7181-82.

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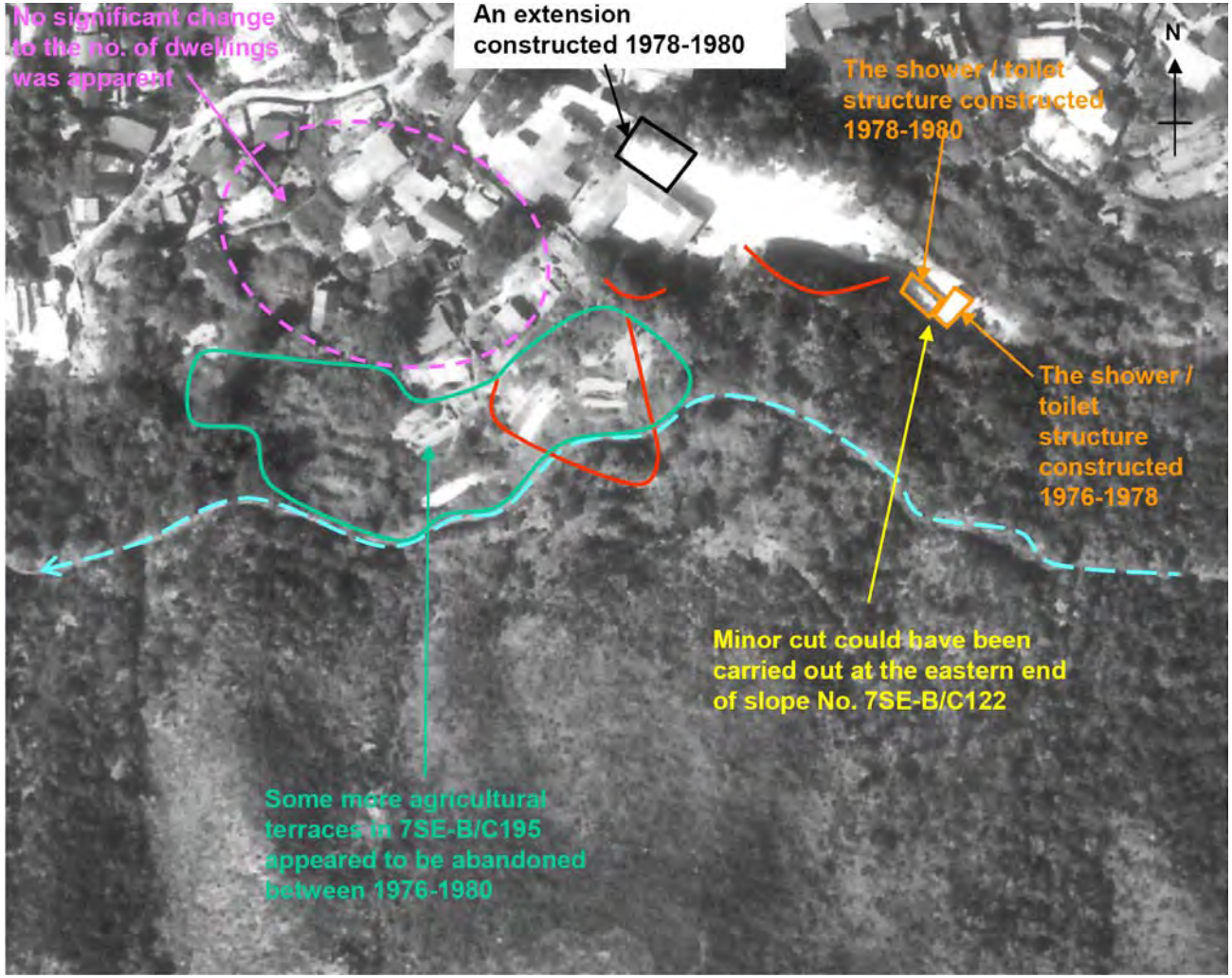

1978-1980

- Some more agricultural terraces in slope No. 7SE-B/C195 appeared to be abandoned between 1976 and 1980.
- An extension to the Lutheran Grace Youth Camp was constructed at some time between 1978 and 1980.
- The shower/toilet block was built at the eastern end of slope No. 7SE-B/C122 between 1976 and 1978 and the shower/toilet block was extended some time between 1978 and 1980.
- Minor cut might have been carried out at the eastern end of slope No. 7SE-B/C122 to accommodate the shower/toilet structures but details were obscured by shadow.

Plate A5 - Aerial Photograph Interpretation (1980 Photograph)

Note: Interpretation carried out on aerial photographs Nos. 31727-28.

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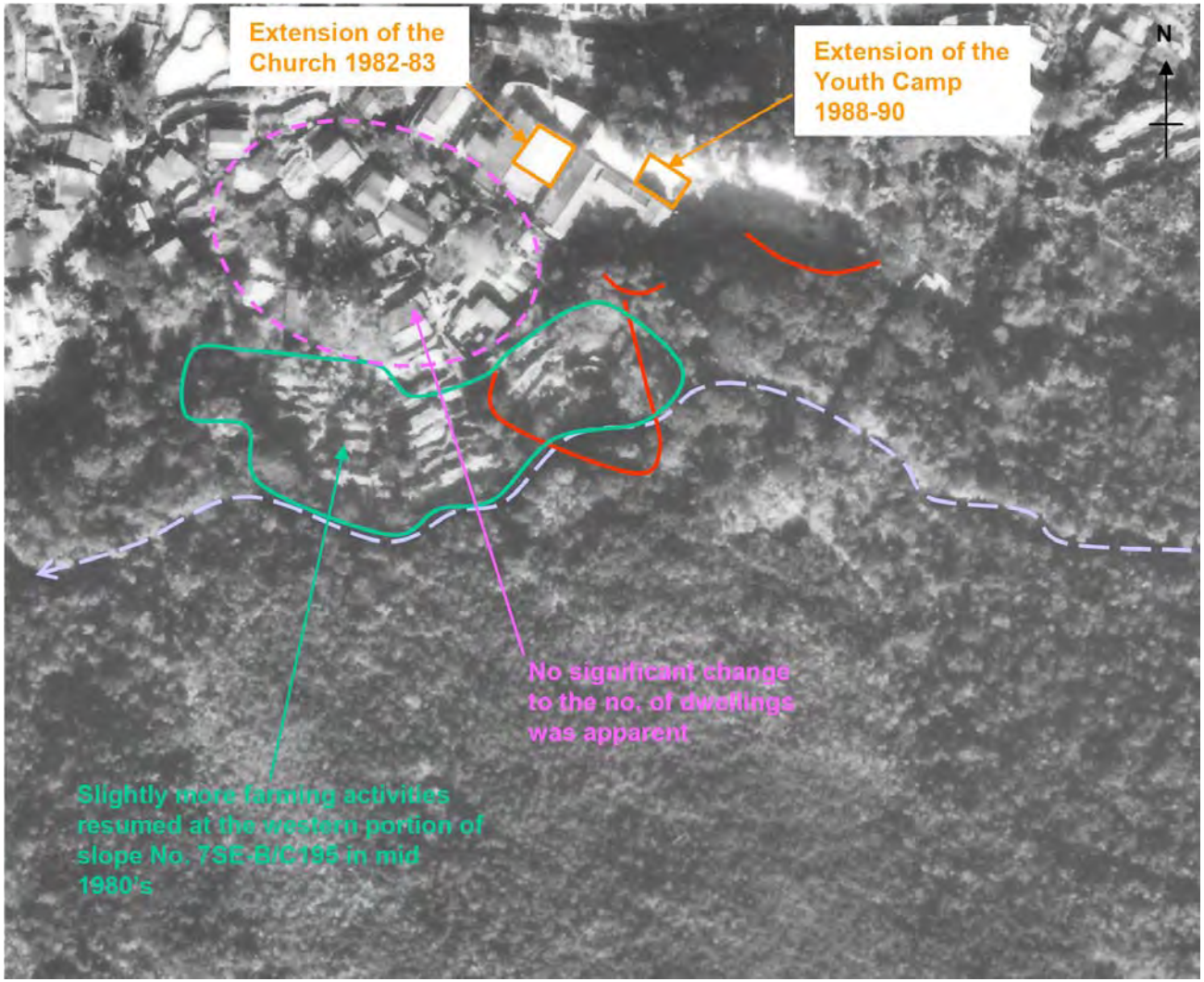

1982-1990

- Slightly more farming activities could be visible at the western portion of slope No. 7SE-B/C195 in mid 1980's.
- An extension of the church below the 2005 landslide was built at some time between 1982 and 1983 and another one to the Youth Camp was built between 1988 and 1990.
- No significant change to the number of dwellings immediately below the landslide site was apparent.

Plate A6 - Aerial Photograph Interpretation (1985 Photograph)

Note: Interpretation carried out on aerial photographs Nos. 68167-68.

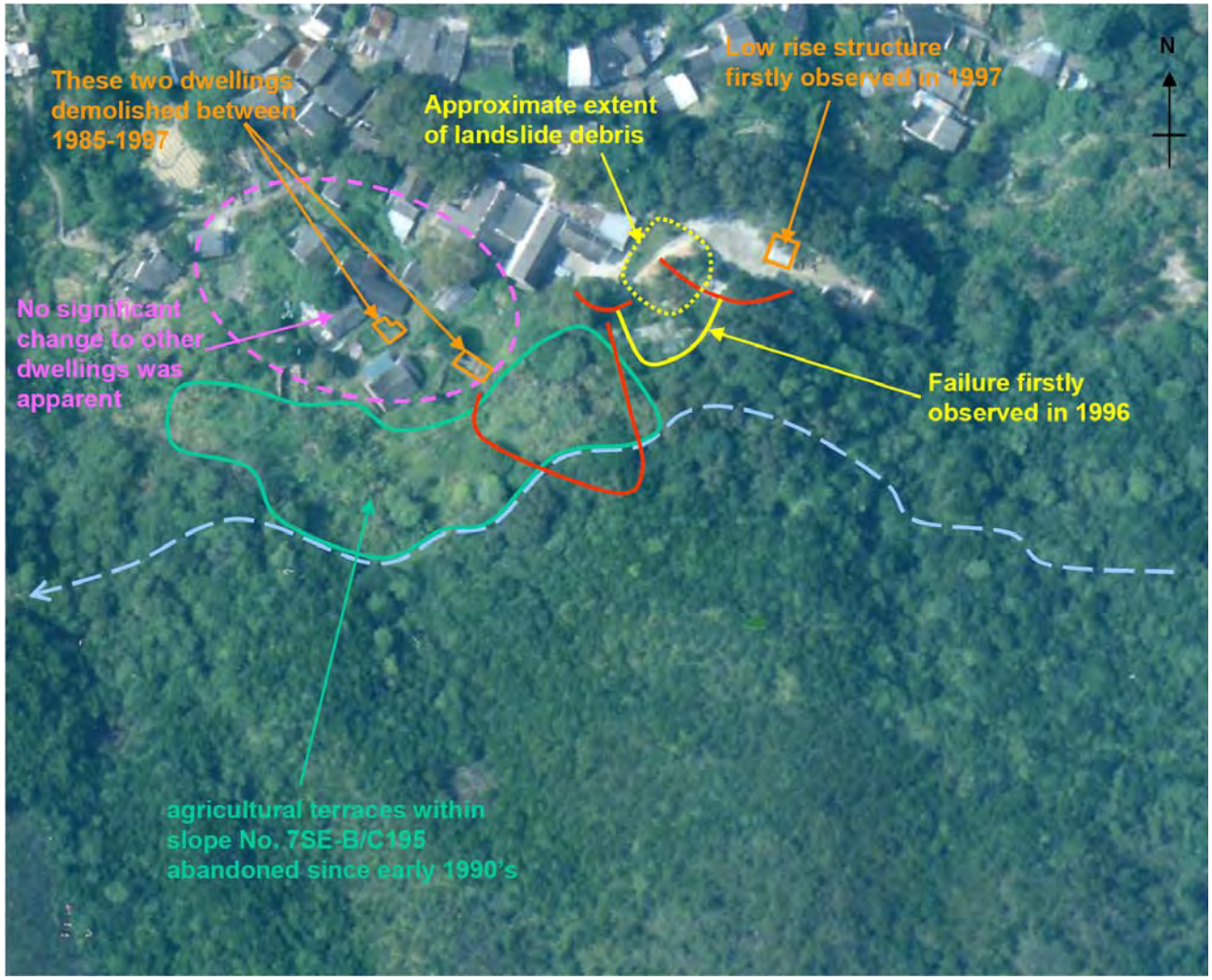

Plate A7 - Aerial Photograph Interpretation (1997 Photograph)

1997

- First date of good quality and low altitude aerial photo available after 1985.
- Photos available from 1988 - 1996 are blurred or covered by haze or taken at high altitude.
- A landslide was observed at slope No. 7SE-B/C122 and the landslide was firstly observed in the 1996 photos. It is believed that this landslide is associated with the 1995 landslide incident ME1995/7/2.
- Some surface protection appeared to have been applied on the landslide scar and vegetation started to grow on top of the landslide debris.
- A new low rise structure has been constructed to the east of the Church below one of the 2005 landslide scars.
- No significant change to the number of dwellings immediately below the 2005 landslide site was apparent.
- The agricultural terraces within slope No. 7SE-B/C195 were abandoned since early 1990's.
- No significant change to the study area was noted since 1997.

Note: Interpretation carried out on aerial photographs Nos. CN17379-80.

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GEOTECHNICAL MANUALS

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

斜坡岩土工程手冊(1998)，308頁(1984年英文版的中文譯本)。

Highway Slope Manual (2000), 114 p.

GEOGUIDES

Geoguide 1	Guide to Retaining Wall Design, 2nd Edition (1993), 258 p. (Reprinted, 2007).
Geoguide 2	Guide to Site Investigation (1987), 359 p. (Reprinted, 2000).
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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.

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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. 1/2000	Technical Guidelines on Landscape Treatment and Bio-engineering for Man-made Slopes and Retaining Walls (2000), 146 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.

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.

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