REVIEW OF THE DISTRESSED HILLSIDE NEAR KWU TUNG RESERVOIR

GEO REPORT No. 267

Halcrow China Limited

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

REVIEW OF THE DISTRESSED HILLSIDE NEAR KWU TUNG RESERVOIR

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Prepared by:

Geotechnical Engineering Office,
Civil Engineering and Development Department,
Civil Engineering and Development Building,
101 Princess Margaret Road,
Homantin, Kowloon,
Hong Kong.

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PREFACE

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

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

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Y.C. Chan
Head, Geotechnical Engineering Office
May 2012

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FOREWORD

This report presents the findings of a study of a distressed hillside near Kwu Tung Reservoir (Incident Nos. LI2007/04/2001, LI2007/04/2002 and LI2007/04/2003). The distress, in the form of tension cracks and landslide scars, was exposed after a hillfire in early April 2007.

The key objectives of this study were to document the facts about the distress and to present relevant background information. The scope of this study includes site inspection, ground investigation and diagnosis of the cause of the incidents.

The report was prepared as part of the Landslide Investigation Consultancy for landslides occurring in Kowloon and the New Territories in 2007, for the Geotechnical Engineering Office, Civil Engineering and Development Department, under Agreement No. CE 53/2006 (GE). This is one of a series of reports produced during the consultancy by Halcrow China Limited.

P.P. Leonard

Gerry Daughton
Project Director
Halcrow China Limited

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

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1. INTRODUCTION

Signs of distress comprising tension cracks and landslide scars, were exposed on the natural hillside near Kwu Tung Reservoir following a hillfire on 1 April 2007, which removed the vegetation cover. The distress was essentially noted in three locations which were allocated Incident Nos. LI2007/04/2001, LI2007/04/2002 and LI2007/04/2003.

Halcrow China Limited (HCL), the 2007 Landslide Investigation Consultants for Kowloon and the New Territories, carried out a review of the distressed hillside for the Geotechnical Engineering Office (GEO) of the Civil Engineering and Development Department (CEDD) under Agreement No. CE 53/2006 (GE).

This review report documents the facts about the distress and presents relevant background information. The scope of the review includes site inspection, ground investigation and diagnosis of the cause of the distress.

2. THE SITE

2.1 Site Description

The subject hillside is located to the east of Kwu Tung Reservoir and rises to a summit at a maximum elevation of about 85 mPD (Figure 1). It has a plan area of approximately 4000 m^2. Two abandoned water tanks are located on the summit, with a pipeline connecting the western water tank to the village at the toe of the south-facing part of the hillside (Figure 2). Extensive loss of vegetation occurred on the north and south-facing parts of the hillside during a hillfire in April 2007.

The north-facing hillside is approximately 70 m in height and is inclined at about 35° to 40° (Figure 3). There is a prominent shallow depression in the central portion of the hillside. The upper portion of this depression is where signs of distress were identified (Plate 1).

A flimsy structure, possibly used for storage, is located approximately 60 m from the toe of the north-facing hillside. The area between the toe of the north-facing hillside and the flimsy structure is fairly level ground (about 5°) occupied by abandoned farmland (Figure 3, Plate 2).

The south-facing hillside is approximately 80 m in height and is inclined at about 25° to 40° (Figures 4 and 5). Two shallow depressions are present in the central and eastern portions of the south-facing hillside. In the vicinity of these depressions are a number of relict and recent landslide scars, distressed ground and tension cracks (Plate 3).

The instability identified on the south-facing hillside potentially threatens a number of occupied squatter structures located at the toe of the hillside (Figures 4 and 5, Plate 4).

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2.2 Geological Setting

According to the Hong Kong Geological Survey (HKGS) 1:20 000 scale Solid and Superficial Geology Map Sheet No. 2 (GCO, 1989) and The Pre-Quaternary Geology of Hong Kong (Sewell et al, 2000), the subject hillside is underlain by schistose lapilli lithic-bearing coarse ash crystal tuff of the Tai Mo Shan Formation. A NE-SW trending quartz vein is mapped to the east of the summit (Figure 6).

2.3 Geotechnical Area Studies Programme (GASP)

Geotechnical data relating to the study area were compiled as part of the Geotechnical Control Office's (GCO, renamed GEO in 1991) Geotechnical Area Studies Programme (GASP) Report No. IV, North West New Territories (GCO, 1987). The data are shown on 1:20 000 scale maps, which are used for regional appraisal and strategic planning purposes. It should be noted that these maps are not intended for the assessment of local areas, such as the subject hillside, because of the limited resolution of the maps.

The GASP Engineering Geology Map indicates that the subject hillside predominantly comprises pyroclastic rocks with deposits of colluvium at the toe of the north-facing hillside and alluvium covering the toe of the south-facing hillside. The area in the vicinity of the distressed hillside is denoted as an area of general instability. The Physical Constraints Map indicates that the types of physical constraints which affect the hillside are slopes on in-situ terrain, which are generally steeper than 30°. The Geotechnical Land Use Map (GLUM) designates the terrain as GLUM Class III (i.e. with high geotechnical limitations).

3. SITE HISTORY AND PAST INSTABILITIES

3.1 Site History

The development history of the site has been established from an interpretation of aerial photographs taken between 1945 and 2007 and a review of available relevant documentary records (Figure 7). A detailed account of the aerial photograph interpretation (API) is presented in Appendix A. Key observations are summarised below.

The earliest available aerial photographs, taken in 1945, show that the hillside is part of a northeast trending spur extending from Ki Lun Shan. Extensive farmlands are present along the banks of the River Beas below the south-facing hillside and on the low-lying flatlands below the north-facing hillside.

By 1954, the construction of the water tanks at the summit of the hillside and the associated pipeline was underway.

By 1963, the two rectangular shaped water tanks at the summit of the hillside and the pipeline connecting to the village at the toe of the south-facing hillside had been constructed. Kwu Tung Reservoir was also constructed and remnants of old terraces appeared across the lower portion of the north-facing hillside. From the 1963 aerial photographs, it is evident that previous instability has occurred at several locations on the south-facing hillside (E1, R1

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to R5) (see Section 3.2). These features are not evident from the earlier, poor resolution aerial photographs taken in 1945 and 1954.

By 1973, the concentration of cottages/squatters at the foothills appears to increase significantly at the south-facing hillside.

In the 1982 aerial photographs, curvilinear features, possibly tension cracks, appear at the western portion of the north-facing hillside (T1).

The aerial photographic records between 1982 and 1996 indicate that previous instability has occurred at several locations on the south-facing hillside (T1, L1 to L10) (see Section 3.2).

Extensive areas of the hillside were affected by hillfires between 1984 and 2007. The curvilinear features (T1) first observed in the 1982 aerial photographs can only be observed later in the 1999 aerial photographs.

The tension cracks on the north-facing hillside are difficult to identify in aerial photographs taken after the hillfire in 2007, even without vegetation cover.

3.2 Past Instabilities

3.2.1 GEO's Large Landslide Database

The GEO's Large Landslide Database (Scott Wilson, 1999) contains no records of any reported landslides in the study area.

3.2.2 Enhanced Natural Terrain Landslide Inventory (ENTLI)

In 2004, GEO commenced on the Enhanced Natural Terrain Landslide Inventory (ENTLI) project using low-altitude (8,000 ft and below) aerial photographs to improve the identification of landslides and update the existing NTLI.

The ENTLI records four relict landslides (ENTLI Nos. 02SEB0214E, 02SEB0215E, 02SEB0216E and 02SEB0217E) and three recent landslides (ENTLI Nos. 02SEB0286E, 02SEB0295E and 02SEB0296E) on the south-facing hillside (Figure 8).

There are no ENTLI records of landslides on the north-facing hillside.

Landslides with ENTLI Nos. 02SEB0286E and 02SEB0214E are located within Historical Landslide Catchment (HLC) No. 2SE-B/DF1 and landslides with ENTLI Nos. 02SEB0215E, 02SEB0216E, 02SEB0295E and 02SEB0296E are located within HLC No. 2SE-B/DF2. An HLC is defined as a catchment, with an ENTLI record, that is considered to present a potential hazard to an important facility downslope.

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3.2.3 GEO's Landslide Database

According to the GEO's Landslide Database, one previous landslide (Incident No. MW94/8/24) has been recorded on the study hillside (Figure 8). The incident occurred at the north-eastern toe of the study hillside on 6 August 1994 with a failure volume of about 150 m^3.

3.2.4 Aerial Photograph Interpretation

Based on API and site observations, it is evident that instability, comprising widespread ground distress in conjunction with localized landslides, has been ongoing on the hillside for many years (API indicates signs of instability prior to 1963) (Figure 9).

In the 1963 aerial photographs, five well defined local topographic depressions inferred as relict landslides (R1 to R5) can be identified on the south-facing hillside. Surface erosion (E1), approximately 20 m wide, is also evident at the upper south-facing hillside above the head of an ephemeral drainage line (S3).

On the north-facing hillside, a subtle convex change in slope is identified near the head of an ephemeral drainage line (S1). At the central portion of the north-facing hillside, a well defined convex break in slope, possibly associated with previous instability, is also observed. Further east on the north-facing hillside a concave change in slope is evident above several areas of man made disturbance, possibly grave sites.

In the 1982 aerial photographs, curvilinear features approximately 40 m long (T1) are evident at the western portion of the north-facing hillside near the head of an ephemeral drainage line (S1). These features are possibly the tension cracks later exposed in 2007 after the hillfire. Two recent landslide scars (L1 and L2) are also evident on the terrain to the east of Kwu Tung reservoir and at the mid slope of the south-facing hillside, respectively.

In the 1989 aerial photographs a recent landslide scar (L3) is evident at the head of an ephemeral drainage line (S3), the debris from which appears to have channelised and traveled down to the lower reaches of the south-facing hillside. Another minor recent landslide scar (L4) is evident about 30 m to the south east of L3.

In the 1993 aerial photographs, two recent landslide scars (L5 and L6) are evident at the head of an ephemeral drainage line (S2) on the south-facing hillside.

In the 1994 aerial photographs, two recent landslide scars (L7 and L8) are observed at the lower eastern portion of the north-facing hillside in the vicinity of the concave change in slope identified in the 1963 aerial photographs.

In the 1996 aerial photographs, two small recent landslide scars (L9 and L10) are observed in the vicinity of L7 and L8 at the lower eastern portion of the north-facing hillside.

In the 1999 aerial photographs, the curvilinear features (T1) observed in 1982 aerial photographs are evident.

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Field mapping by HCL has confirmed the observations made from API and has also identified three recent landslides (LS1 to LS3) on the south-facing hillside that were not observed from the aerial photographs.

3.3 Facilities Affected

The south-facing hillside potentially affects a number of registered squatter structures as well as a residential structure on leased land (Figure 10).

In 1993, Category 2 Clearance under the Non Development Clearance (NDC) Programme was recommended to clear four registered squatter structures located at the toe of the south-facing hillside. In September 2007 (i.e. following the reported incidents), Category 2 Clearance was recommended for further eight squatter structures, affecting five families, at the toe of the south-facing hillside (Figure 10). However, the occupants refused to leave. Lands Department advised that no clearance action of the Category 2 NDC structures could be executed under the current arrangement.

4. DESCRIPTION OF THE DISTRESSED HILLSIDE

4.1 General

Signs of distress, comprising extensive tension cracks on the north-facing hillside and landslide scars, distressed ground and tension cracks on the south-facing hillside were exposed following a hillfire on 1 April 2007, which removed the vegetation cover (Plates 1 to 12).

The hillside is generally covered with a thin veneer of colluvium comprising firm to stiff, moist, yellowish brown, dappled grey, sandy silt with some sub-angular fine to coarse gravel and cobbles.

At the upper portion of the hillside, the depth to rock head is shallow and numerous outcrops of strong to moderately strong, light grey, slightly to moderately decomposed, slightly foliated coarse ash crystal tuff are exposed.

Numerous boulders with maximum size of 1.5 x 1.0 x 0.8 m are scattered along the ridgeline (Plate 13).

4.2 Description of the Distressed North-facing Hillside

Several tension cracks were exposed after the hillfire on the north-facing hillside at an elevation of approximately 40 – 60 mPD i.e. 20 – 40 m above the toe of the hillside (Plate 1 and Plates 5 to 6). The distressed area bounded by the tension cracks is located at the head of a slightly concave break in slope, which forms a shallow linear depression (an ephemeral drainage line) at the upper portion of the hillside where the gradient is up to 45° locally (Figure 3). The longest tension crack was approximately 35 m in length and was located below a slightly concave break of slope with rock outcrops above. A soil pipe was exposed in the main scarp of the tension crack within the ephemeral drainage line (Figure 9, Plate 7). The width of the tension cracks ranged from 150 mm to 250 mm and the depth from 600 mm

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to 800 mm. The cracks were infilled by rootlets, burnt vegetation and organic materials, indicating that they were probably at least a few years old. Only colluvial material was observed in the walls of the tension cracks.

4.3 Description of the Distressed South-facing Hillside

Two ephemeral drainage lines run from northwest to southeast at the central and eastern portions of the hillside (Figure 9). After the hillfire, several recent landslide scars were exposed towards the head of these ephemeral drainage lines on the steeper part of the hillside where gradient is up to about 40° locally (Figure 5, Plate 3 and Plates 8 to 11).

All of the landslides identified were shallow open hill slope failures. The depths of the landslide scarps were less than 1 m and the estimated landslide volumes ranged between <5 m^3 and 150 m^3. The lengths of the debris trails ranged between <5 m and 50 m long and the estimated travel angles were between 20° and 30°.

Inspection of the landslide scars revealed that the regolith comprised colluvium of about 300 mm to 400 mm in thickness, overlying a thin veneer of saprolite of approximately 100 mm in thickness. The in-situ bedrock was very close to the slope surface.

Several tension cracks were also identified at an elevation of approximately 55 mPD and 75 mPD in the vicinity of the landslide scars (Plate 12). The longest tension crack, approximately 8 m long, was located above the largest recent landslide scar (L3). The width and depth of the tension cracks ranged from 100 mm to 300 mm and from 400 mm to 500 mm respectively. Only colluvial material was observed in the walls of the tension cracks.

At the time of HCL's inspection in November 2007 the tension cracks above L3 and the main scarp of L3 had been sealed with cement soil mortar by HyD's term contractor, following the reporting of the incidents to HyD on 17 August 2007.

5. SITE INVESTIGATION

5.1 Ground Investigation Fieldwork

5.1.1 Introduction

As part of the current study, ground investigation fieldworks comprising one trial pit and one trial trench at the north-facing hillside and four trial pits, one trial trench and one inspection pit at the south-facing hillside were carried out by Gammon Construction Limited between June and August 2008 under the supervision of HCL (GCL, 2008). The trial pits and trial trenches were positioned across the distressed areas of the hillside in order to investigate the extent of the tension cracks and the nature of slope forming materials.

The investigation encountered colluvium overlying coarse ash crystal tuff. The colluvium was between 0.6 m and 1.9 m thick. The colluvium could be categorized into two types, forming an upper and lower layer respectively. Based on field observations, the lower colluvium layer comprised a coarser grained material with higher gravel content. This may have been due to eluviation arising from concentrated groundwater flows within this material either prior to or after deposition of the upper colluvium layer. A layer of residual soil was

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also identified at the boundary between the colluvium and tuff (Trial Pit TP4). Regional dynamic metamorphism and deformation has resulted in the development of foliation (schistosity) in the tuff. Typically the foliation is inclined at moderate angle towards the north (340° – 010°/ 40° – 55°). At the north-facing hillside, the foliation has similar dip direction to that of the slope. At the south-facing hillside, the foliation dips into the slope. Cracks, voids and shear planes were identified in a number of locations.

The locations of the ground investigation stations are shown in Figure 11 and detailed logs are included in Appendix B. The findings from the trial pits and trial trenches are summarized at the following sections.

5.1.2 Trial Pits

Trial Pit TP1 was positioned on the eastern flank of a tension crack on the north-facing hillside (Figure 11) and encountered colluvium of up to 0.8 m thick, comprising gravelly sandy silt with cobbles of tuff overlying Grade V/IV tuff. Tension cracks ranging from 8 mm to 300 mm wide and pervaded by rootlets were identified extending into the colluvium to 0.4 m below ground level. Several voids with maximum dimensions 0.45 m (W) x 0.15 m (H) x 0.25 m (D) were also encountered within the colluvium to depths of up to 0.4 m.

Trial Pit TP2 was positioned above landslide scar L3 (ENTLI landslide No. 02SEB0286E) on the south-facing hillside and encountered colluvium of up to 1.0 m thick, overlying Grade V/IV tuff. Generally, the colluvium can be divided into an upper layer of up to 0.5 m thick comprising firm, sandy silt with some medium to coarse gravel and occasional cobbles of rock fragments and a lower layer of up to 0.5 m thick comprising gravel and cobble sized tuff and quartz fragments in a firm to stiff light brown sandy silt matrix. Evidence of past movement in the form of infilling materials comprising gravelly clayey silt extending to between 1.3 m and 1.7 m below ground level into in-situ materials was identified.

Trial Pit TP3 was positioned on the lower western flank of landslide scar L3 on the south-facing hillside and encountered two distinct layers of colluvium up to 1.2 m thick overlying Grade V/IV foliated tuff. The upper colluvium layer was up to 0.6 m thick and comprised stiff, yellowish brown sandy silt. The lower colluvium layer also up to 0.6 m thick comprised gravel and cobble sized Grade IV tuff fragments in a stiff, yellowish brown sandy silt matrix. A gently inclined (15°) 20 mm wide shear plane was identified between the upper and lower colluvium layers at 0.35 m below the ground surface. Several kaolin infilled joints (max. 1 mm thick) were identified in the Grave IV tuff at 1 m to 2 m below ground level.

Trial pit TP4, positioned outside the western flank of landslide scar L3 on the south-facing hillside, encountered two layers of colluvium up to 1.0 m thick overlying residual soil. The upper colluvium layer was up to 0.7 m thick and comprised sandy clayey silt with occasional medium to coarse gravel. Many sub-vertical root-infilled cracks were identified in the upper colluvium layer. The lower colluvium layer was up to 0.3 m thick and comprised clayey silt with some medium to coarse gravel and occasional cobble sized rock fragments. The layer of residual soil was up to 1m thick and comprised firm brownish red slightly sandy clayey silt overlying Grade V tuff. At the interface between the colluvium

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and residual soil at Face B of the trial pit, a dilated crack, about 70 mm wide and 1.35 m long, infilled by sandy silt with many small voids was identified. Numerous tension cracks about 0.05 m to 0.3 m wide were observed extending upslope. The cracks were infilled by rootlets and organic materials indicating that they were probably at least a few years old.

Trial pit TP5 was positioned above the landslide scar L5 (ENTLI landslide No. 02SEB0295E) and encountered two layers of colluvium up to 1.3 m thick overlying Grade V/IV tuff. The upper colluvium layer was up to 0.6 m thick and comprised firm, sandy clayey silt with many fine to coarse gravels and occasional cobbles of rock fragments aligned parallel to the ground surface (dipping at about 30°). The lower colluvium layer was up to 0.7 m thick and comprised gravel and cobble sized Grade IV/III tuff and quartz fragments (dipping at about 50°) in a stiff, clayey silt matrix. Evidence of past movement in the form of infilling materials up to 200 mm thick comprising gravelly clayey silt extending up to 2.8 m below ground level into Grade IV tuff was identified (Plate 15).

5.1.3 Trial Trenches

Trial Trench TT1 was positioned across three tension cracks at the north-facing hillside and encountered colluvium up to 0.8 m thick comprising firm, yellowish brown sandy silt with some gravel and occasional cobble sized rock fragments, overlying Grade V/IV tuff. Several root-filled sub-vertical cracks were identified within the colluvium layer. At Face B of the excavation, tension cracks of between 8 mm and 300 mm in width converged to a shear plane at about 0.6 m below ground level at the interface between the colluvium and Grade IV tuff. A disturbed zone was identified beneath the shear plane in which blocks of decomposed tuff had apparently rotated within the rock mass, suggesting that movement has extended into the upper zone of the tuff (Plate 16). The tension cracks and the shear plane were infilled by dark grey, loose silty sand and organic materials with many rootlets. Evidence of past movement in the form of infilling materials up to 300 mm thick, comprising coarse gravel and cobble sized rock fragments in a firm, brownish yellow clayey silt matrix was also identified within the Grade IV tuff. Grade III foliated tuff with iron oxide stained joints parallel to the foliation was encountered at a depth of 1.25 m below ground level at the corner of Face A and Face B of the excavation. At Face D, tension cracks of between 5 mm and 220 mm in width converged to a shear plane at about 0.5 m to 0.7 m below ground level, at the interface between the colluvium and Grade IV/V tuff. The shear plane was up to about 250 mm wide and partially infilled by loose yellowish brown silty sand with many rootlets (Plates 17 and 18).

Trial trench TT2 was positioned across the tension cracks and main scarp of landslide scar L3 on the south-facing hillside and encountered two layers of colluvium up to 1.3 m thick overlying Grade V/IV tuff (Plate 19). The upper colluvium layer was up to 1.0 m thick and comprised sandy silt with some coarse gravel and cobble sized Grade V/IV tuff fragments and with several root-filled sub-vertical cracks. The lower colluvium was up to 0.8 m thick and comprised sandy silt with many gravel, cobble and occasional boulder sized Grade V/IV tuff fragments. At Face C, recent movement in the form of discontinuous open cracks with maximum aperture of 25 mm was identified at the interface between the upper and lower colluvium, at about 0.35 m below the ground surface. Evidence of past movement in the form of infilling materials up to 200 mm wide, partially infilled and open cracks between 50 mm and 150 mm wide and voids was identified extending from the base of the lower

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colluvium into the Grade V/IV tuff. In Face C, the void in the Grade IV tuff was 0.46 m wide, 0.3 m high and 0.6 m deep (Plate 20), which is located at about 1.5 m below ground (i.e. 0.7 m below the interface of colluvium and Grade IV/V tuff). In Face D of the trial trench sub-horizontal open joints up to 3 mm wide were observed at shallow depth (about 1 m below ground) within the Grade IV tuff, suggesting previous movement (Plate 20). Manganese and iron oxide staining on some of the joint surfaces indicates the presence of water flowing through the open joints in the past.

5.1.4 Groundwater Conditions

No seepage was observed during site inspections carried out between April 2007 and August 2008 either from the tension cracks, the landslide scars or from the trial pits and trial trenches.

5.2 Ground Movement Monitoring

5.2.1 Movement Monitoring Pins

Fifteen sets of movement monitoring pins, nine sets at the south-facing hillside and six sets at the north-facing hillside, were installed by HCL in May 2007. Each set comprises a pair of pins installed across a tension crack in order to measure the relative displacement. Monitoring carried out monthly between May 2007 and April 2008 did not record any significant movement across the tension cracks.

5.2.2 Survey Monitoring Stations

In November 2007, 26 survey monitoring stations (sixteen at the south-facing hillside and ten at the north-facing hillside) in the vicinity of the tension cracks (Figure 12) were constructed by Gammon Construction Limited. Following the installation, measurement of the lateral and vertical displacement was carried out by CEDD’s Survey Division using surveying instruments at monthly intervals commencing from January 2008. The range of the surveying instrument’s accuracy is ±10 mm. Monitoring up to the end of April 2009, including the period of heavy rainfall in June 2008, did not show any significant movement nor trend of increasing movement. The results fluctuated between +4 mm (heaving) and –13 mm (settlement). Details of the monitoring results are included in Appendix C.

6. ANALYSIS OF RAINFALL RECORDS

Rainfall data were obtained from the nearest GEO automatic raingauge No. N34, which is located at Sheung Shui Water Treatment Plant, Fu Tei Au Road at about 3 km to the north-east of the Site (Figure 1). The raingauge records and transmits rainfall data at 5-minute intervals to the Hong Kong Observatory and GEO. The daily rainfall data for the period between January 2008 and April 2009 are included in Appendix C.

As the time of the landslide event (or events) is unknown, it is not possible to undertake a meaningful analysis of the rainfall records.

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7. DISCUSSION

API, limited ground investigation and field mapping have revealed that a thin mantle of colluvium is present across the hillside and that there has been extensive signs of shallow instability within the near surface material since at least 1963. These observations are in line with the findings of Evans & King (1997), which suggest that natural terrain comprising fine to coarse ash tuff, including a thin (less than 2 m) colluvial cover, with a slope angle between 25° and 50° has a high degree of susceptibility to shallow failure.

The tension cracks observed in the trial excavations can only be traced over a short distance through the colluvium before stopping at the boundary with the underlying tuff. The cracks tend to flatten out in a direction roughly parallel with the ground surface as they approach the interface between the colluvium and tuff, suggesting that movement is shallow and occurs at or near the colluvium/tuff interface. However, there is some evidence, in the form of open joints, cracks and voids in the tuff, together with local rotation of the foliation within sections of the tuff at depths from 0.5 m to 2.8 m, indicating that some movement may have extended into the tuff at shallow depth. Evidence of both recent movement, in the form of cracks with no infill, and historical movement, in the form of infilled cracks has been identified.

The distressed areas are located on the relatively steep parts of the hillsides where the gradient is up to 45° locally. In addition, the hydrogeological setting of the hillside, comprising mainly a thin mantle of colluvium overlying Grade IV/V tuff with open joints is favourable to the build-up of groundwater pressure arising in the near ground mass from surface infiltration. Manganese staining on some of the joint surfaces as observed in the trial excavations indicates the presence of water flowing through open joints in the past. Furthermore, the small to medium sized voids identified in the colluvium could act as soil pipes, forming preferential groundwater flow paths, which would have further promoted infiltration into the subsoil resulting in possible build-up of transient groundwater locally in the colluvium. This would lead to gradual reduction in the effective stress and shear strength of the colluvium and subsequent movement of the near ground mass. The tension cracks could have resulted from the progressive downslope movement of the colluvium associated with locally steep profiles.

In the ENTLI, a number of relict and recent landslides were identified on the south-facing hillside. The tension cracks on the north-facing hillside were not identified under the ENTLI Project. Potential hazards on heavily vegetated natural terrain may therefore remain undetected by detailed API alone.

The opportunity to undertake detailed API and site inspections for natural terrain catchments following hillfire and removal of vegetation should be further explored in order that potential hazards may be more readily identified.

8. CONCLUSION

The hillside has shown intermittent movements as evidenced by the presence of many relict and recent landslides, and many old and new tension cracks. The movements appear to have involved mainly the near surface materials. In addition, based on the ground movement

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monitoring results, no significant movement or any trend of increasing movement has been recorded since the commencement of the monitoring in May 2007.

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Scott Wilson (Hong Kong) Ltd. (1999). Specialist API Services for the Natural Terrain Landslide Study - Task B Final Report. Report to Geotechnical Engineering Office, Hong Kong, 9 p. plus 4 maps.

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

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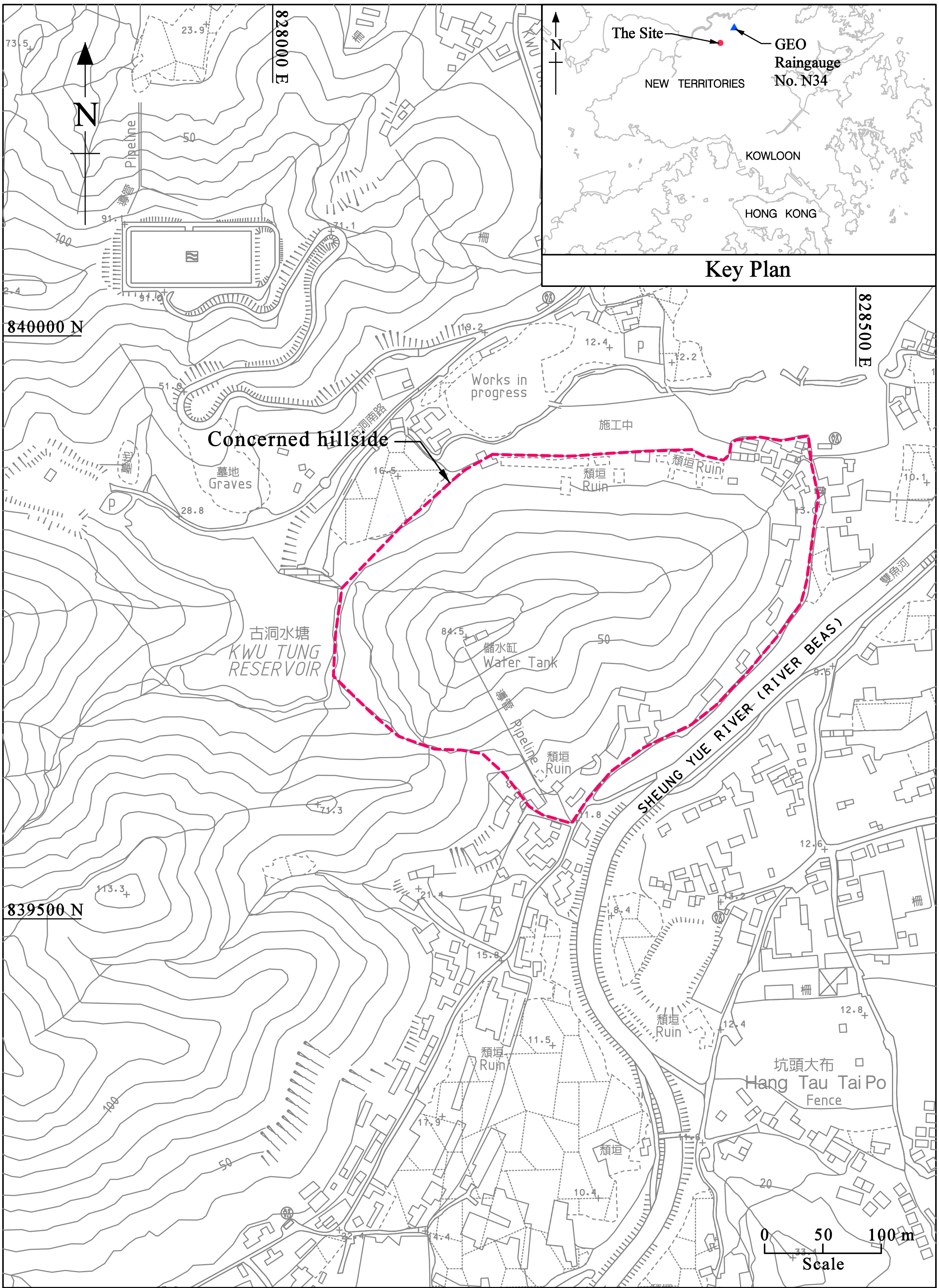

Note : Base map is extracted from survey sheet No. 2SE-B, Scale 1:5000.

Figure 1 - Location Plan

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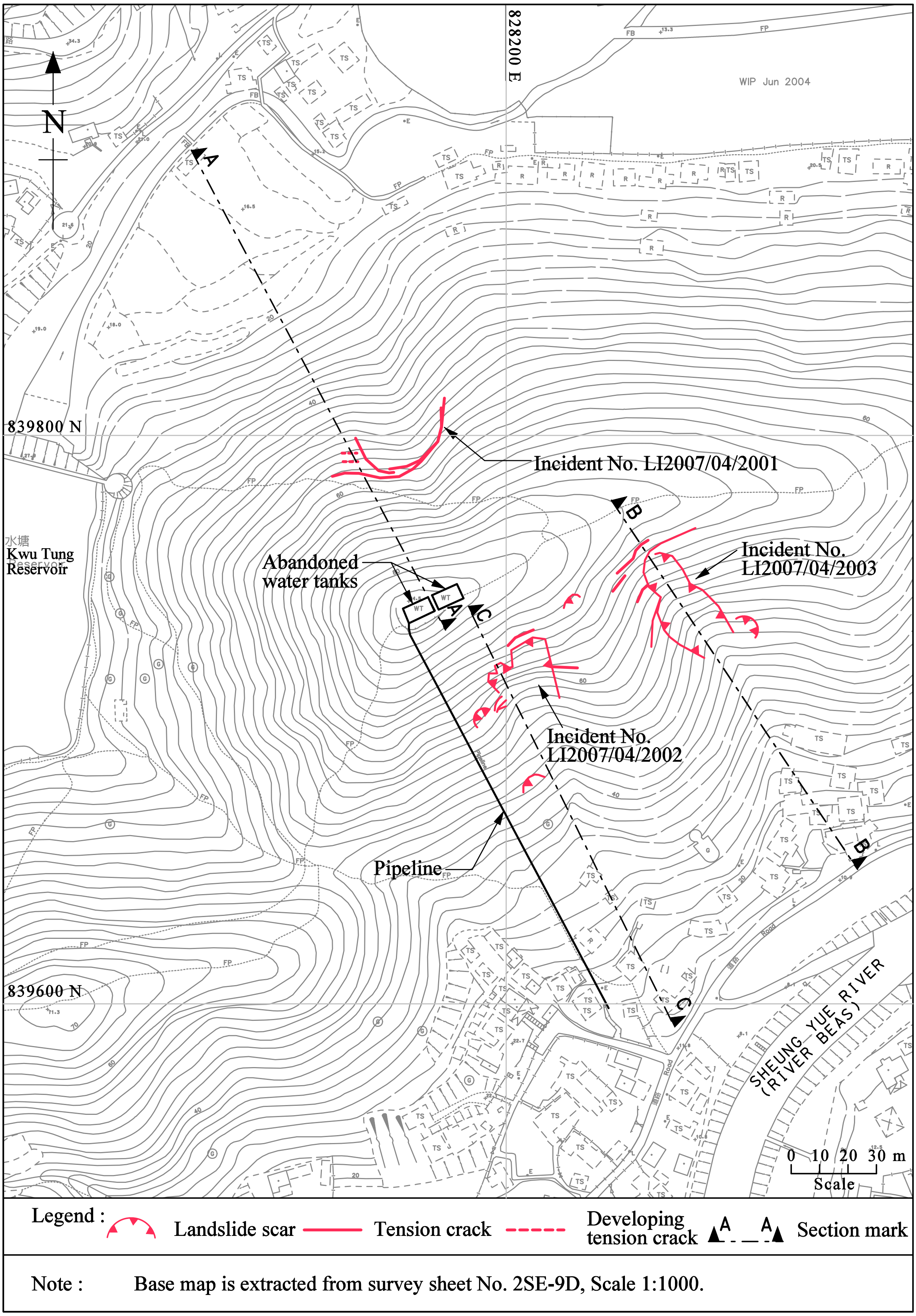

Figure 2 - Site Location Plan

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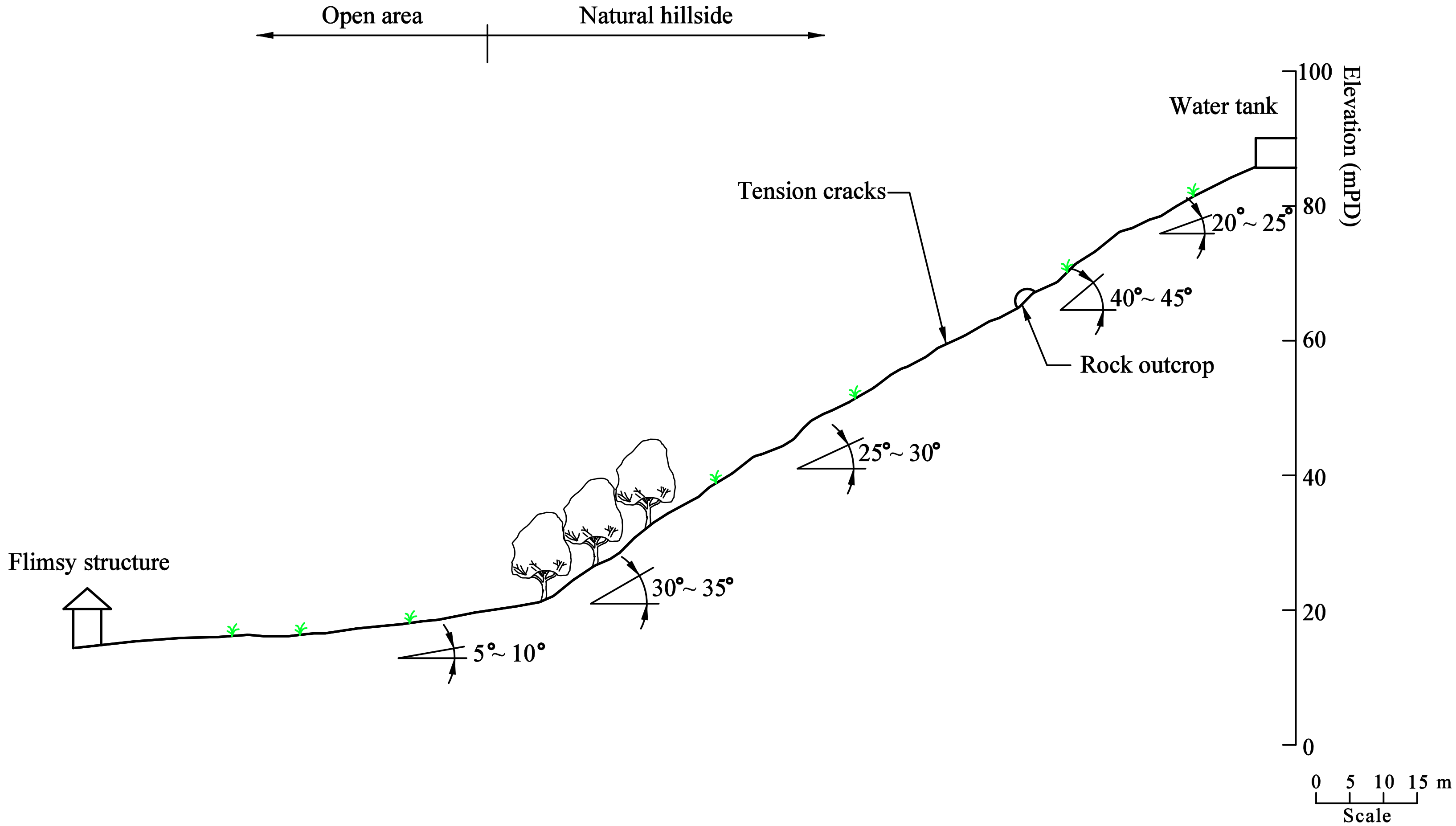

Note : See Figure 2 for the location of cross-section.

Figure 3 - Section A-A (North-facing Hillside)

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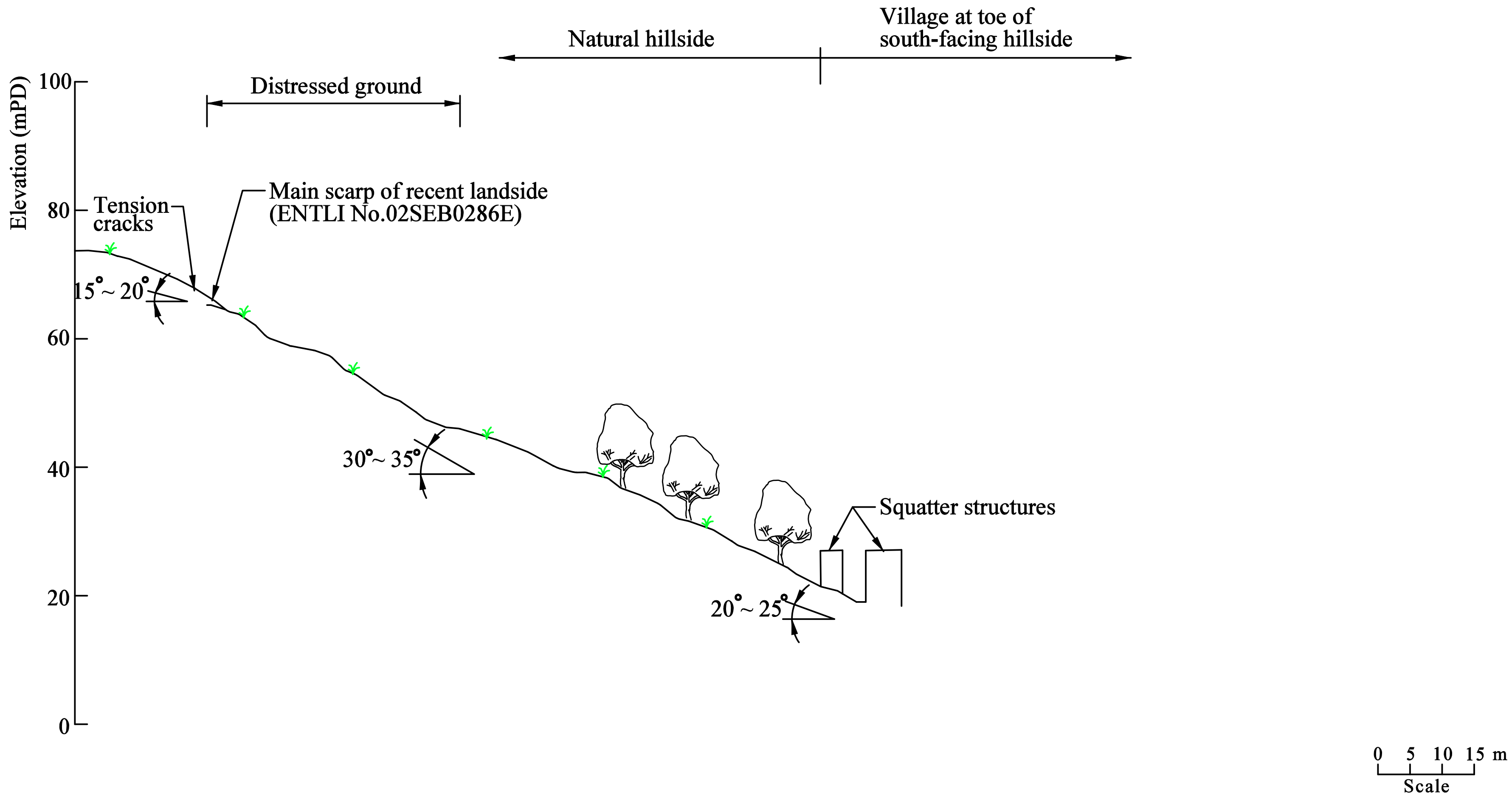

Note : See Figure 2 for the location of cross-section.

Figure 4 - Section B-B (South-facing Hillside)

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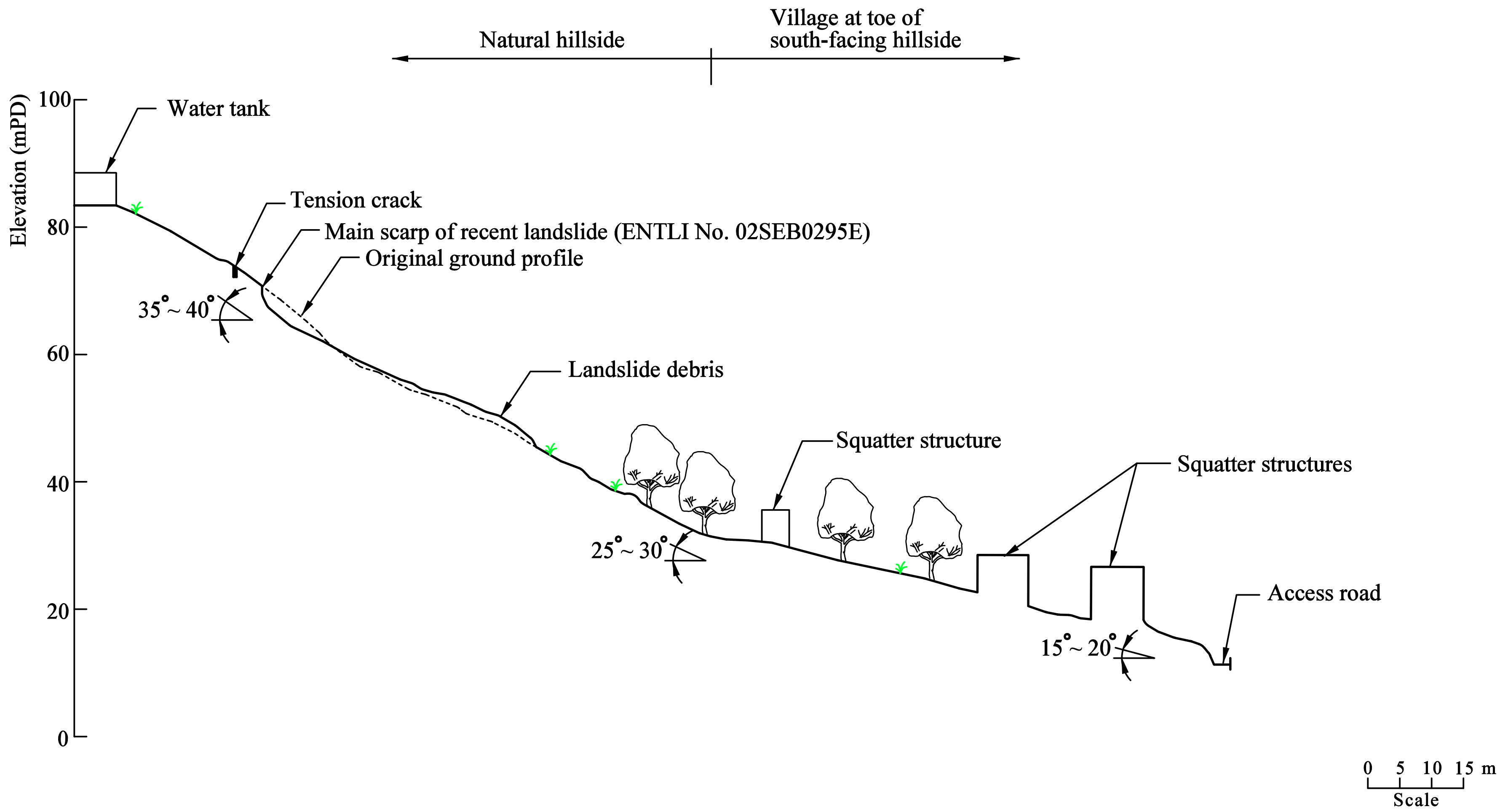

Note : See Figure 2 for the location of cross-section.

Figure 5 - Section C-C (South-facing Hillside)

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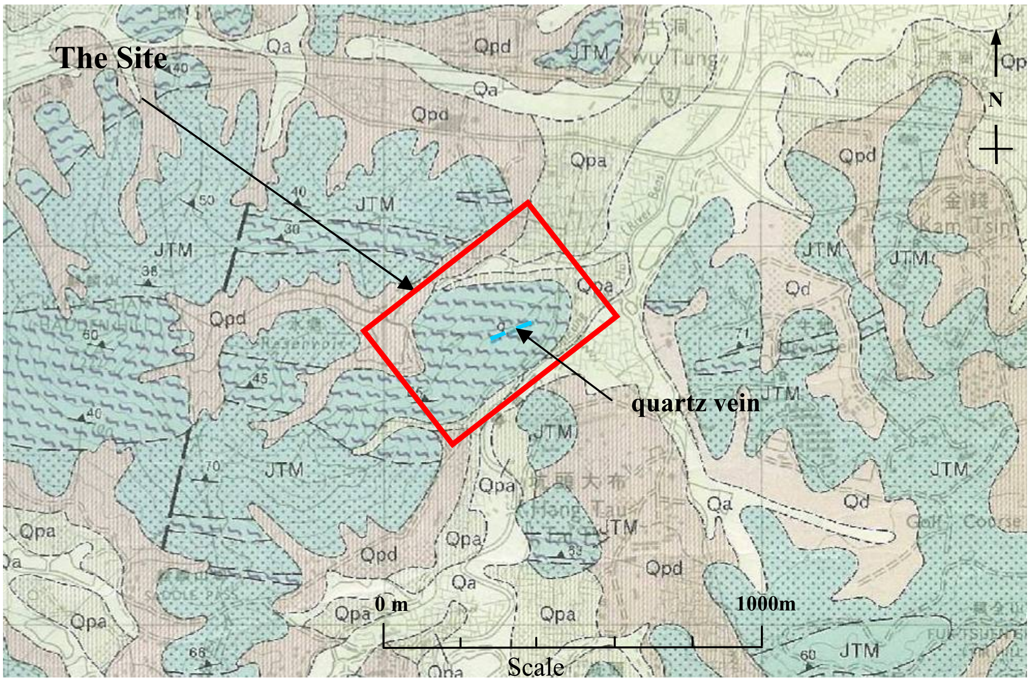

LEGEND:

SUPERFICIAL DEPOSITS

Fill

Qa Alluvium

Qpa Terraced alluvium

Qpd Debris flow deposits

SOLID GEOLOGY

JTM Undivided, coarse ash crystal tuff

Schist

q Quartz vein

Slightly metamorphosed tuff

GEOLOGICAL LINES

Geological boundary, superficial deposit

1982 Fill boundary, with limit of reclamation at date shown

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

Fault (crossmark indicates downthrow side)

Thrust, teeth pointing to upper plate

Photogeological lineament

Mineral vein

STRUCTURAL SYMBOLS

40 Foliation

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

Figure 6 - Regional Geology

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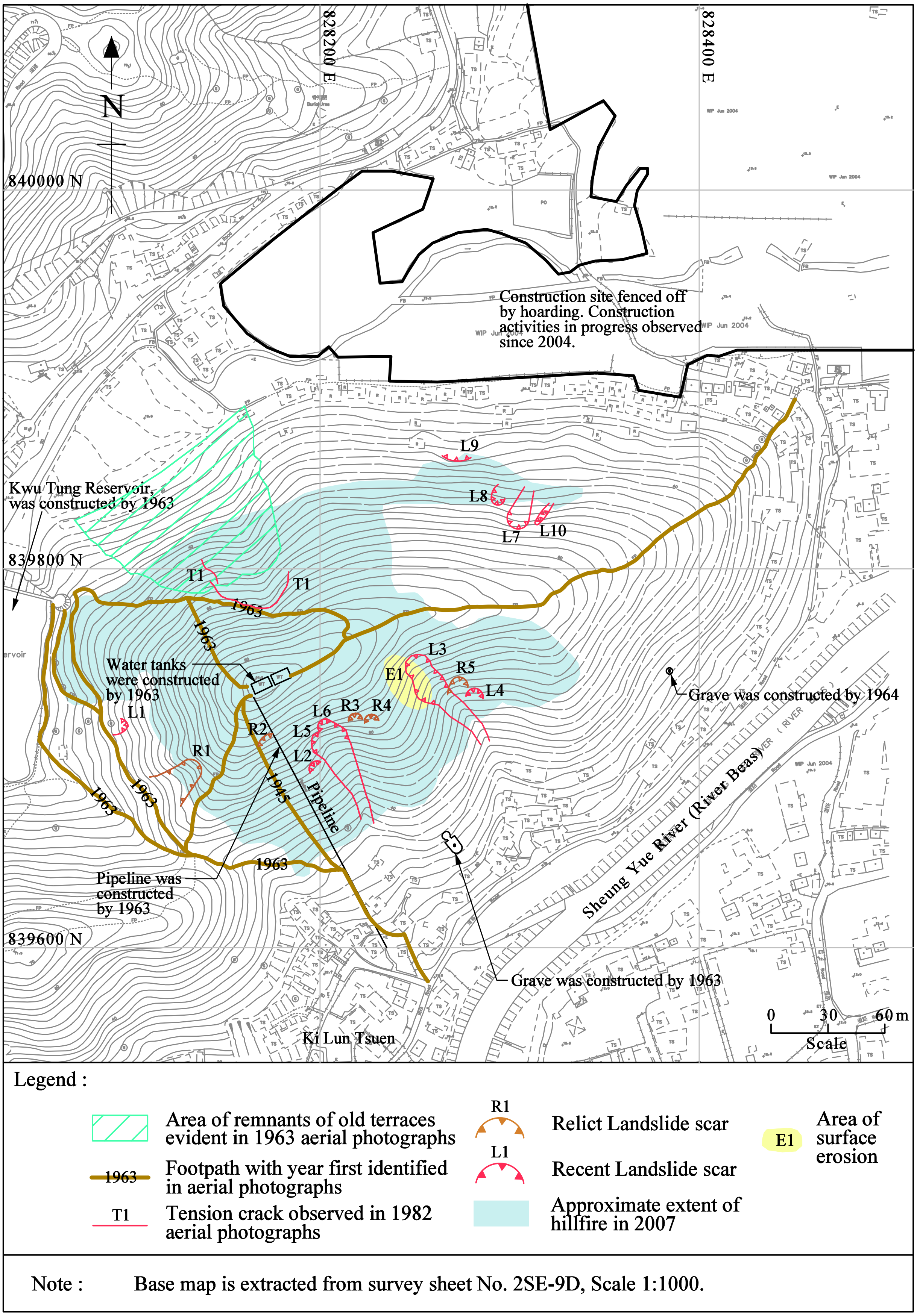

Figure 7 - Site History

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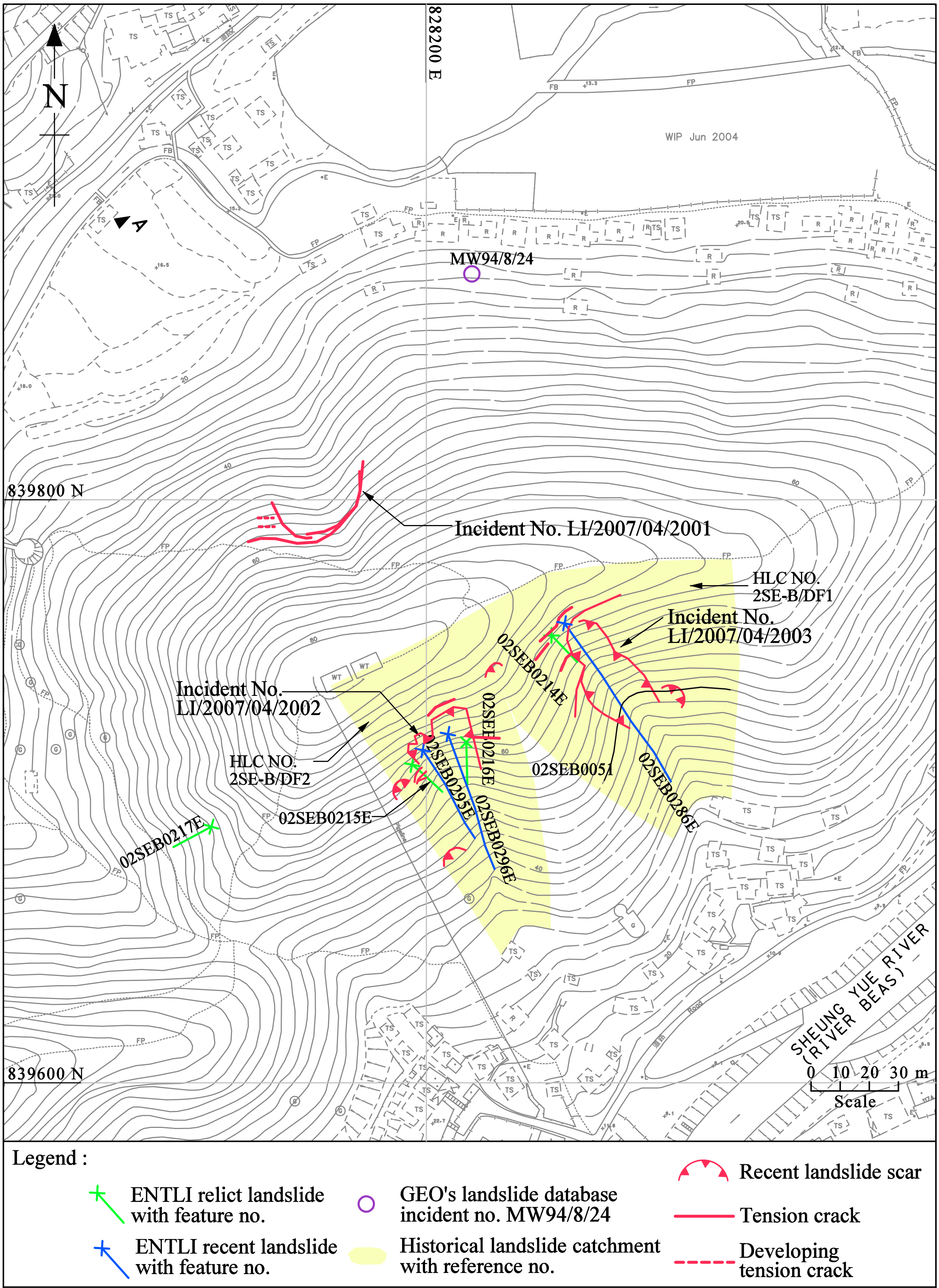

Note : Base map is extracted from survey sheet No. 2SE-9D, Scale 1:1000.

Figure 8 - Past Instabilities

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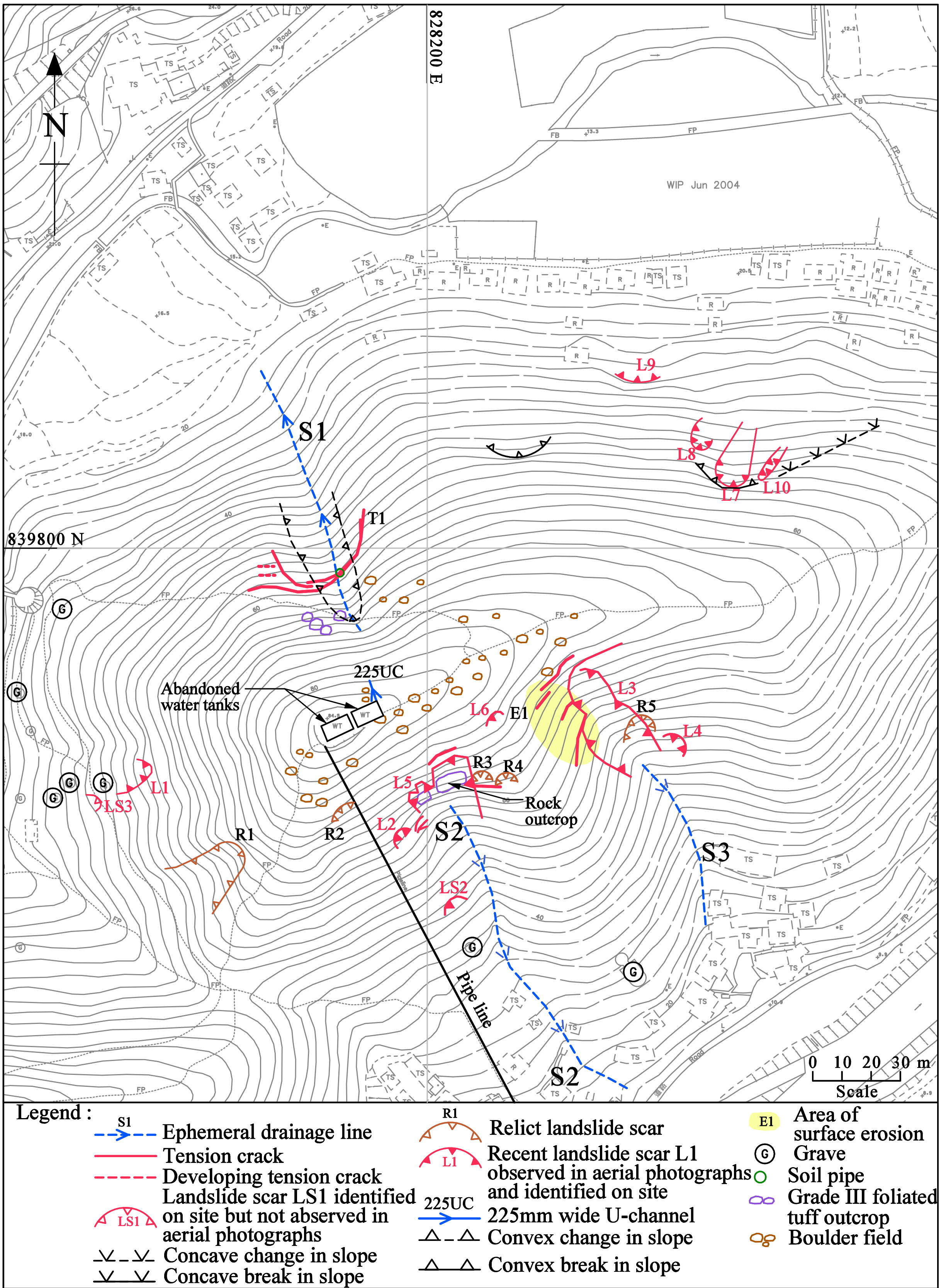
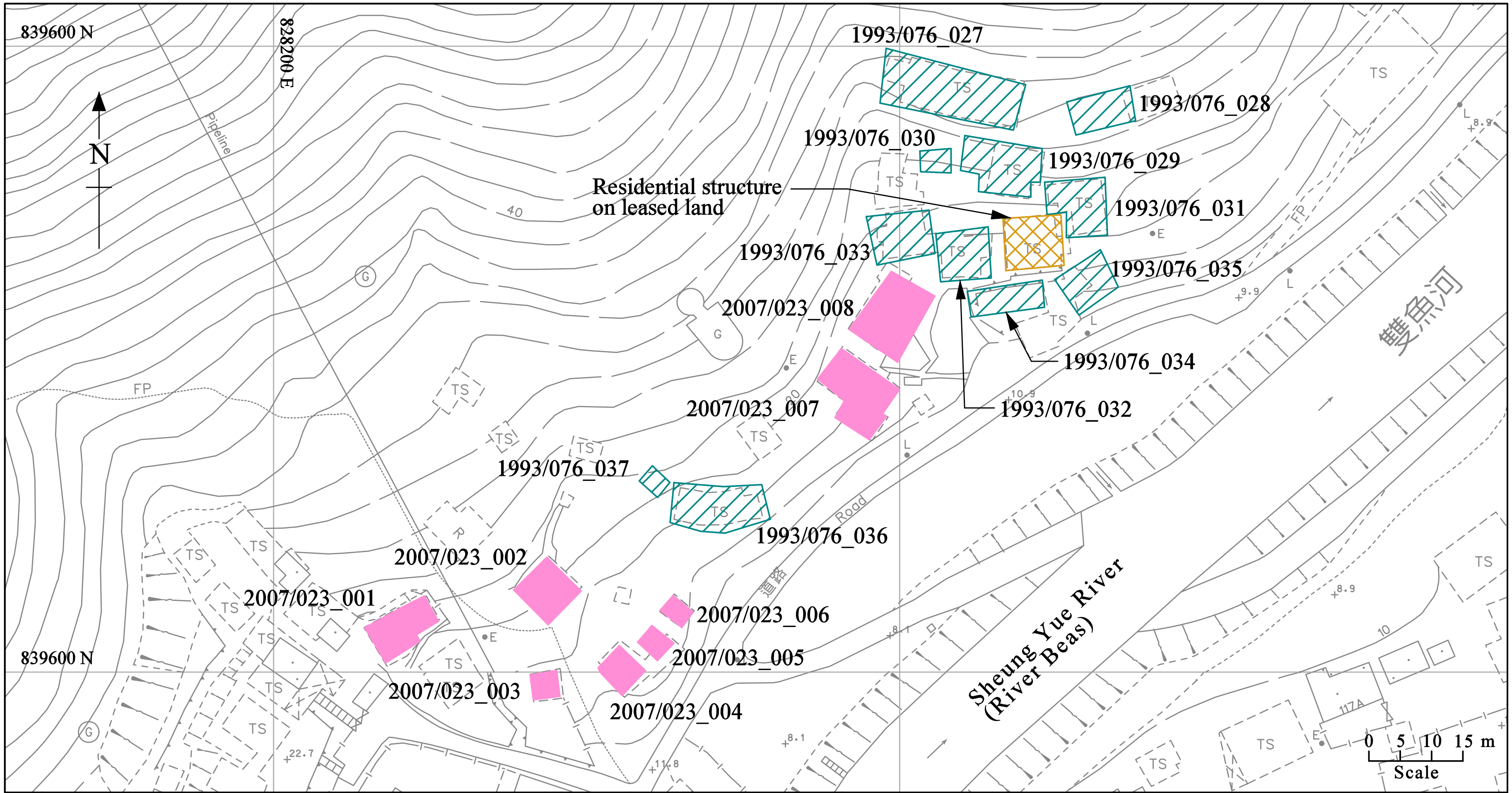


Note : Base map is extracted from survey sheet No. 2SE-9D, Scale 1:1000.

Figure 9 - Aerial Photograph Interpretation



Legend : Structure recommended for Cat 2 clearance in 1993 (Ref: GCMW 1993/076) Structure recommended for Cat 2 clearance in 2007 (Ref: GCMW 2007/023)

Note : Base map is extracted from survey sheet No. 2SE-9D and 2SE-14B, Scale 1:1000.

Figure 10 - Recommendations for Non Development Clearance

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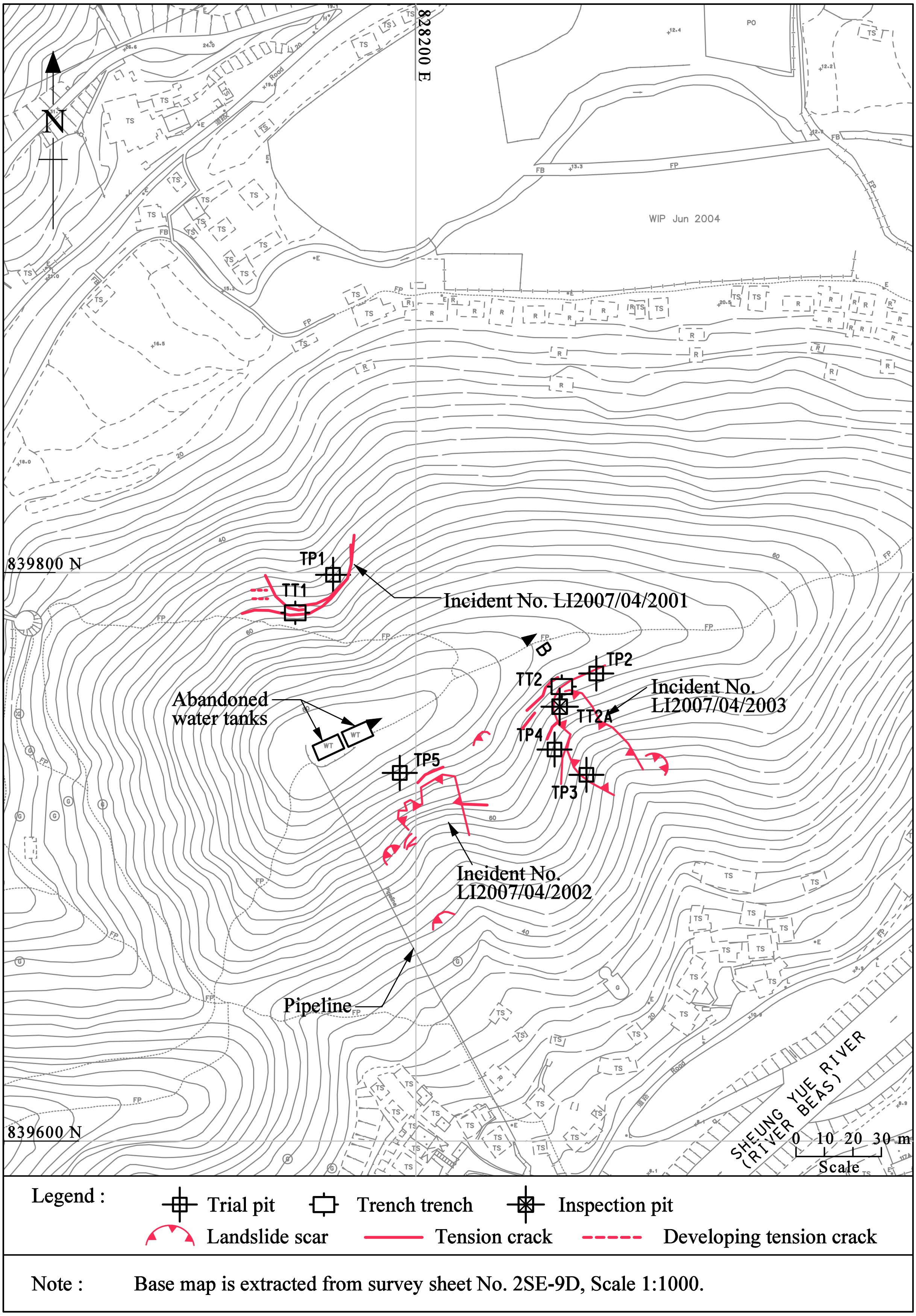

Figure 11 - Ground Investigation Location Plan

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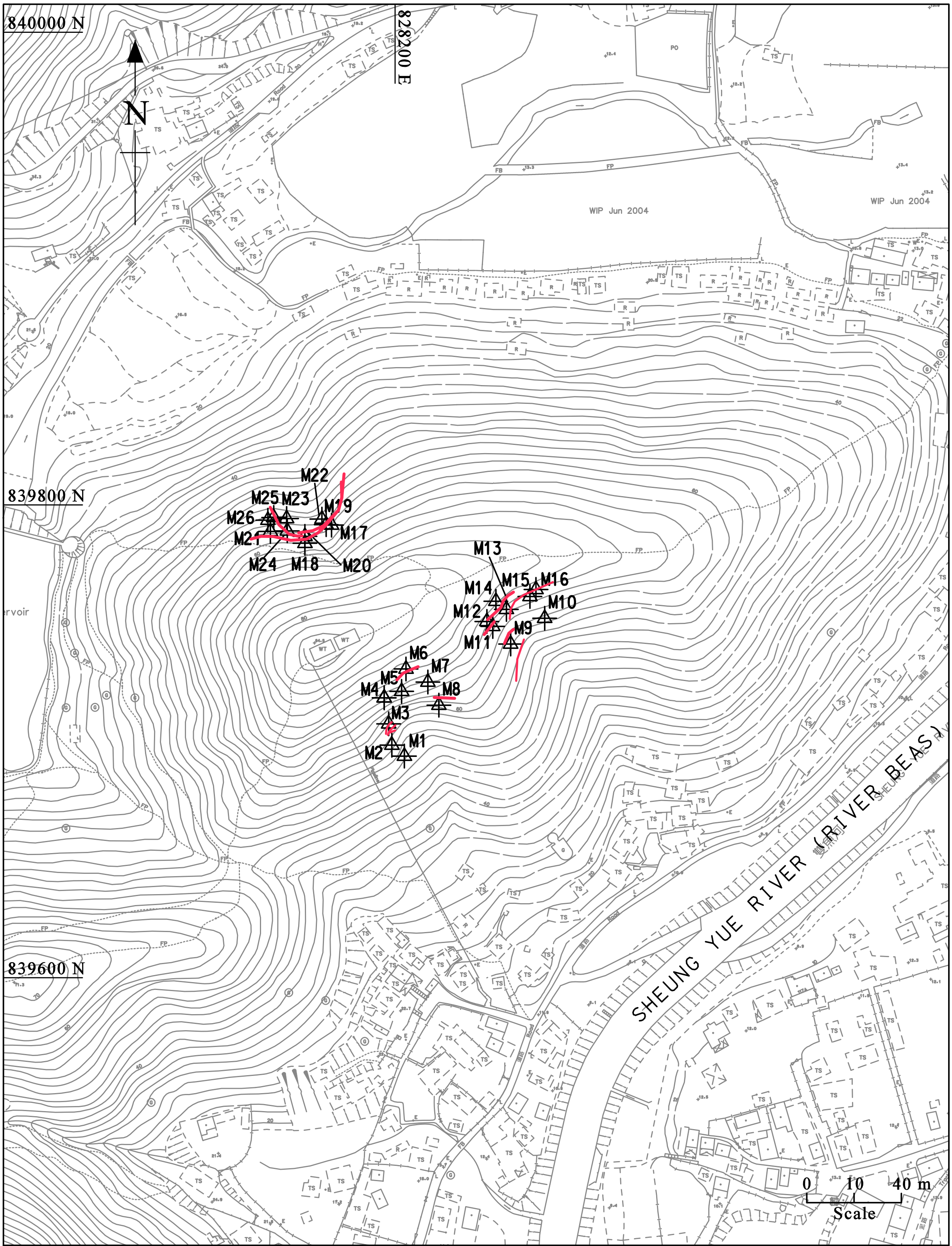

Legend : Monitoring point — Tension crack

Note : Base map is extracted from survey sheet No. 2SE-9D & 2SE-14B, Scale 1:1000.

Figure 12 - Location of Ground Movement Monitoring Points

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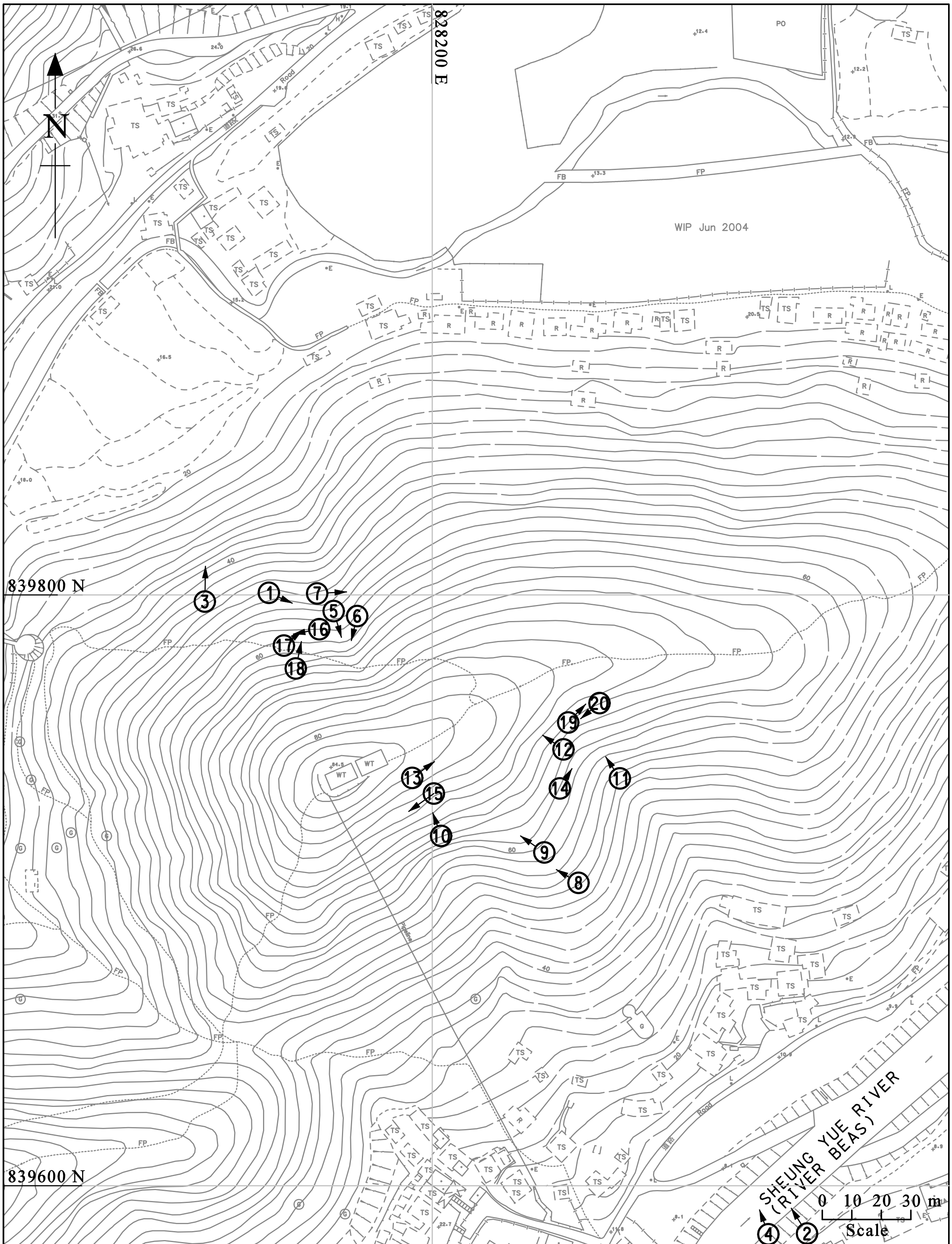

Legend :	① Direction of Plate
Note :	Base map is extracted from survey sheet No. 2SE-9D, Scale 1:1000.

Figure 13 - Locations and Directions of Photographs Taken

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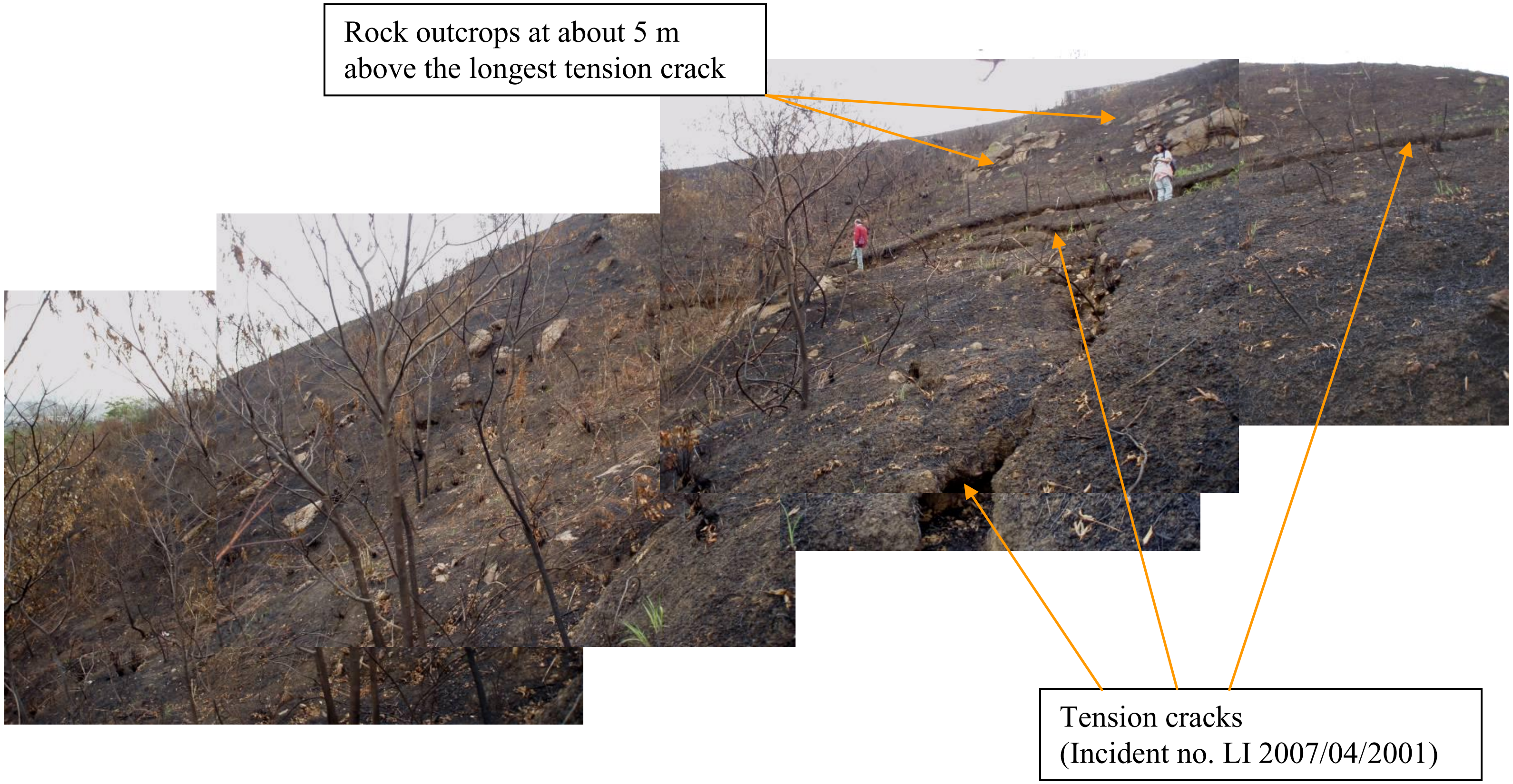

Plate 1 - General View of the Tension Cracks on the North-facing Hillside (Photograph taken on 23 April 2007)

Note: See Figure 13 for location and direction of photograph.

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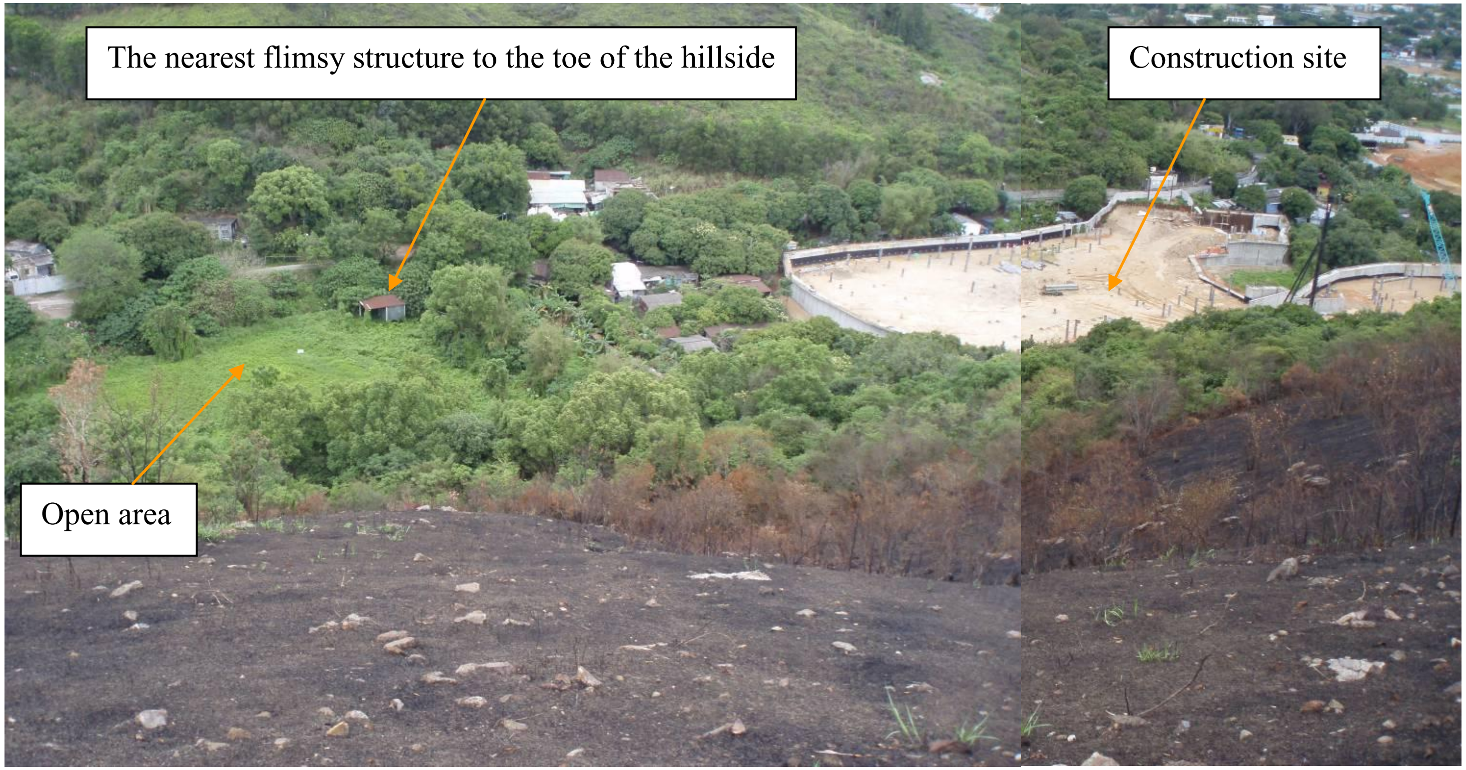

Plate 2 - Facilities at the Toe of the North-facing Hillside (Photograph taken on 23 April 2007)

Note: See Figure 13 for location and direction of photograph.

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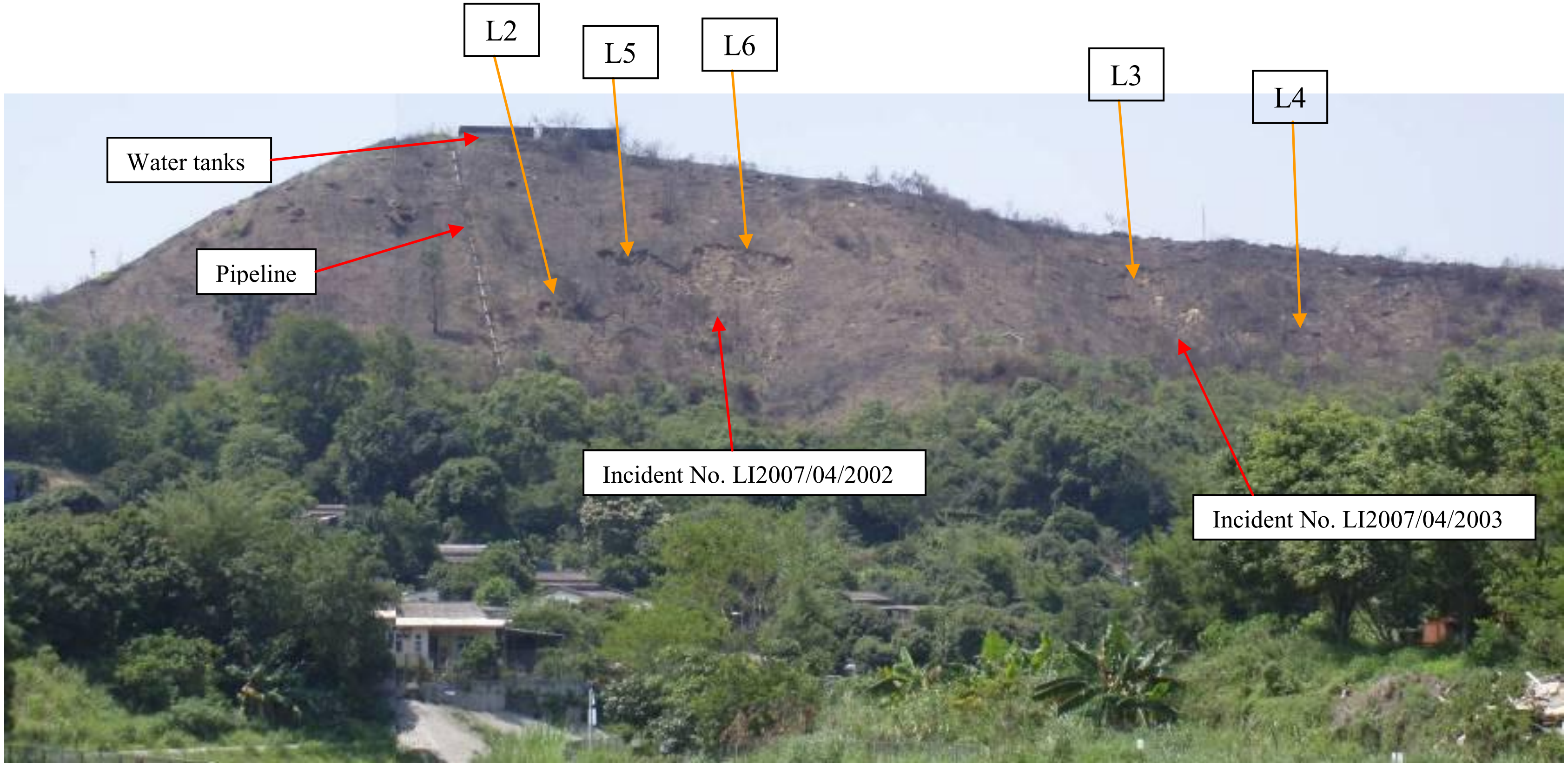

Plate 3 - Signs of Distress on the South-facing Hillside (Photograph taken on 7 May 2007)

Note: See Figure 13 for location and direction of photograph.

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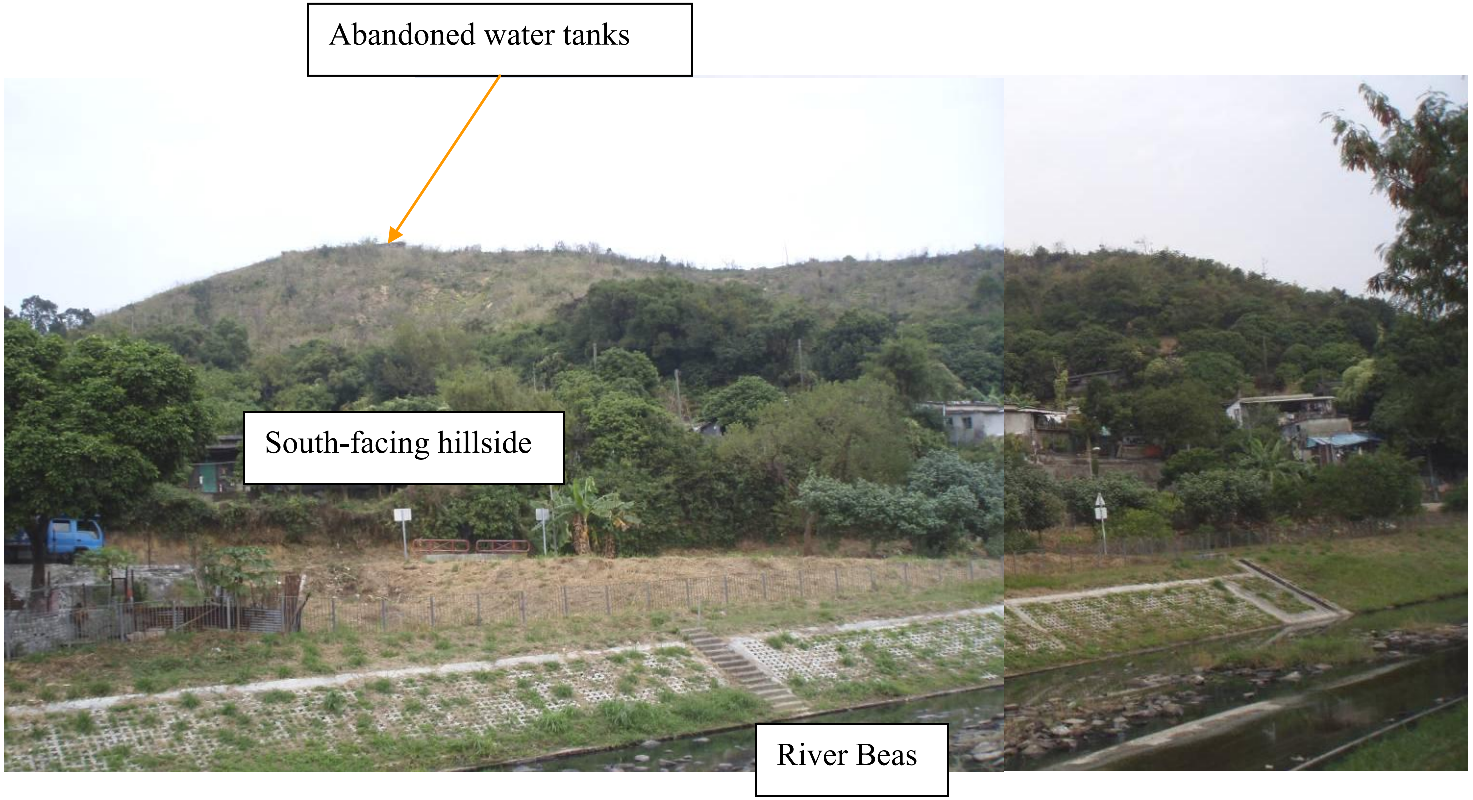

Plate 4 - Facilities at Toe of the South-facing Hillside (Photograph taken on 26 November 2007)

Note: See Figure 13 for location and direction of photograph.

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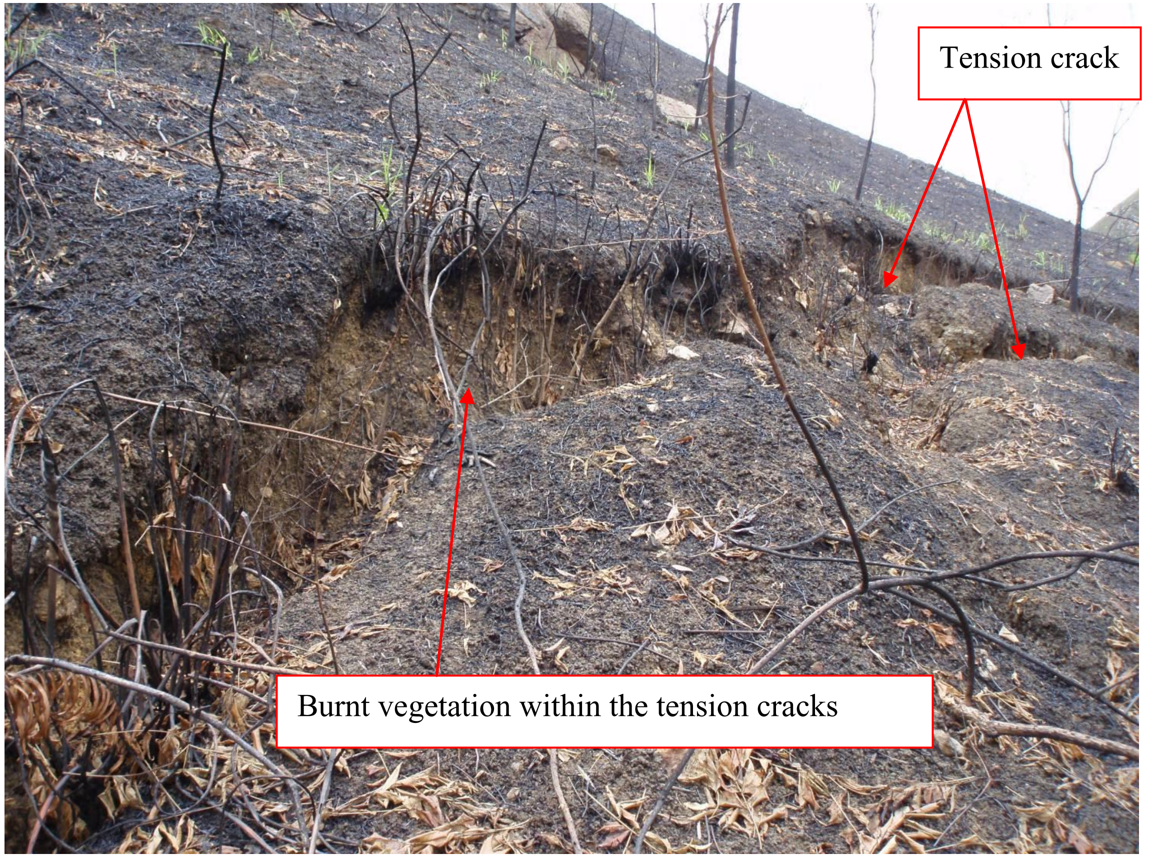

Plate 5 - View of the Central Portion of the Tension Cracks at the North-facing Hillside (Photograph taken on 23 April 2007)

Note: See Figure 13 for location and direction of photograph.

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Plate 6 - Close-up of the Main Tension Crack at the North-facing Hillside (Photograph taken on 23 April 2007)

Note: See Figure 13 for location and direction of photograph.

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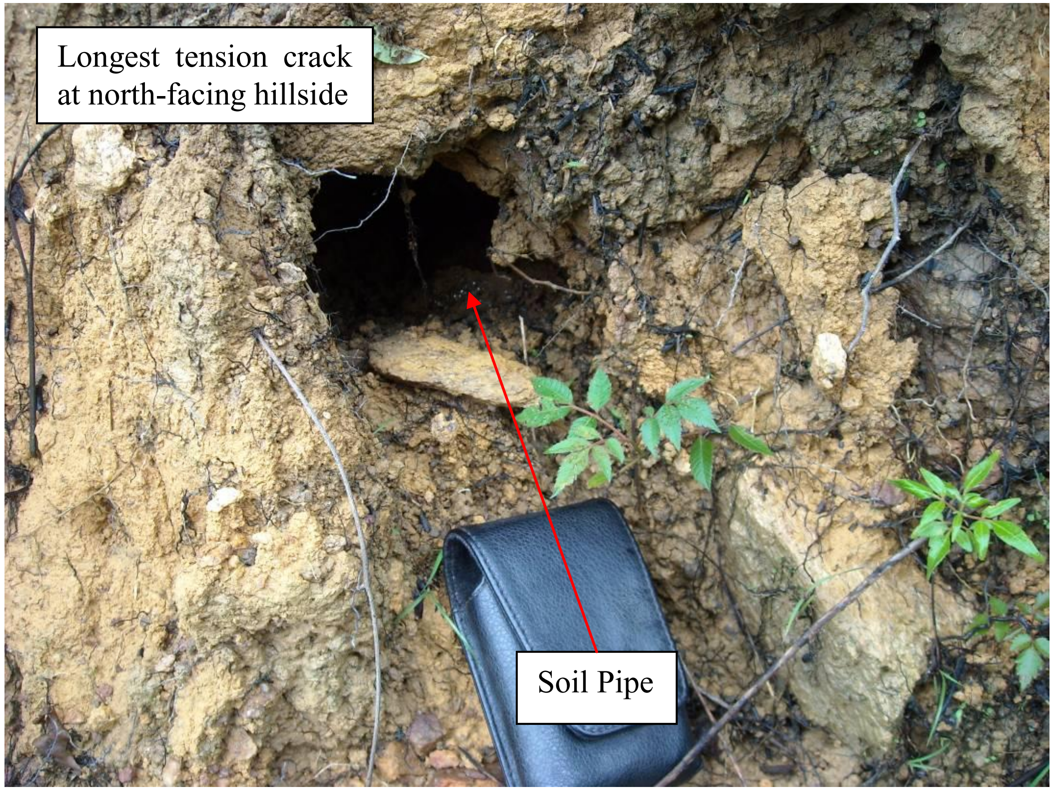

Plate 7 - Soil Pipe at Main Tension Crack on the North-facing Hillside (Photograph taken on 30 June 2008)

Note: See Figure 13 for location and direction of photograph.

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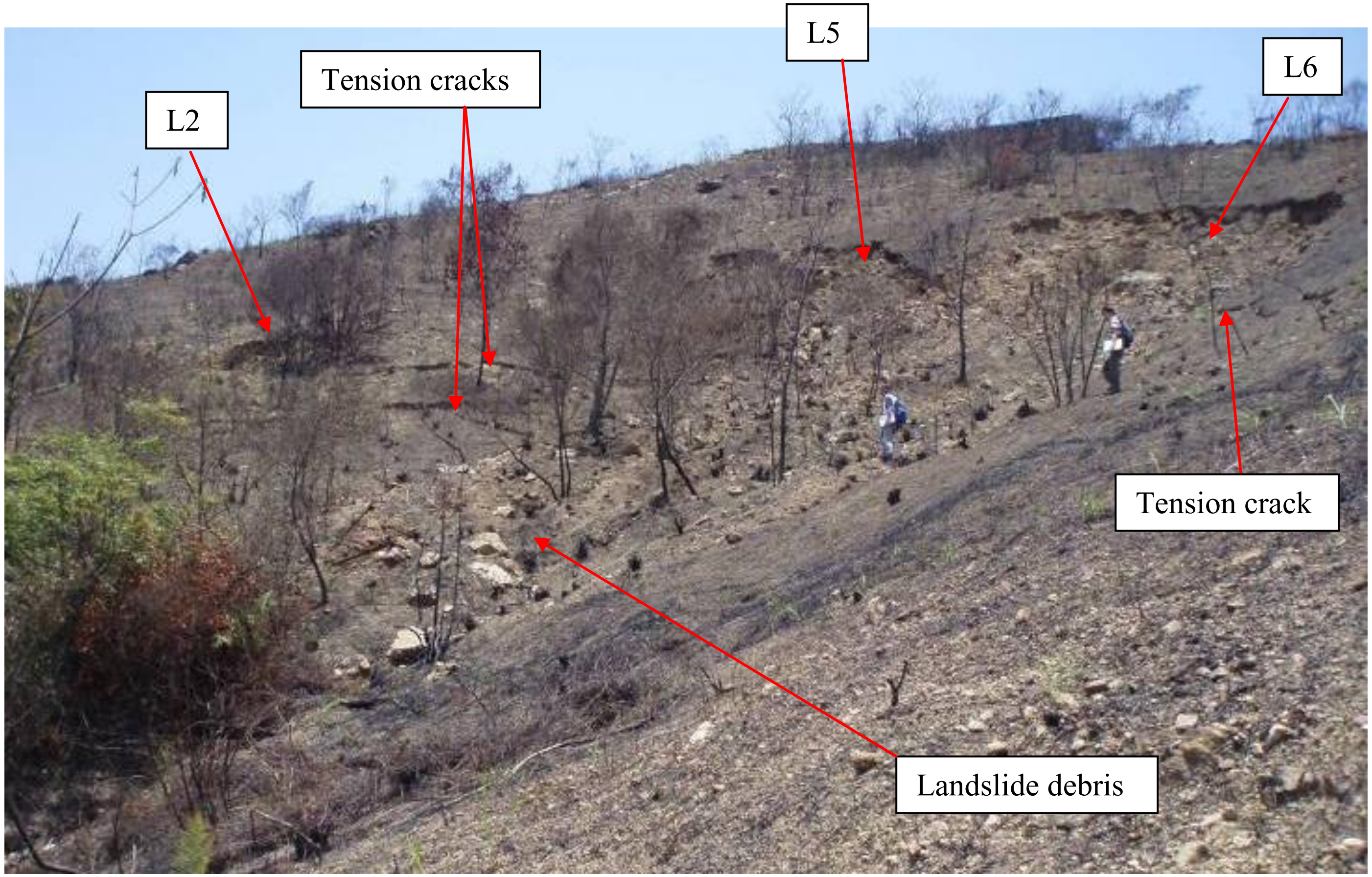

Plate 8 - General View of the Landslide Scars and Tension Cracks of Incident No. LI2007/04/2002 on the South-facing Hillside(Photograph taken on 7 May 2007)

Note: See Figure 13 for location and direction of photograph.

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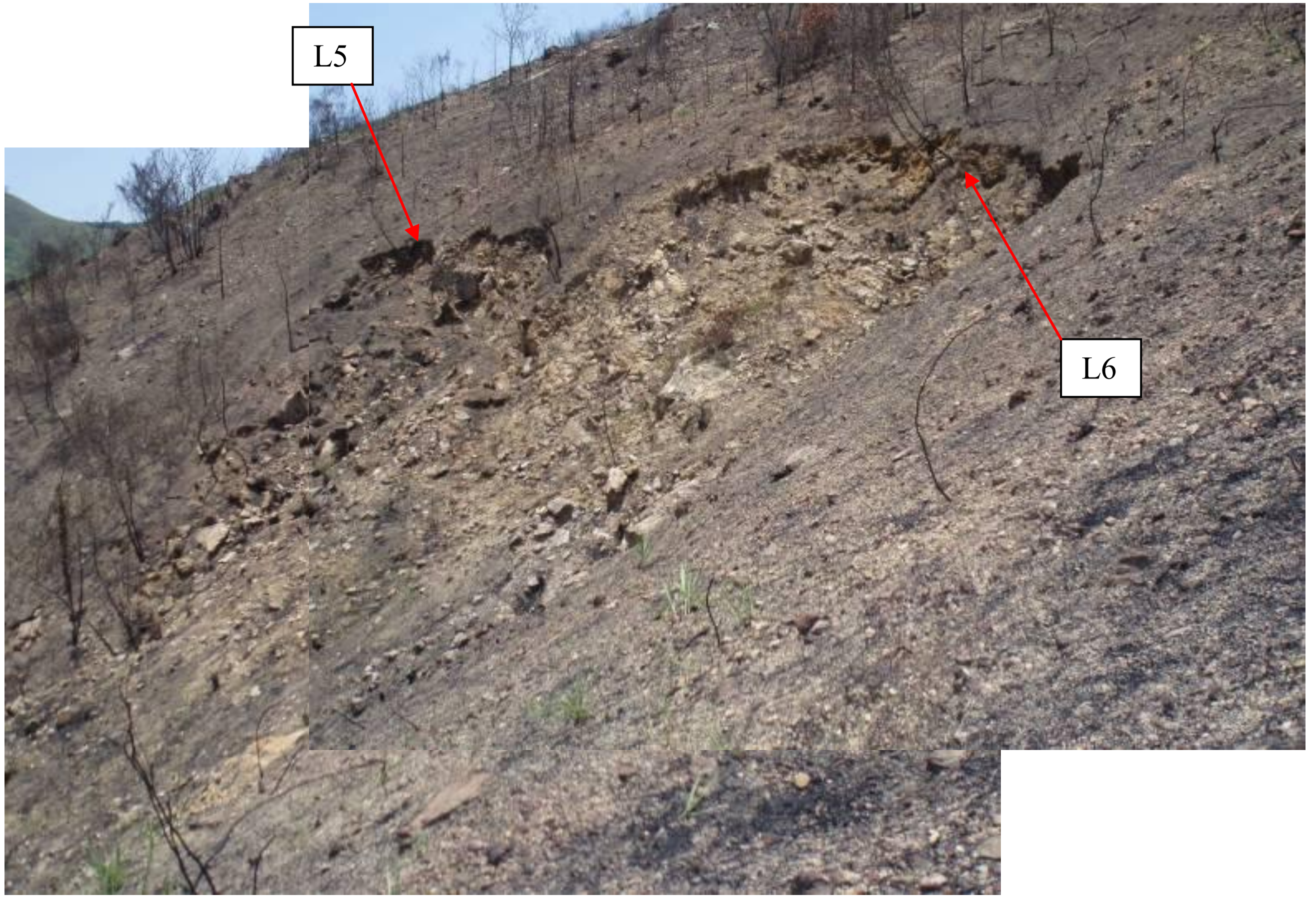

Plate 9 - Close-up of Main Scarps of the Landslide Scars of Incident No. LI2007/04/2002 on the South-facing Hillside (Photograph taken on 7 May 2007)

Note: See Figure 13 for location and direction of photograph.

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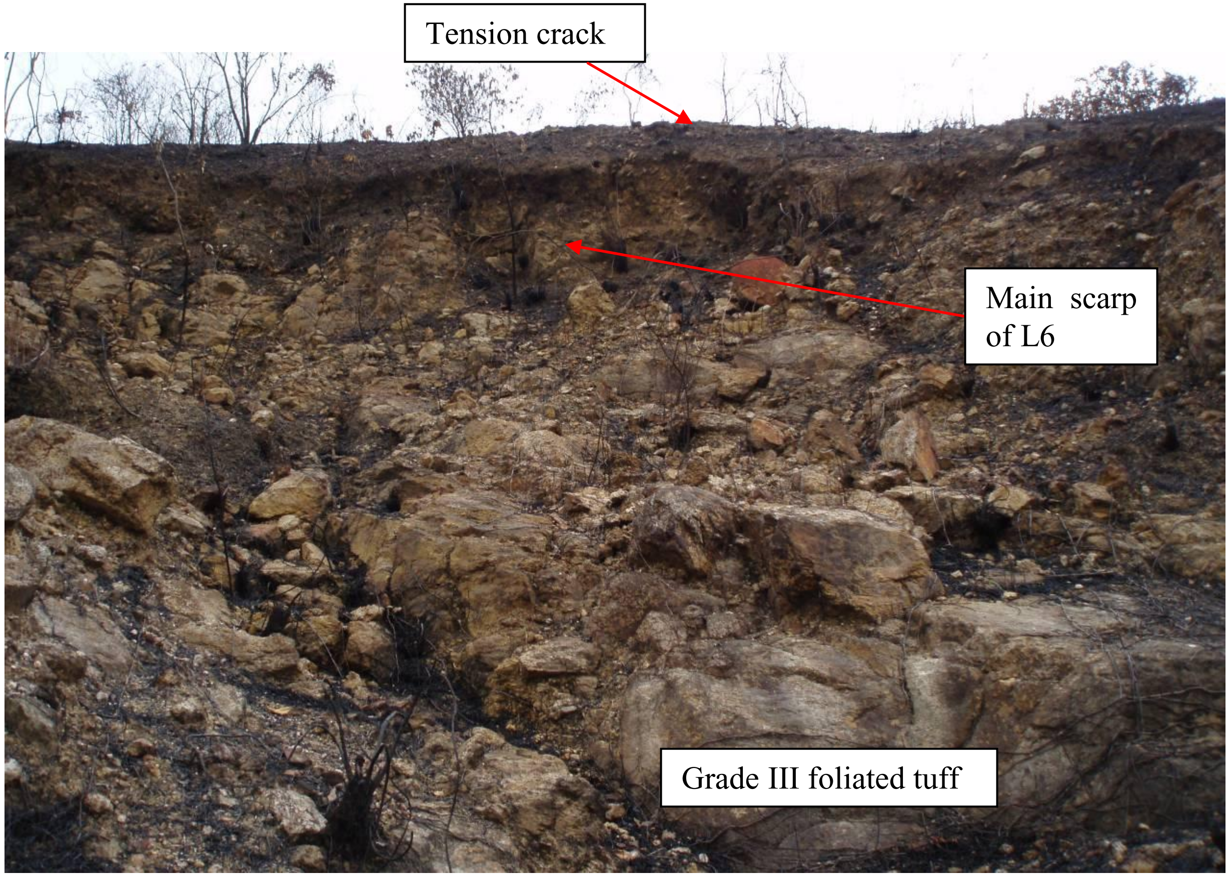

Plate 10 - Close-up of the Main Scarp of Landslide Scar L6 on the South-facing Hillside
(Photograph taken on 23 April 2007)

Note: See Figure 13 for location and direction of photograph.

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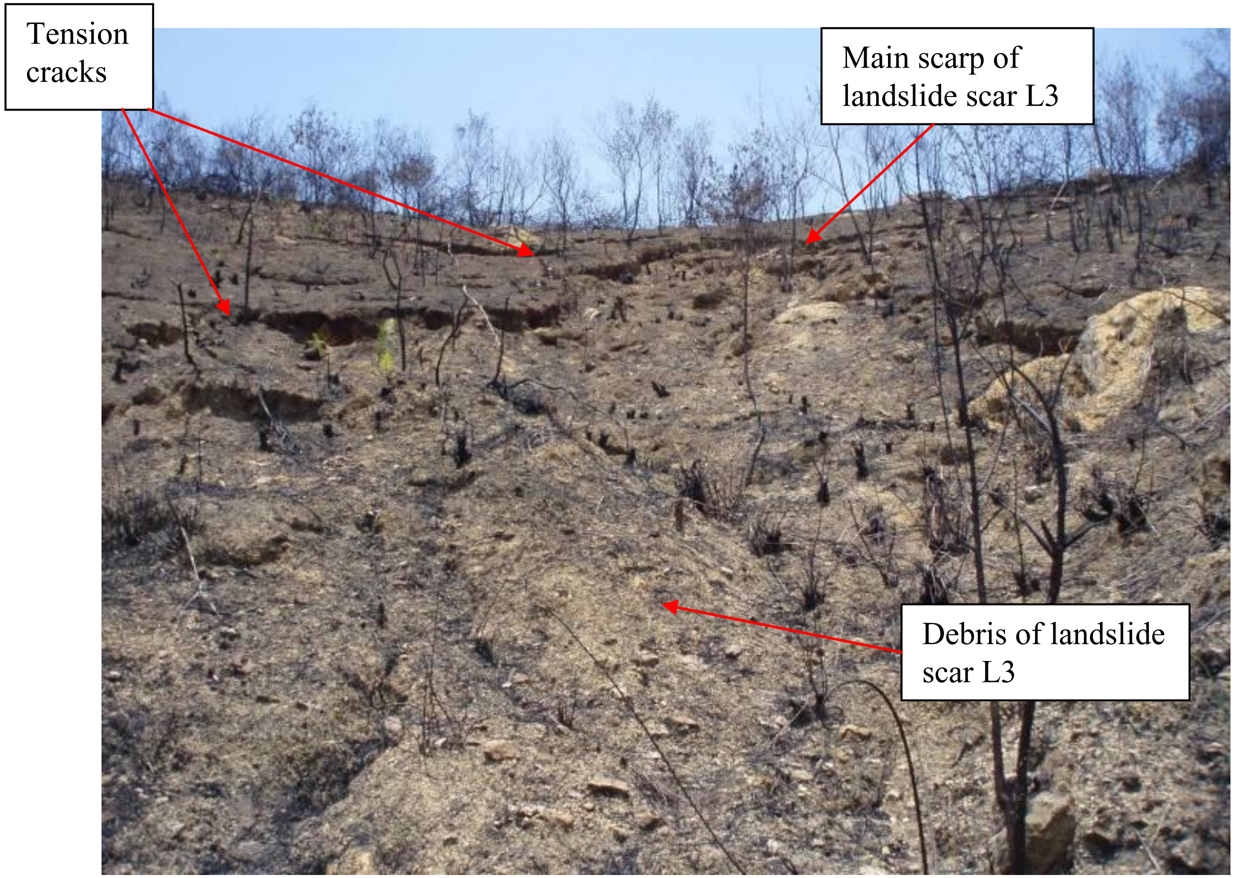

Plate 11 - General View of the Landslide Scar and Tension Cracks of Incident No. LI2007/04/2003 on the South-facing Hillside (Photograph taken on 7 May 2007)

Note: See Figure 13 for location and direction of photograph.

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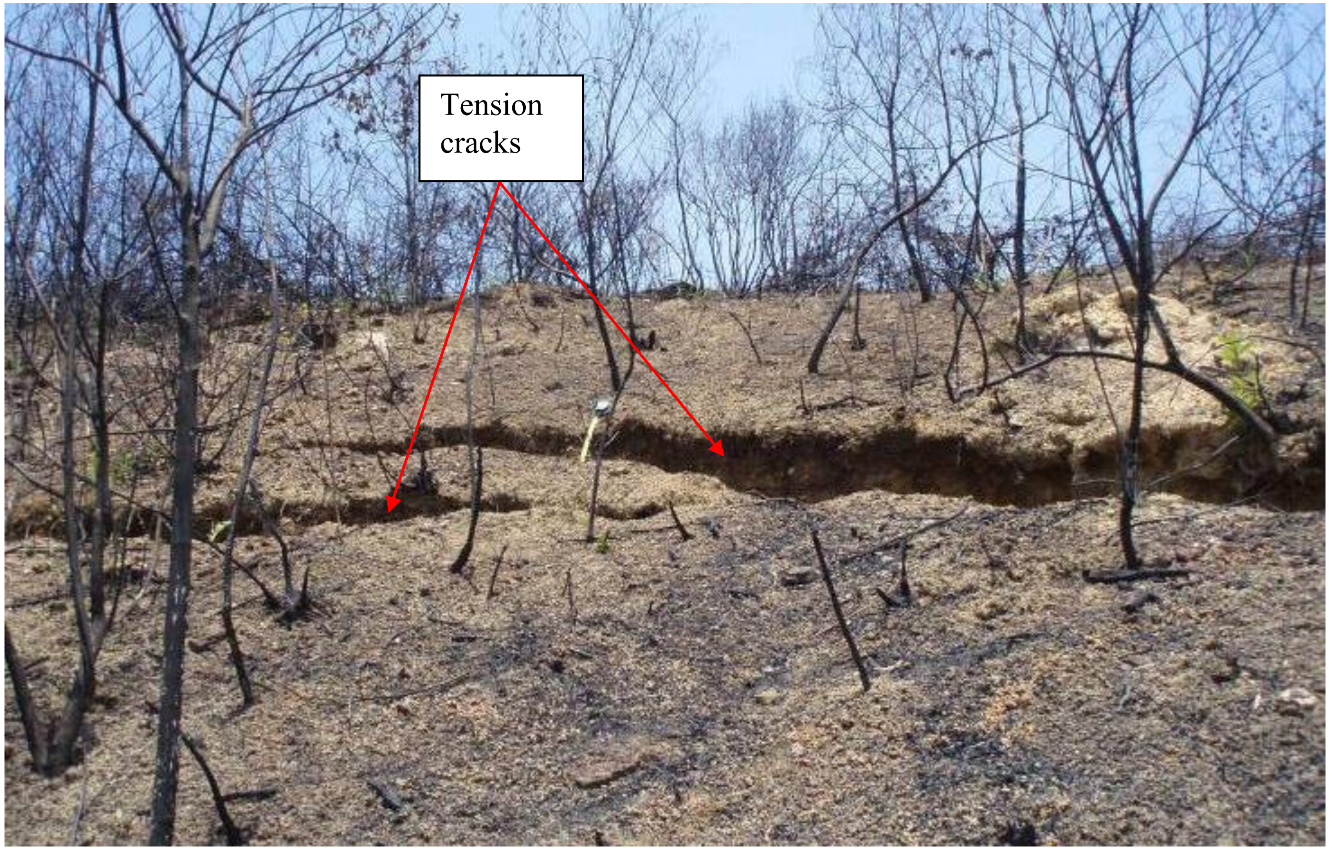

Plate 12 - Close-up of Tension Crack above Landslide Scar L3 of Incident No. LI2007/04/2003 on the South-facing Hillside (Photograph taken on 7 May 2007)

Note: See Figure 13 for location and direction of photograph.

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Plate 13 - View of Boulders Scattered along the Ridgeline (Photograph taken on 7 May 2007)

Note: See Figure 13 for location and direction of photograph.

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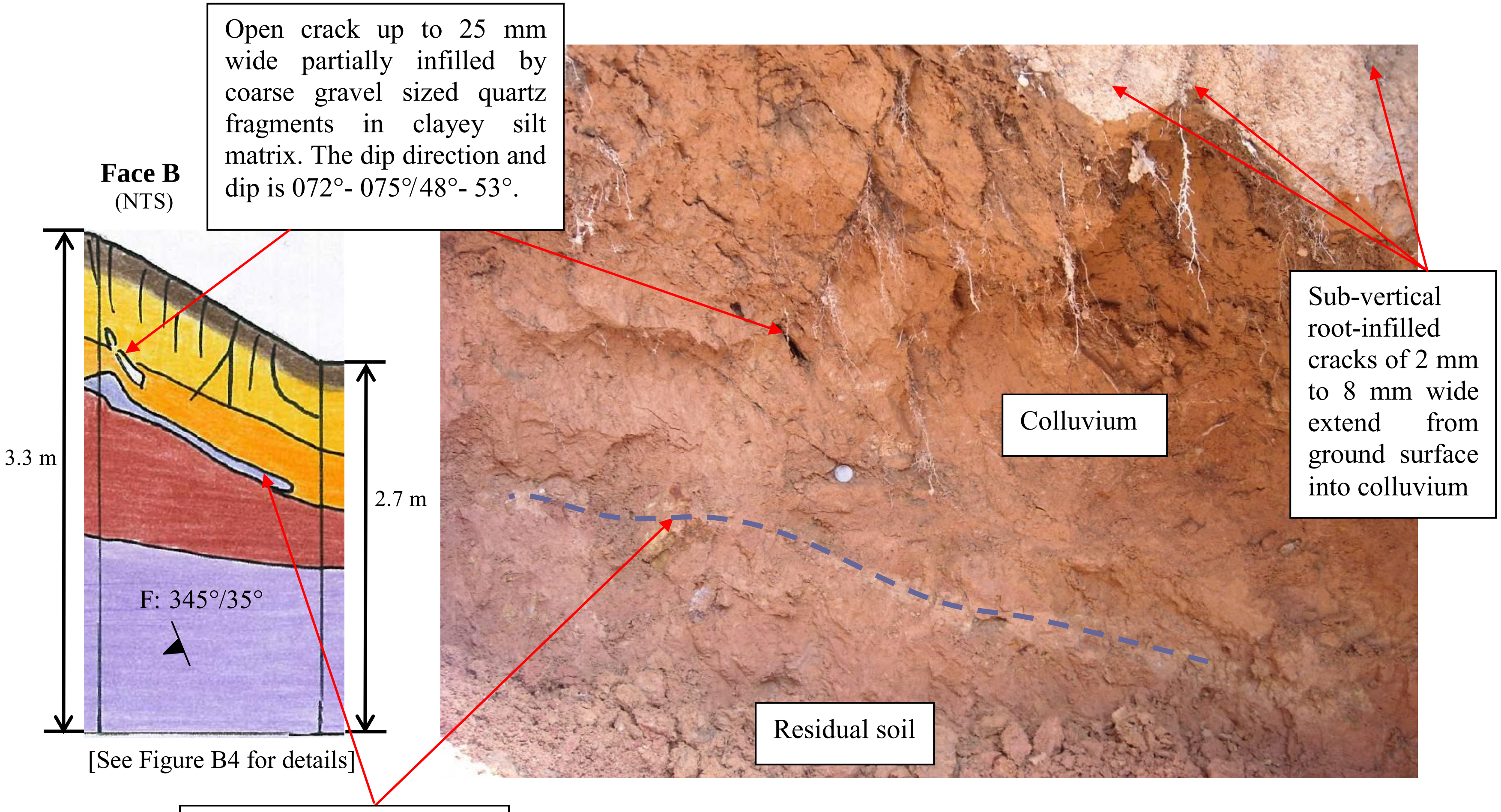

Plate 14 - View and Sketch of Trial Pit TP4, Face B
(Photograph taken on 25 July 2008)

Note: See Figure 13 for location and direction of photograph.

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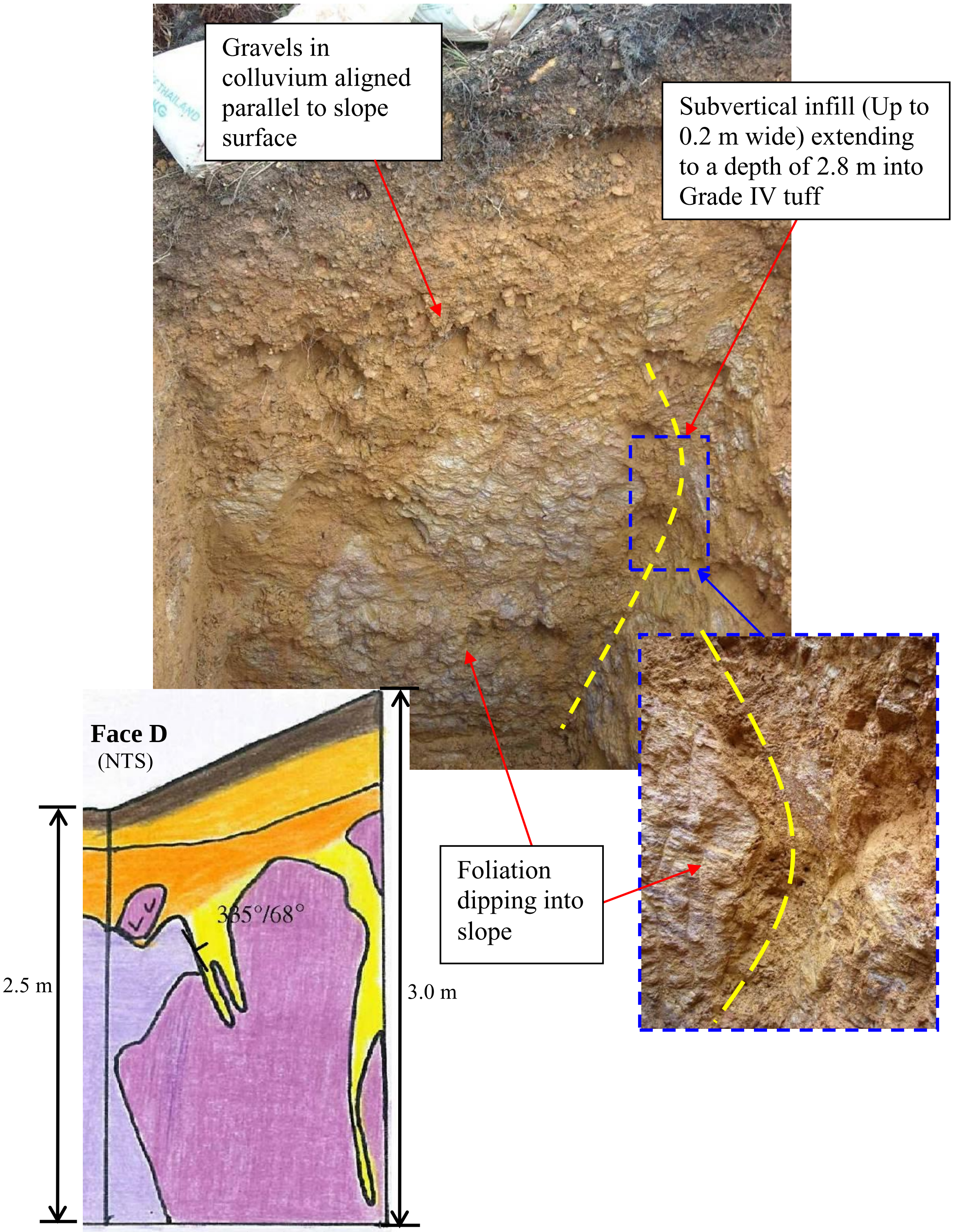

[See Figure B5 for details]

Plate 15 - View and Sketch of Trial Pit TP5, Face D (Photograph taken on 11 Aug 2008)

Note: See Figure 13 for location and direction of photograph.

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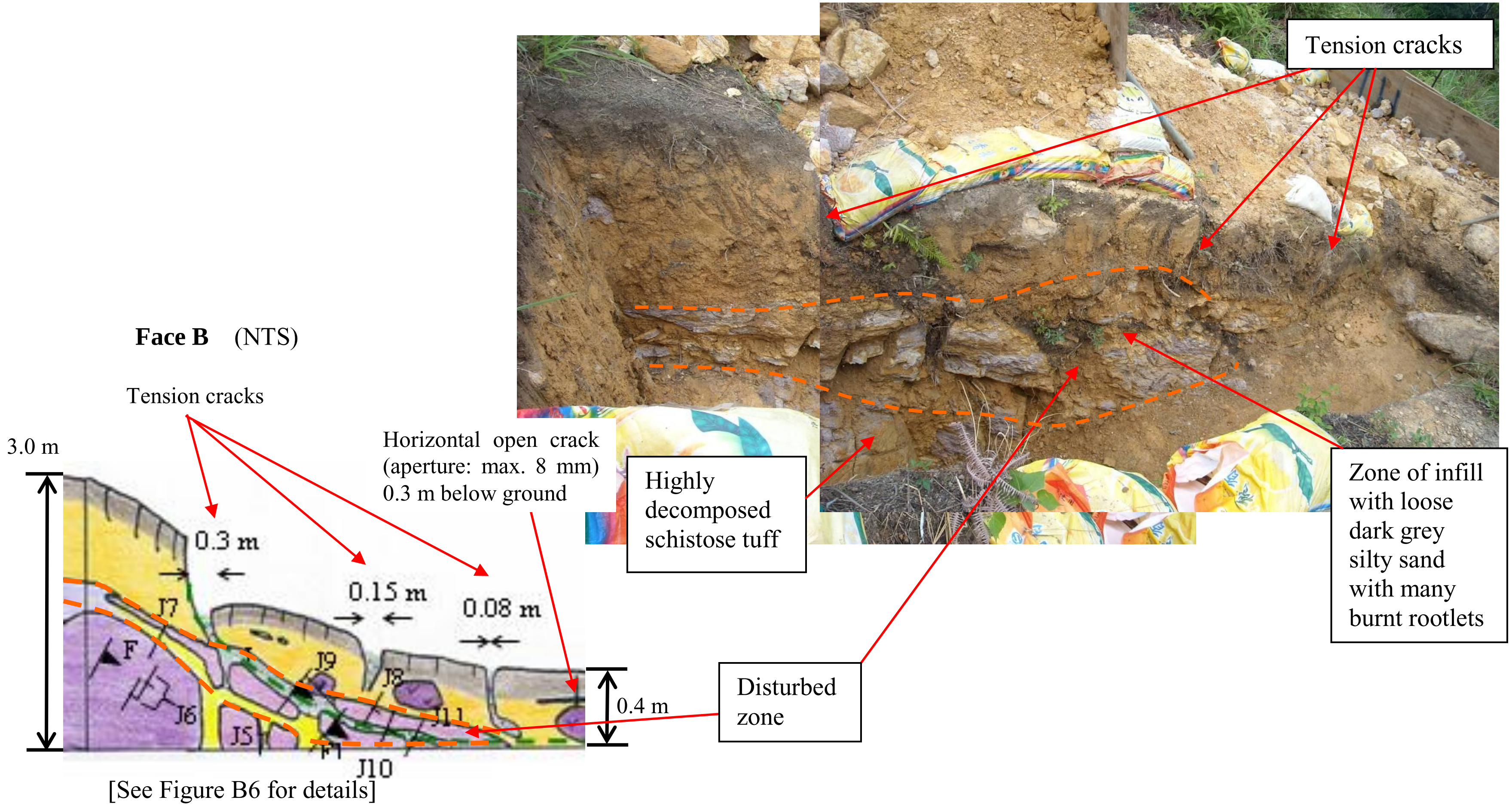

Plate 16 - View and Sketch of Trial Trench TT1, Face B (Photograph taken on 29 July 2008)

Note: See Figure 13 for location and direction of photograph.

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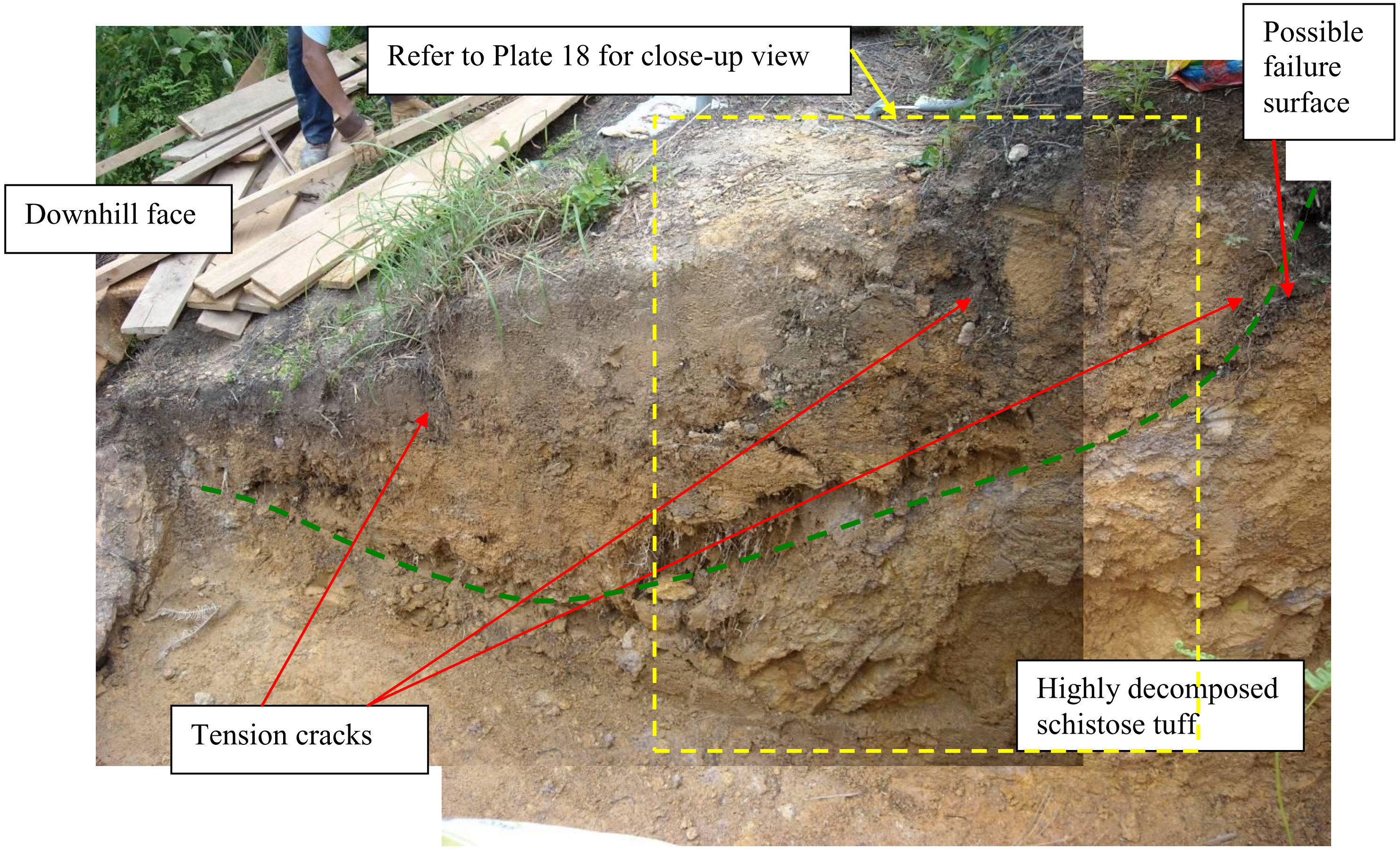

Plate 17 - View of Trial Trench TT1, Face D (Photograph taken on 29 July 2008)

Note: See Figure 13 for location and direction of photograph.

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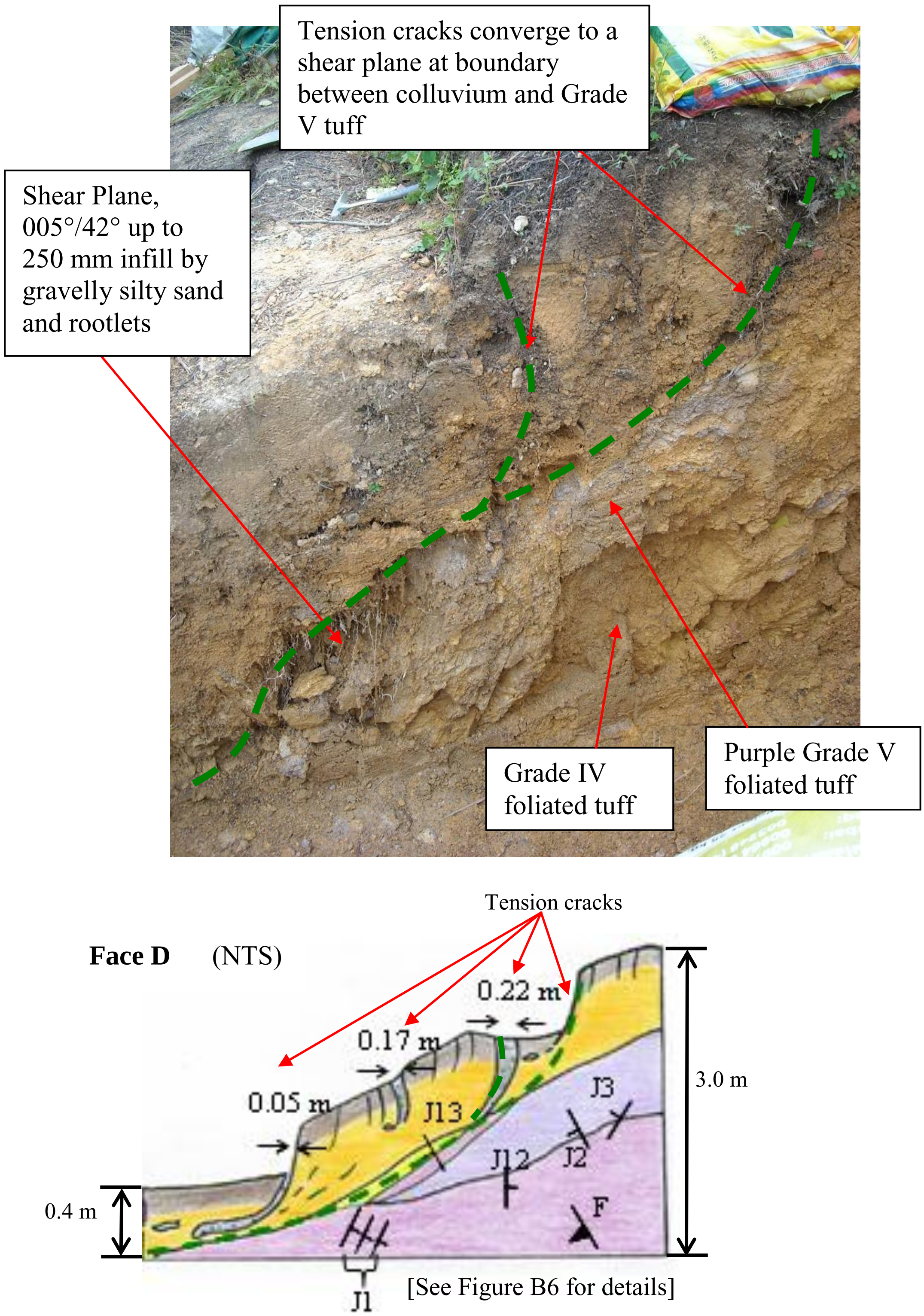

Plate 18 - Close-up of Tension Cracks at Face D of TT1 (Photograph taken on 29 July 2008)

Note: See Figure 13 for location and direction of photograph.

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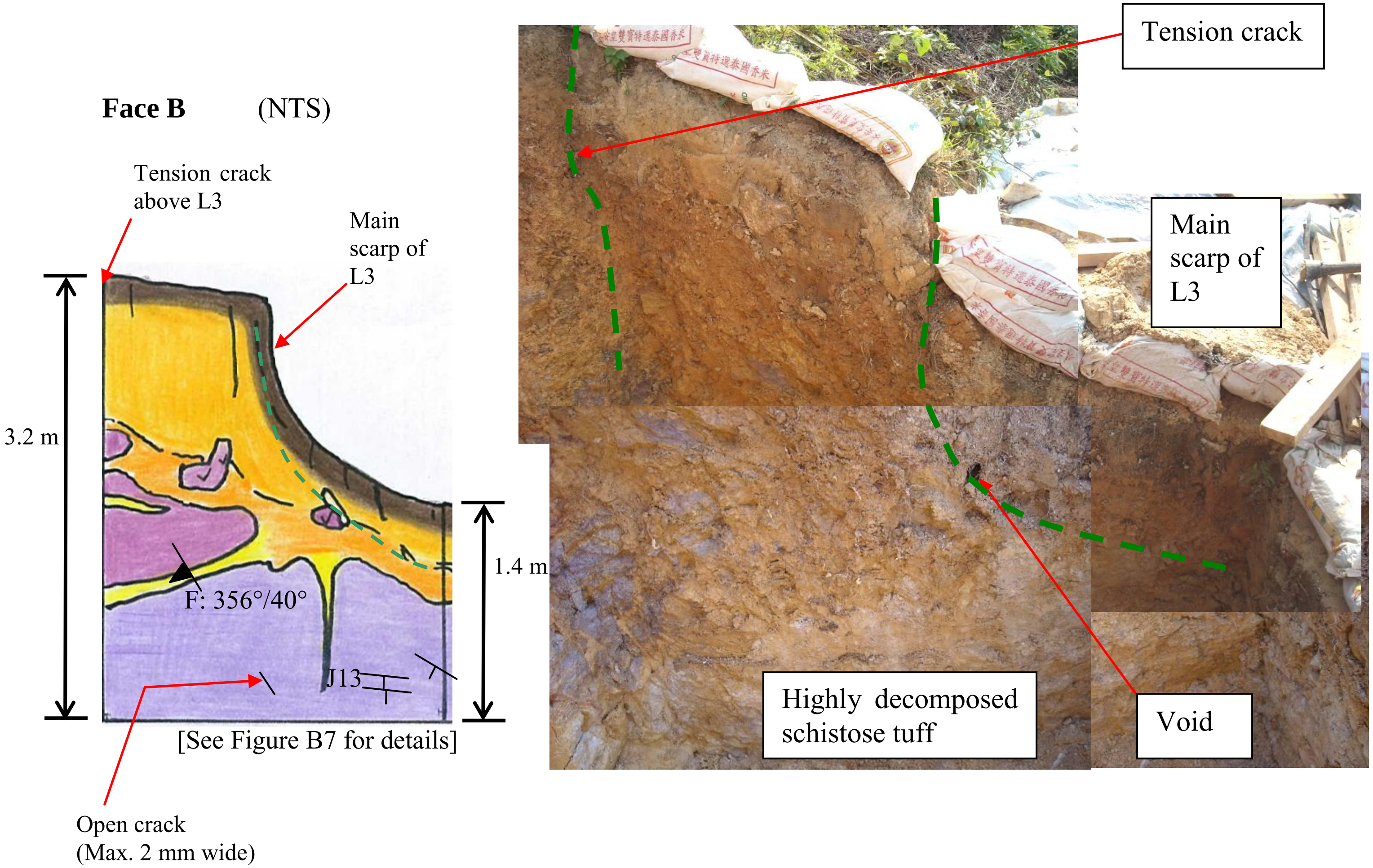

Plate 19 - View and Sketch of Trial Trench TT2, Face B (Photograph taken on 27 July 2008)

Note: See Figure 13 for location and direction of photograph.

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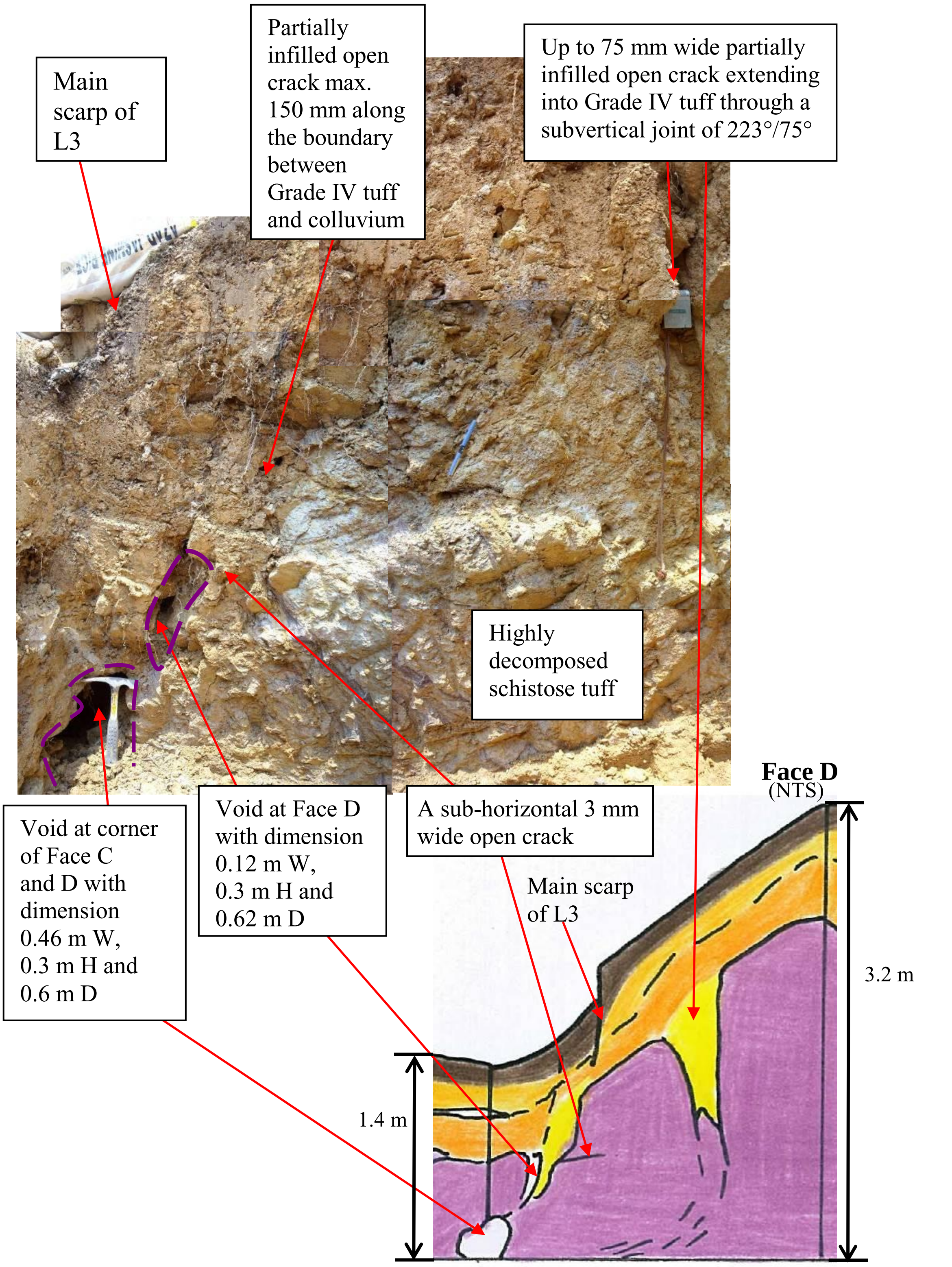

Plate 20 - View and Sketch of Trial Trench TT2, Face D (Photograph taken on 27 July 2008)

Note: See Figure 13 for location and direction of photograph.

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APPENDIX A

AERIAL PHOTOGRAPH INTERPRETATION

CONTENTS

A.1 DETAILED OBSERVATIONS

The following report comprises the detailed observations made from the examination of aerial photographs taken between 1945 and 2007. A list of aerial photographs examined in this study is presented in Table A1 and the main observations of the API are shown in Figure A1 and Plates A1 and A2.

YEAR	OBSERVATIONS
1945	High altitude pairs and poor resolution. The study area is part of a northeast trending spur extending from Ki Lun Shan. A sub-rounded ridge line separates the study area into two hillsides, northern and southern. The northern hillside is generally facing north to northwest and is overgrown with moderate vegetation, while the southern hillside is mainly facing southeast and is relatively less vegetated with short grass and locally patches of bare surface. Sheung Yue River is located in front of the toe of the southern hillside. Extensive farmlands appear along the banks of the Sheung Yue River and the low-lying flatlands below the northern hillside. Patches of high reflective area appear at the upper portion of the southern hillside, possibly associated with anthropogenic activities or surface erosion. Due to the poor resolution of the photographs, details of these features cannot be observed. Kwu Tung Reservoir, the water tanks on the summit of the hillsides and the associated pipeline are not yet constructed. The present location of Kwu Tung reservoir appears to be occupied by agricultural farmland.
1954	High altitude, poor resolution single photograph. No significant change to the subject hillsides since 1945 except that a narrow strip of vegetation clearance (M1) appears from the summit running down to the toe of the southern hillside. This is probably associated with the construction of the water pipeline and the water tanks. There does not appear to be any sign of distress within the subject study area.
1963	Low altitude and good resolution pairs. Two rectangular shaped water tanks (M2) with covers are constructed at the summit of the subject hillsides. A water pipeline appears to be connected between these water tanks and the village at the southern foothill. Several footpaths (M3) are also formed along the ridge line and across the hillsides. Patches of bare surface appear immediately to the east of the water tanks, possibly due to man-made disturbance (M4). The dam (M5) for the Kwu Tung reservoir is constructed to the west of the study area. Two concave changes in slope are observed at the hillside to the east of Kwu Tung Reservoir. A possible relict landslide scar (R1), appearing as a

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YEAR	OBSERVATIONS

semi-circular depression, is also identified to the southeast of these concave changes in slope.

Northern Hillside:

The northern hillside is relatively planar and with a slightly shallower gradient than the southern hillside. The hillside is overgrown with short grass and sporadic young trees, approximately 2 to 3 m high.

One ephemeral drainage line (S1) which runs from SSE to NNW is apparent at the central portion of the hillside. The hummocky appearance along the drainage line is indicative of the deposition of a thin veneer of colluvial cobbles and boulders.

Linear features (M6) appear across the lower portion of the hillside, probably remnants of old terraces because the lineations run parallel to the hillside contours.

A subtle convex change in slope is observed near the head of the ephemeral drainage line S1. Another well defined convex break in slope is located at the central portion of the northern hillside, possibly associated with previous instability. Further east of this convex break in slope, a concave change in slope is identified above several areas of man-made disturbance, possibly grave sites.

Extensive agricultural farmlands still appear at the lower reaches of the hillside. Cottages are concentrated along the eastern foothill.

The smooth and uniform appearance of the hillside is probably indicative of a thin veneer of slope wash overlying saprolitic soil.

Southern Hillside:

The slope gradient of the southern hillside is relatively steeper than the northern hillside. Two distinct hollows are indicative that the weathering and erosion process is more advanced than the northern aspect. Within these hollows, two ephemeral drainage lines (S2 and S3) running from northwest to southeast are identified. Generally, the hillside is more vegetated and the trees are more mature than on the northern hillside.

Individual scattered boulders are identified along the ridge line, probably exhumed corestones (B1).

A semi-circular depression, possibly relict landslide scar (R2), is identified at the upper portion of the hillside to the west of the pipeline.

A convex break in slope appears at the upper terrain near the head of S2. Below this break, loose colluvium is accumulated along the ephemeral drainage line. To the northeast of this break in slope, two possible relict

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YEAR	**OBSERVATIONS**
	landslide scars (R3 and R4) are observed as shallow depressions with minor erosion.
	A patch of lighter tone of reflective area located at the head of S3 is possibly indicative of previous minor surface erosion/instability (E1). Immediately to the southeast of this area, a semi-circular depression, probably a relict landslide scar (R5) is observed.
	A man-made structure, probably a rubble wall (M7), is identified at the mid slope of the eastern portion of the southern hillside.
	Disturbed terrain and squatters (M8) occupy most of the hillside at the toe of the southern hillside.
1964	High altitude stereo pairs.
	A break in slope appears at the mid slope of the eastern portion of the northern hillside.
	A high reflective area, probably associated with a grave construction is observed at the eastern lower portion of the southern hillside.
	There does not seem to have been any significant change to the subject hillsides since 1963 except a slight increase of vegetation growth.
1973	High altitude stereo pairs.
	Dense and mature trees were overgrown at the lower portion of both the northern and southern hillsides.
	No sign of instability or distress is identified within the subject hillsides.
1974	High altitude and single photograph.
	No significant change to the subject hillside since 1973.
	Several grave sites are constructed at the lower portion of the hillside to the east of Kwu Tung Reservoir.
1975	High altitude stereo pairs.
	Generally, there does not seem to have been any significant observable change to the northern hillside.
	Agricultural terracing (M9) is clearly evident at the toe of S3 on the southern hillside. A linear white toned feature connected to S3, possibly a footpath (M10) is observed at the terrain above these terraces.

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YEAR	**OBSERVATIONS**
1976	High altitude stereo pairs. Agricultural terracing (M11) is observed at the lower portion of the northern hillside. Previously identified footpath M10 is clearly evident at the southern hillside. A small white reflective area is observed at the upper eastern terrain of the southern hillside indicating the possibility of instability/grave/erosion (I1). Due to the poor resolution of the photographs, further details of this feature cannot be discerned.
1978	High altitude and single photograph. No significant change to the subject hillside except an increase of vegetation growth over the hillside.
1979	High altitude and single photograph. No observable significant change to the subject hillside since 1978.
1981	High altitude, colour and blur stereo pairs. No sign of distress is identified within the study area. A circular high reflective area appears at the lower portion of the southern hillside to the east of the water pipeline, possibly associated with the construction of a grave site.
1982	Low altitude, high resolution stereo pairs. Curvilinear features (T1) appear at the western portion of the northern hillside. These are possibly tension cracks as there appears to be a sudden change in topographic relief. A recent landslide scar (L1) is evident at the terrain next to a grave site to the east of Kwu Tung Reservoir. Another recent landslide scar (L2) is clearly evident at the mid slope to the east of the water pipeline of the southern hillside.
1983	High altitude stereo pairs. There is a slight increase in vegetation density around the study area. A footpath (M12) is constructed across the mid slope of the southern hillside. A high reflective area is observed between the two hollows adjoining the upslope of this footpath, possibly associated with human disturbance,

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YEAR	OBSERVATIONS
	probably a grave site.
	Re-construction of the grave at the western hillside is observed.
	Re-vegetation on the landslide scars observed in 1982.
1984	Low altitude and high resolution stereo pairs.
	The western portion of the northern hillside appears to have suffered hillfire (HF1) probably between 1983 and 1984.
	Individual boulders are observed besides the ephemeral drainage line S1.
	No observable significant change to the subject hillsides since 1983.
1985	High altitude stereo pairs.
	No significant change to the study hillsides except an increase in vegetation density.
1986	High altitude stereo pairs.
	No sign of distress/instability/erosion is observed in the study area.
1987	Low altitude and high resolution stereo pairs.
	Patches of vegetation clearance (M13) appear at the eastern portion of the hillside, possibly associated with anthropogenic activities.
	No other sign of distress/instability is observed from the subject hillsides.
1988	Low altitude and high resolution stereo pairs.
	No significant change to the study area except an increase in vegetation density since 1987.
1989	High altitude stereo pairs.
	An obvious recent landslide (L3) is observed at the head of the ephemeral drainage line S3. The debris appears to have been channelized down to the lower reaches of the southern hillside, however, it is obscured by the dense growth of trees at the foothills.
	Another minor landslide (L4) is also evident at mid slope to the east of the ephemeral drainage line S3, about 30m southeast of the landslide L3.

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YEAR	**OBSERVATIONS**
1990	Low altitude and high resolution stereo pairs. No significant change since 1989. Previously identified possible tension cracks on the northern hillside were indistinct because of the vegetation cover.
1991	High altitude, fair resolution stereo pairs. There is a significant increase in vegetation growth over the subject hillsides. Previous landslide scars L3 and L4 are re-vegetated.
1992	Low altitude and high resolution stereo pairs. A footpath (M14) is formed on the western portion of the northern hillside below the water tanks. No sign of instability is observed on the study hillsides.
1993	Low altitude and high resolution stereo pairs. Two recent landslide scars (L5 and L6) are identified at the head of the ephemeral drainage line S2 on the western portion of the southern hillside. A footpath (M15) is formed across the middle portion of the northern hillside.
1994	Low altitude colour stereo pairs. Two recent landslides (L7 and L8) are observed at the eastern portion of the northern hillside in the vicinity of the concave break in slope area. A small area of dark grey colour, possibly burnt following hillfire (HF2), appears at the hilltop near the water tanks.
1995	High altitude colour stereo pairs. Landslide scars L3 and L4 are completely re-vegetated. Landslide scars L5 and L6 still appear as bare surfaces. A circular high reflective area (M16) appears at the ridge line 20 m to the east of the water tanks, probably associated with the construction of the survey station.
1996	Low altitude colour stereo pairs. Two small recent landslide scars (L9 and L10) are observed in the vicinity of L7 and L8 on the lower northern hillside.

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YEAR	OBSERVATIONS
	Vegetation clearance appears on a relatively extensive area on the western portion of the northern hillside, possibly for agricultural purposes. Increase in density of vegetation on the landslides observed in 1993 at the southern hillside and in 1994 at the northern hillside.
1997	Low altitude colour stereo pairs. No significant change to the subject hillsides except an increase in vegetation density.
1998	Low altitude and high resolution colour photographs. No observable significant change to the subject hillsides since 1997.
Mar 1999	Low altitude and high resolution stereo B/W pairs. The western portion of the northern hillside has suffered hillfire. Rock outcrops (C1) are observed at the terrain below the water tanks on the northern hillside. Two distinct linear features (T1) with a sudden drop in topographic relief, possibly tension cracks identified in 1982 are observed about 15 m below the rock outcrops C1 on the northern hillside.
Sep 1999	Low altitude and high resolution stereo colour pairs. Extensive areas of the subject hillsides and the adjacent hillsides suffered hillfire between 1998 and 1999. No sign of distress is identified within the study hillsides.
2000	Low altitude and high resolution B/W stereo pairs. The eastern portion of the subject hillsides suffered hillfire. No sign of instability is observed from the study area.
2001	Low altitude and stereo colour pairs. No observable significant change to the subject hillsides.
2002	Low altitude and stereo colour pairs. No significant change except an increase in vegetation growth over the subject hillsides.

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YEAR	**OBSERVATIONS**
2003	Low altitude and stereo colour photographs. No significant change to the subject hillsides since 2002.
2004	Low altitude and stereo colour but poor resolution photographs. The western portion of the subject hillsides suffered from hillfire. No sign of instability is identified from the subject hillsides.
2005	Low altitude but poor resolution. No significant change to the subject hillsides except an increase of vegetation growth.
2006	Low altitude stereo colour pairs. No observable significant change to the subject hillsides since 2005.
2007	Low altitude stereo colour pairs. Extensive areas of the subject hillsides and the adjacent hillsides suffered from hillfire. Significant signs of distress were observed on the south-facing hillside (Plate A1). The tension cracks observed on the north-facing hillside are difficult to identify from the 2007 aerial photographs even following the removal of the vegetation cover (Plate A2). Apart from the 1982 and 1999 aerial photographs, the tension cracks are not identified in aerial photographs taken in other years.

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Table A1 - List of Aerial Photographs

Year Taken	Altitude (ft)	Photograph Number
1945	20,000	Y00902-3
1954	29,200	Y02931
1963	3,900	Y10117-8, Y10046-7
1964	12,500	Y13091-2
1973	12,500	7865-66
1974	12,500	10062
1975	12,500	11921-2
1976	12,500	16319-20
1978	12,500	20620, 24504
1979	10,000	28364-5
1981	10,000	35593-4
1982	4,000	43630-1
1983	10,000	52298-9
1984	4,000	55855-6
1985	10,000	A01829-30
1986	10,000	A07955-6
1987	4,000	A09734-5
1988	4,000	A13178-9
1989	10,000	A19117-8
1990	4,000	A23483-4
1991	4,000	A27129-30
1992	4,000	A30752-3
1993	4,000	A36353-4
1994	4,000	CN8686-7
1995	10,000	CN12526-7
1996	3,500	CN14554-5
1997	3,500	CN16959-60
1998	4,000	A48550-1 CN19661-3

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Year Taken	Altitude (ft)	Photograph Number
1999	3,500	CN23699-70
2000	3,000	A51043-4
2001	4,500	CW30513-4
2002	8,000	CW44524-5
2003	3,000	CW46776-7
2004	7,000	CW63295-6
2005	4,000	CW66261-2
2006	3,000	CS04334-5
2007	3,000	CW77713-4
Note: All aerial photographs are in black and white except for those prefixed with CN, CW or RW.		

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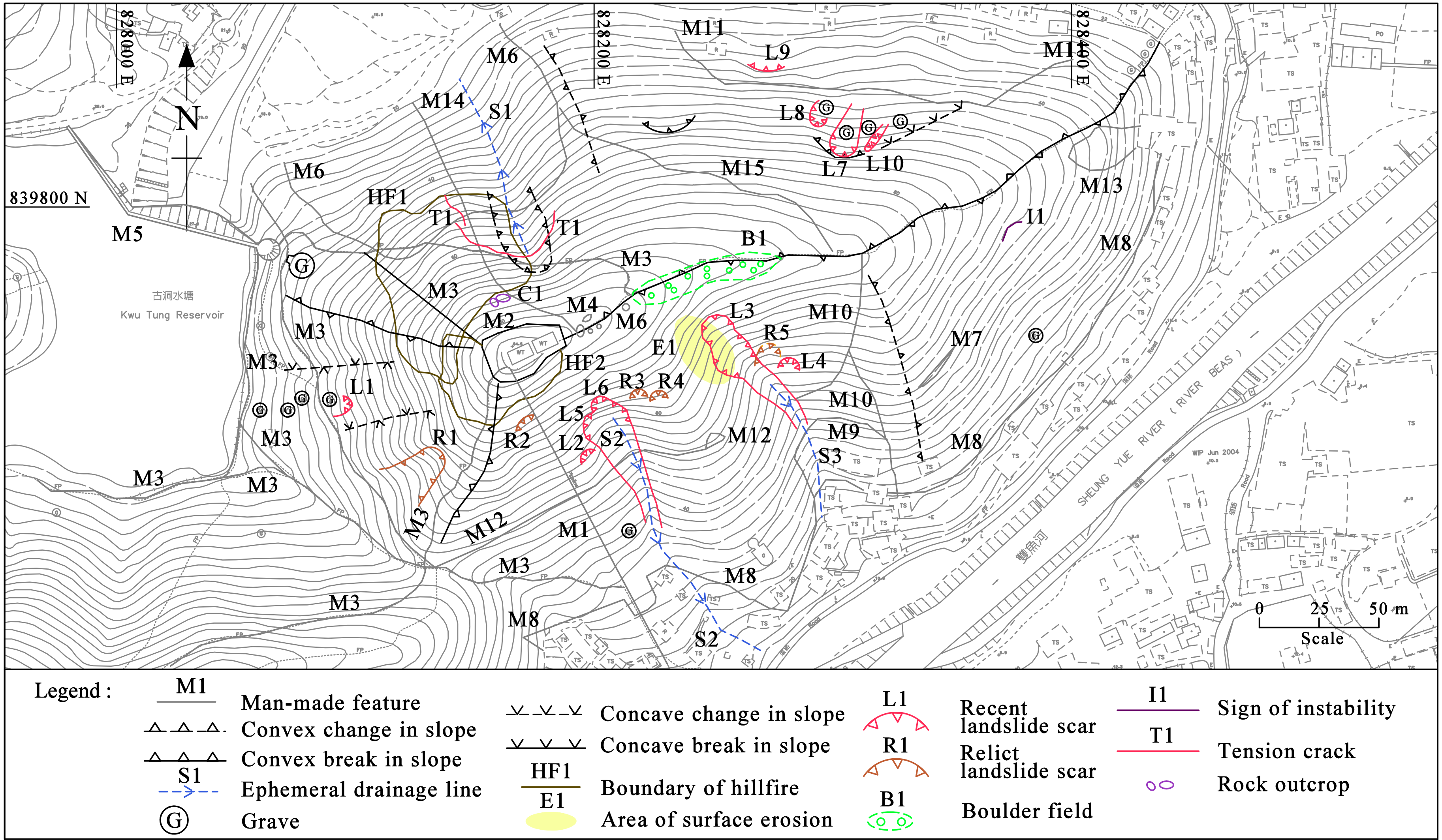
LIST OF FIGURES



Note : Base map is extracted from survey sheet No. 2SE-9D and 2SE-10C, Scale 1:1000.

Figure A1 - API Findings

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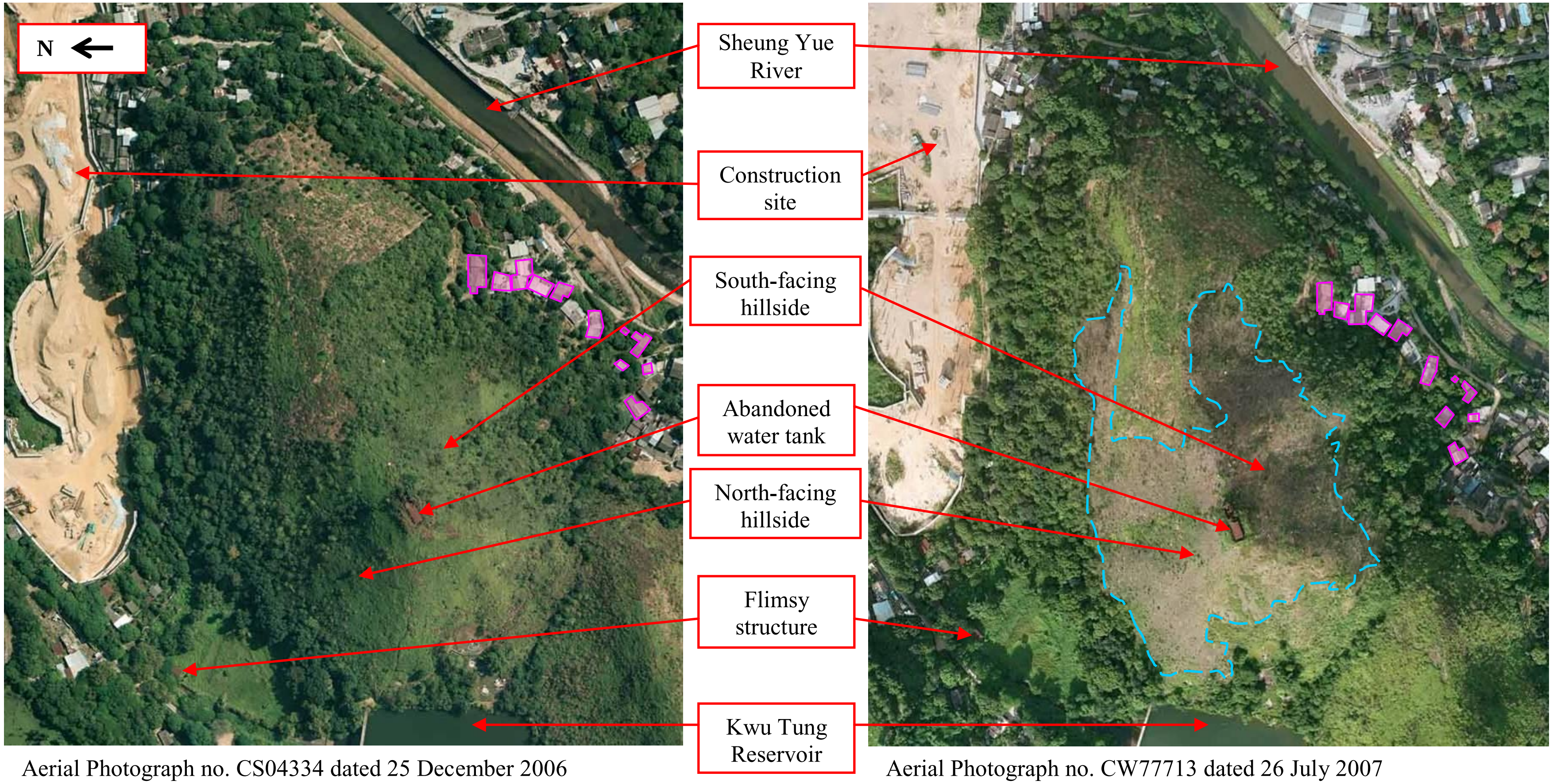
LIST OF PLATES



Aerial Photograph no. CS04334 dated 25 December 2006
before the hillfire on 1 April 2007

Aerial Photograph no. CW77713 dated 26 July 2007
after the hillfire on 1 April 2007

Legend:
Approximate extent of hillfire occurred on 1 April 2007
Squatter dwellings with Category 2 Non-Development Clearance recommended

Plate A1 - Aerial View of the Distressed Hillsides to the East of Kwu Tung Reservoir (December 2006 and July 2007)

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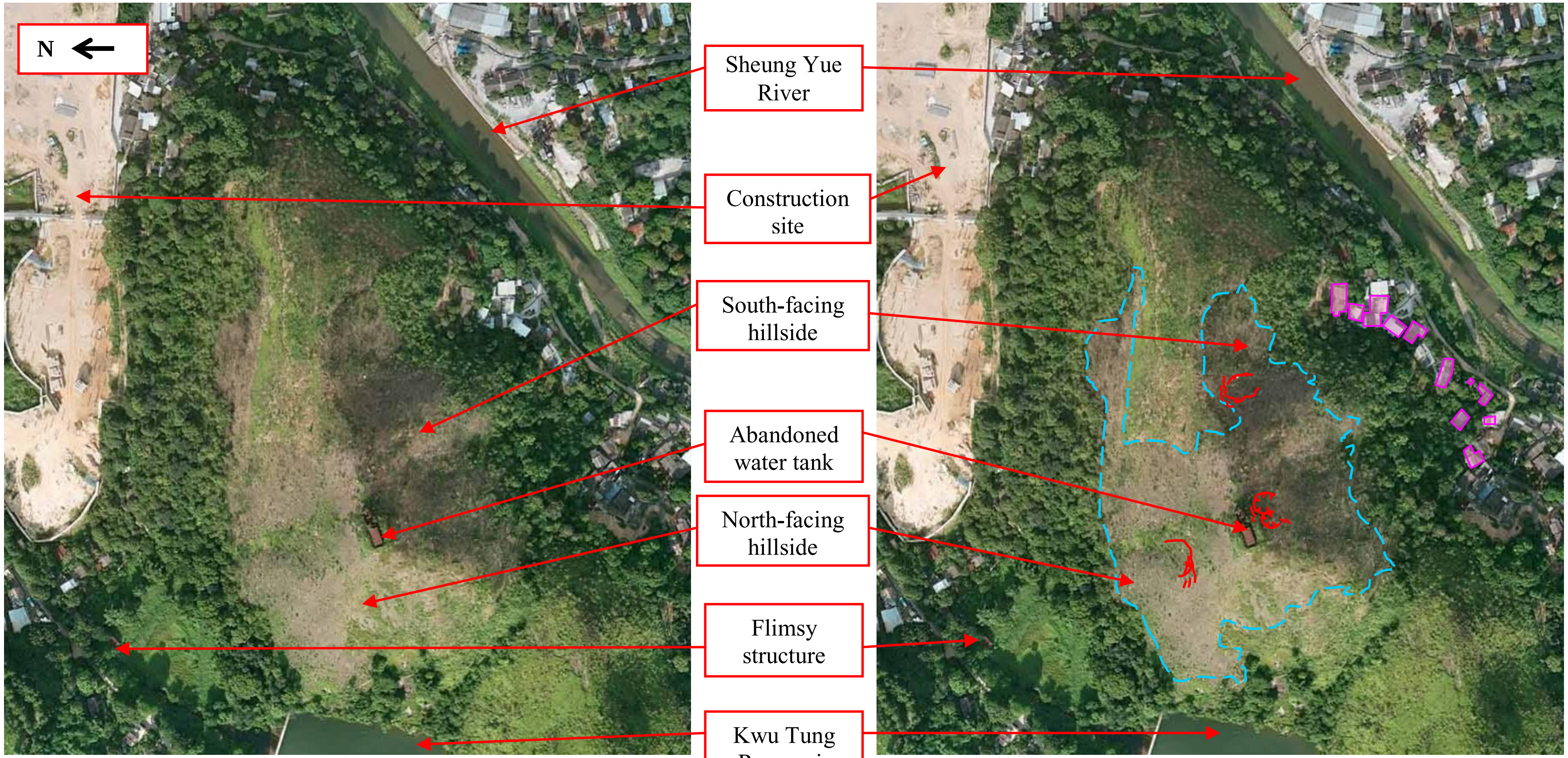

Aerial Photograph no. CW77713 dated 26 July 2007
after the hillfire on 1 April 2007

Aerial Photograph no. CW77713 dated 26 July 2007
after the hillfire on 1 April 2007 with tension cracks

Legend:

Approximate extent of hillfire occurred on 1 April 2007

Squatter dwellings with Category 2 Non-Development Clearance recommended

Tension crack

Landslide scar

Plate A2 - Aerial View of the Distressed Hillsides to the East of Kwu Tung Reservoir (July 2007)

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APPENDIX B

TRIAL PIT AND TRIAL TRENCH LOGS

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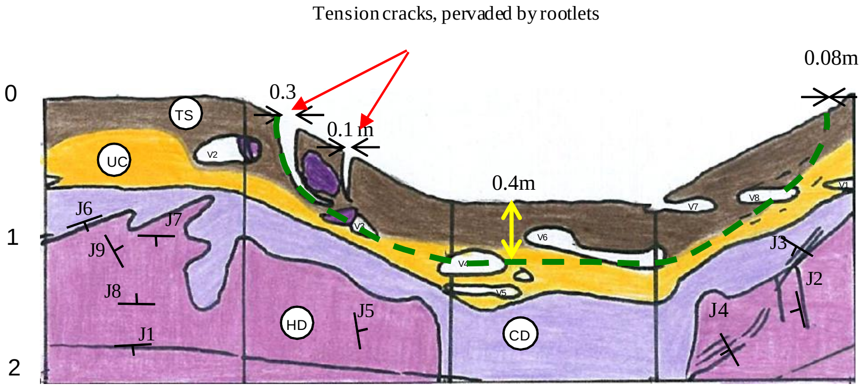
Halcrow China Limited - Agreement No. CE 53/2006 Landslip Investigation Consultancy for Kowloon and the New Territories in 2007 Distressed Hillside near Kwu Tung Reservoir	TRIAL PIT RECORD		Sheet 1 of 1
	TRIAL PIT NO. TP1	Excavation Date: 24-25/6/08	Backfilling Date: 30/7/08
	Co-ordinates: E 828170.85 N 839799.25 Ground Level: +50.82mPD	Logged By: YJC	Date: 28/7/08
		Checked By: PC	Date: 01/9/08

Depth (m) FACE A: 1.5 m FACE B: 1.4 m FACE C: 1.5 m FACE D: 1.4 m



Dip direction/Dip:
J1: 325°/18°
J2: 143°/72°
J3: 355°/48°
J4: 349°/26°
J5: 026°/73°
J6: 170°/40°
J7: 338°/50°
J8: 148°/76°
J9: 265°/68°
F: 348°/43°

Dimension of voids:

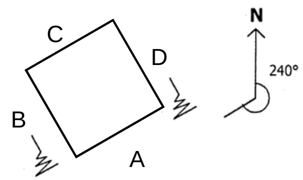
V1: 0.4 m (W) x 0.05 m (H) x 0.18 m (D)
V2: 0.25 m (W) x 0.2 m (H) x 0.2 m (D)
V3: 0.1 m (W) x 0.15 m (H) x 0.16 m (D)
V4: 0.4 m (W) x 0.2 m (H) x 0.63 m (D)
V5: 0.4 m (W) x 0.05 m (H) x 0.16 m (D)
V6: 1 m (W) x 0.2 m (H) x 0.4 m (D)
V7: 0.4 m (W) x 0.18 m (H) x 0.25 m (D)
V8: 0.45 m (W) x 0.15 m (H) x 0.25 m (D)

Description

TS	Firm, brownish grey, silty SAND with some subangular fine to coarse gravel of rock fragments, rootlets and some voids. (TOPSOIL)
UC	Firm, yellowish brown, sandy SILT with some angular to subangular coarse gravel, occasional cobble and boulder of rock fragments, rootlets and some voids. (COLLUVIUM)
CD	Extremely weak, light yellowish brown striped purple, completely decomposed foliated coarse ash crystal TUFF. (Stiff, sandy clayey SILT)
HD	Weak, light grey striped purple, highly decomposed foliated coarse ash crystal TUFF. Joints are very closely to closely spaced, smooth planar, narrow, occasional up to 80mm, iron oxide stained and clay infilled.

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

PLAN (not to scale)



KEY

	Potential plane of movement
	Joint with orientation and dip angle
	Foliation

SECTION

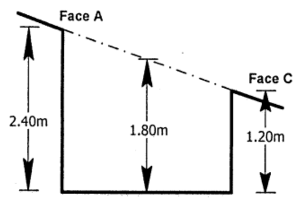


Figure B1 - Investigation Trial Pit TP1

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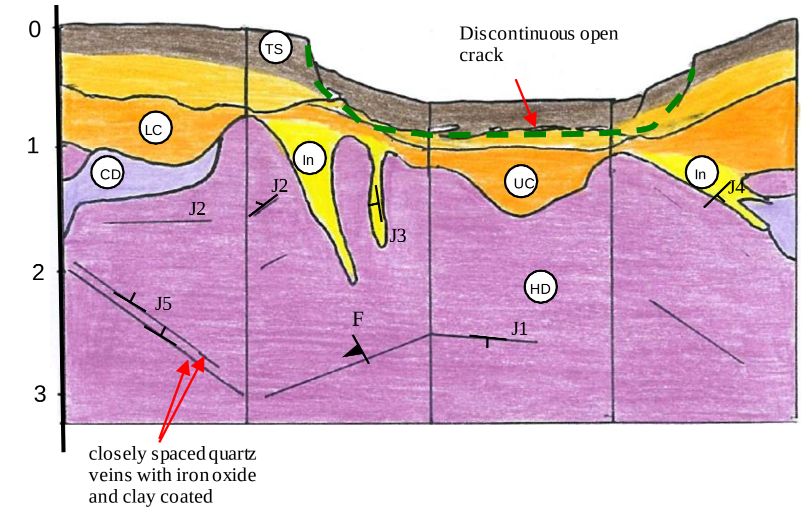
Halcrow China Limited - Agreement No. CE 53/2006 Landslip Investigation Consultancy for Kowloon and the New Territories in 2007 Distressed Hillside near Kwu Tung Reservoir	TRIAL PIT RECORD		Sheet 1 of 1
	TRIAL PIT NO. TP2	Excavation Date: 18-26/6/08	Backfilling Date: 23/7/08
	Co-ordinates: E 828263.44 N 839764.51 Ground Level: +66.61mPD	Logged By: YJC	Date: 04/7/08
		Checked By: PC	Date: 01/9/08

Depth (m)

FACE A: 1.5 m | FACE B: 1.5 m | FACE C: 1.5 m | FACE D: 1.5 m



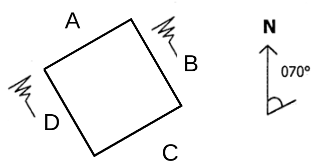
J1: 005°/40°
J2: 013°/42°
J3: 335°/85°
J4: 335°/40°
J5: 315°/56°
F: 355°-013°/42°-48°

Description

TS	Firm greyish brown sandy SILT with occasional gravel and rootlets. (TOPSOIL)
UC	Firm, sandy silt with some medium to coarse gravel and occasional cobble of weak tuff fragments. (Upper Colluvium)
LC	Stiff, sandy silt with much gravels and sone cobble sized quartz and weak tuff fragments. (Lower Colluvium)
CD	Extremely weak, light brownish yellow, completely decomposed SCHIST. (Gravelly sandy SILT)
HD	Weak, white striped brown, highly decomposed SCHIST. Joints are very closely to closely spaced, smooth or planar or undulating, iron oxide stained and clay infill (Max. 2mm).
In	Firm, yellowish brown, gravelly clayey SILT.

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

PLAN (not to scale)



KEY

	Potential plane of movement
	Joint with orientation and dip angle
	Foliation

SECTION

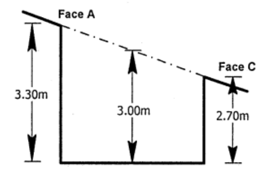


Figure B2 - Investigation Trial Pit TP2

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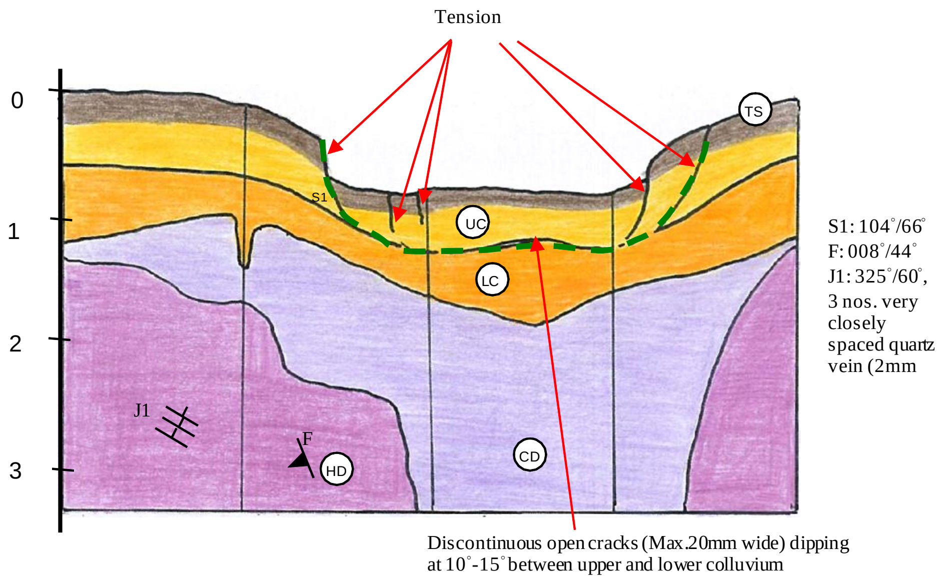
Halcrow China Limited - Agreement No. CE 53/2006 Landslip Investigation Consultancy for Kowloon and the New Territories in 2007 Distressed Hillside near Kwu Tung Reservoir	TRIAL PIT RECORD		Sheet 1 of 1
	TRIAL PIT NO. TP3	Excavation Date: 20-23/6/2008 Backfilling Date: 25/7/2008	
	Co-ordinates: E 828259.98 N 839728.89 Ground Level: +51.22mPD	Logged By: YJC	Date: 25/7/08
		Checked By: PC	Date: 01/9/08

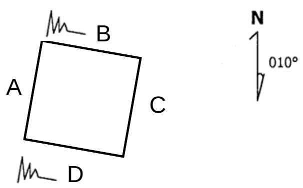
Depth (m) | FACE A: 1.5 m | FACE B: 1.5 m | FACE C: 1.5 m | FACE D: 1.5 m



	Description
TS	Firm, brownish grey, sandy SILT with some rootlets (TOPSOIL).
UC	Stiff, yellowish brown, sandy SILT with some voids. (Upper Colluvium)
LC	Stiff, yellowish brown, sandy SILT with some angular to subangular coarse gravel and cobble of weak tuff fragments. (Lower Colluvium)
CD	Extremely weak, light brownish yellow, completely decomposed foliated coarse ash crystal TUFF. (Gravelly silty SAND)
HD	Weak, light brownish yellow, highly decomposed foliated coarse ash crystal TUFF. Joints are very closely to closely spaced, smooth or planar or undulating, iron oxide stained. Below 1m-2m at corner of Face A and B: numerous kaolin infill veins (<1mm thick)

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

PLAN (not to scale)



KEY

	Potential plane of movement
	Joint with orientation and dip angle
	Foliation

SECTION

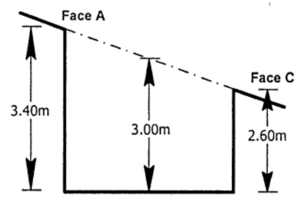


Figure B3 - Investigation Trial Pit TP3

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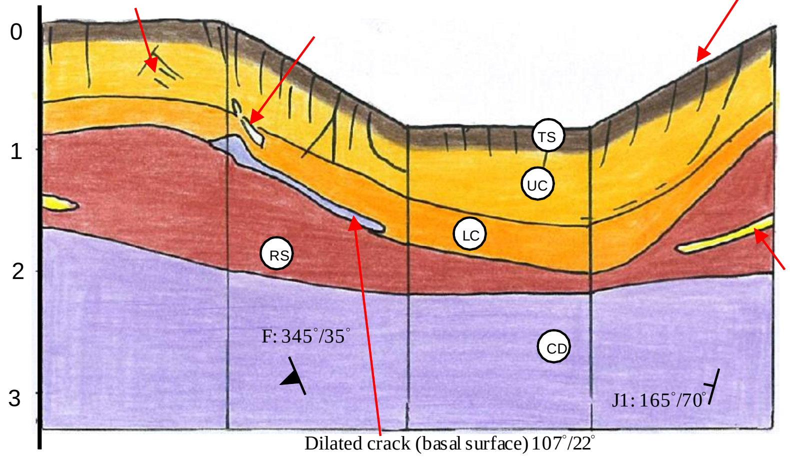
Halcrow China Limited - Agreement No. CE 53/2006 Landslip Investigation Consultancy for Kowloon and the New Territories in 2007 Distressed Hillside near Kwu Tung Reservoir	TRIAL PIT RECORD	Sheet 1 of 1
	TRIAL PIT NO. TP4	Excavation Date: 16-18/6/08 Backfilling Date: 26/7/08
	Co-ordinates: E 828248.75 N 839797.78 Ground Level: +59.28mPD	Logged By: YJC Date: 24/7/08 Checked By: PC Date: 01/9/08

Depth (m) FACE A: 1.5 m FACE B: 1.5 m FACE C: 1.5 m FACE D: 1.5 m

Series of open cracks 72°-75°/40°-45° with aperture max.20mm extending beyond face A

Open crack (max.25 mm thick), partially infilling by sandy silt and quartz fragments. Its basal surface is 075°/48°.

Numerous root-filled sub-vertical cracks extending into upper colluvium



Dilated crack of 25mm thick infilling by sandy silt

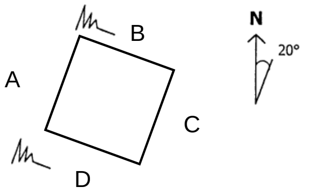
Dilated crack (basal surface) 107°/22° of 70mm thick infilling by soft sandy silt with many voids

Description

TS	Loose, brownish grey silty SAND with occasional gravel and some rootlets (TOPSOIL).
UC	Firm, pinkish brown, sandy clayey SILT with occasional subangular fine to coarse gravel of tuff fragments. (Upper Colluvium)
LC	Firm, pinkish brown, slightly sandy clayey SILT with some subangular coarse gravel and occasional cobble of weak tuff fragments. (Lower Colluvium)
RS	Firm, brownish red, slightly sandy clayey SILT with occassional gravel sized pockets of CDT. (Residual Soil)
CD	Extremely weak, light purplish red, completely decomposed foliated coarse ash crystal TUFF. (Stiff, sandy CLAY/SILT)

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

PLAN (not to scale)



KEY

Joint with orientation and dip angle

Foliation

SECTION

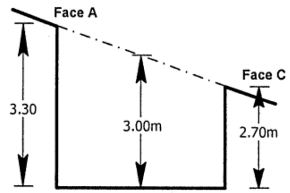


Figure B4 - Investigation Trial Pit TP4

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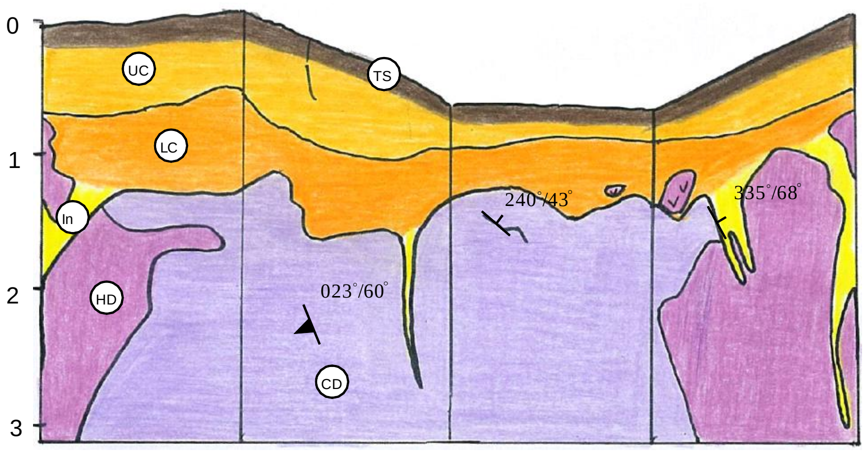
Halcrow China Limited - Agreement No. CE 53/2006 Landslip Investigation Consultancy for Kowloon and the New Territories in 2007 Distressed Hillside near Kwu Tung Reservoir	TRIAL PIT RECORD		Sheet 1 of 1
	TRIAL PIT NO. TP5	Excavation Date: 29-31/7/08	Backfilling Date: 11/8/08
	Co-ordinates: E 828194.32 N 839729.55 Ground Level: +74.36 mPD	Logged By: YJC	Date: 11/8/208
		Checked By: PC	Date: 01/9/08

Depth (m) FACE A: 1.5 m FACE B: 1.5 m FACE C: 1.5 m FACE D: 1.5 m

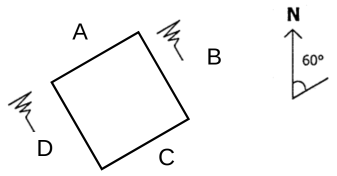


Description

TS	Loose, greyish brown, silty SAND with some rootlets (TOPSOIL).
UC	Firm, brown, sandy silt with some subangular fine to coarse gravel and occasional cobbles of tuff fragments aligned parelled to the slope surface (~30°) (Upper Colluvium)
LC	Firm, yellowish brown, sandy silty with many subangular coarse gravel and cobble of tuff fragments aligned at 55°. (Lower Colluvium)
CD	Extremely weak, light grey mottled purple, completely decomposed foliated coarse ash crystal TUFF. (Gravelly silty SAND)
HD	Weak to moderately weak, light grey striped purple, highly decomposed foliated coarse ash crystal TUFF. Joints are very closely to closely spaced, smooth or planar or undulating, iron oxide stained and clay infilled (Max.20mm).
In	Soft, brownish yellow, gravelly clayey SILT.

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

PLAN (not to scale)



KEY

Joint with orientation and dip angle

Foliation

SECTION

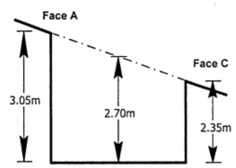


Figure B5 - Investigation Trial Pit TP5

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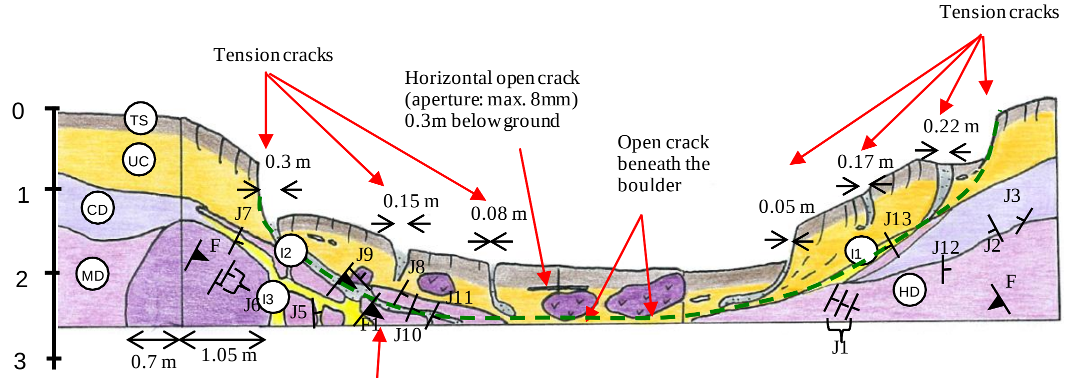
Halcrow China Limited - Agreement No. CE 53/2006 Landslip Investigation Consultancy for Kowloon and the New Territories in 2007 Distressed Hillside near Kwu Tung Reservoir	TRIAL PIT RECORD		Sheet 1 of 1
	TRIAL TRENCH NO. TT1	Excavation Date: 2-7/7/08	Backfilling Date: 30/7/08
	Co-ordinates: E 828158.68 N 839784.00 Ground Level: +57.61 mPD	Logged By: YJC	Date: 30/7/08
	Co-ordinates: E 828156.30 N 839787.81 Ground Level: +55.01 mPD	Checked By: PC	Date: 1/9/08

Depth (m) FACE A: 1.5 m FACE B: 4.5 m FACE C: 1.5 m FACE D: 4.5 m



Foliation changed locally at 030°/88° (F1) suggesting that there has been movement in the upper zone of the tuff

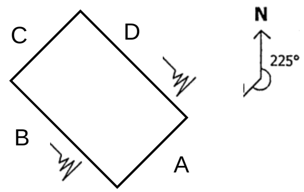
J1: 026°/70°-75°	J2: 303°/60°
J3: 342°/66°	J4: 040°/74°
J5: 036°/82°	J6: 320°/40°
J7: 208°/62°	J8: 332°/50°
J9: 196°/60°	J10: 020°/38°
J11: 010°/40°	J12: 220°/80°
J13: 335°/43°	F: 325°-335°/40°-55°

Description

TS	Firm, brownish grey silty SAND with some subangular fine to coarse gravel of rock fragments and rootlets. (Topsoil)
UC	Firm, yellowish brown, sandy silty with some subangular fine to coarse gravel and occasional cobble of weak tuff fragments. (Colluvium)
CD	Extremely weak to very weak, light brownish purple, completely decomposed foliated coarse ash crystal TUFF. (Stiff, sandy clayey SILT)
HD	Weak, light grey striped purple, highly decomposed foliated coarse ash crystal TUFF. (Silty SAND with many gravel)
MD	Moderately strong, light purple and yellowish brown, moderartely decomposed foliated coarse ash crystal TUFF.
I1	Loose, yellowish brown, silty SAND with rootlets.
I2	Tension crack infilled by dark grey, silty sand with organic materials and rootlets.
I3	Zone of infill (Soft, brownish yellow, gravelly clay/silt)

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

PLAN (not to scale)



KEY

	Potential plane of movement
	Joint with orientation and dip angle
	Foliation

SECTION

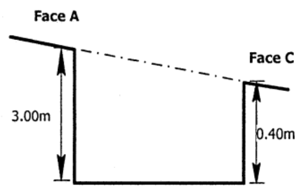


Figure B6 - Investigation Trial Trench TT1

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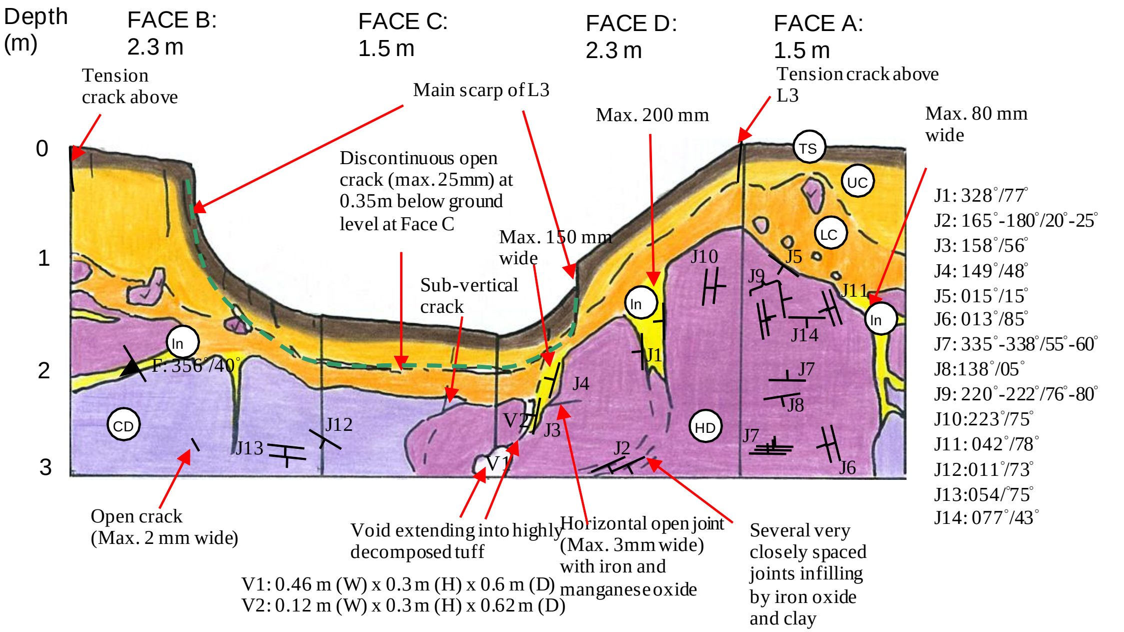
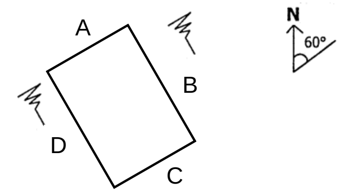
Halcrow China Limited - Agreement No. CE 53/2006 Landslip Investigation Consultancy for Kowloon and the New Territories in 2007 Distressed Hillside near Kwu Tung Reservoir	TRIAL PIT RECORD		Sheet 1 of 1
	TRIAL TRENCH NO. TT2	Excavation Date: 27-30/6/08	Backfilling Date: 31/7/08
	Co-ordinates: E 828250.53 N 839760.73 Ground Level: +67.33 mPD	Logged By: YJC	Date: 31/7/08
	Co-ordinates: E 828252.13 N 839759.11 Ground Level: +65.53 mPD	Checked By: PC	Date: 01/9/08



	Description
TS	Loose greyish brown silty SAND with some rootlets (TOPSOIL).
UC	Firm, brown, sandy silt with some subangular fine to coarse gravel of tuff fragments. (Upper Colluvium)
LC	Firm, yeloowish brown, sandy silty with many subangular coarse gravel and cobble of weak tuff fragments. (Lower Colluvium)
CD	Extremely weak, light grey mottled purple, completely decomposed foliated coarse ash crystal TUFF. (Gravelly silty SAND)
HD	Weak to moderately weak, light grey striped purple, highly decomposed foliated coarse ash crystal TUFF. Joints are very closely to closely spaced, smooth or planar or undulating, iron oxide stained and clay infilled (Max.20mm).
In	Firm, bronwish yellow, slightly sandy gravelly CLAY/SILT. (Infilling material)

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

PLAN (not to scale)



KEY

- Potential plane of movement
- Joint with orientation and dip angle
- Foliation

SECTION

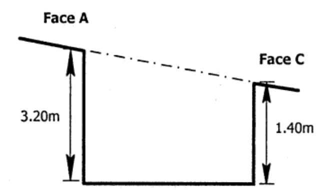


Figure B7 - Investigation Trial Trench TT2

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APPENDIX C

GROUND MOVEMENT MONITORING RESULTS

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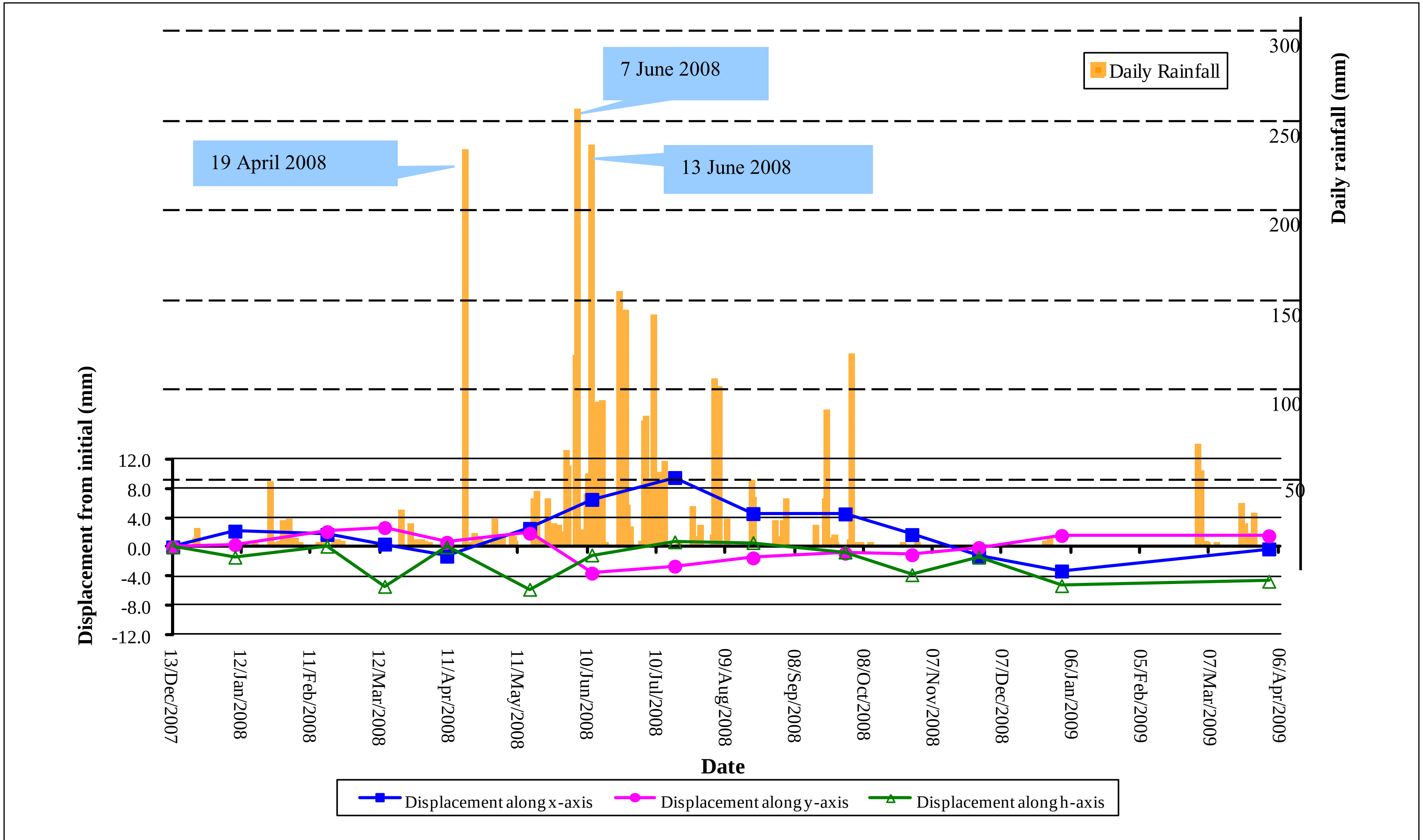

Note : See Figure C27 for direction of axes at Southern Hillside and Northern Hillside.

Figure C1 - Movement Monitoring Result of Station M1 with Daily Rainfall during the Monitoring Period

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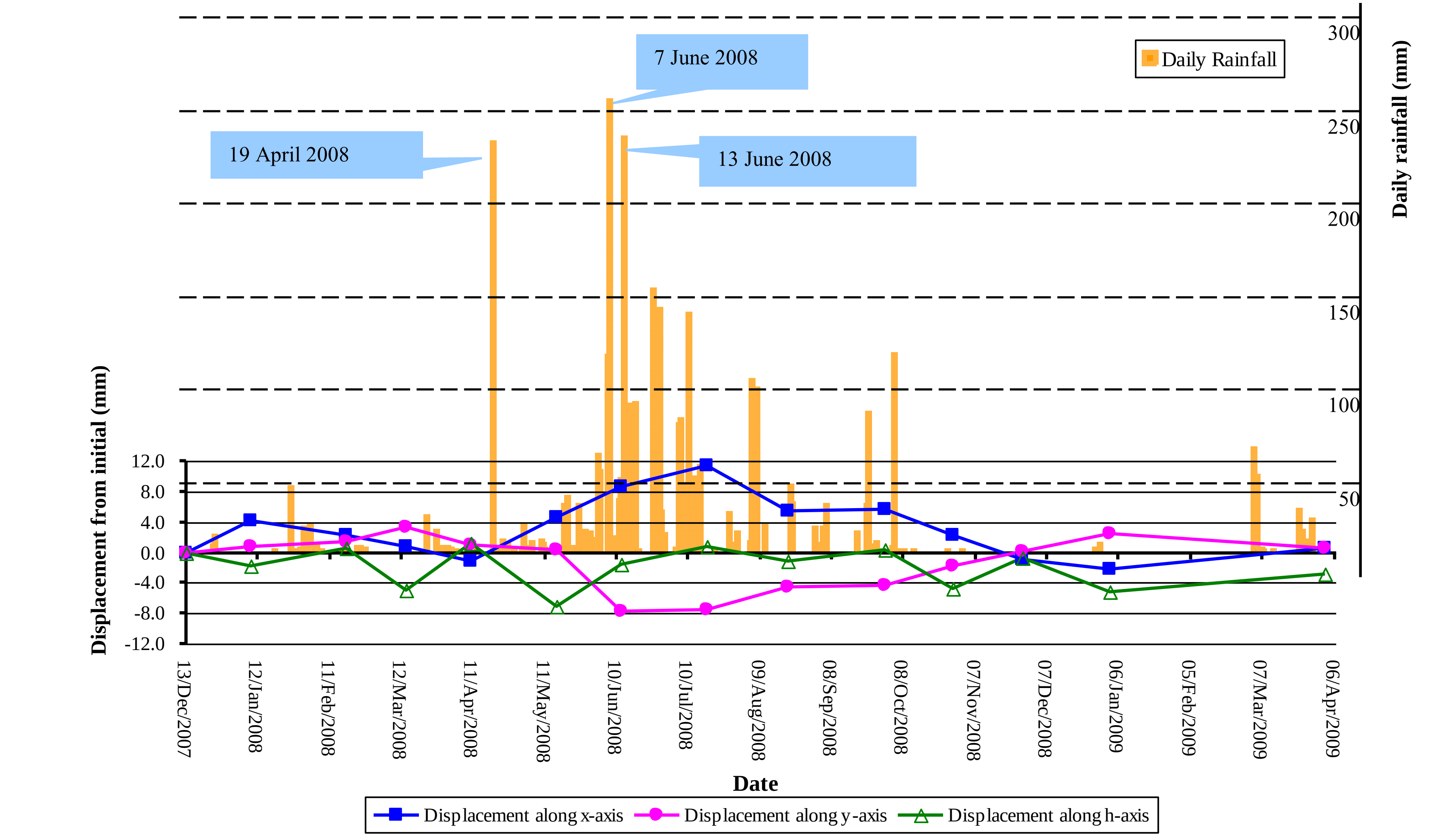

Note : See Figure C27 for direction of axes at Southern Hillside and Northern Hillside.

Figure C2 - Movement Monitoring Result of Station M2 with Daily Rainfall during the Monitoring Period

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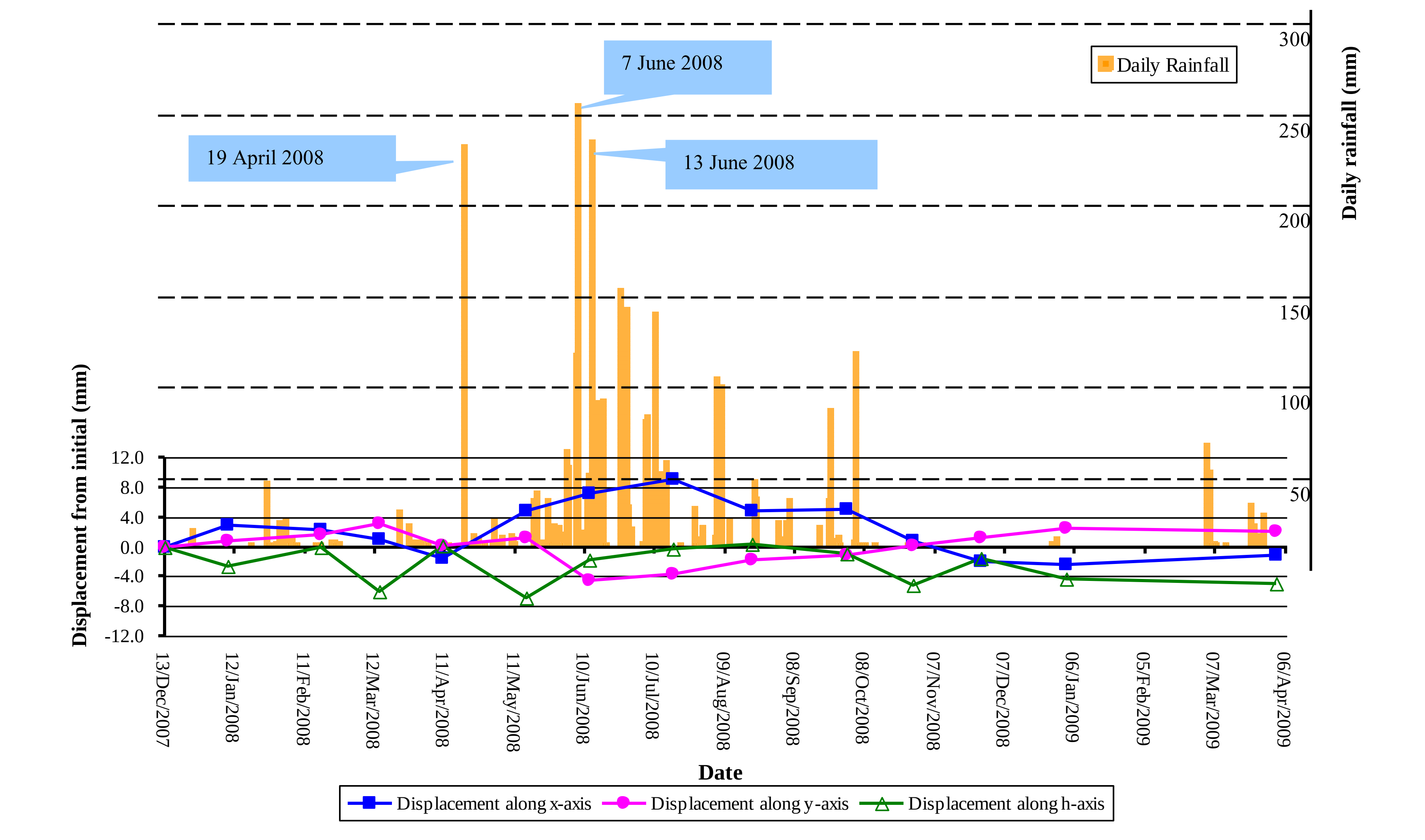

Note : See Figure C27 for direction of axes at Southern Hillside and Northern Hillside.

Figure C3 - Movement Monitoring Result of Station M3 with Daily Rainfall during the Monitoring Period

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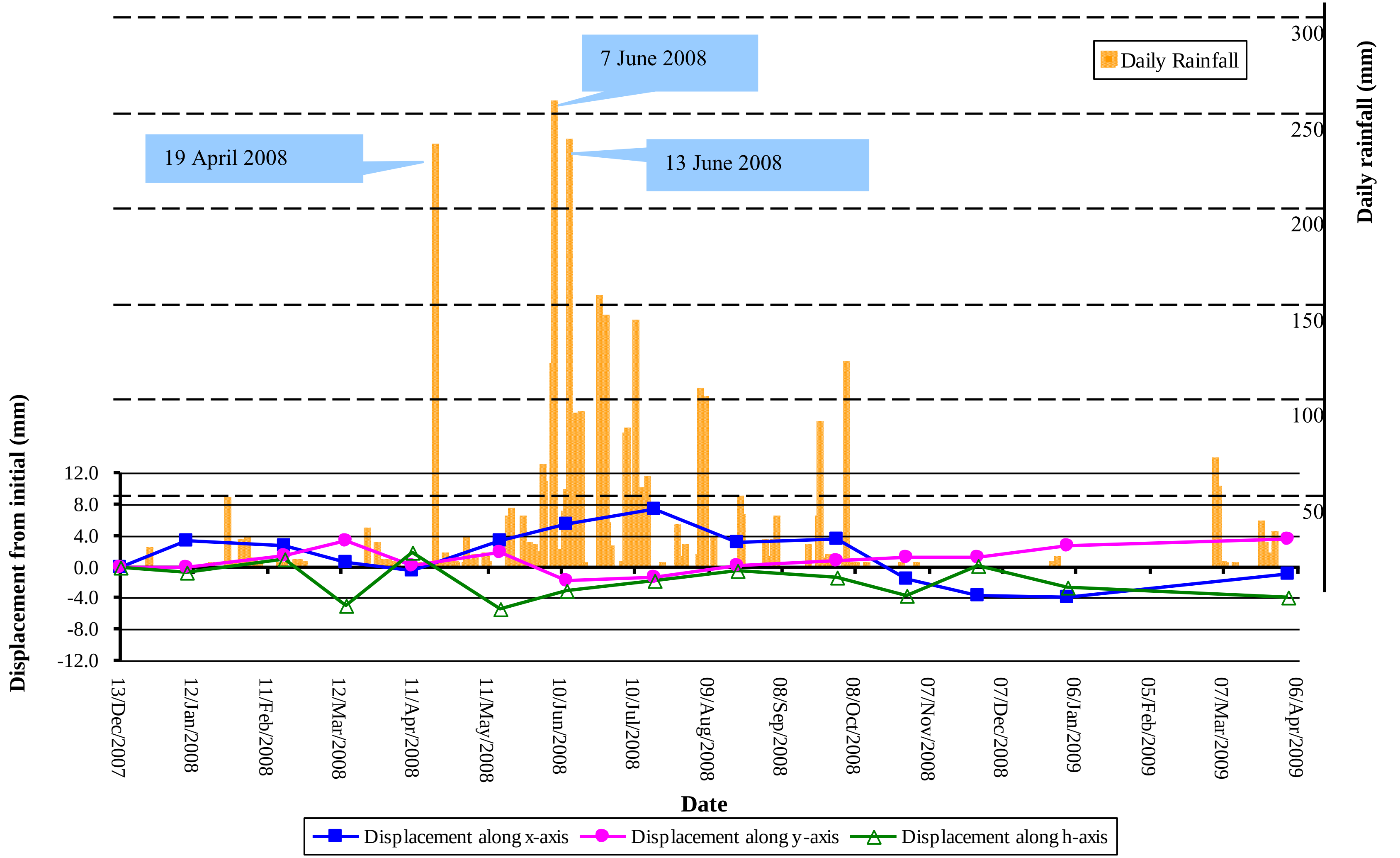

Note : See Figure C27 for direction of axes at Southern Hillside and Northern Hillside.

Figure C4 - Movement Monitoring Result of Station M4 with Daily Rainfall during the Monitoring Period

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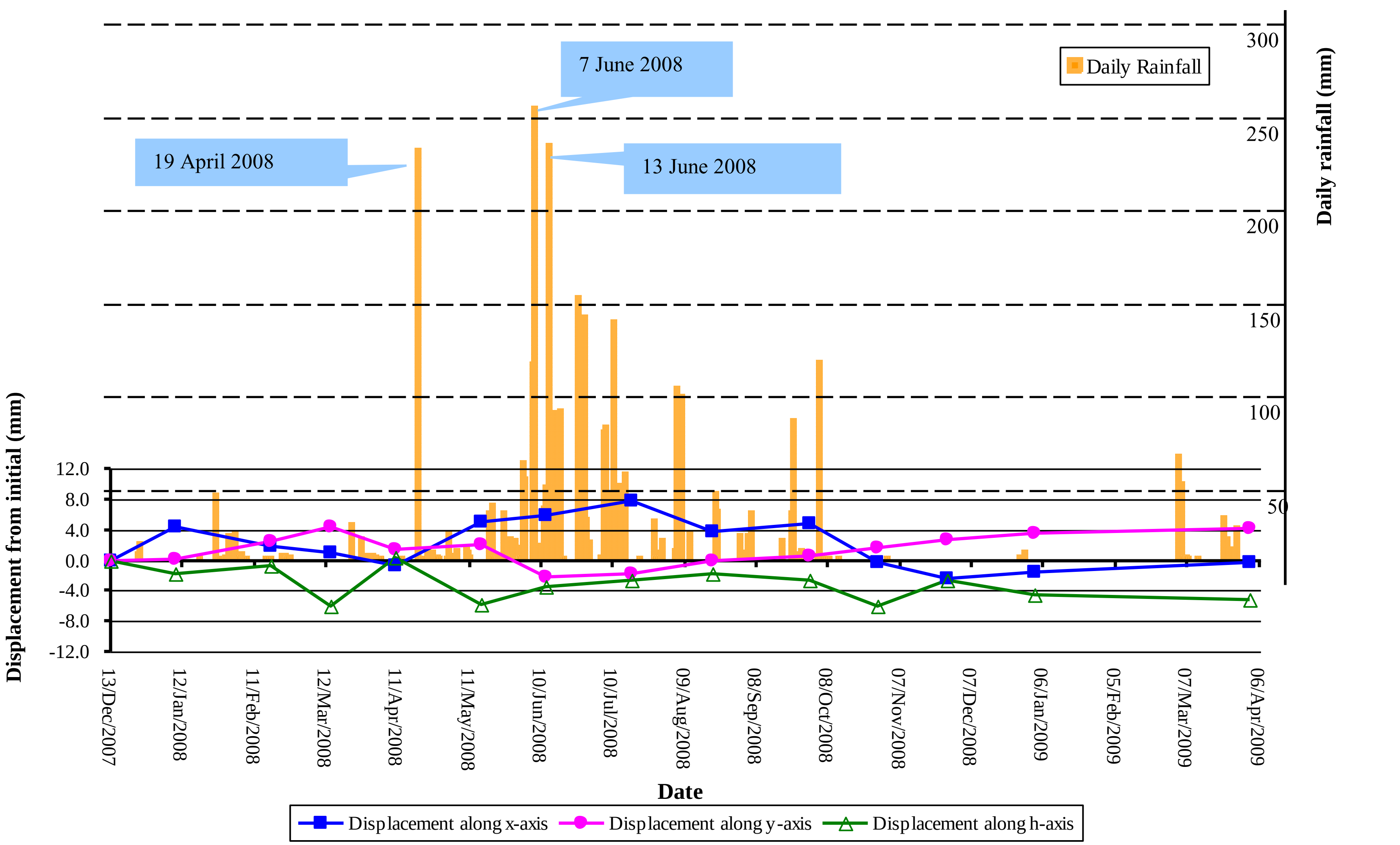

Note : See Figure C27 for direction of axes at Southern Hillside and Northern Hillside.

Figure C5 - Movement Monitoring Result of Station M5 with Daily Rainfall during the Monitoring Period

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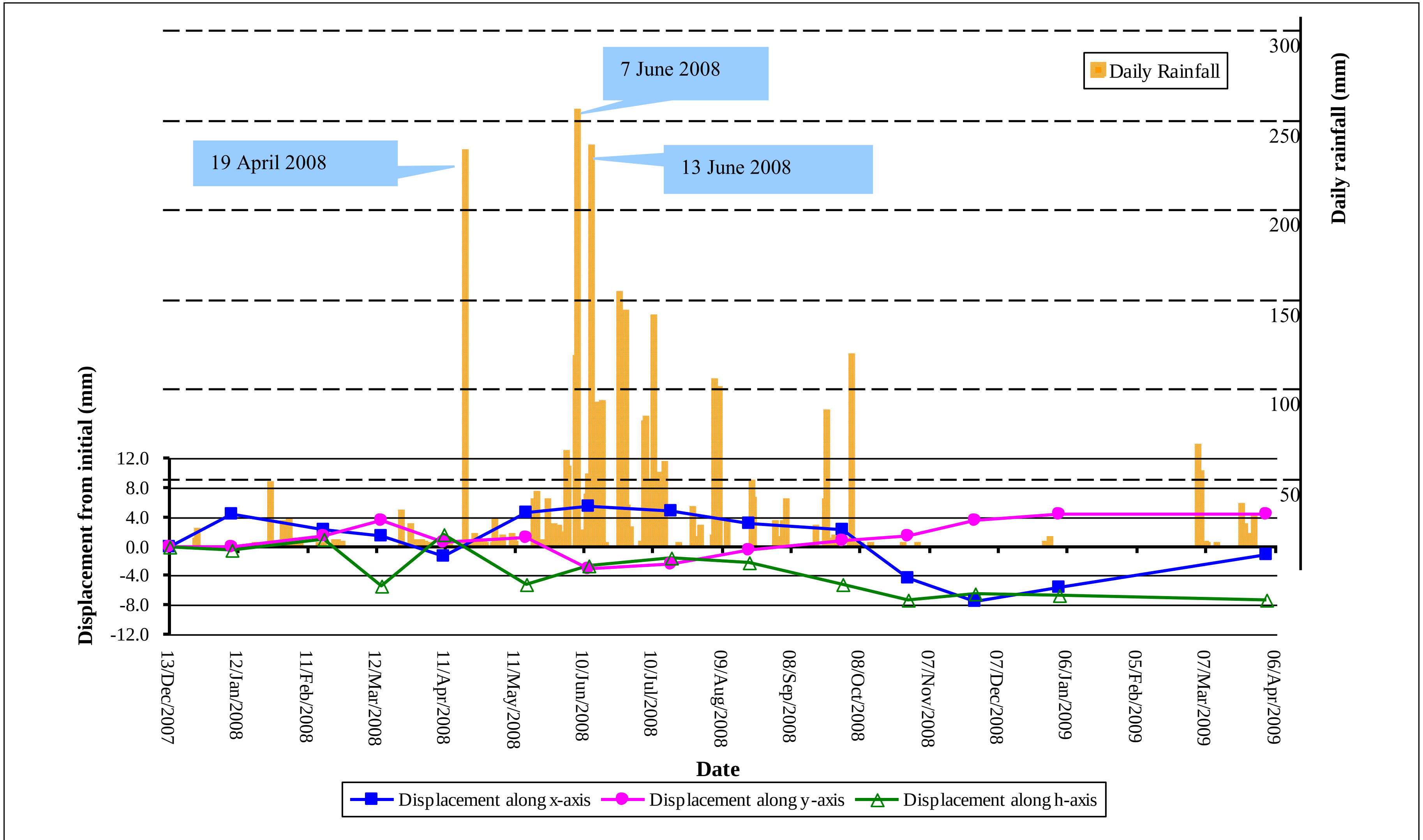

Note : See Figure C27 for direction of axes at Southern Hillside and Northern Hillside.

Figure C6 - Movement Monitoring Result of Station M6 with Daily Rainfall during the Monitoring Period

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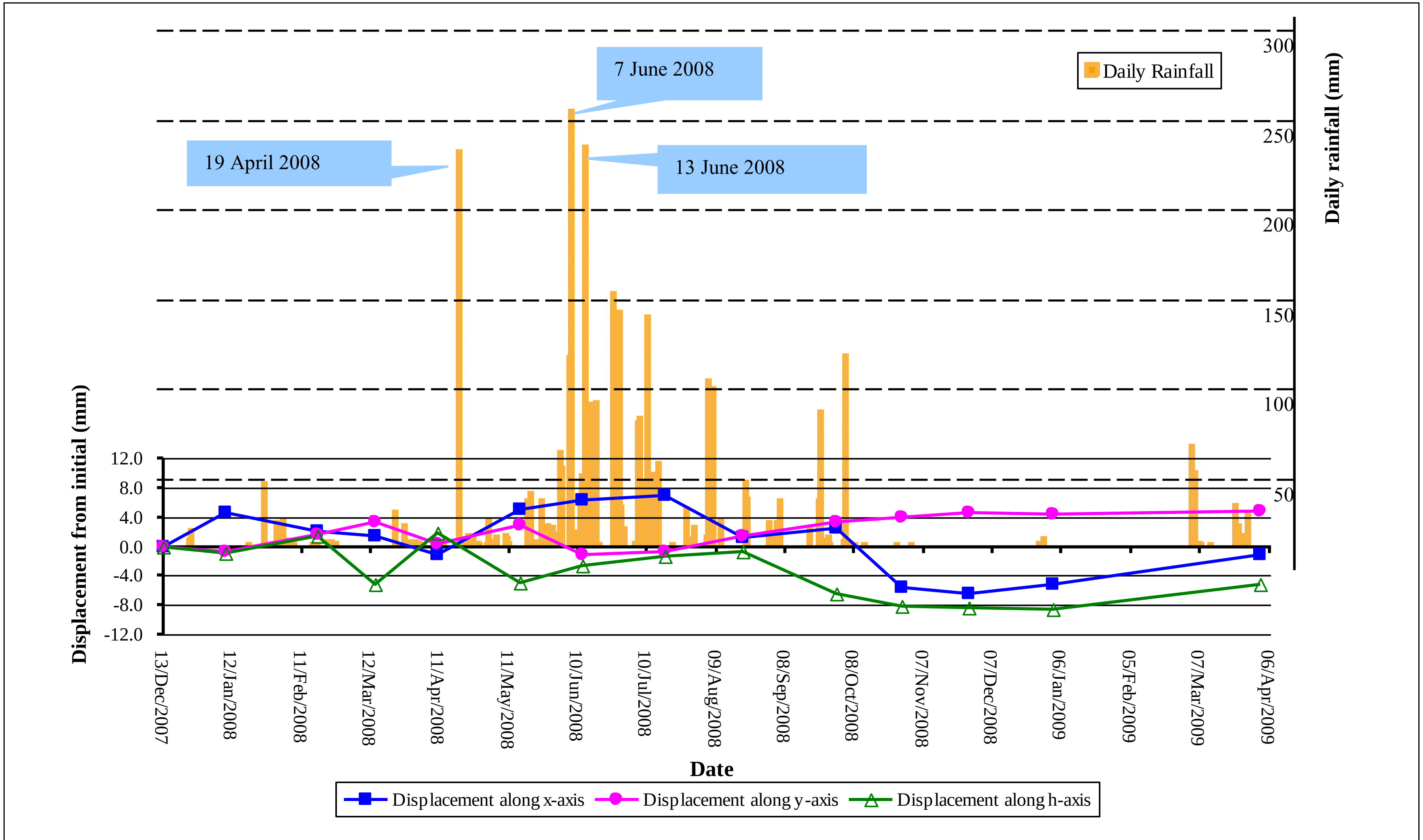

Note : See Figure C27 for direction of axes at Southern Hillside and Northern Hillside.

Figure C7 - Movement Monitoring Result of Station M7 with Daily Rainfall during the Monitoring Period

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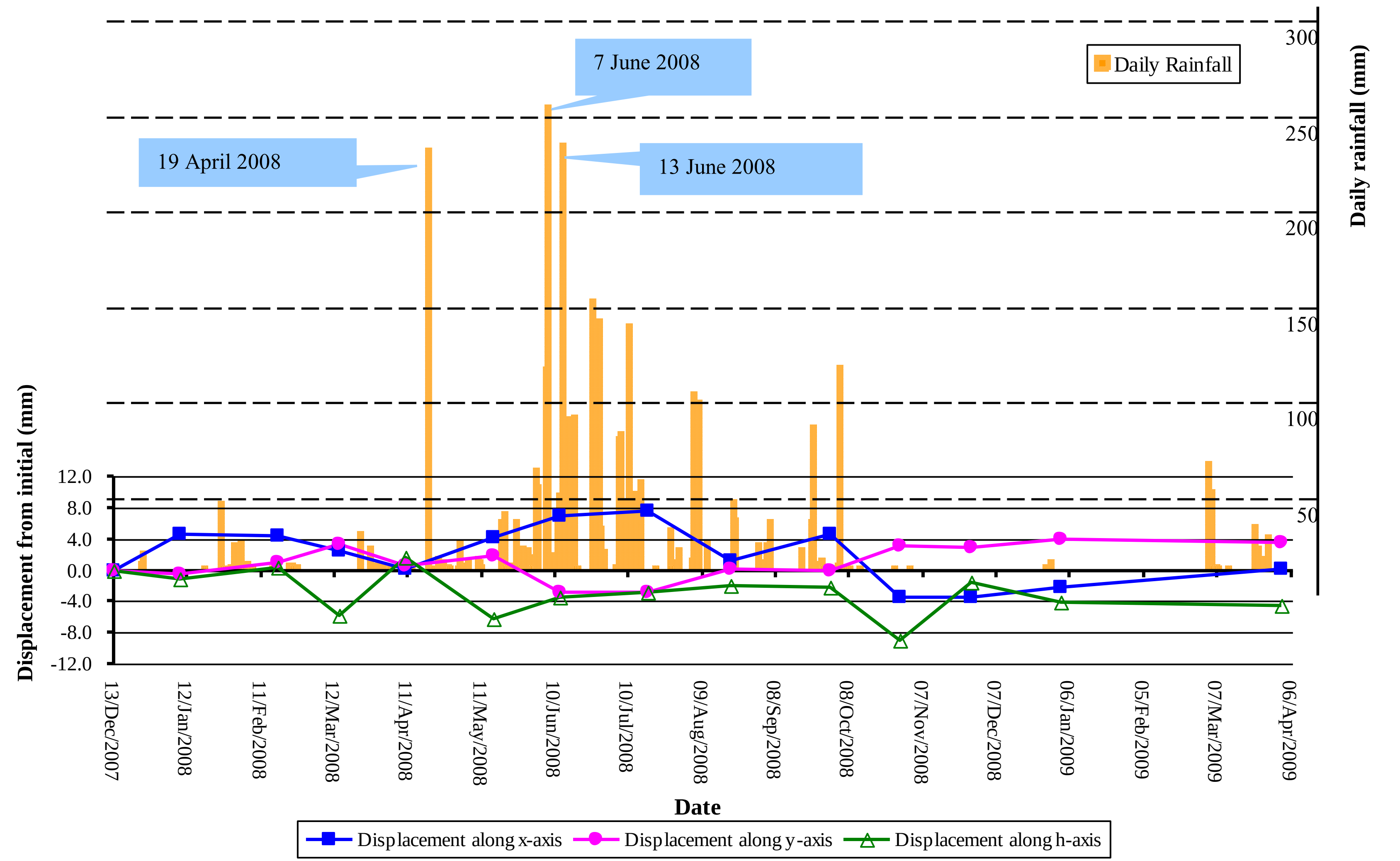

Note : See Figure C27 for direction of axes at Southern Hillside and Northern Hillside.

Figure C8 - Movement Monitoring Result of Station M8 with Daily Rainfall during the Monitoring Period

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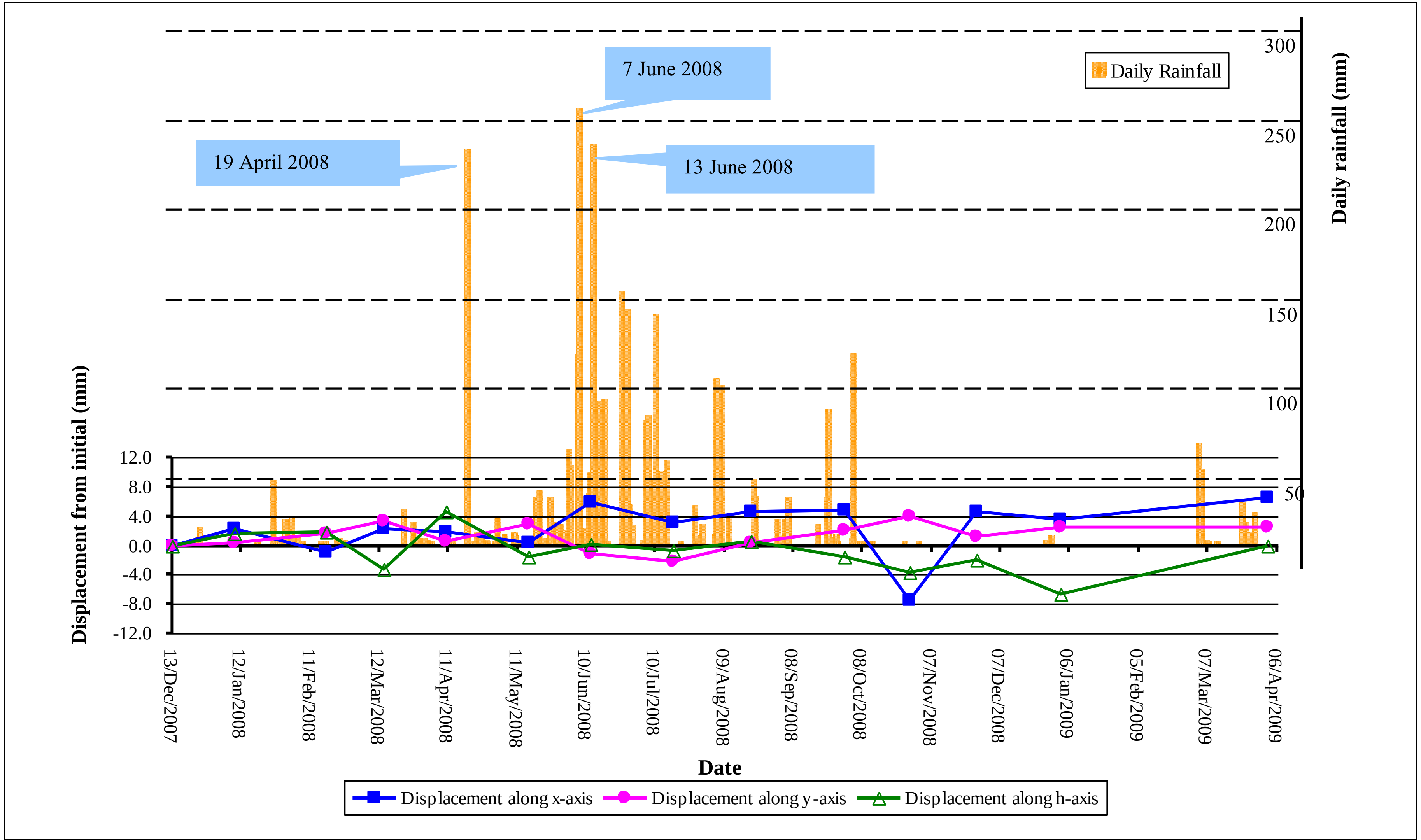

Note : See Figure C27 for direction of axes at Southern Hillside and Northern Hillside.

Figure C9 - Movement Monitoring Result of Station M9 with Daily Rainfall during the Monitoring Period

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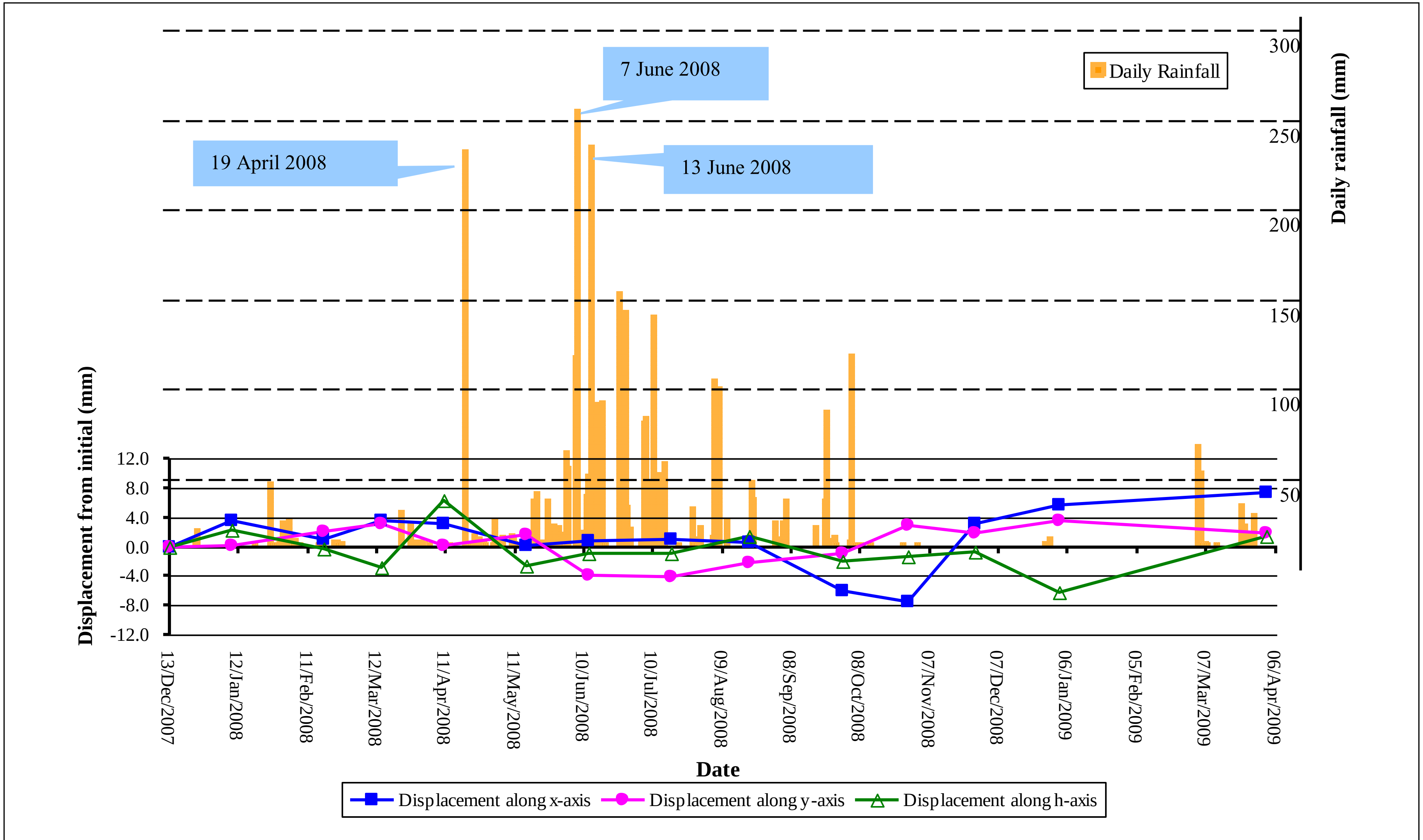

Note : See Figure C27 for direction of axes at Southern Hillside and Northern Hillside.

Figure C10 - Movement Monitoring Result of Station M10 with Daily Rainfall during the Monitoring Period

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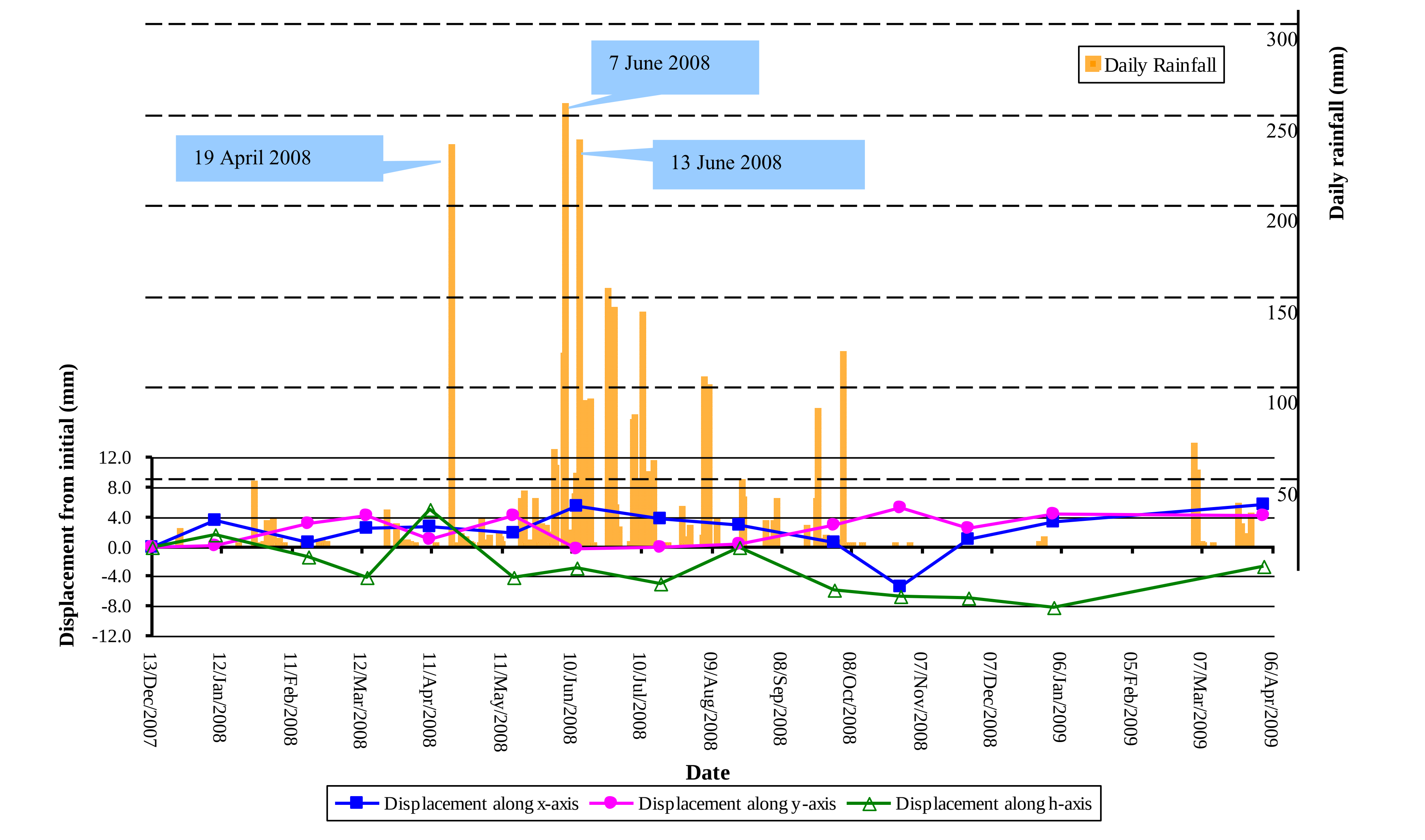

Note : See Figure C27 for direction of axes at Southern Hillside and Northern Hillside.

Figure C11 - Movement Monitoring Result of Station M11 with Daily Rainfall during the Monitoring Period

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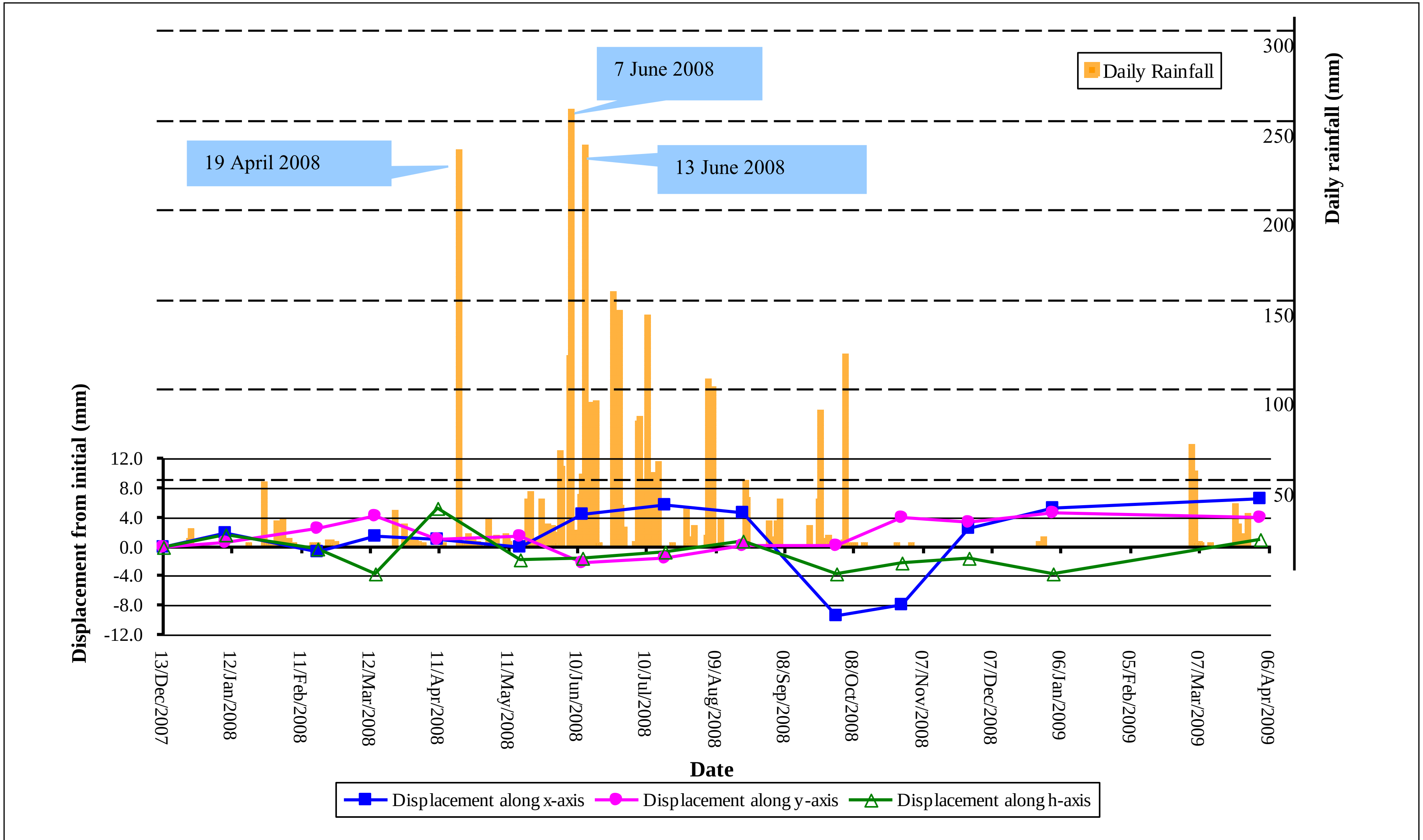

Note : See Figure C27 for direction of axes at Southern Hillside and Northern Hillside.

Figure C12 - Movement Monitoring Result of Station M12 with Daily Rainfall during the Monitoring Period

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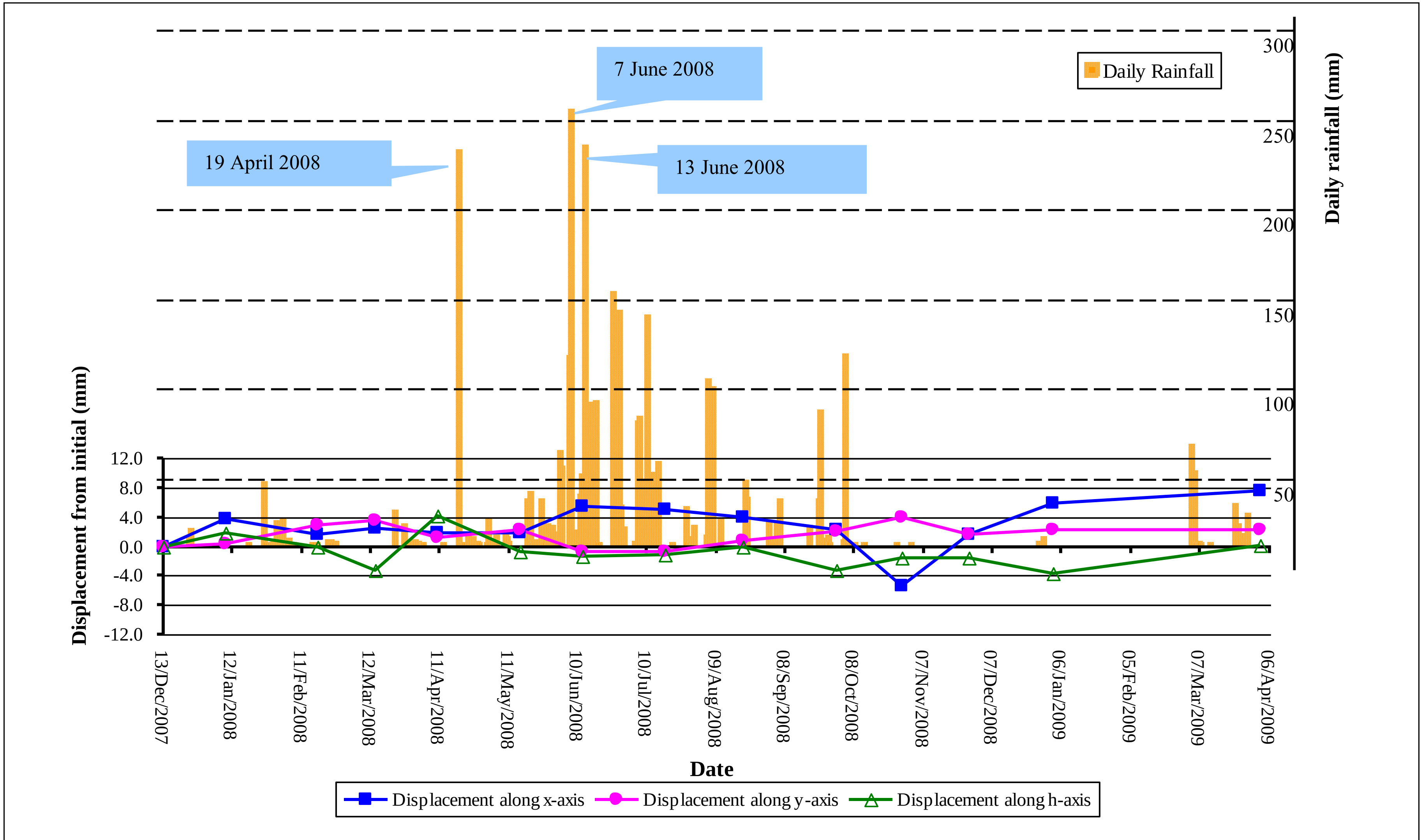

Note : See Figure C27 for direction of axes at Southern Hillside and Northern Hillside.

Figure C13 - Movement Monitoring Result of Station M13 with Daily Rainfall during the Monitoring Period

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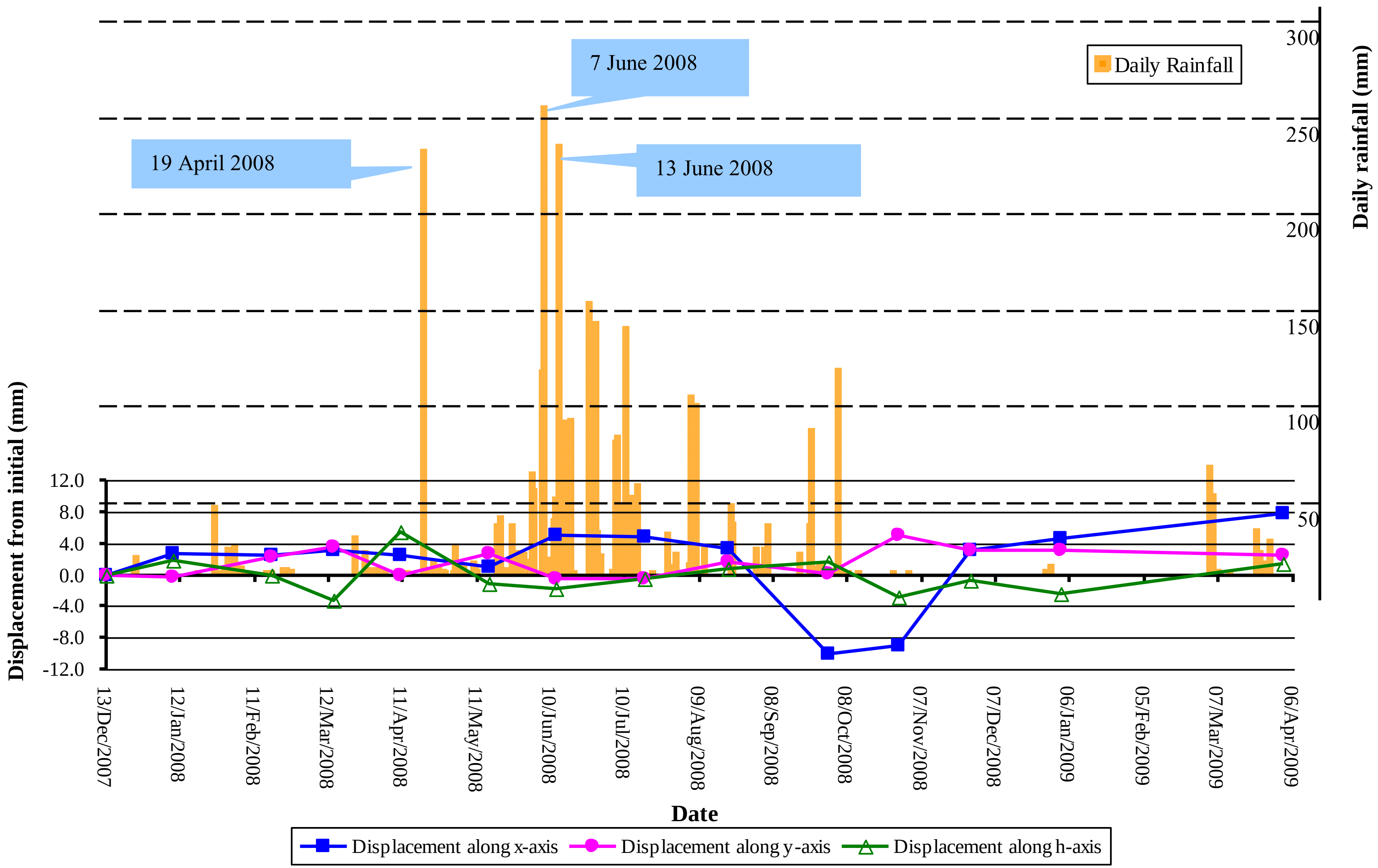

Note : See Figure C27 for direction of axes at Southern Hillside and Northern Hillside.

Figure C14 - Movement Monitoring Result of Station M14 with Daily Rainfall during the Monitoring Period

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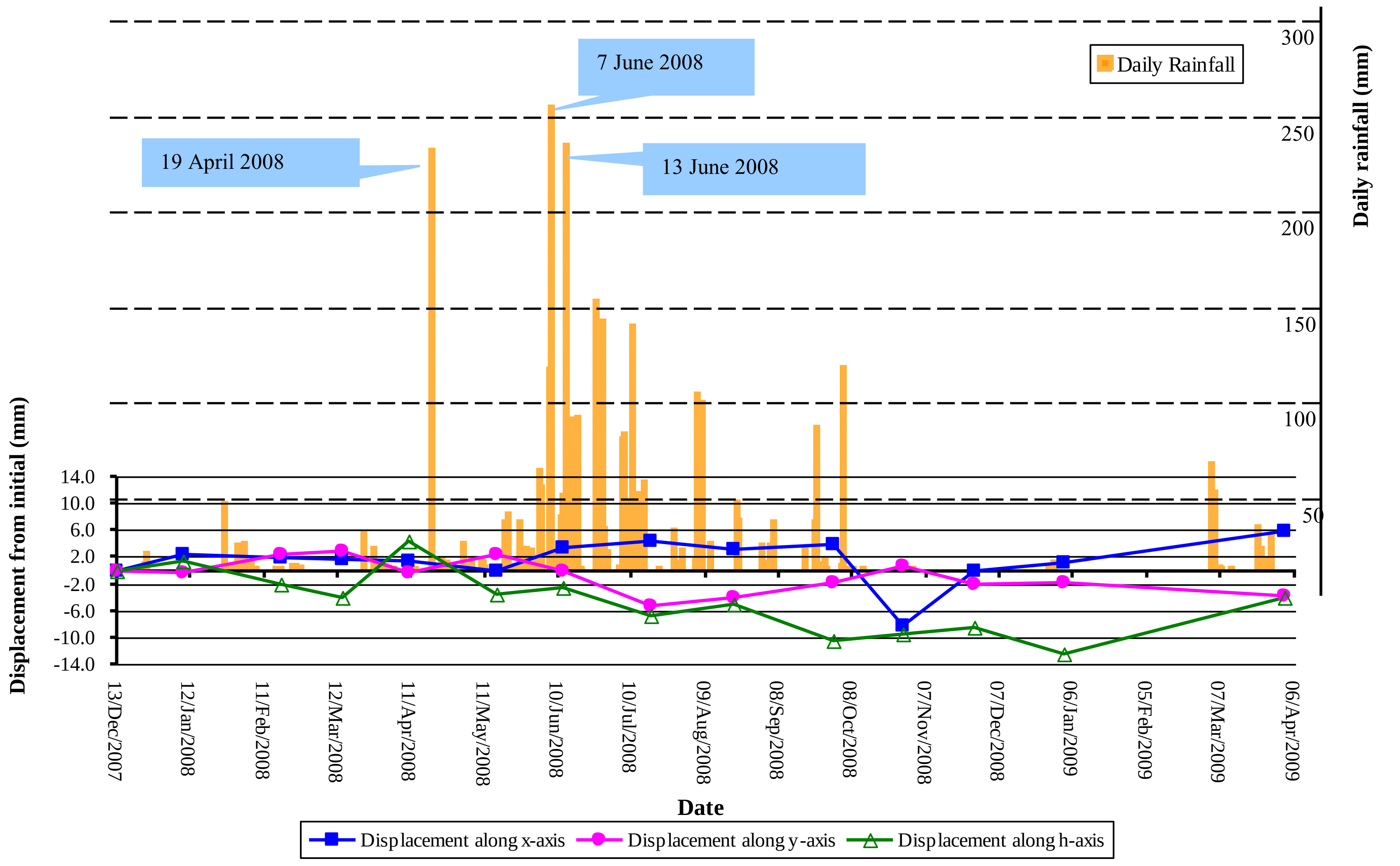

Note : See Figure C27 for direction of axes at Southern Hillside and Northern Hillside.

Figure C15 - Movement Monitoring Result of Station M15 with Daily Rainfall during the Monitoring Period

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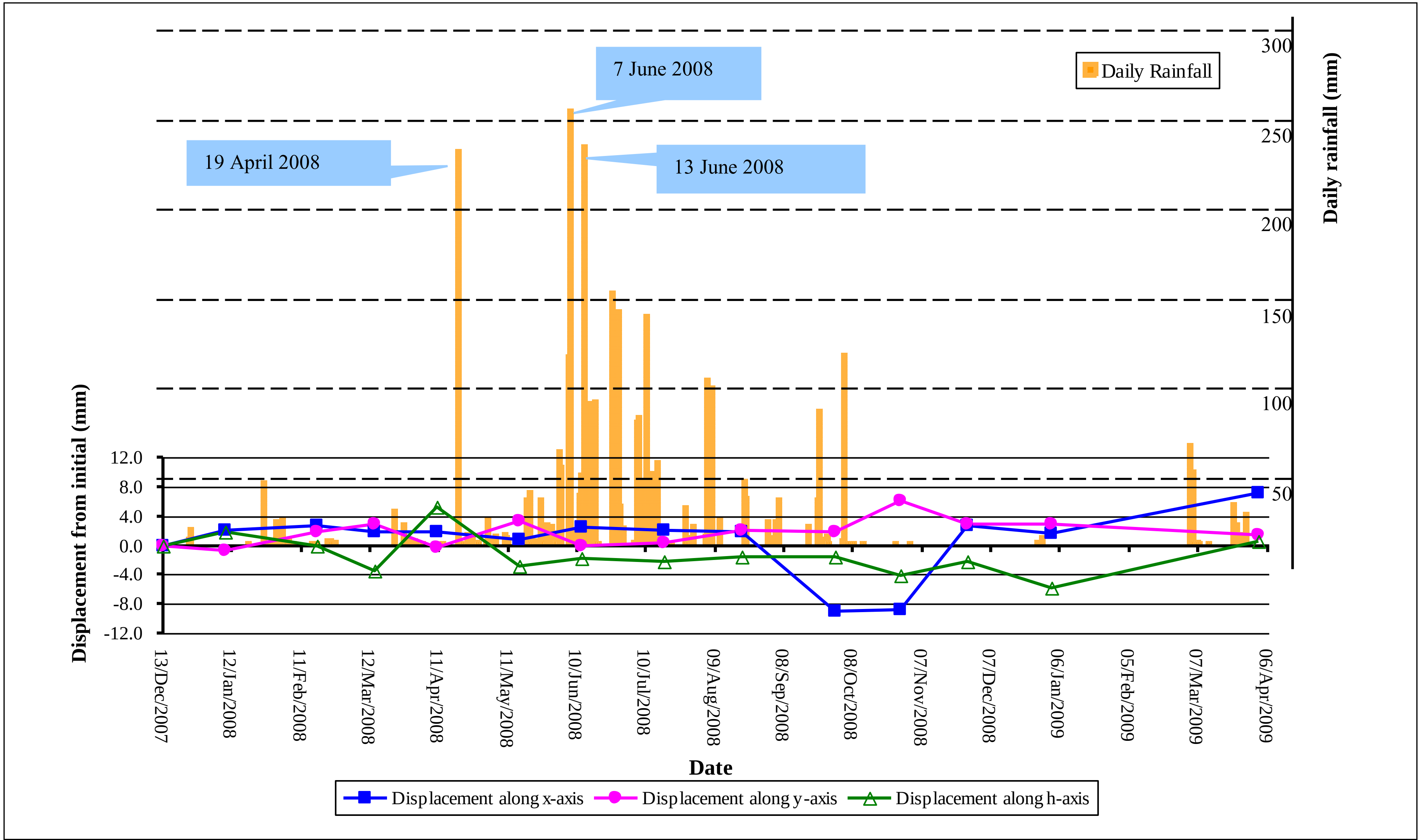

Note : See Figure C27 for direction of axes at Southern Hillside and Northern Hillside.

Figure C16 - Movement Monitoring Result of Station M16 with Daily Rainfall during the Monitoring Period

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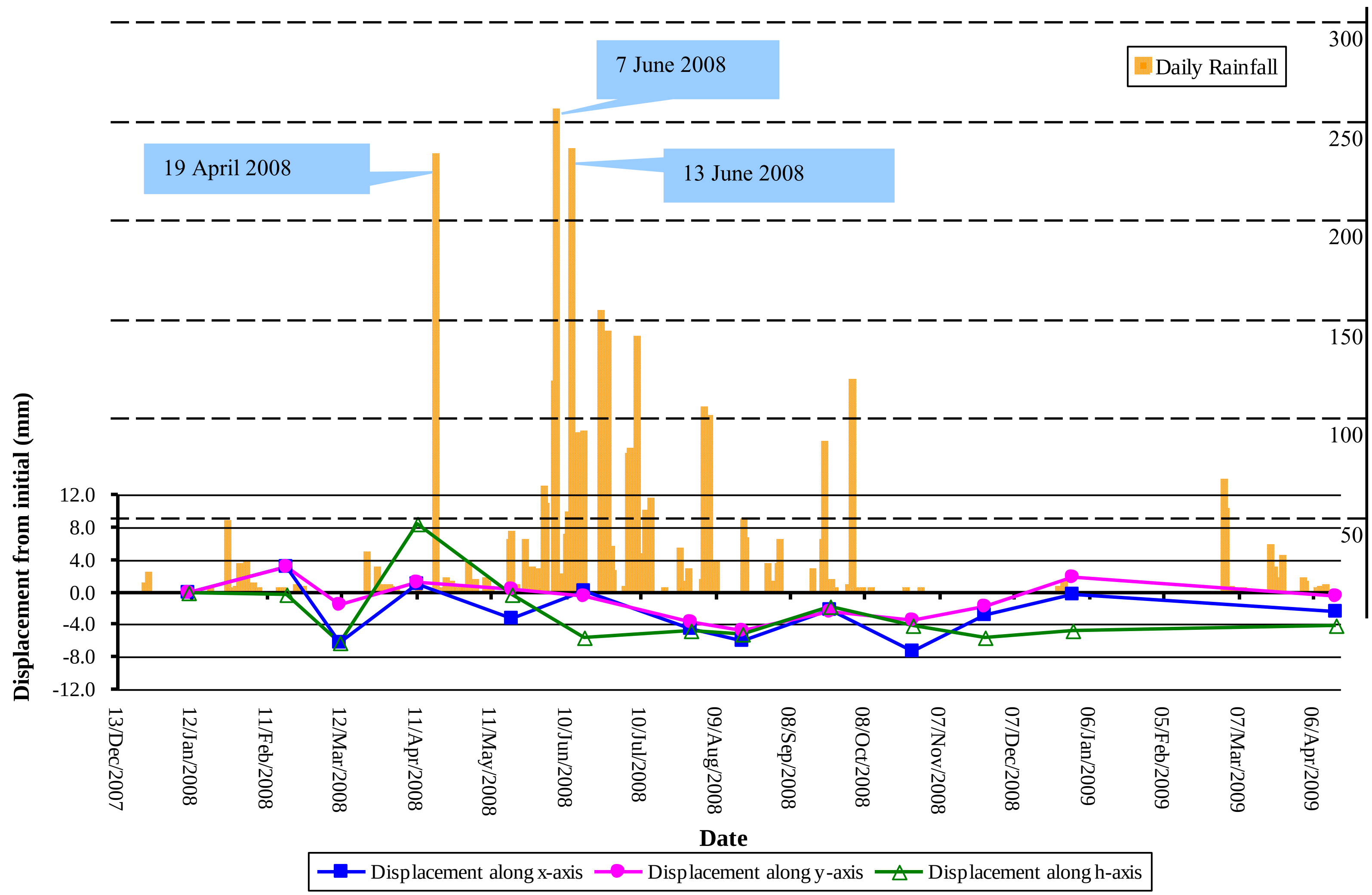

Note : See Figure C27 for direction of axes at Southern Hillside and Northern Hillside.

Figure C17 - Movement Monitoring Result of Station M17 with Daily Rainfall during the Monitoring Period

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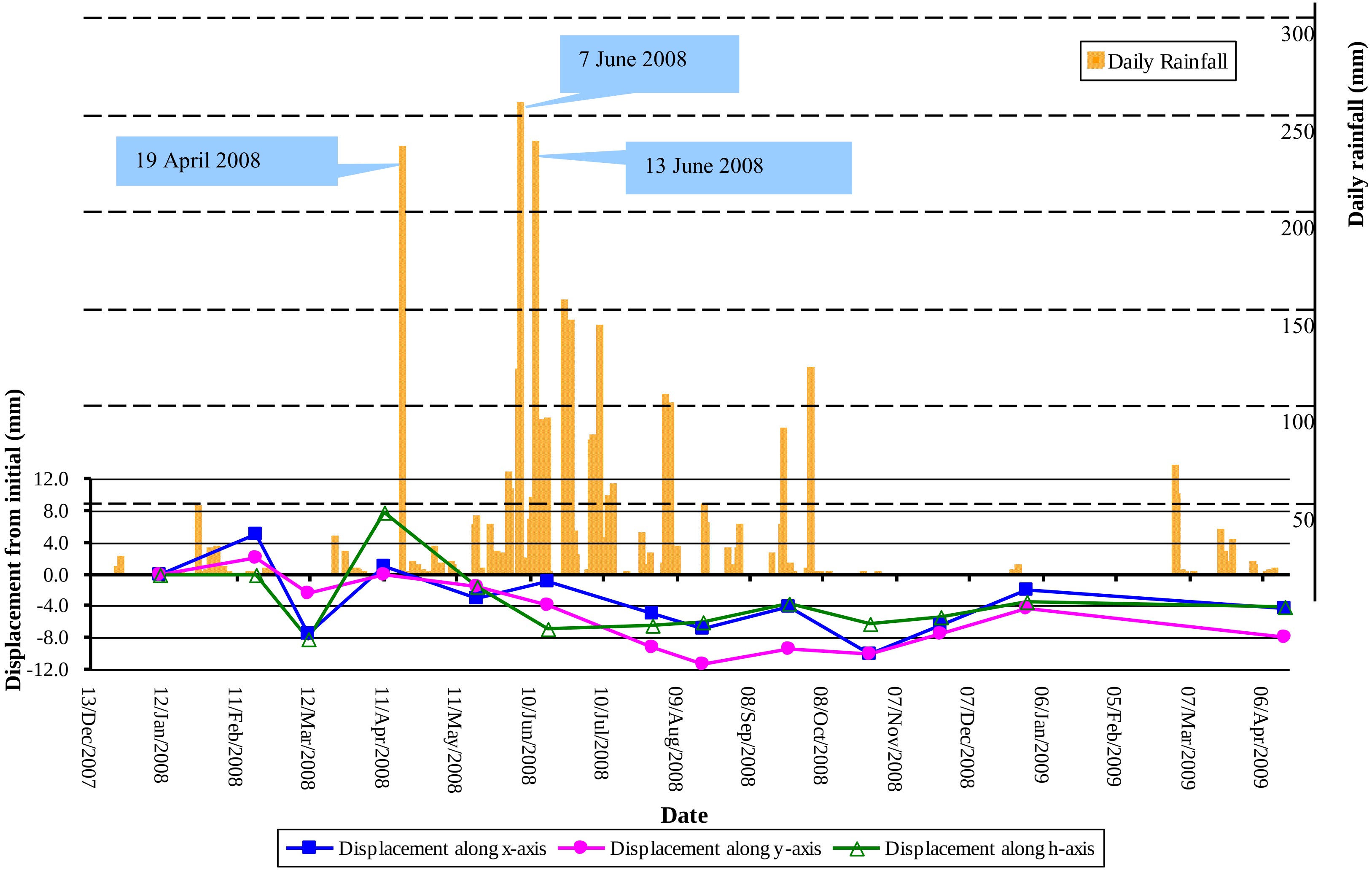

Note : See Figure C27 for direction of axes at Southern Hillside and Northern Hillside.

Figure C18 - Movement Monitoring Result of Station M18 with Daily Rainfall during the Monitoring Period

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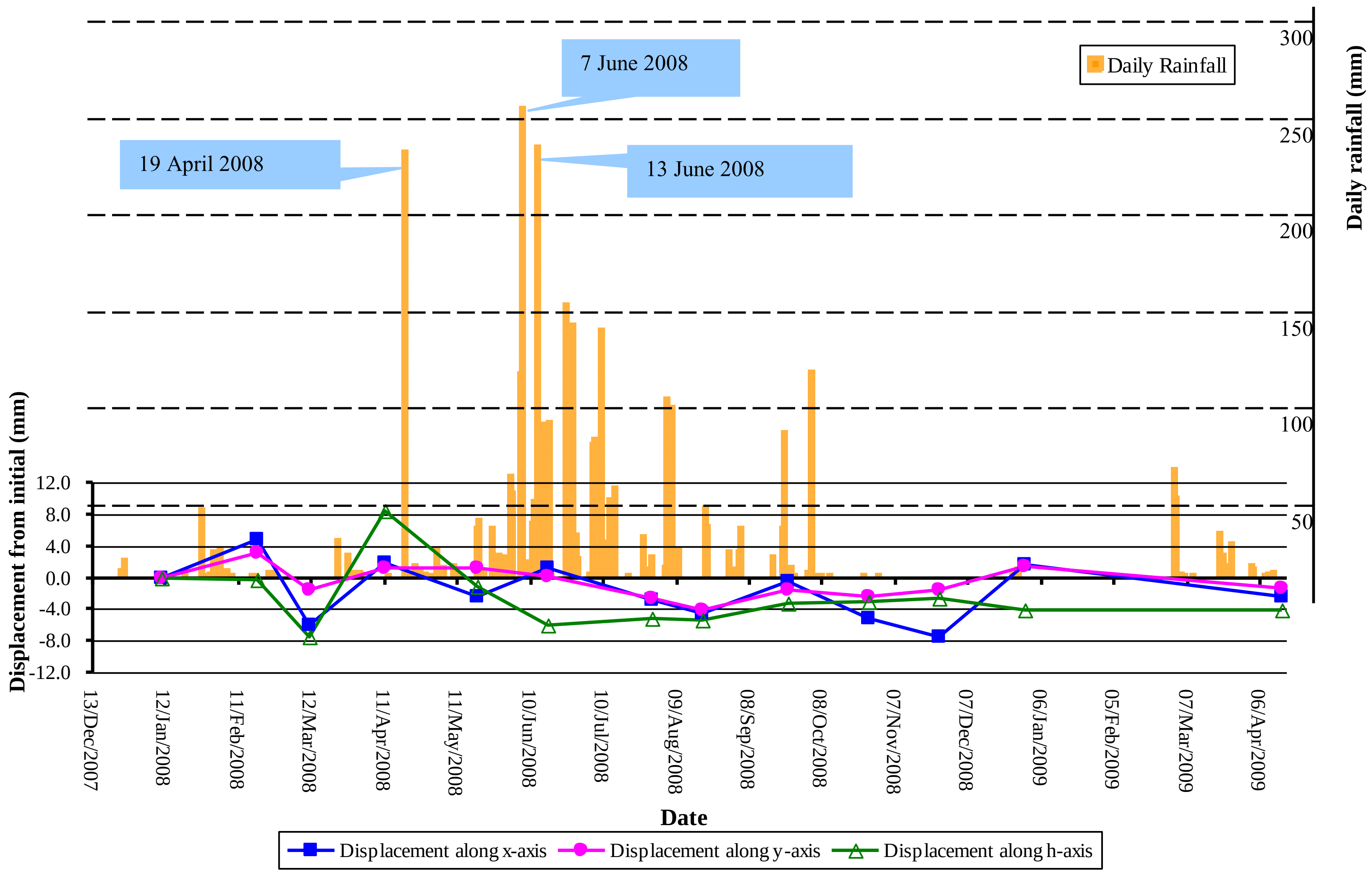

Note : See Figure C27 for direction of axes at Southern Hillside and Northern Hillside.

Figure C19 - Movement Monitoring Result of Station M19 with Daily Rainfall during the Monitoring Period

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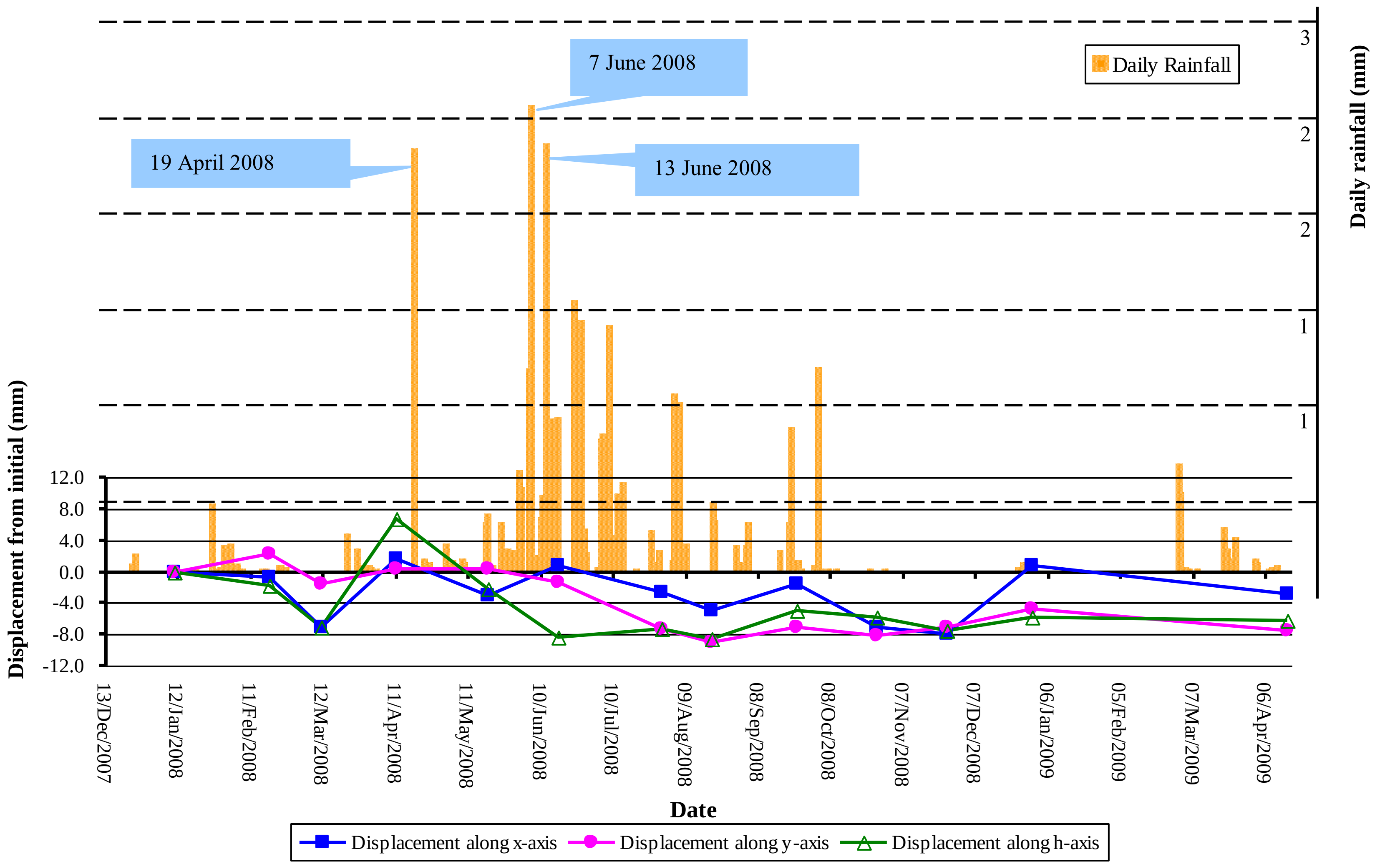

Note : See Figure C27 for direction of axes at Southern Hillside and Northern Hillside.

Figure C20 - Movement Monitoring Result of Station M20 with Daily Rainfall during the Monitoring Period

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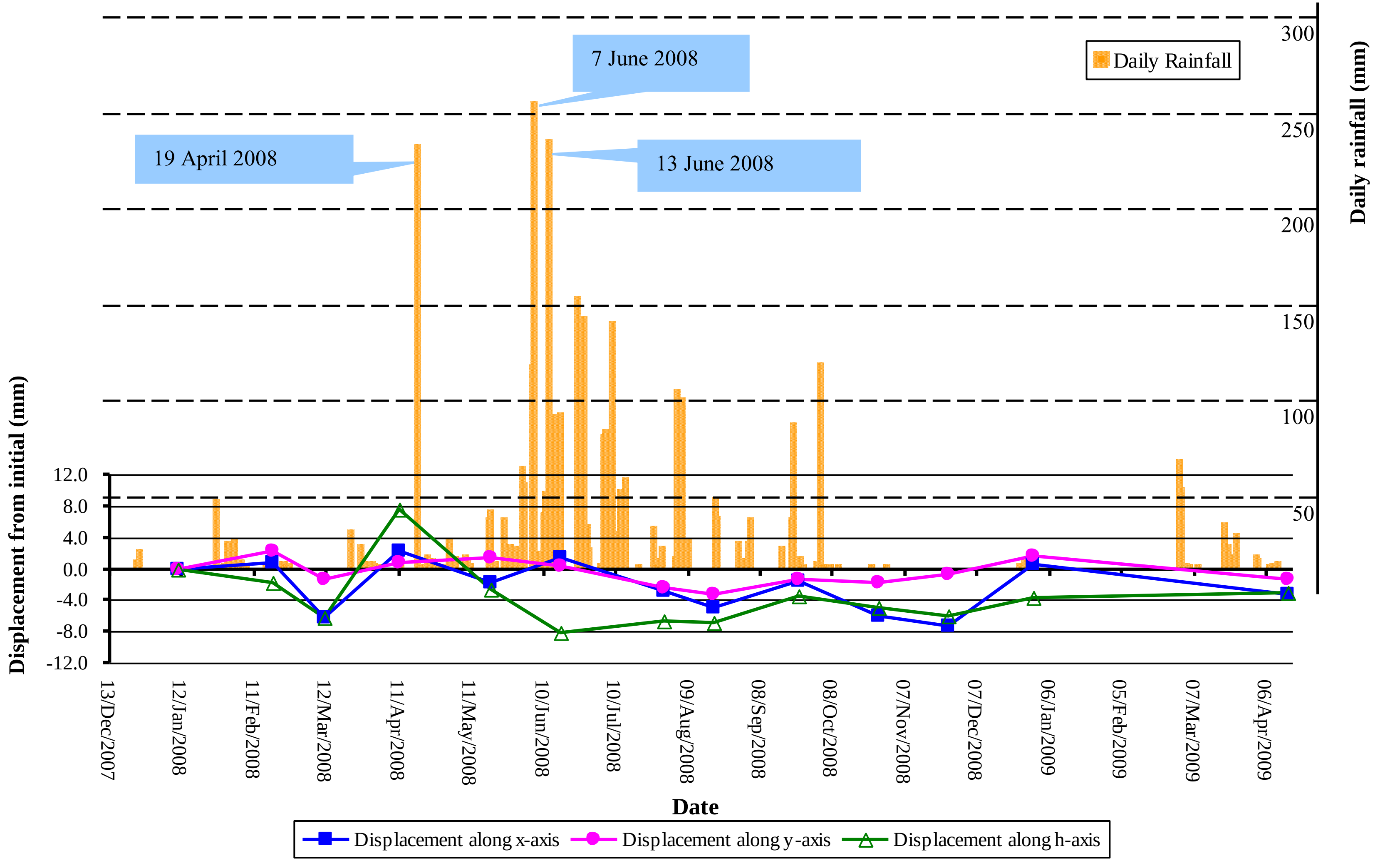

Note : See Figure C27 for direction of axes at Southern Hillside and Northern Hillside.

Figure C21 - Movement Monitoring Result of Station M21 with Daily Rainfall during the Monitoring Period

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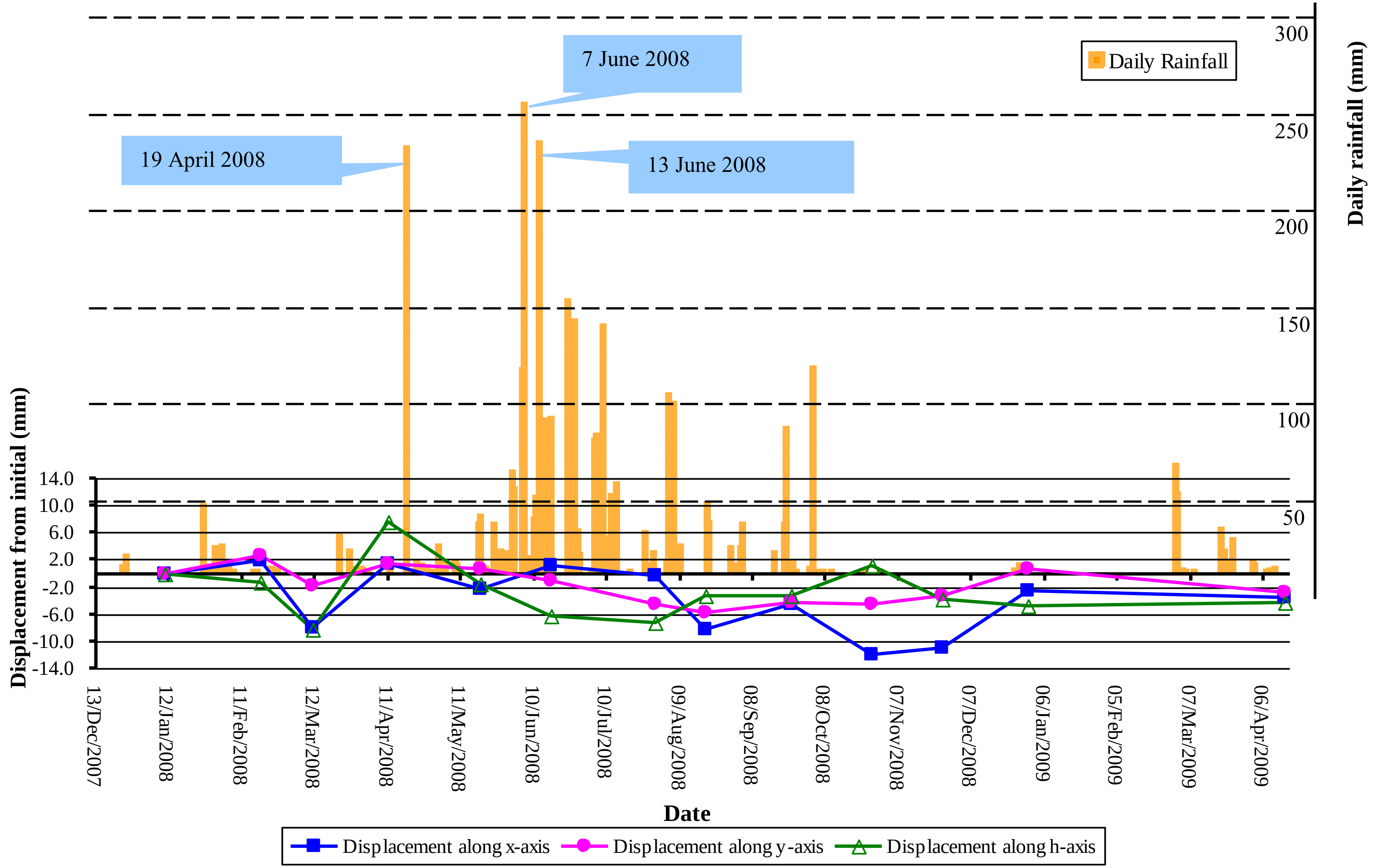

Note : See Figure C27 for direction of axes at Southern Hillside and Northern Hillside.

Figure C22 - Movement Monitoring Result of Station M22 with Daily Rainfall during the Monitoring Period

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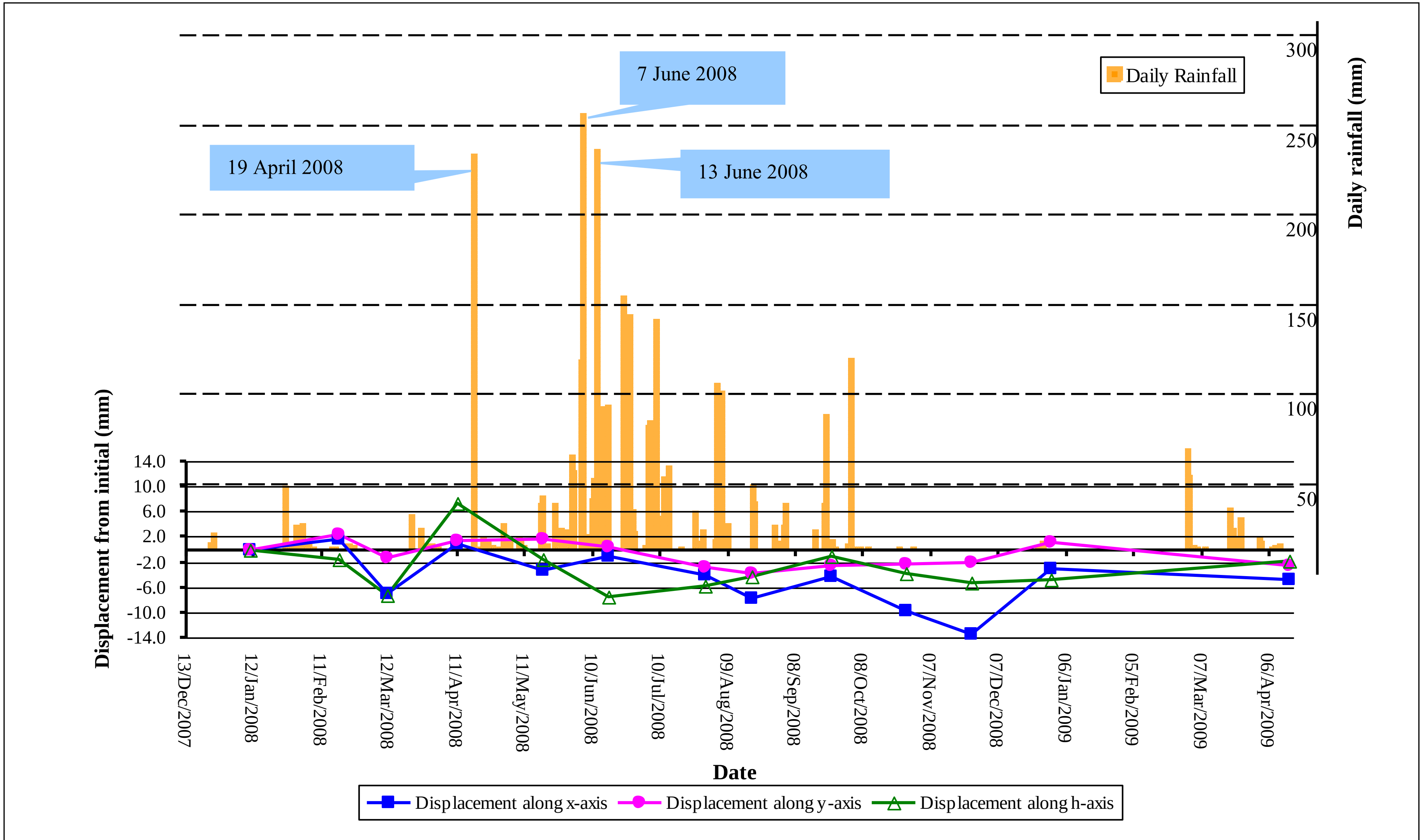

Note : See Figure C27 for direction of axes at Southern Hillside and Northern Hillside.

Figure C23 - Movement Monitoring Result of Station M23 with Daily Rainfall during the Monitoring Period

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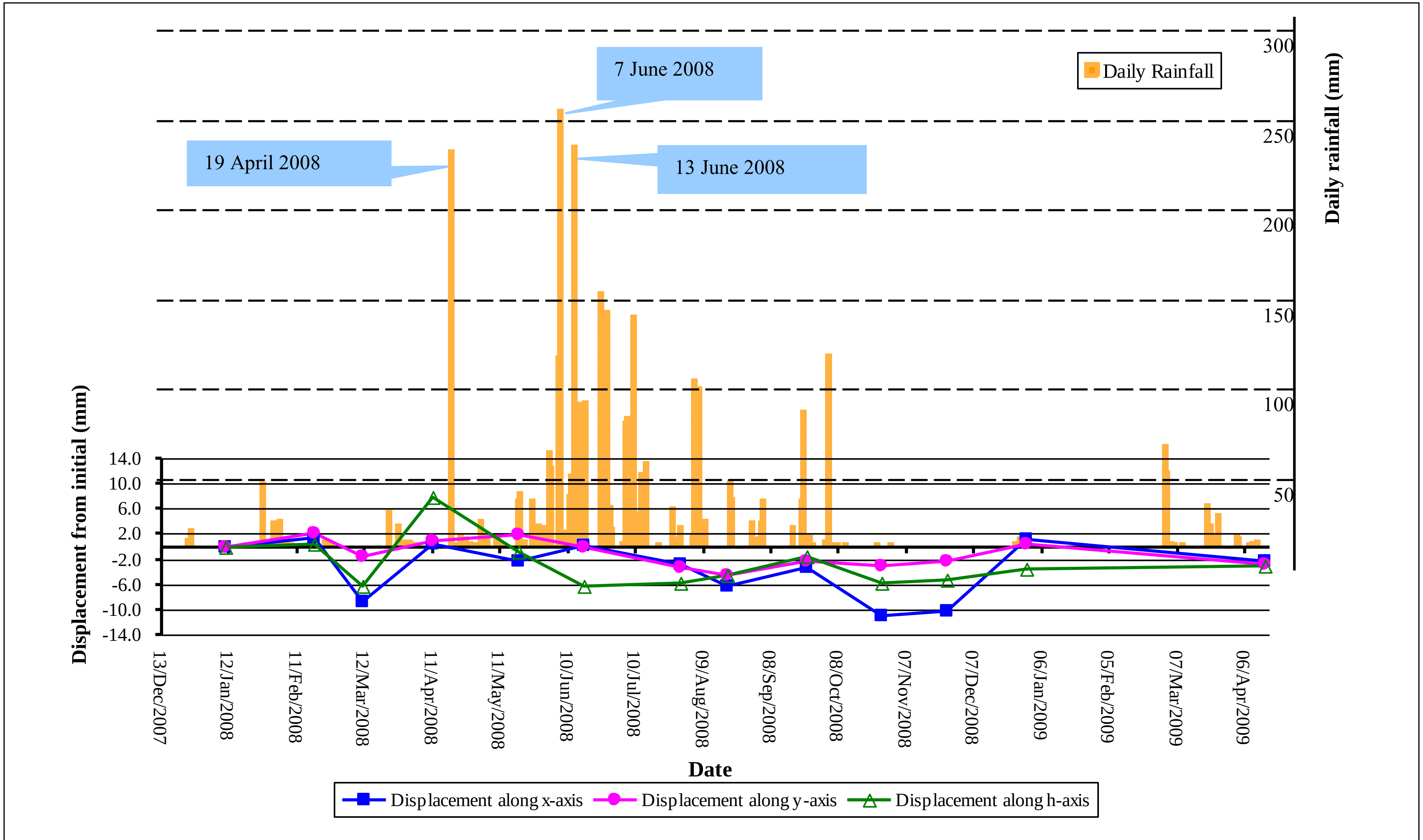

Note : See Figure C27 for direction of axes at Southern Hillside and Northern Hillside.

Figure C24 - Movement Monitoring Result of Station M24 with Daily Rainfall during the Monitoring Period

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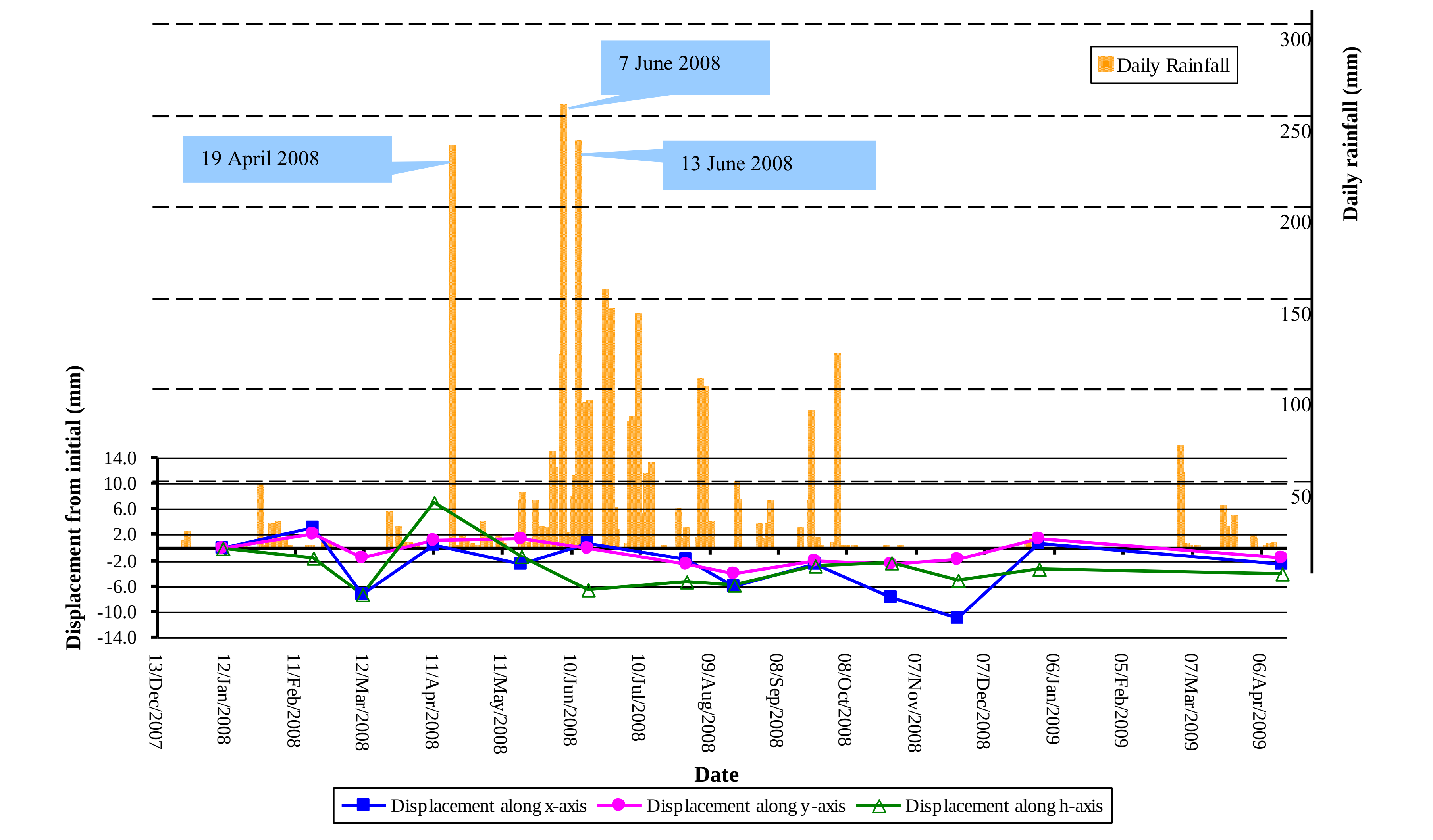

Note : See Figure C27 for direction of axes at Southern Hillside and Northern Hillside.

Figure C25 - Movement Monitoring Result of Station M25 with Daily Rainfall during the Monitoring Period

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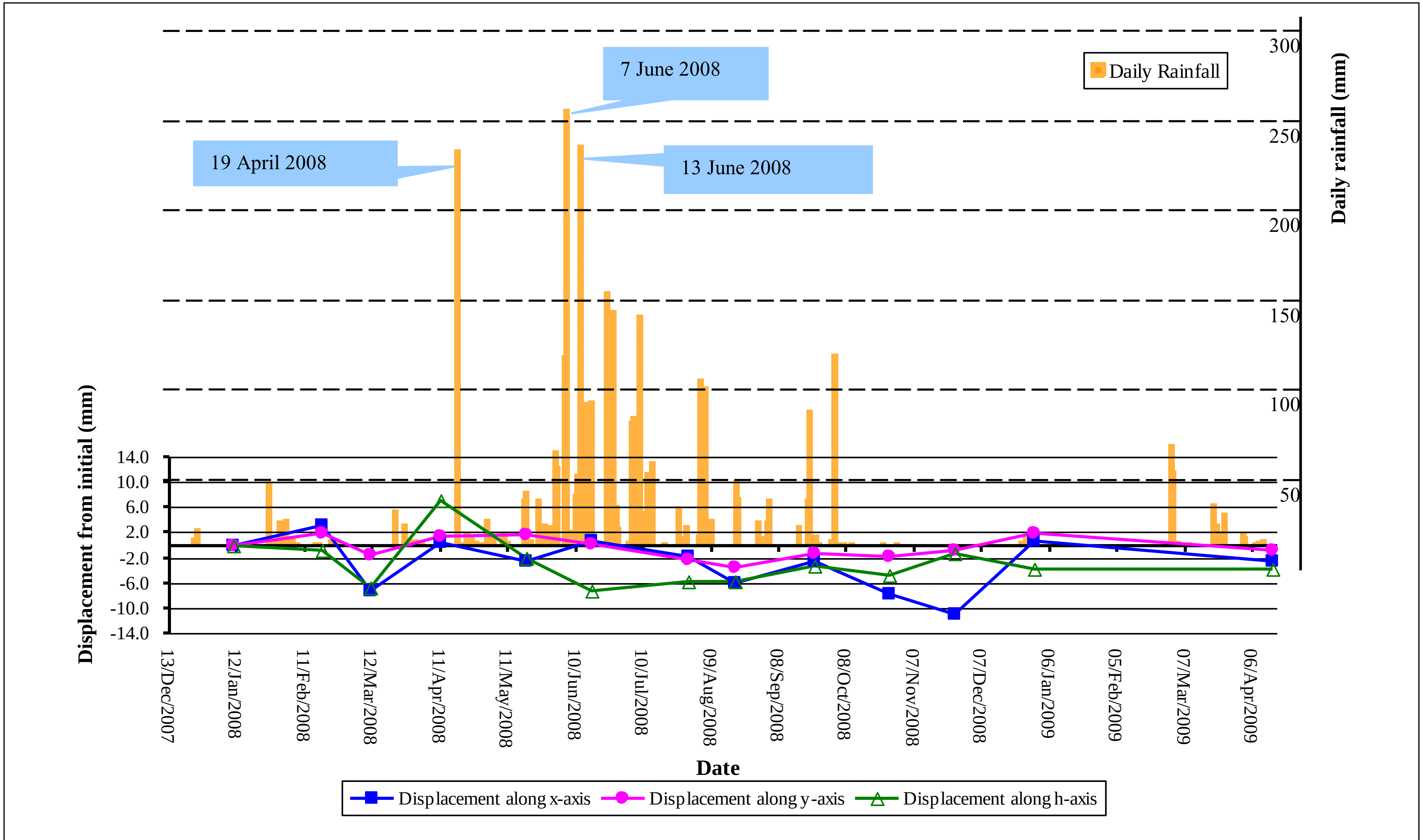

Note : See Figure C27 for direction of axes at Southern Hillside and Northern Hillside.

Figure C26 - Movement Monitoring Result of Station M26 with Daily Rainfall during the Monitoring Period

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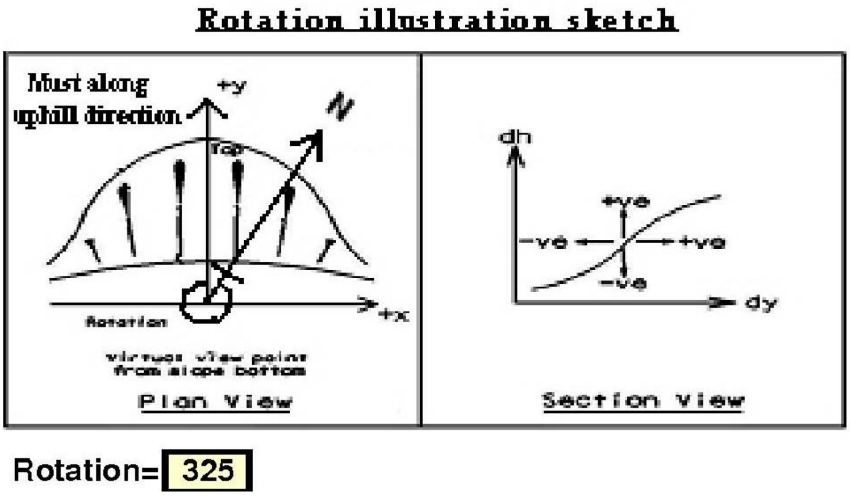
Direction of axes at Southern Hillside



Direction of axes at Northern Hillside

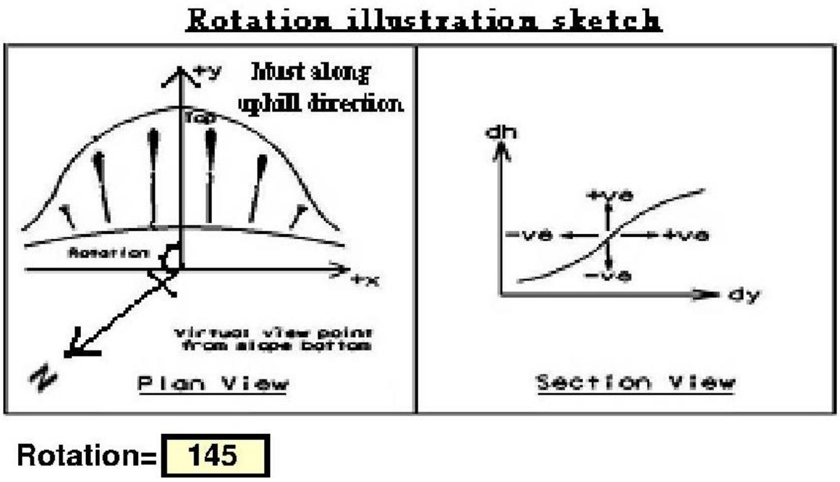


Figure C27 - Direction of axes at Northern hillside and Southern Hillside

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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.

部份土力工程處的主要刊物目錄刊載於下頁。而詳盡及最新的土力工程處刊物目錄，則登載於土木工程拓展署的互聯網網頁 http://www.cedd.gov.hk 的"刊物"版面之內。刊物的摘要及更新刊物內容的工程技術指引，亦可在這個網址找到。

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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