SECTION 2 : DETAILED STUDY OF THE LANDSLIDE AT THE OUTWARD BOUND SCHOOL ON 9 JUNE 1998

Fugro Scott Wilson Joint Venture

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FOREWORD

This report presents the findings of a detailed study of the landslide (GEO Incident No. ME 98/6/55) that occurred on the natural hillside adjacent to the Outward Bound School, Tai Mong Tsai, near Sai Kung in the Eastern New Territories on 9 June 1998. The landslide involved the failure of approximately 30 m of the natural hillside close to the main ridgeline of a coastal peninsula. The resulting debris, estimated at about 900 m^3 in volume, came within 20 m of a house at the foot of the hillside, with the subsequent alluvial outwash reaching the road and beach below. The house was uninhabited at the time of the landslide. No fatalities or injuries were reported following the landslide.

The key objectives of the detailed study were to document the facts about the landslide, present relevant background information and establish the probable causes of the failure. The scope of the study was generally limited to site reconnaissance, desk study and analysis. Recommendations for follow-up actions are reported separately.

The report was prepared as part of the 1998 Landslide Investigation Consultancy (LIC) for the Geotechnical Engineering Office (GEO), Civil Engineering Department (CED), under Agreement No. CE 74/97. This is one of a series of reports produced during the consultancy by Fugro Scott Wilson Joint Venture (FSW). The report was written by Mr G Taylor and reviewed by Mr Y C Koo. The assistance of the GEO in the preparation of the report is gratefully acknowledged.

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1. INTRODUCTION

At about 5:30 p.m. on 9 June 1998 during heavy rain, a landslide (GEO Incident No. ME 98/6/55) occurred on the natural hillside above the Outward Bound School, Tai Mong Tsai near Sai Kung in the Eastern New Territories (Figure 1 and Plate 1). The failure involved about 900 m^3 of material, and debris from the main body of the landslide came within 20 m of a dwelling known as the "Captain's House" at the toe of the hillside. The subsequent outwash from the event reached the crest area of the cut slope immediately behind this building, before entering an existing drainage line and continuing to a local access road and beach below. The house was unoccupied at the time of the incident. No fatalities or injuries were reported as a result of the landslide.

Following the landslide, Fugro Scott Wilson Joint Venture (the 1998 Landslide Investigation Consultants) carried out a detailed study of the failure for the Geotechnical Engineering Office (GEO), Civil Engineering Department (CED), under Agreement No. CE 74/97. This is one of a series of reports produced during the consultancy by Fugro Scott Wilson Joint Venture (FSW).

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

This report presents the findings of the detailed study, which comprised the following key tasks:

(a) desk study, including a review of relevant documentary records and old topographic maps relating to the history of the site,

(b) aerial photograph interpretation (API),

(c) interviews with concerned persons,

(d) topographic surveys, geomorphological and geological mapping, and detailed observations and measurements at the landslide site,

(e) limited ground investigation of the hillside together with laboratory testing of soil samples collected from the landslide site,

(f) analysis of rainfall data,

(g) engineering analyses of the hillside that failed, and

(h) diagnosis of the probable causes of failure.

2. THE SITE

2.1 Site Description

The Outward Bound School is located on a densely-vegetated hilly coastal peninsula to the south of the village of Tai Mong Tsai near Sai Kung in the Eastern New Territories (Figure 1 and Plate 1). The peninsula comprises a generally northwest-southeast trending main ridgeline with associated spur and valley profiles, approximately perpendicular to the ridgeline, on both its eastern and western flanks. It is confined to the east by an estuary, and to the south and west by the sea (Figure 2 and Plate 2).

The 9 June 1998 landslide occurred on the southwest-facing terrain of the peninsula within a depression flanked by two spurs, just below the main ridgeline and footpath, above and to the southeast of the Outward Bound School. The terrain of this part of the peninsula consists generally of moderately, locally steeply, sloping densely-vegetated natural hillside with gradients varying typically between 20° and 45°. Two dwellings, quarters for members of staff of the Outward Bound School, are situated towards the toe of the hillside, adjacent to a local access road. Of these dwellings, it is the two-storey building known as the "Captain's House" which the landslide debris came closest to impinging upon (within 20 m).

2.2 Geology

The Hong Kong Geological Survey's 1:20 000 scale map, Sheet 8 Sai Kung Solid and Superficial Geology, indicates that the site is underlain by sedimentary and volcanic rocks, mainly tuffaceous mudstone, siltstone and breccia, of the Mang Kung Uk Formation of the Repulse Bay Volcanic Group (Figure 3), which is Upper Jurassic to Lower Cretaceous in age (Geotechnical Control Office, 1989). Within the general vicinity of the 1998 landslide, bedding of these strata is indicated as being typically eastward-dipping at about 20°.

The accompanying geological memoir (GCO, 1990) notes the presence of eastward-dipping, well-bedded pale grey tuffite along the shoreline to the south of the Outward Bound School, at the tip of the peninsula. Additionally, a series of minor intraformational unconformities between the tuffite units is noted as being exposed between high and low water marks in this area.

The Engineering Geology Map from the Geotechnical Area Studies Programme (GASP) Report IX, East New Territories (GCO, 1988) indicates that a lithological boundary traverses the 1998 landslide scar. The upper half of the area affected by the recent landsliding is shown as comprising volcaniclastic rocks whilst the lower half is indicated as consisting of pyroclastic rocks. A similar bedding orientation to that noted above is indicated on this map for the volcaniclastic rocks. The information shown on this map is based on the earlier work of Allen & Stephens (1971).

In addition, a photogeological lineament, orientated approximately north-south across the upper part of the slope, was identified on the 1963 aerial photographs during the API which was carried out as part of the current study (Figure 4). This lineament appears to coincide approximately with the lithological boundary between the tuffaceous sedimentary unit and the pyroclastic rock unit shown on the GASP Engineering Geology Map. This photogeological lineament was observed again on the 1979 aerial photographs of the area. Additionally, two further lineaments, with the same general orientation to this lineament, were observed traversing the lower part of the hillside in both the 1979 and 1985 aerial photographs.

2.3 Services

As part of this investigation both Government and private utility providers were contacted for details of any services within the vicinity of the landslide site. The responses indicate that there are no utilities, in particular water-bearing services, located in the vicinity of the landslide scar.

2.4 Registered Slopes

The landslide scar is located wholly on unregistered hillside. However, there are two cut slopes, both approximately 3 m high and each with a chunam cover, located at the base of the hillside. Both slopes are associated with the site formation works for the adjacent houses. Only one of these slopes, No. 8SW-B/C98, has been registered (Figure 1).

2.5 Maintenance Responsibility

According to the District Lands Office, the landslide is located within Sai Kung West Country Park. Under this designation the failure occurred on unallocated Government land.

3. SITE HISTORY AND PREVIOUS STUDIES

3.1 General

The history of the site has been determined from an interpretation of a sequential series of aerial photographs (observations are summarised in Table 1, and Figures 4, 5 and 6), as well as a review of relevant available documentary information. Information sources consulted during this detailed study are summarised in Table 2. The key findings are presented in the following sections.

3.2 Site Development History

The API has concluded that the hillside within the vicinity of the 1998 landslide is essentially natural and, apart from the formation of the ridgeline footpath and some graves at the toes of the depressions which flank the ridge, devoid of human influence. The ridgeline footpath adjacent to the 1998 landslide site was first noted on the 1945 aerial photographs.

Development commencing in the late 1960's/early 1970's has, however, taken place at the toe of the concerned hillside. The Outward Bound School facilities, including one of the single-storey buildings near the toe of the failure (which serves as quarters for members of staff) were constructed during this period. The adjacent "Captain's House" was built soon after, during the early 1980's.

Between 1985 and 1993 development, comprising the construction of two three-storey villas, took place to the south of the 1998 landslide site (Figure 5).

Although vegetation clearance has been noted at the base of the hillside adjacent to the 1998 landslide from the 1979 aerial photographs, no documentary evidence has been found of either controlled or uncontrolled burning of the hillside. This is supported by discussions with staff at The Outward Bound School.

The vegetation covering the hillside is noted as generally becoming denser with the passage of time.

3.3 Previous Studies

The GCO's (GCO renamed GEO in 1991) GASP Report IX, East New Territories (GCO, 1988), produced at a scale of 1:20 000 for regional appraisal and outline and strategic planning purposes, designated the 1998 landslide site and the adjacent area as a zone of "general instability", associated predominantly with insitu terrain, which "provides an indication of the inherent weakness of the terrain and/or the occurrence of unfavourable groundwater conditions". The slopes on the other side of the ridgeline were also designated in this report as a zone of "general instability" associated with predominantly insitu terrain.

The 1:20 000 scale Terrain Classification Map shows the main ridgeline to comprise a 15° to 30° sloping hill crest with no appreciable signs of erosion. The corresponding southwest-facing terrain is classified as having concave side slopes of 30° to 40° attitude, which exhibit signs of relict instability. The northeast-facing terrain on the opposite side of the ridge is also classified as an area, which exhibits signs of relict instability, with side slopes of between 30° and 40° in attitude.

3.4 Past Landslides

A depression flanked by two spurs which is interpreted as a possible relict landslide scar(s), and in which the majority of the 1998 landslide is situated, is evident on the 1924 aerial photograph. It is well-defined on the later 1945 and 1963 aerial photographs (Figure 6). The depression could have been formed by more than one event.

In addition, possible instability on the northern fringe of the area affected by the 1998 landslide was also noted on the 1924 photograph of the peninsula. The location corresponds approximately to the area of tension cracking observed during FSW's post-landslide field mapping in July 1998 (see Figure 7 and Section 4).

A small erosion scar was also noted at the toe of the hillside, to the rear of the house (built between 1968 and 1978), and to the south of the northern spur (of the depression), on the 1979 aerial photographs, whilst a further local erosion scar, located within the drainage line below the northern spur, was recorded on the 1985 photographs. Another local erosion scar was observed, in a similar location to that noted in 1985, on the 1994 aerial photographs (Figure 6).

The Natural Terrain Landslide Inventory (NTLI), compiled by the GEO from the interpretation of high-level aerial photographs dating from 1945 to 1994, has identified numerous relict landslide scars on both sides of the peninsula, see Figure 2 (Evans et al, 1997, and King, 1997). The majority of these scars are located on the opposite side of the ridge to the 1998 landslide. The crowns of the landslides on the northeast-facing slopes are located generally about mid-slope and, according to the Engineering Geology Map from the GASP report, appear to have occurred within the volcaniclastic strata (GCO, 1988). In addition, four relict landslide scars have been identified on the western flank of the ridge, between about 80 m and 180 m to the south of the 1998 event, suggesting the possibility of past large-scale failures on the southwest-facing slopes. These relict landslides appear to be located generally within the upper (volcaniclastic) slopes, but with their heads below that of the 1998 landslide.

The detailed API carried out as part of this study has generally confirmed the NTLI information. However, the possible relict landslide scar within which the 1998 landslide is located was not identified by the NTLI.

4. DESCRIPTION OF THE LANDSLIDE

4.1 General

An oblique photograph of the landslide is shown in Plate 2. A plan and a cross-section through the landslide site are given in Figures 7 and 8 respectively. The locations of the various features referred to in this Section are shown in Figure 7.

The 1998 landslide was located within a concave depression between two spurs on the western flank of the main ridgeline of a coastal peninsula at Tai Mong Tsai and involved about 900 m^3 of material.

4.2 Observations Made Prior to the Landslide

There were no eye-witnesses to the landslide and therefore it is not possible to make any observations regarding the condition of the hillside shortly before failure.

4.3 Description of the Landslide

The landslide scar was first noted by a member of staff of the Outward Bound School shortly after 5:30 p.m. on 9 June 1998. At about 9:00 a.m. the following morning the housekeeper of the "Captain's House" inspected the building for damage and none was noted. The landslide was subsequently reported to the GEO at about 10:30 a.m. on 10 June 1998. A representative of the Mainland East Division of the GEO subsequently visited the site during the early part of that afternoon.

The first inspection of the landslide site by FSW was made during the afternoon of 11 June 1998. Unfortunately, a comprehensive inspection was not possible at that time. The immediate vicinity was very densely-vegetated, making access to the site difficult (Plates 1 and 2). Additionally, the saturated nature of the debris made the landslide scar potentially dangerous to traverse. Much surface water flow as well as erosion channels were also evident within the landslide debris at this time, some 48 hours after the event.

The "Captain's House" had, with the exception of the daily visits by the housekeeper, been unoccupied for some time preceding the landslide. The adjacent dwelling, however, had been occupied on the day the landslide took place. The member of staff of the Outward Bound School who first observed the landslide scar, the housekeeper of the "Captain's House" and the occupants of the adjacent dwelling, have all been interviewed by FSW. Unfortunately, they could not provide any significant information regarding the failure.

The next inspection by FSW, following vegetation clearance (Plate 2), was almost two weeks later on 24 June 1998. Surface water flow was still evident at this time. Water was again observed issuing from the landslide debris both within the main drainage lines and, to a lesser extent, over the small spur-type feature (Plates 3 and 4). The debris was generally soft to firm throughout the landslide scar during this inspection, and great care had still to be exercised when traversing many areas.

The landslide scar was observed to consist of several distinct areas possibly corresponding to different phases of landsliding. Two main backscarps (termed "upper" and "lower") were identified, as were zones of depletion and accumulation (Figures 7 and 8, and Plates 5, 6 and 7). The upper backscarp, which corresponds to the main area of failure, was located immediately below the main ridgeline of the peninsula, trending approximately parallel to it and was about 30 m in length and typically between 2 and 3 m high.

A feature of the upper backscarp was the presence of the remnants of a small thin ridge-type feature (Plates 2 and 8), which effectively divided the upper backscarp into southern and northern portions. This feature was also clearly identified on the 1945 and 1963 aerial photographs (Figure 6). Tuff-derived residual soil, was exposed in the southern portion of this backscarp and formed a "spoon-shaped" surface of rupture. This zone was bounded on both sides by slightly to moderately decomposed volcaniclastic rocks. Probable erosion pipes, typically 5 mm in diameter, were recorded in this part of the upper backscarp. A larger possible erosion pipe, approximately 50 mm in diameter, was also observed in this area (Plates 9 and 10). To the southwest of this portion of the upper backscarp, and directly above the lower backscarp, a tension crack with a vertical displacement of between 0.5 m and 1 m and typically 0.2 m wide was noted. This feature extended to the adjacent north-facing slopes of the southern spur to the depression. Some short linear depressions, typically about 2 m in length and 0.2 m in depth were also evident on these north-facing slopes during FSW's field mapping.

The northern portion of the upper backscarp was generally sub-vertical, ranging generally from 2 to 3 m in height, and comprising moderately decomposed volcaniclastic rock overlying highly to completely decomposed pyroclastic rocks.

On the northern periphery of the landslide scar, at the junction between the upper backscarp and the south-facing slopes of the depression, an area of tension cracking was noted (Figure 7 and Plate 11). The cracks were typically 0.6 m in depth and 0.2 m wide with a corresponding vertical displacement of the order of 0.3 m. Some of the tension cracking had resulted in the formation of discrete rafts of intact material, which moved downslope a distance typically between about 1 m and 2 m during the 1998 landslide.

A small erosion scar in a similar location to those identified on the 1985 and 1994 aerial photographs (within the drainage line below the northern spur), was also observed in the field during FSW's field mapping (Plate 7). The scar was approximately 3 m long with a vertical displacement of about 0.2 m.

Inspection of the slopes between the upper backscarp and the main ridgeline footpath above, and those of the northern and southern spurs, revealed generally hummocky ground.

Saturated remoulded debris, with many generally rectangular sub-angular to sub-rounded rock blocks of maximum dimension of about 0.3 m, was observed in the gently-sloping area below the upper backscarp and directly above a small spur-type feature located in the centre of the depression (Plates 7 and 8). The failed material, which covered the small spur-type feature also consisted predominantly of cobble and boulder-sized blocks of rock (tuffite) in a saturated remoulded matrix of yellowish brown sandy silt. The depth of these deposits varied typically between 0.5 m and 1 m. Numerous erosion channels were noted within this landslide debris.

A notable feature of the landslide scar was the tendency for the main zone of accumulation (below the small spur-type feature) to consist of a number of discrete rafts of relatively intact material deposited on a bed of remoulded debris and rock blocks. These rafts were typically between 0.5 m and 1 m thick and held together by vegetation (Figure 7 and Plate 12).

The main part of the lower backscarp was about 15 m wide and 6 m high (maximum) with slope angles typically between 35° and 50°. The remainder of the backscarp was typically 1 m high and extended in a generally westward direction, for a further 10 m to 15 m (Figure 7). The depth of the lower landslide was of the order of 1 m. Moderately to highly decomposed volcaniclastic rock was exposed in the upper portion of the backscarp. The volcaniclastic rock is underlain by highly to completely decomposed tuff. Possible columnar jointing was observed in the highly decomposed tuff.

The material, which was displaced as part of this lower translational failure, comprised essentially rafts of intact material about 1 m thick. The remoulded landslide debris, which was evident in the upper landsliding, was largely absent, possibly because less weathered material and water were involved in the failure. The remoulded debris present was located on the tops of the rafts. The "clean break" evident between this material and the edges of the rafts suggests that the debris had been deposited before the rafts were displaced. The rafts of material from the lower failure also appear to have been far less mobile than the corresponding rafts associated with the upper, main phase of landsliding. Additionally, at the junction delineating the lower landslide debris from the material released during the main phase of landsliding, possible localised scouring, maximum dimension about 0.25 m, was observed (at the base of the rafts).

Following the landslides fine-grained material, essentially a sandy silt, was "washed down" the slope by continuing rainfall. This material was channelled into the existing drainage line towards the centre of the depression before "outfalling" to the local access road and beach below, forming a plume of sediment in the sea.

The travel angle of the landslide debris, determined after Wong & Ho (1996a) and ignoring the subsequent outwash, was approximately 27°. For the volume involved this is towards the lower end of the typical values, which have been recorded in Hong Kong indicating a relatively mobile failure.

The trees and shrubs, which covered the slopes at this site, apparently offered little resistance to landsliding and debris movement. On inspection of the landslide backscarp, major root penetration generally appeared to be limited to about the upper half metre below the ground surface and corresponding to the incidence of some of the erosion pipes.

4.4 Consequences of the Landslide

Following the landslide, and at the recommendation of the GEO, the "Captain's House" was temporarily evacuated from 10 June 1998 until early December 1998. In addition, the residents of the adjacent dwelling were warned of the possible danger of landsliding on the natural hillside above, particularly during heavy rainfall.

Emergency remedial works, comprising the removal of landslide debris and trimming back the failed area to a flatter gradient as well as the provision of a shotcrete surface protection layer with weepholes and drainage channels, were completed by the Highways Department in early October 1998, based on the GEO's advice.

5. GEOMORPHOLOGY, GEOLOGY AND HYDROGEOLOGY OF THE LANDSLIDE SITE

5.1 General

The ground conditions at the site were determined using information obtained from both desk and field studies. The desk studies included a review of the available documentation supplemented by API, whilst the field studies included the results of detailed post-failure geomorphological and geological mapping as well as limited ground investigation.

Initial field mapping of the landslide site was carried out by FSW in July 1998. Further field mapping was undertaken during September 1998 following additional vegetation clearance. Contemporaneously, four trial pits, located within the landslide scar, were dug by FSW. Additionally, bulk disturbed soil samples were collected from various locations along the landslide debris trail. Classification and index tests were subsequently performed on these samples at the Public Works Central Laboratory to determine the composition and nature of the material. The test results are summarised in Table 3 whilst the trial pit logs prepared by FSW are included as Appendix A.

The landslide debris remained in place during the course of the fieldwork. Removal of debris, as part of the urgent repair works, was not carried out until late September/early October 1998.

5.2 Geomorphology

The geomorphology of this part of the Eastern New Territories is a reflection of the complex Quaternary history of the area. Erosional and depositional periods, associated with climatic changes and eustatic sea level fluctuations, have resulted in the formation of mountainous, lowland, colluvial and alluvial terrain. The landslide under consideration in this study occurred within the upper part of a coastal slope on a hilly peninsula.

The peninsula comprises a generally northwest-southeast trending main ridgeline with associated spur and valley features on both flanks. The western flank, in particular, is characterised by a series of depressions, each representing an individual catchment area, separated by spurs dipping towards the coastline. The main geomorphological features of these southwest-facing slopes of the peninsula, as presented in Figure 4, have been interpreted largely from the 1963 aerial photographs, when vegetation cover was generally sparse. Detailed geomorphological observations concerning the landslide site and the immediate vicinity, as discussed below, are presented in Figures 5 and 6.

The area affected by the recent landslide is part of a concave topographical depression between two spurs on the western flank of the main ridgeline. This feature is interpreted as a possible relict landslide scar which was well-defined in the 1945 and 1963 aerial photographs, as indicated by a convex break of slope along the southern spur, which extended northwards, becoming approximately parallel to the main ridgeline before joining the adjacent northern spur (Figure 6). The slopes dipping into the depression from the southern spur are inclined at a steeper angle than those from the northern spur.

A small spur-type feature has been identified in the upper half of the depression from both API and subsequent field inspection (Sections 3.3 and 4.3). This feature is bounded to both the north and south by what appear to be ephemeral drainage lines. The drainage line to the north appears to coincide approximately with the northern extent of the scar produced by the recent landsliding. These drainage lines merge at the base of the small spur-type feature, approximately one third of the way between the main ridgeline and the coast. The drainage line thus formed roughly follows a line between the centre and the southern edge of the depression to the coast.

Prior to the recent failure the area between the small spur-type feature and the main ridgeline above appears to have comprised a series of subtle hollows and small ridges, approximately perpendicular to the main ridgeline, defined to the west by a slight concave break of slope above the spur-type feature. The small drainage lines within these hollows generally converged on the drainage line which bounds the small spur-type feature in the north, indicating a general northwestwards fall across the upper portion of the depression (Figure 6).

The lower part of the depression below the small spur-type feature comprises gently undulating, hummocky ground, suggesting the presence of colluvial deposits in this area, which is corroborated by post-failure ground investigation and site observations (Section 5.3).

Depressions are also evident on the remainder of the western flank of the main ridgeline to both the north and south of the 1998 landslide site, as well as on the corresponding eastern flank. These spur and valley profiles typically trend normal to the ridgeline of the peninsula although local variations, which possibly reflect a change in the underlying geology, are also evident. In addition, the majority of the relict landslide scars identified in the NTLI are located on the opposite side of the ridge to the 1998 landslide (Figure 2) and it is uncertain as to whether the geological constraints prevalent on this side of the ridge are similar to those at the 1998 landslide site.

The two broad depressions identified some 135 m and 240 m to the northwest of the landslide site respectively (Figure 4), and the convex breaks of slope which mark their upper boundaries, do not appear to be the result of relict landsliding. The first depression, located immediately to the northwest of the Outward Bound School, is characterised by rounded, gently-inclined valleys, exhibiting no signs of active erosion, nor comprising any hummocky ground. Consequently, this landform is considered to be "mature" with regard to denudation. The access road to the north of the Outward Bound School traverses the second depression. In contrast to the first depression, this depression is characterised by incised gullies suggesting active erosion and denudation.

5.3 Geological Mapping

The geological features mapped at the site by FSW following the landslide, together with the locations of the trial pits excavated during this fieldwork, are shown on the geological map of the landslide area (Figure 9). Sections showing the postulated stratigraphy at various locations throughout the landslide site are shown in Figures 10, 11, 12 and 13.

The general geology at the landslide site comprises weathered pyroclastic rock overlain unconformably by less weathered volcaniclastic rock, and colluvium. These findings are broadly consistent with the published geology for the area. The weathered pyroclastic rock was encountered as completely decomposed coarse ash tuff and residual soil whilst the less weathered volcaniclastic rock, tuffite, was found to consist of interbedded shale and fine- to coarse-grained tuffaceous sedimentary rocks (i.e. siltstones, fine- to coarse-grained sandstones and breccias). The colluvium comprised generally angular cobbles and boulders of highly to completely decomposed tuffite in a clayey, sandy silt matrix.

A notable feature of the geology of the landslide site is the presence of faults traversing the slope. In particular, a sub-vertical fault plane was encountered within the southern portion of the upper backscarp bounding the southern periphery of a band of tuff-derived residual soil, approximately 3 m wide (Figure 9). Geological interpretation of the site indicates that this band of tuff-derived residual soil is also bounded to the north by a fault plane. However, only the southern fault plane has been positively identified on site during field mapping. From measurements taken at the southern boundary of the fault zone the fault planes appear to have an essentially sub-vertical dip. The corresponding northwest-southeast strike-slip movement has been inferred from the relative displacement of the volcaniclastic-pyroclastic lithological boundary on either side of the fault zone. This displacement is estimated to be approximately 13 m. This boundary and the associated fault zone are illustrated on Plates 13 and 14.

Similar movement, although less severe, estimated at approximately 1 m, has also been inferred from the relative displacement of the tuffite on either side of slickensided surfaces identified on what is considered to be a fault plane outcropping within the northern portion of the upper backscarp (Figure 9). This slickensided surface is shown in Plate 15 whilst a general view of the fault plane is given in Plate 16. In this case, however, the fault is not associated with a band of residual soil, the strike is westnorthwest-eastsoutheast and the fault plane is "capped" by beds of shale to shaley siltstone, dipping gently towards the southeast. These shaley deposits eventually grade upwards into medium-grained tuffites. Within the fault zone to the south the shaley capping is generally absent and more highly weathered on the boundaries of the adjacent fault planes. The orientation of the observed faults is in general agreement with the corresponding regional pattern of strike-slip movement.

Completely decomposed tuff underlies the tuffite in both the upper and lower landslide backscarps, and was also identified below colluvium in Trial Pit No. 3, which was excavated adjacent to the northern drainage line bounding the small spur-type feature. The tuff was typically encountered as a stiff, orange brown and grey brown speckled white (kaolinite), clayey sandy silt. Erosion pipes up to 50 mm in diameter were encountered in the completely decomposed tuff and residual soil of the backscarps (Plates 9 and 10).

The tuffite, which generally forms the upper 1 to 2 m of both the upper and lower backscarps, is distinctly less weathered than the underlying tuff. The fine- to coarse-grained tuffites (i.e. siltstones, and fine- to coarse-grained sandstones) located immediately above the tuff in the upper backscarp, and forming a large proportion of the lower backscarp, were logged as moderately to highly decomposed whereas the overlying, finer-grained tuffite (shale) was logged predominantly as slightly to moderately decomposed. Bedding planes in the tuffites are moderately inclined, 24° to 30°, towards the northeast in the upper backscarp, and towards the east in the lower backscarp. In the latter area, the bedding in the fine- to coarse-grained tuffite is less conspicuous than in the outcrops below the main ridgeline. Medium-grained tuffite was encountered below recent landslide debris in Trial Pit No. 1, on the top of the small spur-type feature.

The tuffites are pervasively jointed. Two medium to high persistence, closely to medium spaced, moderately to very narrow, smooth and stepped, and moderately steep to steep (48° to 83°) joint sets, dipping in west to west-northwest, and north-northeast directions are dominant. Below the main ridgeline these open joints, illustrated on Plates 17 and 18, are typically infilled with roots and clayey silt. Ill-defined layering, suggesting that some of this infill material may have been water-borne and prevalent for some time, was evident. The joint set which acted as the sliding plane for the lower translational landslide was mapped on site as having a dip of 52° and dipping in a generally westwards direction. The joint planes for the upper and lower backscarps are illustrated in Plates 19 and 20 respectively.

Colluvium was identified at the toe of the cut slope adjacent to the "Captain's House", and below the recent landslide debris in three of the four trial pits excavated during the ground investigation carried out as part of this study. It was absent in Trial Pit No. 1. The colluvium generally comprised medium dense, angular cobbles and occasional boulders of highly to completely decomposed tuffite, in a matrix of yellowish brown clayey sandy silt. In Trial Pit Nos. 2 and 4, the colluvium was overlain by an irregular layer of moist, soft to firm grey very silty, slightly sandy, organic clay with abundant roots. This layer is thought to be the remnants of the original topsoil layer, which formed the ground surface prior to the deposition of the recent landslide debris. A small portion of this topsoil layer was identified above the colluvium in Trial Pit No. 3, which was located at the current ground surface, following erosion of the recent landslide debris from that portion of the slope.

5.4 Hydrogeology

5.4.1 General

The hydrogeological conditions at the site were assessed from observations made during initial post-landslide site inspections and subsequent fieldwork, API and a review of the available groundwater monitoring records. Although the catchment is relatively small the hydrogeological regime at the site is likely to be very complex as a result of the particular local geomorphological and geological features observed, and in particular the fault zone traversing the slope. This will result in non-uniform and highly variable ground water pressure distributions.

5.4.2 Groundwater Conditions

There is evidence to suggest that the geological conditions at the site have a major influence on the groundwater conditions. The fault zone is liable to concentrate subsurface water flow as suggested by the nature of the material within this zone (tuff-derived residual soil).

Additionally, the hydraulic conductivity of the decomposed tuff is likely to be influenced by erosion pipes observed in both the upper and lower backscarps. These features were typically 5 mm in diameter, although possible pipes up to 50 mm in diameter were also noted (Plates 9 and 10). They may have been formed by either root action or bioturbation or a combination of both processes.

Overlying the tuff along the upper backscarp, the volcaniclastic rocks (tuffite) are less weathered and close to the ground surface the tuffite (shale) is closely jointed, suggesting a relatively high mass permeability. Furthermore, the sub-vertical joints mapped in the tuffite are predominantly open, and where present, clayey silt infilling shows signs of having been reworked and eroded. The open nature of the joints is illustrated in Plate 17.

The overall dip (about 20°) of the volcaniclastic (tuffite) strata close to the top of the main ridgeline is towards the northeast (i.e. into the ridge) and away from the western-facing slopes. This would tend not to favour the build-up of ground water pressure close to the surface, below the ridge of the landslide site. However, the transient groundwater response during severe rainfall is probably principally affected by the erosion pipes or other preferential flow paths.

Limited groundwater monitoring data, from instrumentation installed at the base of the hillside (Enpack, 1994a; Lam Geotechnics, 1989), suggest that at the toe of the hillside the groundwater table is about 9 to 13 m below the existing ground level, at about 4 to 5 mPD. Based on the field mapping, there is no permanently high groundwater table at the landslide site.

6. SURFACE WATER FLOW

The API indicates two drainage lines within the landslide site (Figure 6). The first, below the northern spur in the upper portion of the depression, coincides with that observed in the field to the north of the small spur-type feature. The second was identified on site to the south of the small spur-type feature, in the centre of the upper part of the depression. The upper part of this latter drainage line appears to approximately coincide with the upper backscarp of the recent landsliding on the north-facing slopes of the southern spur. The two drainage lines merge in the hummocky ground below the base of the small spur-type feature. Aerial photographs and field observations suggest that the channels are ephemeral surface drainage lines.

Several more subtle surface features were also noted from the API above the small spur-type feature, corresponding to a series of subdued hollows and ridges. A further subdued hollow was identified in front of these features at the head of the small spur-type feature (Figure 6). The subdued hollows and ridges above the spur-type feature could have promoted ponding of surface water, thus facilitating concentrated ingress of water and wetting up of the near-surface materials.

7. ANALYSIS OF RAINFALL RECORDS

The nearest GEO automatic raingauges to the landslide are Raingauge No. N13, located at Yen Ng Fan, High Island Reservoir, approximately 4 km east of the site, and Rainguage No. N15, located on the roof of Sung Tsun Primary School, Yau Ma Po, Sai Kung, about 3 km west of the site (Figure 1). These raingauges record and transmit rainfall data at 5-minute intervals via a telephone line to the GEO. The rainfall data thus recorded is considered to be indicative of the probable rainfall pattern and intensity at the landslide site. For the purposes of rainfall analysis, it has been assumed that the landslide took place at approximately 5:30 p.m. on 9 June 1998.

The daily rainfall recorded by the raingauges for one month preceding and seven days following the landslide are presented in Figures 14 and 15 for raingauges Nos. N13 and N15 respectively. These daily rainfall figures show that the storm was concentrated around the day the landslide occurred, with the rainfall recorded being very severe at Raingauge No. N15 located in Sai Kung. The corresponding hourly data for the period from 6:00 p.m. on 7 June 1998 until midnight on 9 June 1998 (also shown in Figures 14 and 15) indicate, generally, intense rainfall peaks between 4:00 a.m. and 10:00 a.m. and between 4:00 p.m. and 8:00 p.m. on 9 June 1998 at both raingauges.

Isohyets of rainfall for the 24-hour period preceding the landslide for the whole of Hong Kong (Figure 16) indicate that the Sai Kung area experienced the heaviest rainfall on 9 June 1998 (over 500 mm).

Tables 4 and 5 present the estimated return periods for the maximum rolling rainfalls recorded at raingauges Nos. N13 and N15, corresponding to selected durations based on historical rainfall data recorded at the Hong Kong Observatory (Lam & Leung, 1994). The 5-minute to 1-hour maximum rolling rainfalls (i.e. short duration storms) were only moderately heavy with return periods of generally less than 10 years. For the 12 to 24-hour period (i.e. medium duration storms), however, the maximum rolling rainfalls recorded were more severe, the corresponding return periods being generally less than 70 years. The 24-hour rolling rainfall recorded by Raingauge No. N15 (531.5 mm) was the most severe with a corresponding return period of 70 years. Whilst it is acknowledged that this simplified method of rainfall analysis does not necessarily give the true return period for a particular site, as several contributory factors are not taken into account (Wong & Ho, 1996b), it does, nonetheless, provide an indication of the likely relative severity of the various rainfall characteristics assessed.

From the above it can be concluded that the rainstorm on 9 June 1998 was very severe, particularly for the 12-hour to 24-hour durations. This is supported by Figures 17 and 18 which present a comparison of the pattern of rainfall preceding the 1998 landslide and that of selected previous major rainstorms affecting the area, as recorded by rainguages Nos. N13 and N15, since their installation in the mid-1980's.

8. THEORETICAL STABILITY ANALYSIS

Many of the natural terrain landslides encountered in Hong Kong comprise shallow failures of less than 1 to 2 m within colluvial and/or saprolitic profiles on relatively steep terrain (Evans & King, 1998, Franks, 1996 and Wong et al, 1996 & 1997). The landslide above the Outward Bound School comprised two main areas of failure, an upper, major landslide and a lower, minor landslide. The backscarp of the upper landslide was typically between 2 and 3 m high.

Theoretical stability analyses were carried out on a portion of the slope considered to be representative of the upper landslide to assist in the diagnosis of the probable causes and triggering mechanisms of the landslide. The purpose of these analyses was to investigate the likely range of operational shear strength parameters along the postulated surface of rupture for different assumed water levels at the time of failure. It should be noted that the initial phase of instability near the crest of the landslide may have been confined in extent, in which case it probably would have been constrained by local geological features laterally (see Sections 5.3 and 5.4) and thus the two-dimensional slope stability analyses subsequently undertaken should be viewed as being indicative only.

The cross-section through the landslide site, on which the stability analyses were carried out based on the rigorous method of Morgenstern & Price (1965), is presented in Figure 19. The pre-failure slope profile was established from topographical survey plans as well as judgement following post-failure inspections of the site, whilst the geometry of the landslide surface was based on site measurements made by FSW and post-failure topographical survey.

The soil strength parameters assumed for the decomposed tuff have been based on the range of shear strength parameters given for these materials in Geoguide 1 (GEO, 1993), together with an assessment of the nature of the material observed in the field. The ranges of parameters adopted in the stability analyses are also given in Figure 19. Various assumptions of possible groundwater conditions were also considered during the stability analyses.

Additionally, cognisance was taken of the presence of locally open joints within the tuffite due to either past movement, subsequent deterioration following previous failures, the influence of tree root growth exploiting sub-vertical joints or a combination of two or more of these factors, and the possibility that cleft (joint) water pressures also played a part in the failure in addition to, or instead of, the build-up of elevated water pressures within the soil mass. Various assumptions of a typical joint (assumed to be 2 m in depth) being filled with water were examined in sensitivity analyses undertaken to determine the effect of this on the stability of the section.

The results of the stability analyses are summarised in Figure 20. These suggest that the landslide can be explained by either the development of transient elevated water pressures between about 0.5 m and 1.0 m above the postulated surface of rupture (corresponding to a r_u value ranging from approximately 0.1 to 0.2) or the development of cleft water pressures in a typical joint or a combination of both phenomena in a material with fairly typical shear strengths that are consistent with the nature of the material as observed in the landslide scar (i.e. c' up to 4 kPa and ϕ' between 32° and 36°). No exceptionally low strength materials appear to have dominated the landslide, although the presence of localised weak planes may have contributed to the failure.

9. DIAGNOSIS OF THE PROBABLE CAUSES OF THE LANDSLIDE

9.1 Mode and Sequence of the Landslide

The mode of the landslide principally involved sliding failure as evidenced by the various relatively intact rafts of material with vegetation that remain within various parts of the landslide scar. The debris was relatively wet on first inspection soon after the incident and thus it is considered probable that the landslide occurred rapidly. Based on the field mapping and morphology of the landslide, the main failure in the upper part of the slope preceded the minor secondary failure near the mid portion of the hillside. While there are some indications from the field mapping to suggest that the failure may possibly have initiated along the fault zone, the precise sequence of events is difficult to establish given the complex geological setting. The morphology of the landslide debris suggests that the landslide occurred essentially as a "one-go" failure, as opposed to a process of failure with "pulses" lasting for some time.

9.2 Probable Causes of the Landslide

The close correlation between rainfall and the reported time of failure suggests that the landslide was triggered by rainfall. Direct infiltration is considered to be the principal source of water ingress into the hillside.

The landslide occurred within an area with a sharp break in slope, which could be the head of a past failure. The steeper local slope gradient at the source area (between about 35° and 45° pre-landslide) and the presence of colluvium in the lower part of the hillside suggest a "retreating" hillside mechanism involving successive discrete failures retrogressing uphill over a period of time.

The local geological, hydrogeological and geomorphological characteristics of the landslide site are complex and probably had a significant influence on the landslide although the precise contributions of these features are not certain. The small hollows in the centre of the landslide scar provided the setting for ponding of surface water, which would have probably led to concentrated ingress of water in this area.

The absence of the less permeable finer-grained tuffite (shale) "capping" within the fault zone as observed in the landslide scarp may also have led to an increased susceptibility to surface water ingress in this area.

The presence of northwest-southeast trending fault planes (with possibly weaker material within the corresponding fault zone than the surrounding areas) traversing the landslide scar probably resulted in localised concentrated subsurface water flow within the landslide site.

The open-jointed nature of the fine- to coarse-grained tuffite of the upper landslide backscarp also probably promoted direct water ingress to the hillside. Near-surface root growth probably exacerbated this situation by wedging open sub-vertical joints. The presence of numerous near-surface erosion pipes within the mainscarp also probably promoted concentrated subsurface flow within this part of the hillside.

The base groundwater table in the hillside is likely to be well below the surface of rupture of the landslide and thus unlikely to have contributed to the failure.

Water ingress would have wetted up the near-surface material and led to the build-up of water pressure, either through non-vertical subsurface seepage flow or filling up of open joints (i.e. cleft water pressure) or a combination of both. This would have led to a reduction in shear strength resulting in failure.

10. DISCUSSION

Many of the landslides which occur on natural terrain in Hong Kong are shallow failures which occur during intense rainfall and involve near-surface colluvium or saprolite (Evans & King, 1998, Franks, 1996 and Wong et al, 1996 & 1997). The natural terrain landslide at the Outward Bound School did not involve colluvium, the landslide debris comprising largely decomposed rock (Grade II/III tuffite and GradeV coarse ash tuff) and residual soil. The mechanism of this landslide was probably affected by the presence of the fault planes traversing the landslide site and the nature of the associated fault zone, with the decomposed tuff having weathered to a residual soil over a significant depth.

The 1998 landslide is located largely within what has been interpreted as a possible relict landslide scar(s) and has a generally similar areal form to this feature. The depression may have been formed by more than one event. It is possible that the mechanisms of the failures were similar and that the current landslide could have been affected by this feature, either through progressive deterioration of disturbed material (due to the past instability) or adverse effect on the groundwater regime, or a combination of both. However, the available evidence does not permit a detailed assessment of this, and it is uncertain as to the degree, if any, the near-surface slope-forming materials of the depression have been weakened by either the relict instability or any subsequent progressive deterioration. The joints in the tuffites below the ridgeline may have become open (and subsequently infilled) as a result of the previous landslide, or these open joints could have formed progressively following previous failure and release of support.

Evans (1996 & 1997) undertook a preliminary assessment of the influence of rainfall on natural terrain landslide initiation and proposed thresholds, defined in terms of 24-hour rainfall, for different densities of natural terrain landsliding for various geographical groupings throughout Hong Kong, based on mean annual rainfall. Additionally, and to allow for spatial variabilities in rainfall, normalised threshold rainfall values, defined as the 24-hour rainfall divided by the mean annual rainfall for the site under consideration, were postulated.

It was found that all of the postulated thresholds of 24-hour rainfall required to initiate natural terrain landsliding – low, medium and high - were exceeded at the Outward Bound School during the rainstorm of 9 June 1998. Only some of the low and medium postulated thresholds of 24-hour rainfall had been exceeded during the selected major past rainstorms presented in Figures 17 and 18. Thus the landslide was not a surprise given the severe rainfall. However, it should be noted that as the above work relates principally to a global assessment of landslide trigger thresholds, it is not sufficiently refined for site-specific assessments in that the approach does not discriminate between different geomorphological, geological and vegetation units and local variation in behaviour on a site-specific scale can be expected to be significant.

As the landslide primarily involved insitu material, it is unlikely to have involved a reactivation of a past failure. However, the landslide may have involved retrogression of the head of a past failure. Deformed and cracked areas were observed locally around the landslide together with relict infilled open joints (see Section 4), which suggest that the hillside was marginally stable and could have been subject to deterioration with time. These may be exacerbated by root growth and thus promote water ingress which can adversely affect the hillside resulting in further local instabilities.

11. CONCLUSIONS

It is concluded that the 9 June 1998 landslide was triggered by very severe rainfall. The landslide involved the failure of natural terrain in the upper part of a coastal slope. The landslide occurred in an area with a sharp break in slope, which was possibly the head of a past failure. The steeper local slope gradient and the presence of colluvium in the lower part of the hillside suggest a "retreating" hillside mechanism involving successive discrete failures retrogressing uphill over a period of time.

The complex local geological, hydrogeological and geomorphological characteristics of the site probably played a significant role in the landslide although the precise contributions of these features to the failure are not certain.

The open-jointed nature of the volcaniclastic rock in the vicinity of the mainscarp probably resulted in an increased susceptibility to surface water infiltration. The presence of erosion pipes within the near-surface materials would also have promoted concentrated subsurface water flow into this area of the hillside. The failure was probably caused by either the development of cleft water pressures in open joints within the volcaniclastic rocks and/or elevated water pressure in the soil mass.

Deformed and cracked areas were observed locally around the landslide together with relict infilled open joints which suggest that the hillside was marginally stable and could have been subject to deterioration with time.

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LIST OF TABLES

Table 1 – Summary of Site Development from Aerial Photograph Interpretation

Year	Photograph Reference No.	Altitude (feet)	Observations (refer to Figures 4, 5 and 6)
1924	Y00100	-	Photograph of poor quality. The peninsula, and the area currently occupied by The Outward Bound School (including associated buildings and piers) in particular, are generally undeveloped. However, some graves are located towards the toes of several of the depressions. One of these graves is located within the area presently occupied by the two houses at the toe of the 1998 landslide. Possible instability, indicated by thin vegetation divided by two lines of bushes (?), noted below the crest of the slope in the depression in the area of concern, northern side only.
1945	Y00706, Y00707	20000	The peninsula in general remains largely undeveloped. The graves, previously identified, are now mostly overgrown. Relict landslide scars on both the eastern flank of the main ridgeline, adjacent to the area of concern, and the western flank, to the south of this area, are clearly evident. To the north of the affected area two further depressions have been identified. The slope below the main northwest-southeast trending ridgeline in the area of concern appears to form part of a relict landslide scar, comprising a depression flanked by two spurs. The southern spur appears generally steeper than that to the north. A narrow ridge-type feature and a downslope spur-type feature, flanked by possible drainage lines, can also be seen within this relict landslide scar. The slopes are sparsely vegetated. The two lines of bushes identified in 1924 are no longer evident. Footpaths are, however, noted along both the coast and part of the main ridgeline adjacent to the affected area.
1954	Y02776, Y02777	29200	As noted above.

Year	Photograph Reference No.	Altitude (feet)	Observations (refer to Figures 4, 5 and 6)
1963	Y10246, Y10247	7000	Vegetation is generally sparse. However, trees are noted scattered on the ridge and spurs above the relict landslide scar identified in 1945. A photogeological lineament, orientated north-south across the upper part of the slope, was also identified. Otherwise as before.
1964	Y13015, Y13016	12500	A road has been constructed along part of the ridgeline. Additionally, site formation works (associated with the construction of 3 buildings) are evident at the northern end of the peninsula. Otherwise as before.
1968	Y14420, Y14421	-	The slopes are now vegetated with grass, shrubs and occasional trees. Otherwise as before.
1978	23379, 23380	3000	Development of the area has commenced. The house at the toe of the slope adjacent to the (yet-to-be-built) Captain's House has been constructed along with most of the other Outward Bound School buildings, including the northern pier. The southern pier is under construction.
1979	25609, 25610	2500	Construction of the southern pier is now complete. Vegetation has been cleared along the coastline to the south of the affected area and along part of the lower slope. The rest of the slope is vegetated with low shrubs and occasional trees. The narrow ridge-type and spur-type features within the vicinity of the 1998 landslide, noted most clearly in the 1945 and 1963 photographs, are not as noticeable from these photographs. The photogeological lineament observed in the upper part of the slope in 1963 can also be seen on these photographs, orientated northnortheast-

Year	Photograph Reference No.	Altitude (feet)	Observations (refer to Figures 4, 5 and 6)
			southsouthwest. The southern part of this lineament within the 1998 landslide depression is denoted by a steeper slope between the southern spur and the adjacent drainage line. This appears to correspond with the southern portion of the failure scarp of the recent landslide. A further two photolineaments have been identified traversing the lower parts of the slopes of the peninsula, also orientated northnortheast-southsouthwest. A small scar is noted at the rear of the house constructed in 1978, to the south of the northern spur.
1980	2881-2887 2895-2897	-	The slopes are more densely vegetated with trees noted on the southern spur of the affected area. Also, the main drainage line of the depression can be seen above the house constructed in 1978. It appears to start in the northern corner of the depression, immediately to the south of the northern spur, and ends at the coast, to the south of the (yet-to-be-built) "Captain's House".
1981	39172, 39173, 39174	10000	Site formation works associated with the construction of the "Captain's House" are in progress. Vegetation is thinner, generally, than in 1980.
1983	52193, 52194	10000	The "Captain's House" has now been constructed. This building, at the toe of the slope, is located near the bottom of the scar of the recent landslide.
1985	65440, 65441	4500	Two photogeological lineaments trending northnortheast-southsouthwest are noted on the densely-vegetated slope. These correspond to those identified in previous photographs (1979). There appears to be a local erosion scar along the channel below the northern spur.
1988	A11756	4000	The extension to The Outward Bound School Offices has been completed. Otherwise as above.

Year	Photograph Reference No.	Altitude (feet)	Observations (refer to Figures 4, 5 and 6)
1993	CN5138, CN5139	3000	Two drainage lines are noted on either side of the small spur-type feature below the main ridgeline. A narrow ridge-type feature is also noted between the small spur-type feature and the main ridgeline above. Both observations are similar to those made from the 1945 and 1963 photographs. An electricity pylon has been erected on the southern spur. Two photogeological lineaments are noted trending northnortheast-southsouthwest. These correspond to those identified in previous photographs (1979 and 1985). In addition, a further photogeological lineament trending approximately north-south was also identified in the lower half of the depression from these photographs. The slope is densely vegetated.
1994	A39449, A39450	10000	The villas to the south of The Outward Bound School have now been constructed. A possible erosion scar in a similar location to that identified in 1985 is evident. The slope is densely vegetated.
1995-96	CN10923 CN10924 CN14195 CN14196	2500 4000	A triangulation point has been erected on the main ridgeline adjacent to the affected area. The slope remains densely vegetated. Otherwise as above.

Table 2 – Summary of Sources of Information

Source	Documents
GEO Planning Division	(a) Relevant available aerial photographs (see Table 1 for details). (b) Natural Terrain Landslide Inventory (NTLI). (c) Terrain Classification Map
GEO Planning Division, Hong Kong Geological Survey	HKGS Section's Field Notes, Field Data Master and Original Traverse Master.
GEO Mainland East Division	File GCME 2/E2/98-1/ME (Parts 1-3).
Civil Engineering Library (CEL) of the Civil Engineering Department (CED)	(a) 1977/78 Catalogue of Slopes (b) NTLI
Geotechnical Information Unit (GIU) at the CEL	(a) GIU Ref 15011 Additional Site Investigation Works at Outward Bound School Staff Accommodation Lam Geotechnics Limited (b) GIU Ref 26817 Ground Investigation and Soil Laboratory Testing for Proposed New Staff Accommodation Block at Outward Bound School, Tai Mong Tsai, Sai Kung, New Territories Final Fieldwork Report Enpack Geotechnical Engineering Co., Ltd June 1994 (c) GIU Ref 26819 Ground Investigation and Laboratory Testing for Proposed New Staff Accommodation Block at Outward Bound School, Tai Mong Tsai, Sai Kung, New Territories Laboratory Report Enpack Geotechnical Engineering Co., Ltd July 1994 (d) GIU Ref 26818 Works Order No. GCE/95/0004/SI/R Site Investigation Report Outward Bound School, Tai Mong Tsai Sai Kung, New Territories Geotechnics & Concrete Engineering (Hong Kong) Ltd

Source	Documents
GEO Slope Safety Division	SIFT & SIRST – none relevant, natural slope.
GEO Publications, Reports, Maps, Memoirs	(a) Geotechnical Control Office (1988). Geotechnical Area Studies Programme – East New Territories GASP Report No. IX. (b) Geotechnical Control Office (1989). Sai Kung: Solid and Superficial Geology. Hong Kong Geological Survey, Map Series HGM20, Sheet No. 8, 1:20 000 scale. (c) Geotechnical Control Office (1986). Geology of Sai Kung and Clear Water Bay. Hong Kong Geological Survey Memoir No. 4.
GEO Landslide Database	Records of reported and inspected landslide incidents. None relevant.
GEO Landslip Investigation Division	SIS database – slope registration details.
Lands Department, SIMAR Unit, Estate Management Section	Slope Report for Cut Slope Feature No. 8SW-B/C98 – confirms area affected by the landslide is located within Sai Kung West Country Park.
Interviews with Concerned Persons	Little relevant information obtained.
Hong Kong & China Gas Co., Ltd	Existing utility information – no existing plant within the vicinity of the landslide.
Hong Kong Telecom Co., Ltd	Existing utility information – copy of utility plan obtained.
Wharf Cable Ltd	Existing utility information – no existing plant within the vicinity of the landslide.
Hutchison Telephone (HK) Ltd	Existing utility information – no existing plant within the vicinity of the landslide.
New T&T Hong Kong Ltd	Existing utility information – no existing plant within the vicinity of the landslide.
New World Telephone Ltd	Existing utility information – no existing or proposed plant or services within the vicinity of the landslide.

Source	Documents
WSD/MSE	Existing utility information – no existing plant within the vicinity of the landslide.
HyD/NTW	Existing utility information – no existing plant within the vicinity of the landslide.
DSD/MS	Existing utility information – no existing plant in the vicinity of the landslide.
Rediffusion (HK) Ltd	Existing utility information – no existing plant within the vicinity of the landslide.
China Light & Power Co., Ltd	Existing utility information – copy of overhead line record sheets obtained.

Table 3 - Laboratory Test Results

Soil Sample No.		FSW 118/1	FSW 118/2	FSW 118/3
Plastic Limit (%)		28	25	30
Plasticity Index (%)		22	21	16
Particle Size Distribution				
BS Sieve	Particle Size	% Smaller by Weight		
63 mm		100	100	100
20 mm		100	100	100
6.3 mm		100	93	95
2 mm		99	83	94
600 μm		92	61	87
212 μm		87	40	77
63 μm		74	28	62
	0.020 mm	52	22	46
	0.006 mm	44	18	37
	0.002 mm	30	13	24

Note:

Visual descriptions of Soil Samples are sumnmarized as follows:

Sample FSW 118/1 - Moist reddish brown slightly gravelly slightly sandy SILT.

Sample FSW 118/2 - Moist brownish yellow clayey very silty gravelly SAND.

Sample FSW 118/3 - Moist light brownish yellow slightly gravelly slightly sandy SILT.

Table 4 - Maximum Rolling Rainfalls at GEO Raingauge No. N13 and Estimated Return Periods for Different Durations Preceding the Landslide of 9 June 1998

Duration	Maximum Rolling Rainfall (mm)	End of Period (Hours)	Estimated Return Period (Years)
5 Minutes	15	16:30 on 9 June 1998	5
15 Minutes	37	16:35 on 9 June 1998	10
1 Hour	92.5	17:15 on 9 June 1998	6
2 Hours	121.5	7:40 on 9 June 1998	4
4 Hours	160.5	8:50 on 9 June 1998	5
12 Hours	333	17:20 on 9 June 1998	20
24 Hours	417.5	17:30 on 9 June 1998	18
48 Hours	439.5	17:30 on 9 June 1998	10
4 Days	466.5	17:30 on 9 June 1998	6
7 Days	594	17:30 on 9 June 1998	10
15 Days	643.5	17:30 on 9 June 1998	5
31 Days	810.5	17:30 on 9 June 1998	4

Notes :

1 Return periods were derived from Table 3 of Lam & Leung (1994).

2 Maximum rolling rainfall was calculated from 5-minute data for durations up to 48 hours, and from hourly rainfall data for longer rainfall durations.

3 The use of 5-minute data for durations between 2 hours and 48 hours results in better data resolution, but may slightly over-estimate the return periods using Lam & Leung (1994)'s data, which are based on hourly rainfall for these durations.

Table 5 - Maximum Rolling Rainfalls at GEO Raingauge No. N15 and Estimated Return Periods for Different Durations Preceding the Landslide of 9 June 1998

Duration	Maximum Rolling Rainfall (mm)	End of Period (Hours)	Estimated Return Period (Years)
5 Minutes	14	6:15 on 9 June 1998	4
15 Minutes	33.5	6:15 on 9 June 1998	5
1 Hour	87.5	6:15 on 9 June 1998	5
2 Hours	141.5	6:25 on 9 June 1998	9
4 Hours	218.5	7:00 on 9 June 1998	20
12 Hours	358.5	17:25 on 9 June 1998	30
24 Hours	531.5	17:30 on 9 June 1998	70
48 Hours	547	17:30 on 9 June 1998	30
4 Days	572.5	17:30 on 9 June 1998	16
7 Days	625.5	17:30 on 9 June 1998	15
15 Days	711	17:30 on 9 June 1998	8
31 Days	1058.5	17:30 on 9 June 1998	20

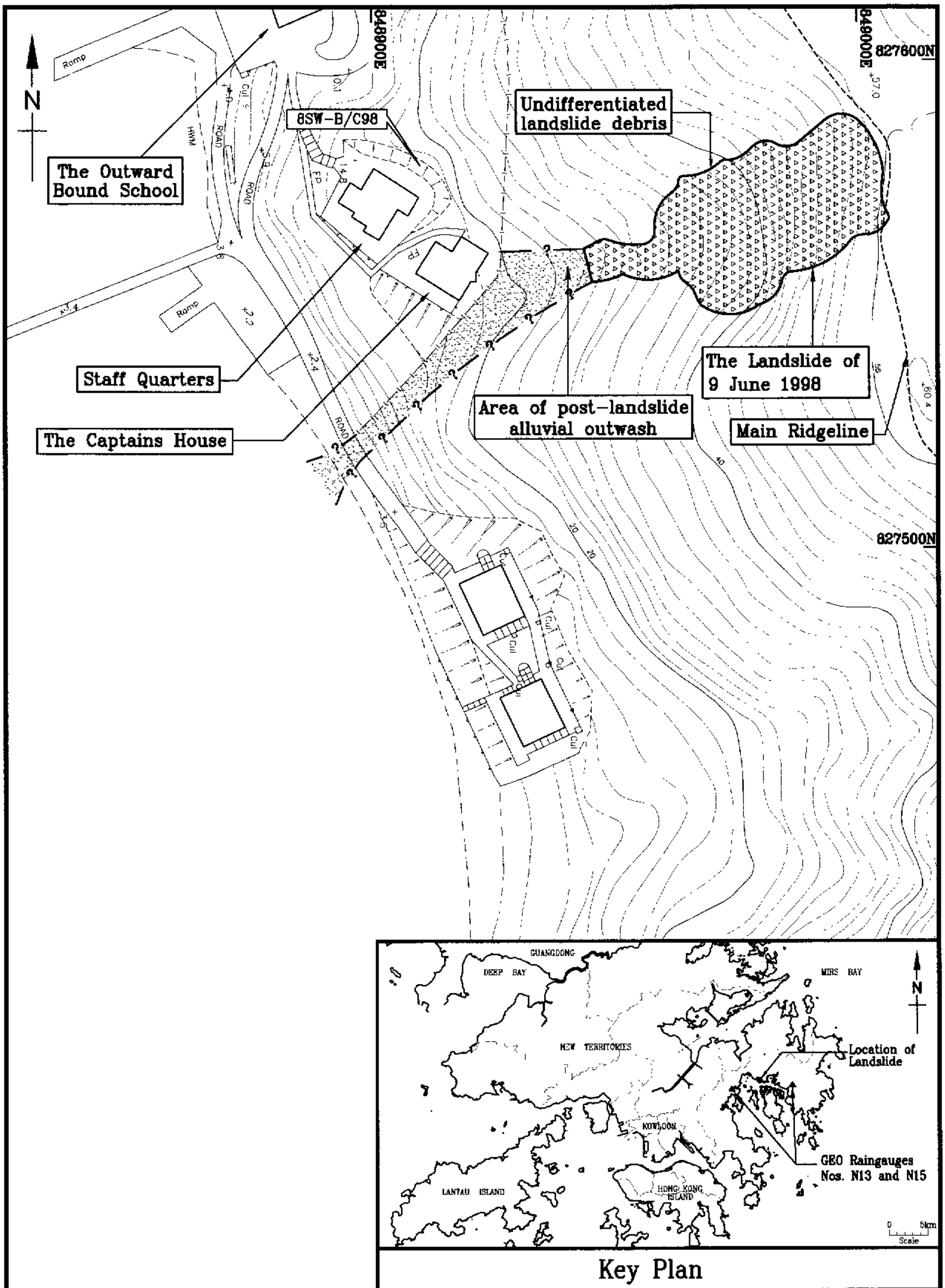
Notes :

1 Return periods were derived from Table 3 of Lam & Leung (1994).

2 Maximum rolling rainfall was calculated from 5-minute data for durations up to 48 hours, and from hourly rainfall data for longer rainfall durations.

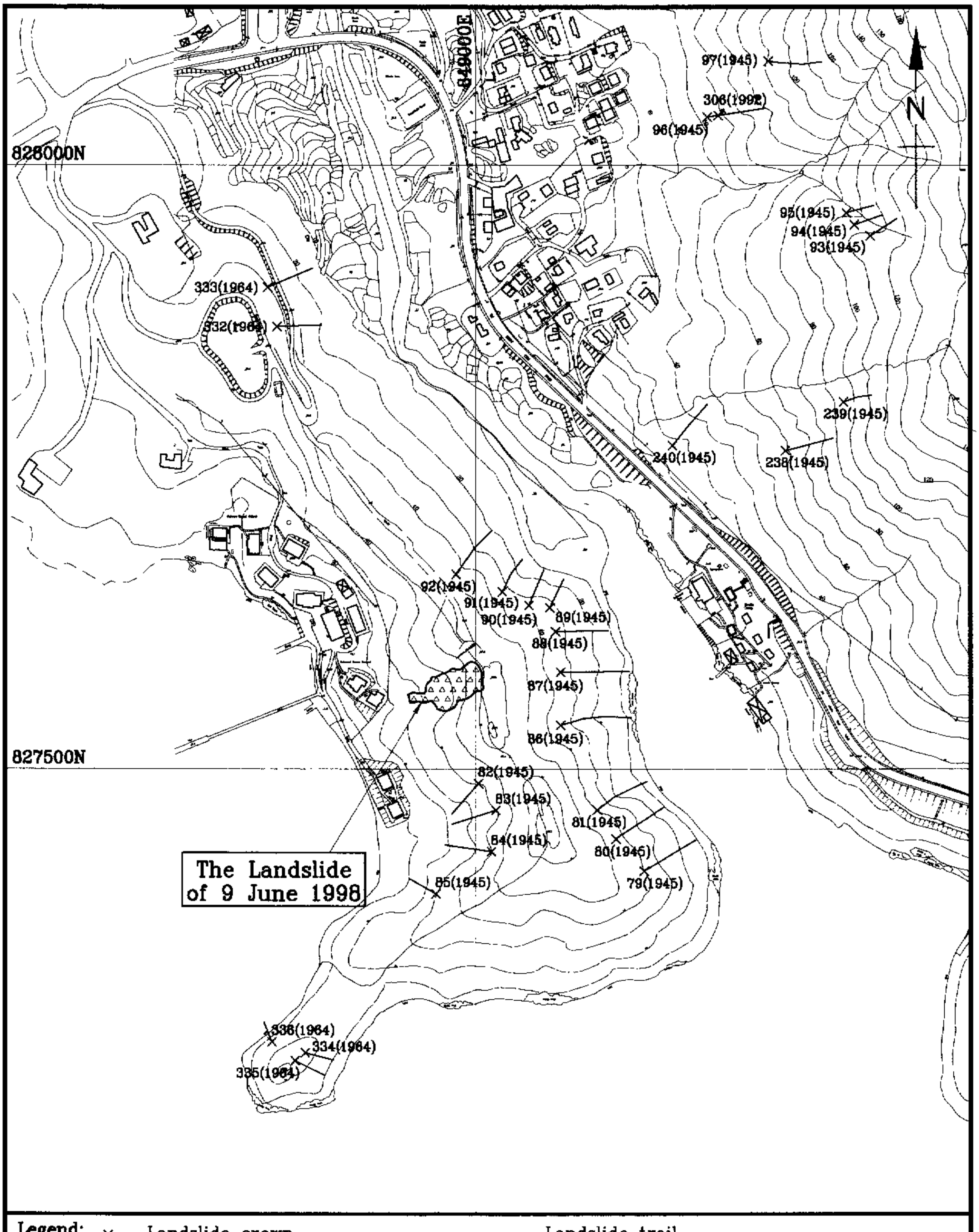
3 The use of 5-minute data for durations between 2 hours and 48 hours results in better data resolution, but may slightly over-estimate the return periods using Lam & Leung (1994)'s data, which are based on hourly rainfall for these durations.

LIST OF FIGURES



Note: Base Map is extracted from Survey Sheet Nos. 8SW-8D & 8SW-13B, scale 1:1 000.

Figure 1 - Site Location Plan

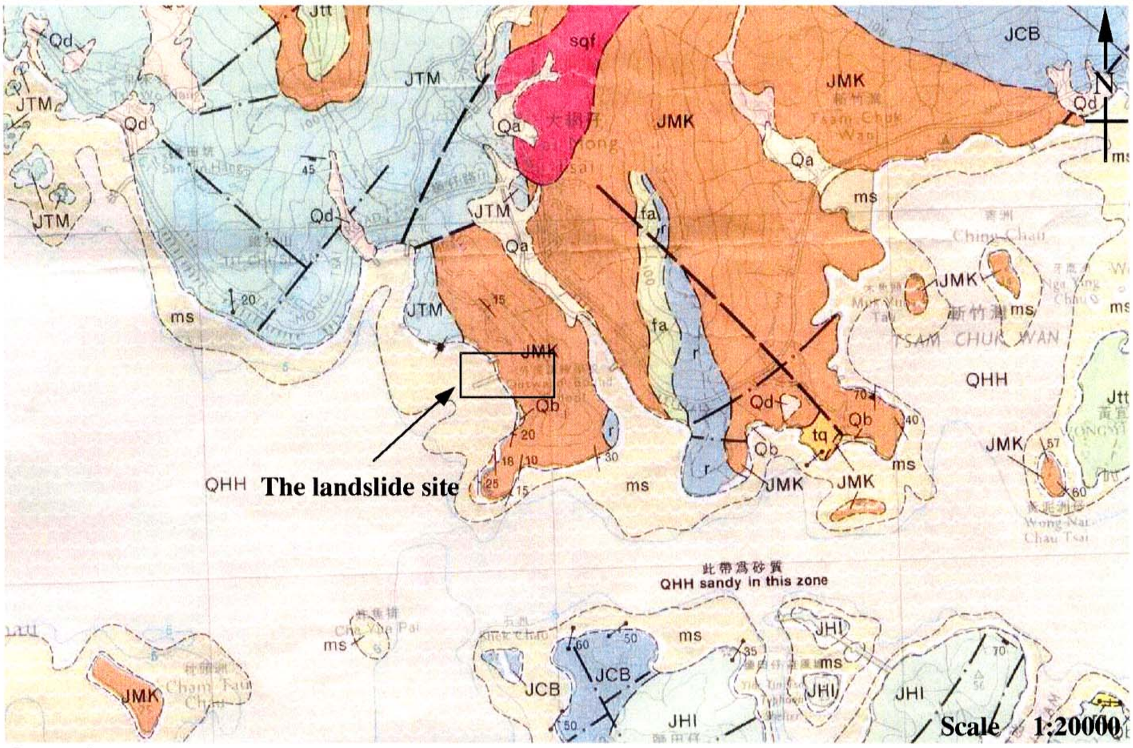


Legend:

- × Landslide crown
- ×79 Landslide reference number, with year first observed in brackets
- ——— Landslide trail
- ——— Outline of 1998 landslide scar
- △△ Undifferentiated landslide debris

Notes: (1) Base map is extracted from Survey Sheets Nos. 8SW-8D & 8SW-13B, scale 1:1 000.
(2) Information shown on this figure is based on the information given in the Natural Terrain Landslide Inventory (Evans et al, 1997).

Figure 2 - Record of Past Landsliding



Legend :

QUARTERNARY SUPERFICIAL DEPOSITS (Onshore)

Qb	Sand
QHH	Undivided, mainly dark grey marine mud
ms	Marine sand, part silty
Qa	Clay/silt, sand and gravel; well-sorted to semi-sorted
Qd	Unsorted sand, gravel, cobbles and boulders; clay/silt matrix

SOLID GEOLOGY

JHI	Undivided, mainly fine ash tuff
JCB	Undivided, mainly trachydacite and rhyolite lava
JMK	Undivided, mainly tuffaceoous mudstone, siltstone and
fa	Fine ash tuff
r	Rhyolite lava
JTM	Undivided, mainly coarse ash crystal tuff
sqf	Fine-grained quartz syenite, ,2 mm
tq	Quartz trachyte

GEOLOGICAL LINES

- - - - - - - - Geological boundary, superficial deposits

———— - - * Geological boundary, solid rock (* Broken lines denote uncertainty)

— · — · — Photogeological lineament

* Broken lines denote uncertainty

STRUCTURAL SYMBOLS

Inclined

20 Bedding

20 Flow fabric

20 Intrusive contact

20 Jointing

Note: Figure is extracted from Hong Kong Geological Survey, Map Series HGM20, Sheet No. 8, 1:20 000 scale (GCO, 1989)

Figure 3 – Regional Geology

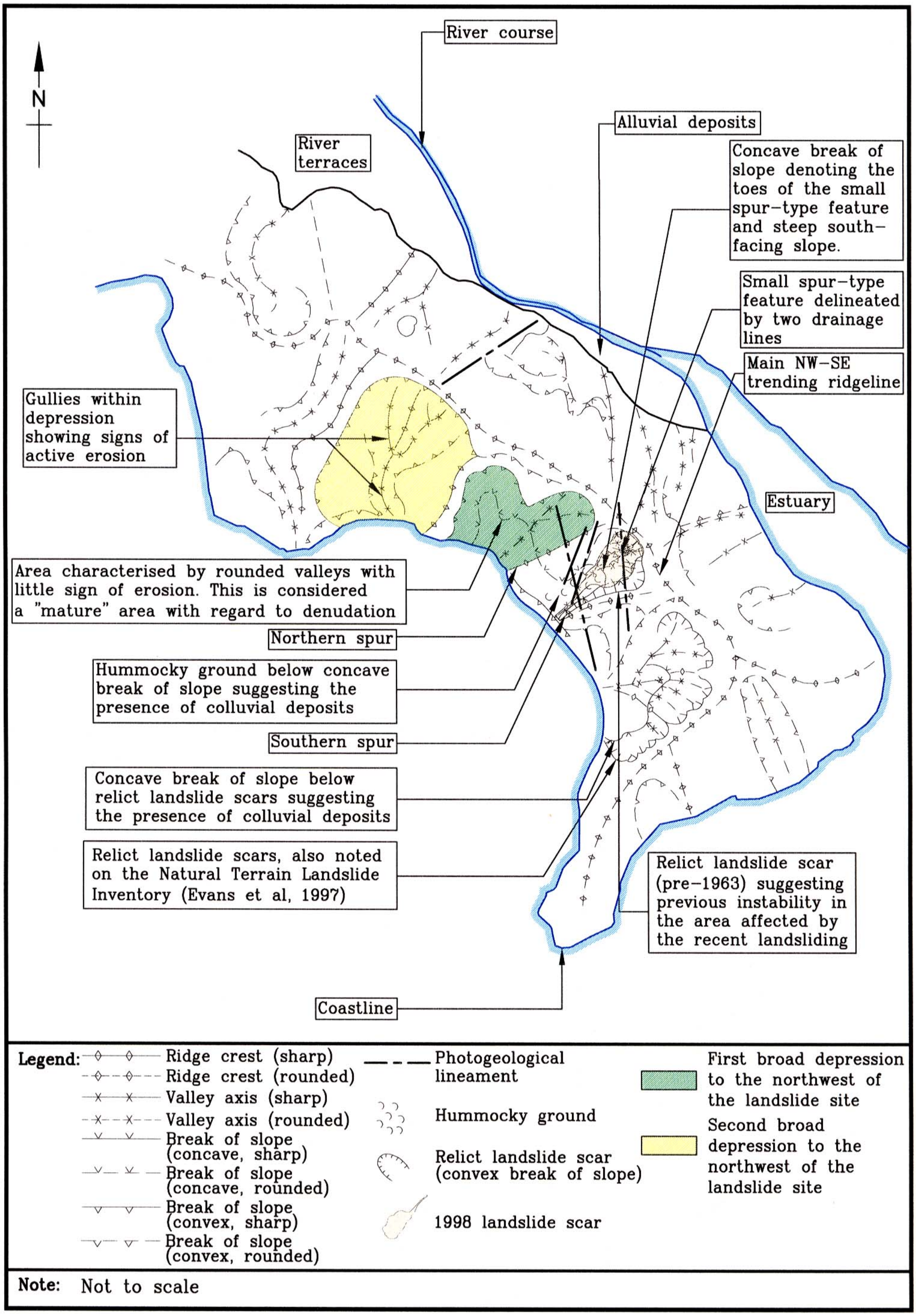


Figure 4 - Aerial Photograph Interpretation of the Peninsula (based on 1963 photographs)

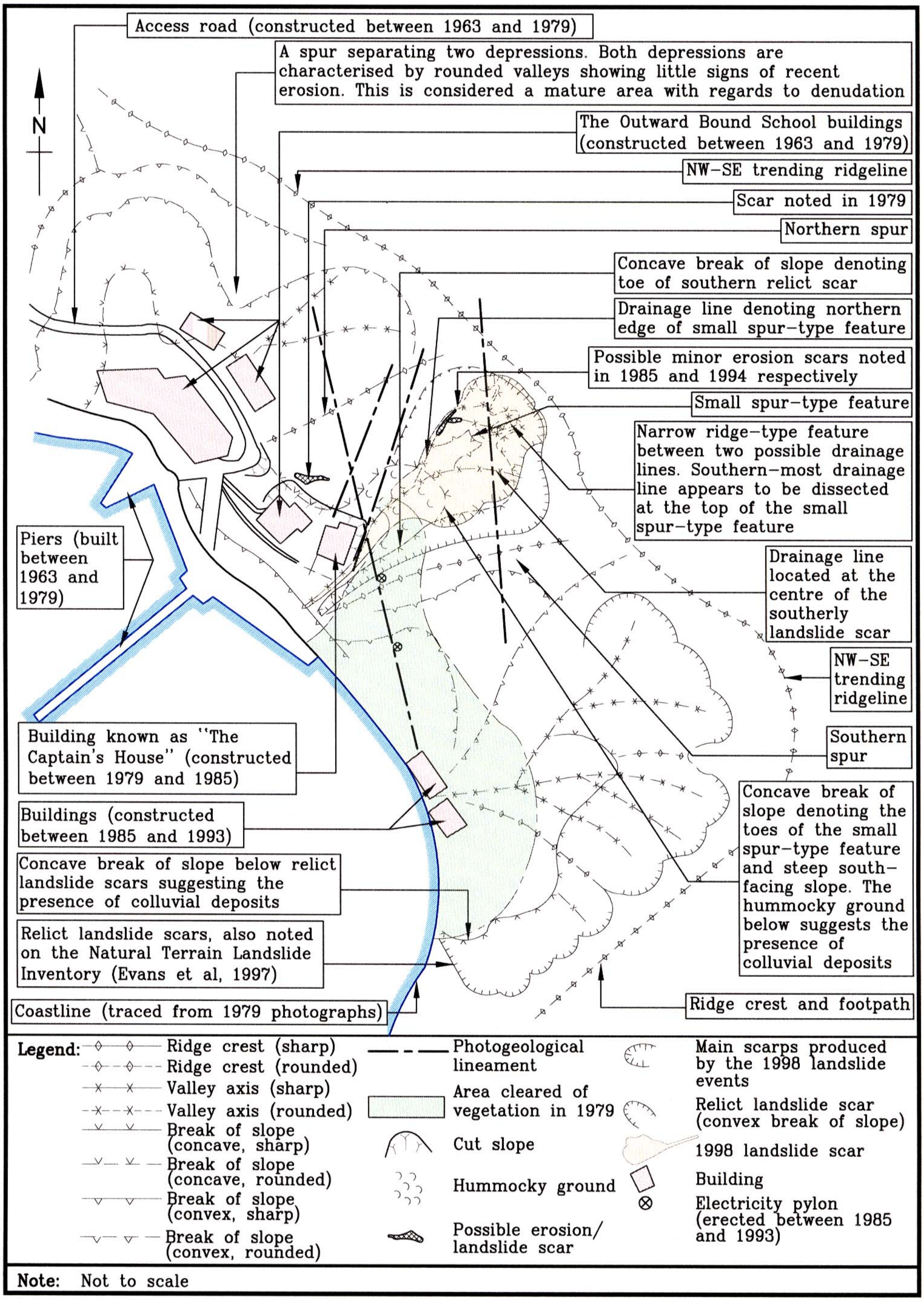


Figure 5 - Aerial Photograph Interpretation of the Southwest-facing Slopes of the Peninsula (based on photographs taken between 1924 and 1997)

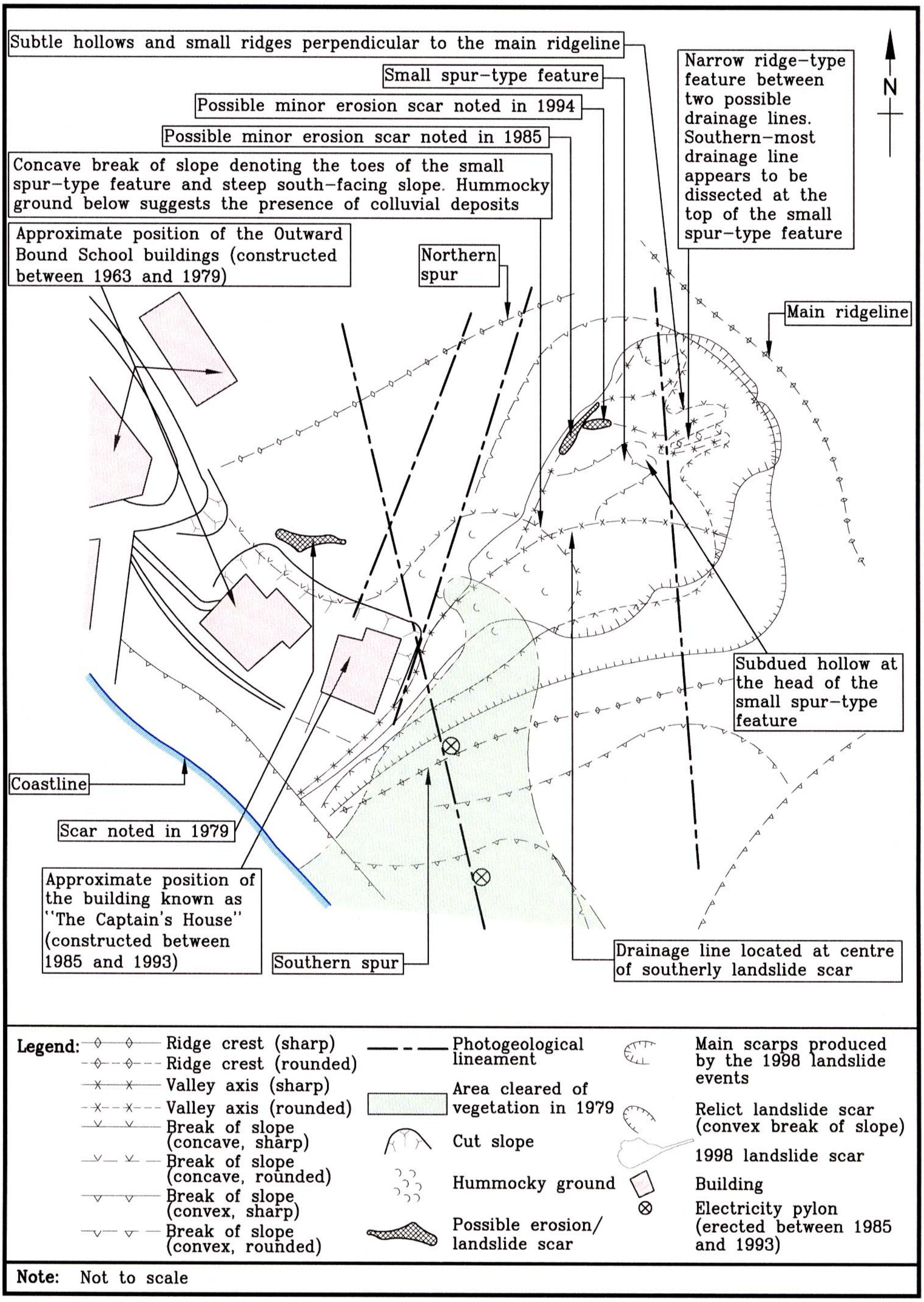
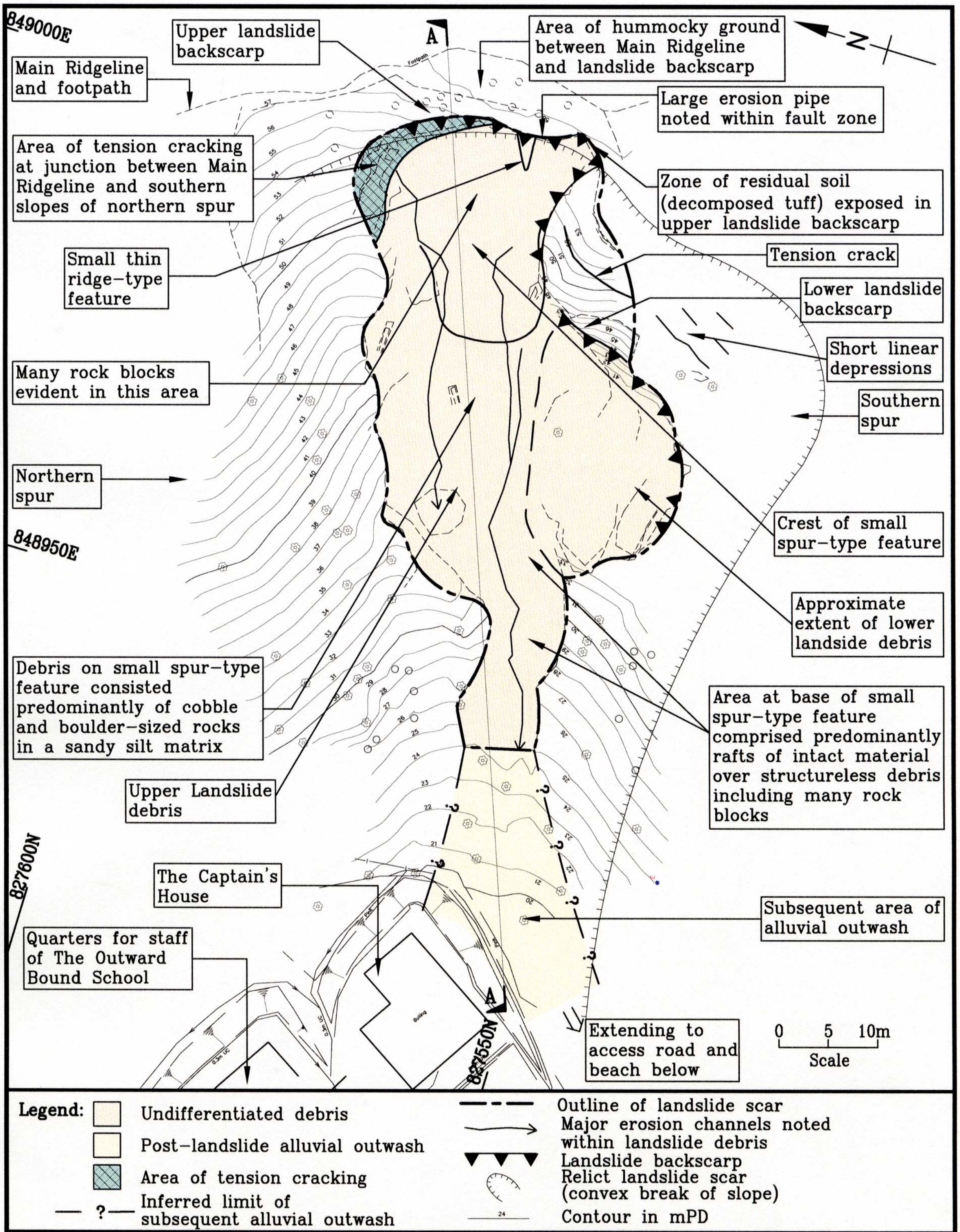
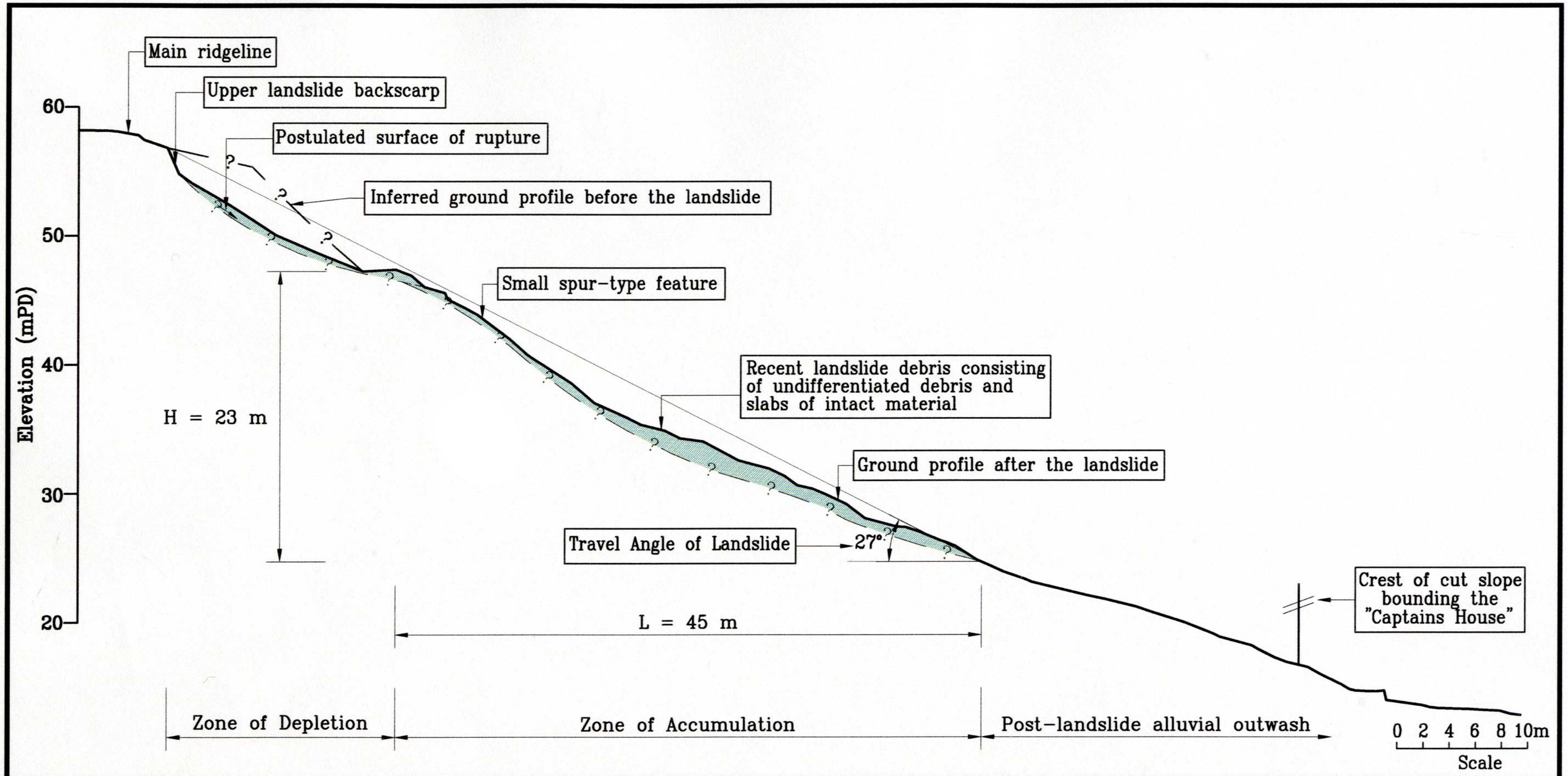


Figure 6 - Aerial Photograph Interpretation of the Landslide Site and Immediate Vicinity (based on photographs taken between 1924 and 1997)



Notes:
(1) Base map is based on topographic survey carried out by Henry Chan Surveyors Ltd after the landslide.
(2) Information shown on this figure is based on topographic survey, geomorphological and engineering geological mapping, field observations and documentary records.
(3) For details of Section A – A refer to Figure 7.

Figure 7 - Plan of the Landslide



Legend:

Recent landslide debris

—— ? —— Inferred geological boundary

Notes: (1) See Figure 7 for location of section.

(2) Information shown in this figure is based on topographic survey, geomorphological and engineering geological mapping, field observations and documentary records.

Figure 8 - Section A-A through the Landslide Site

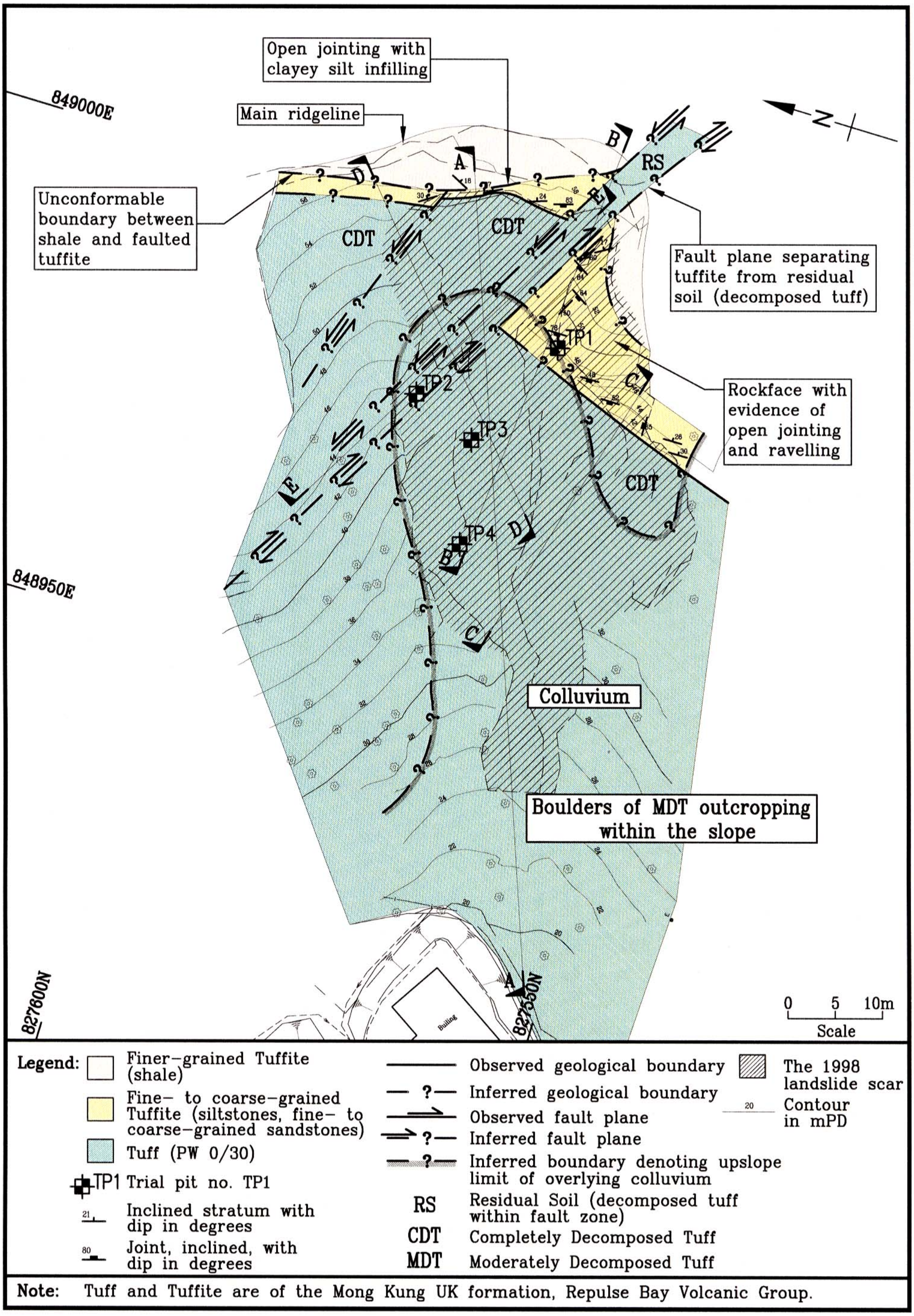


Figure 9 - Geological Map of the Landslide Site

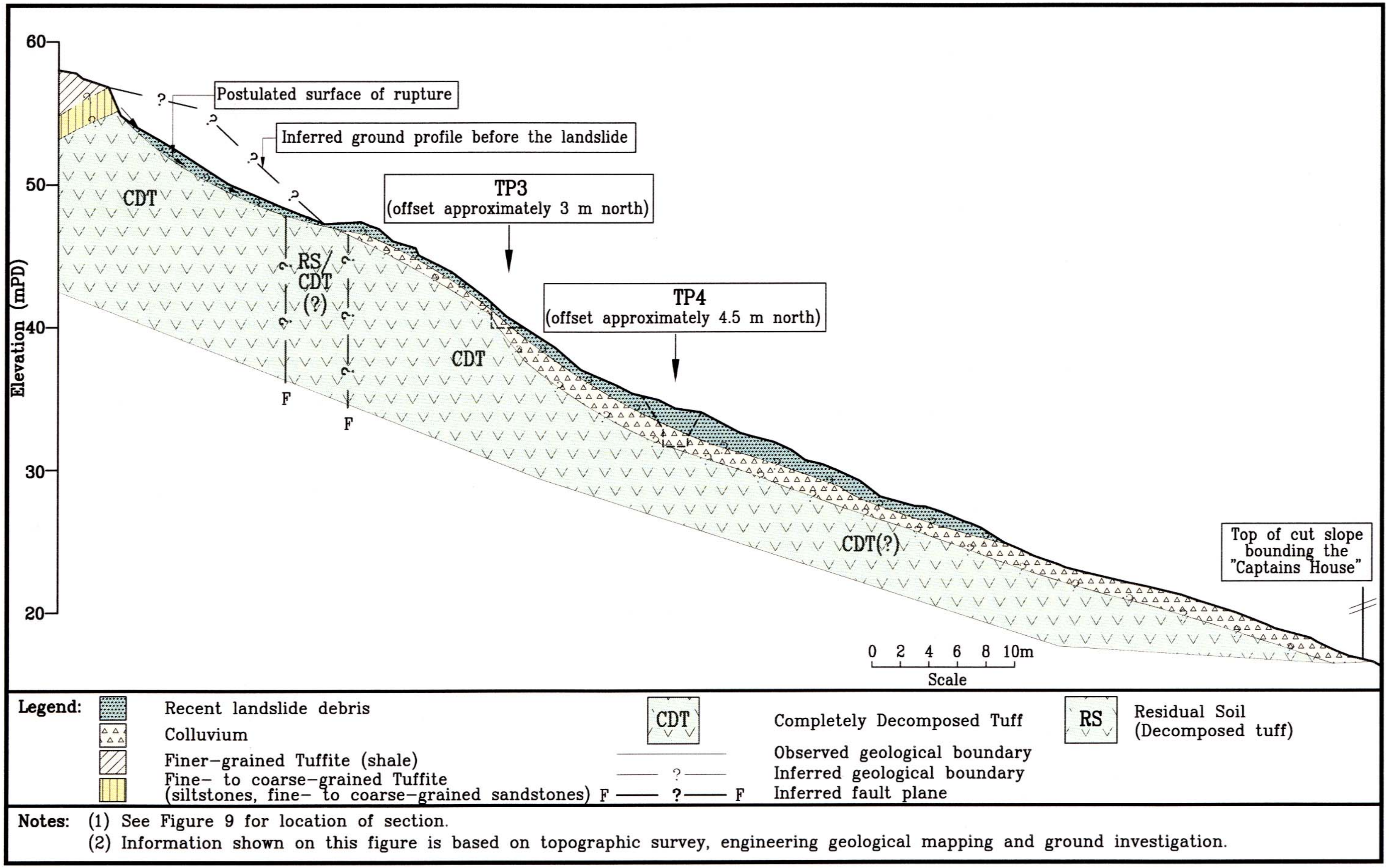


Figure 10 - Section A-A Geological Profile

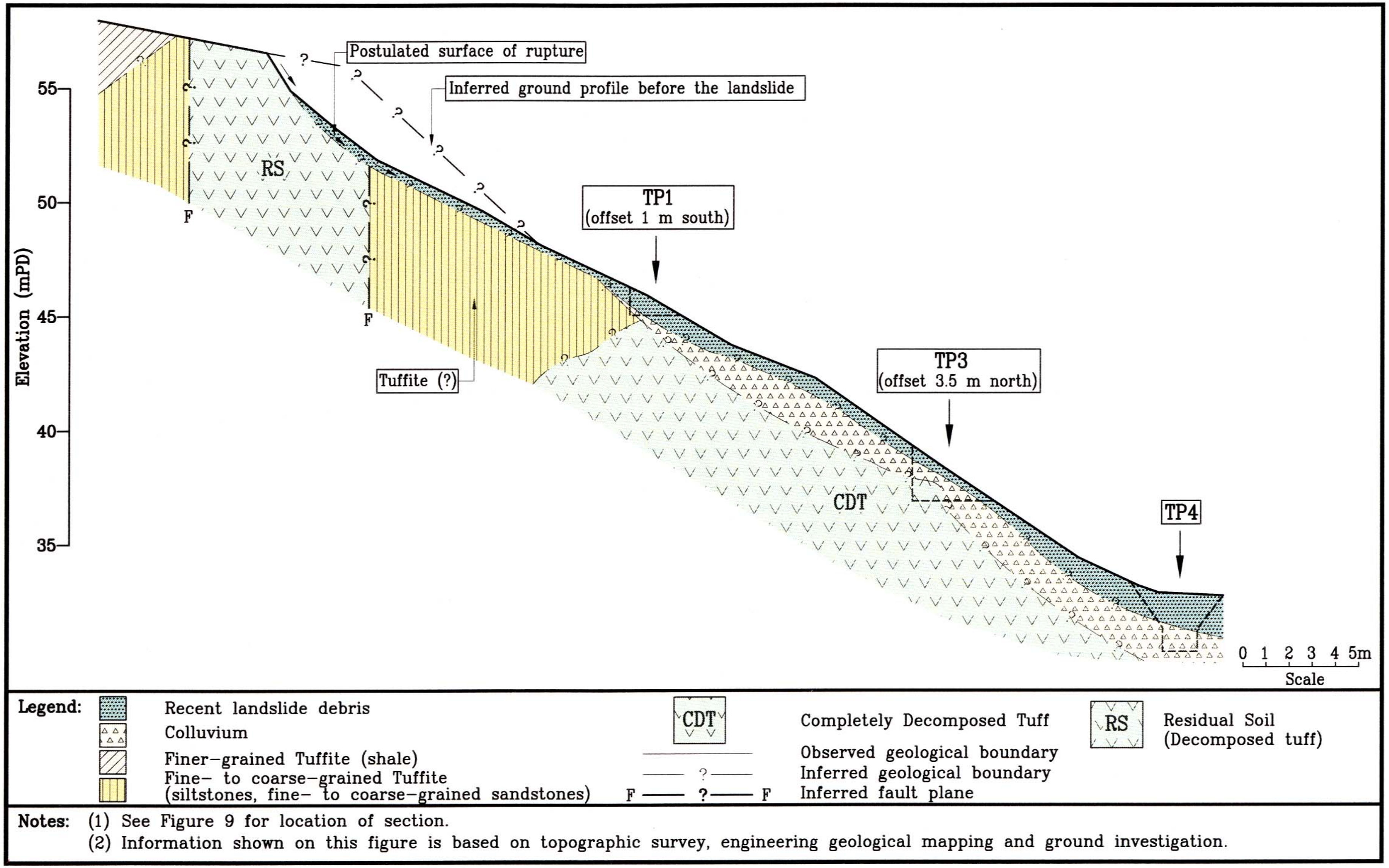
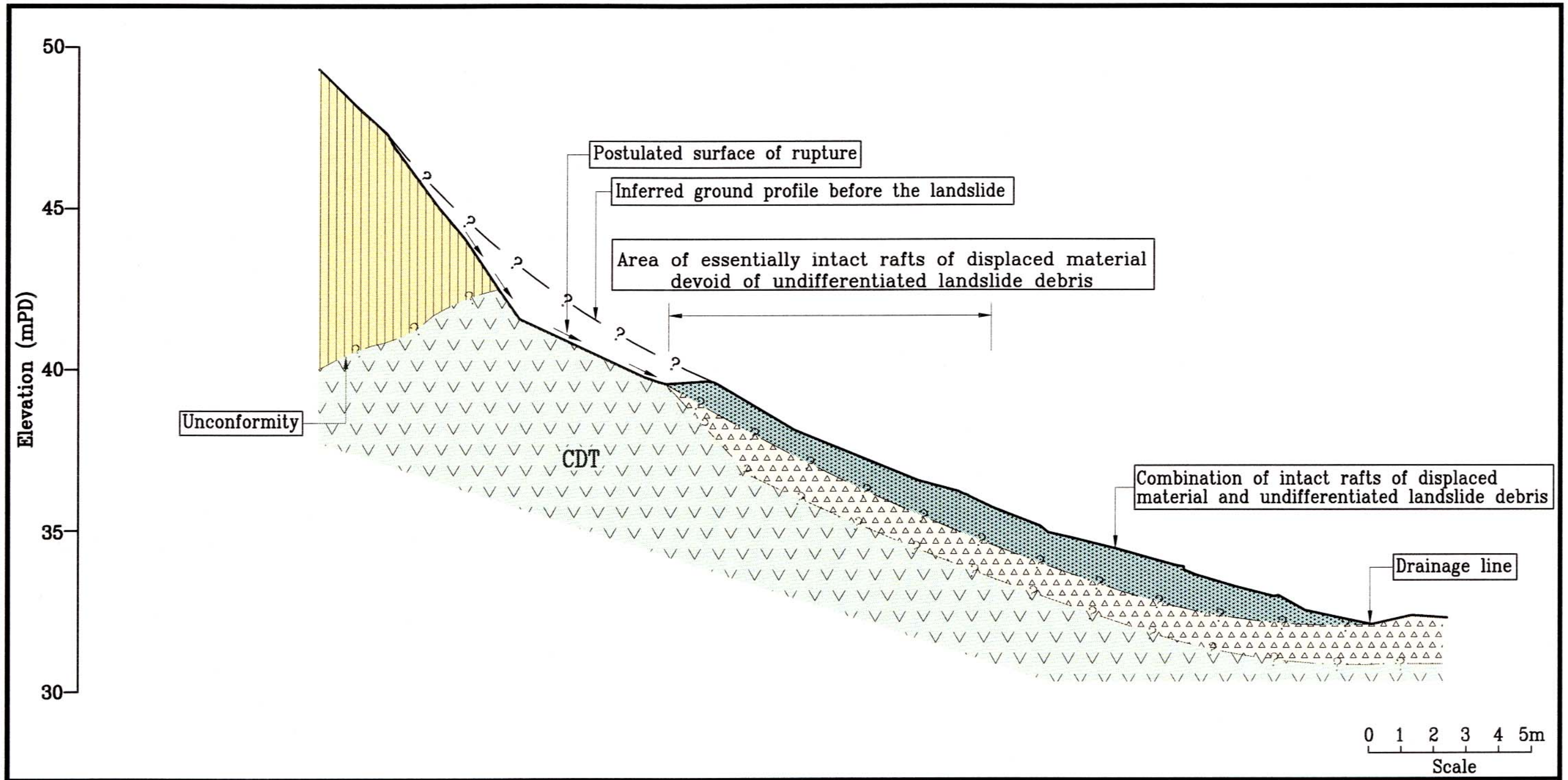


Figure 11 - Section B-B Geological Profile



Legend:

- Recent landslide debris
- Colluvium
- Fine- to coarse-grained Tuffite (siltstones, fine- to coarse-grained sandstones)
- CDT — Completely Decomposed Tuff
- Observed geological boundary
- Inferred geological boundary

Notes:
(1) See Figure 9 for location of section.
(2) Information shown on this figure is based on topographic survey, engineering geological mapping and ground investigation.

Figure 12 - Section C-C Geological Profile

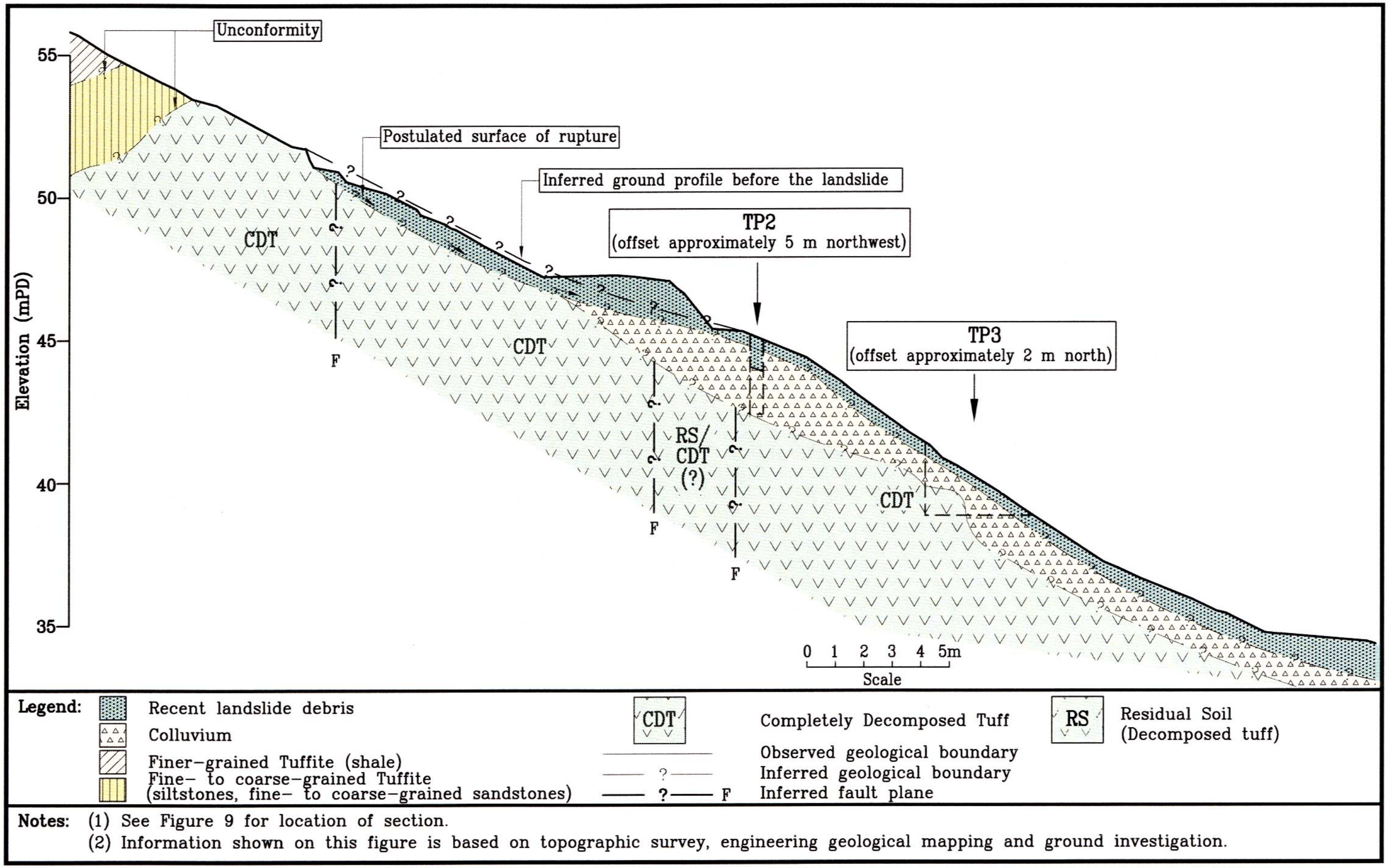
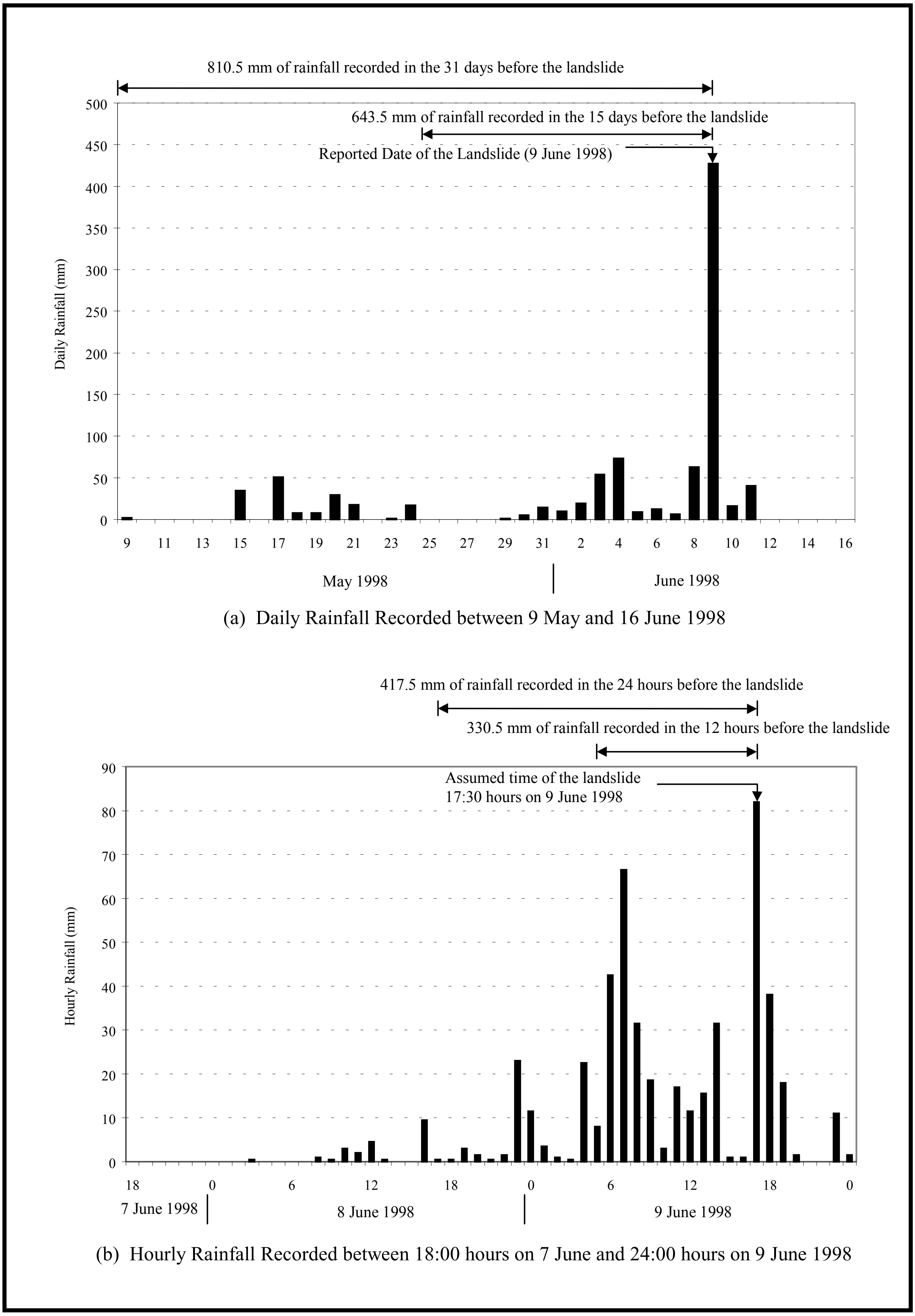


Figure 13 - Section D-D Geological Profile



(a) Daily Rainfall Recorded between 9 May and 16 June 1998

(b) Hourly Rainfall Recorded between 18:00 hours on 7 June and 24:00 hours on 9 June 1998

Figure 14 – Rainfall Recorded at GEO Raingauge No. N13

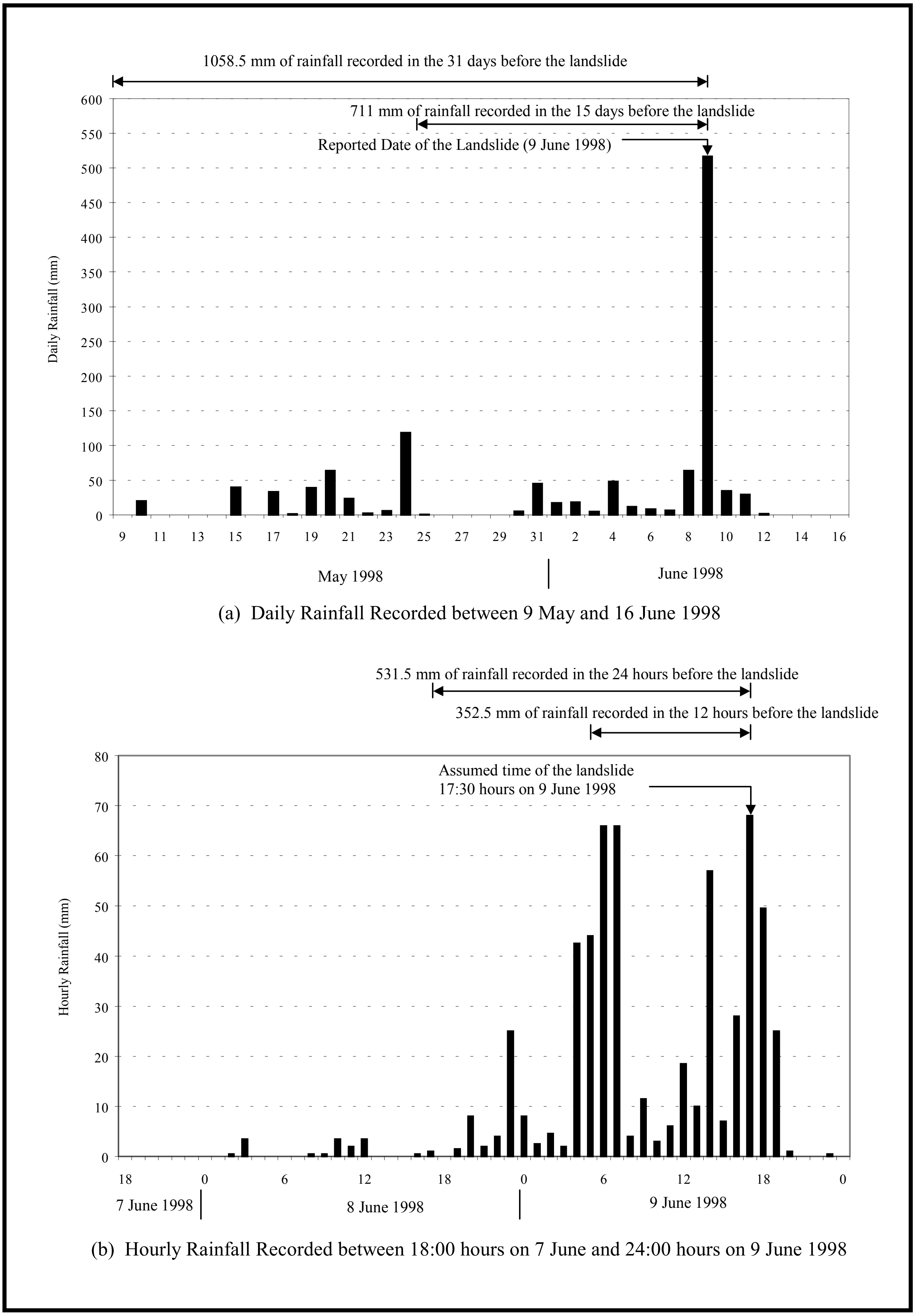
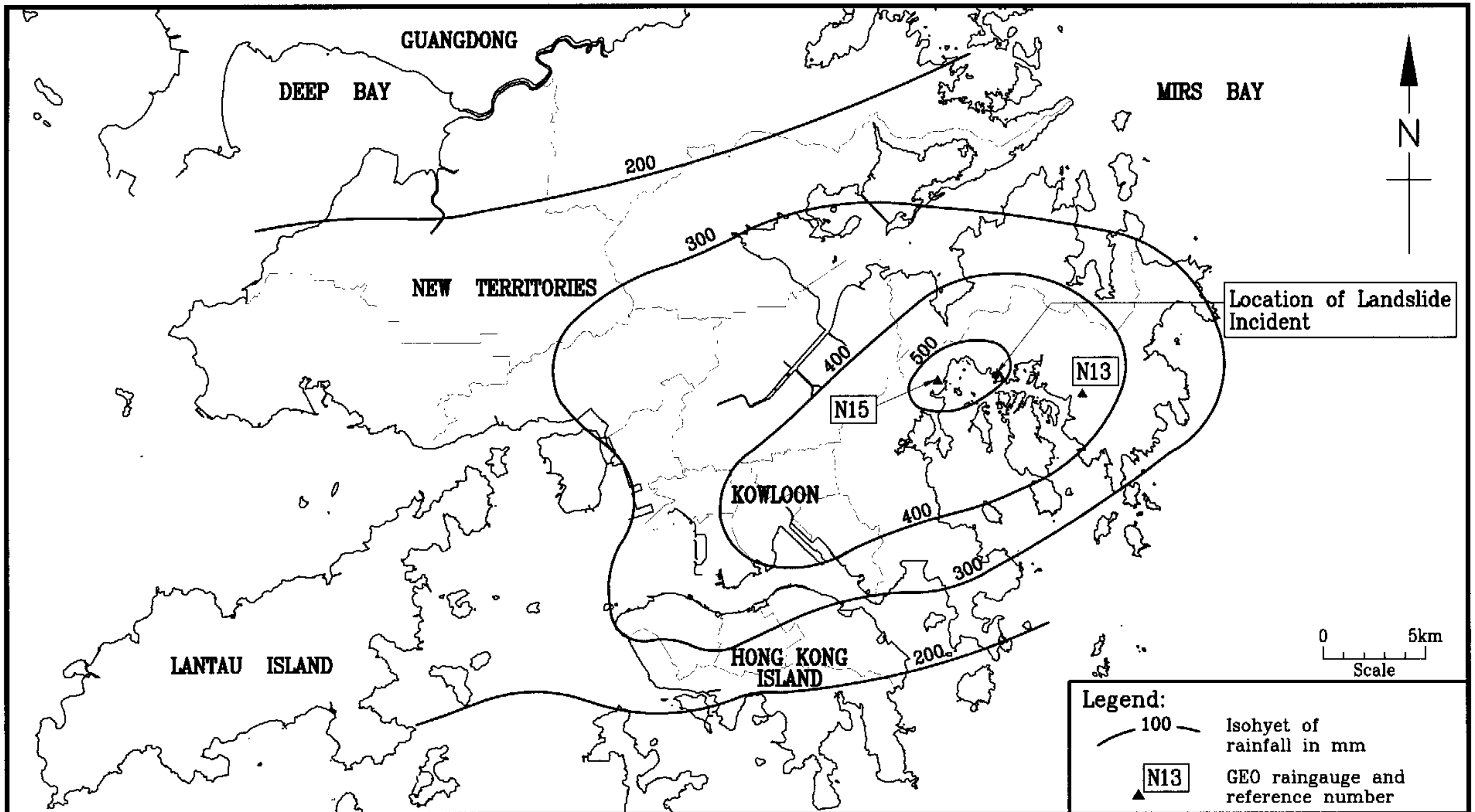
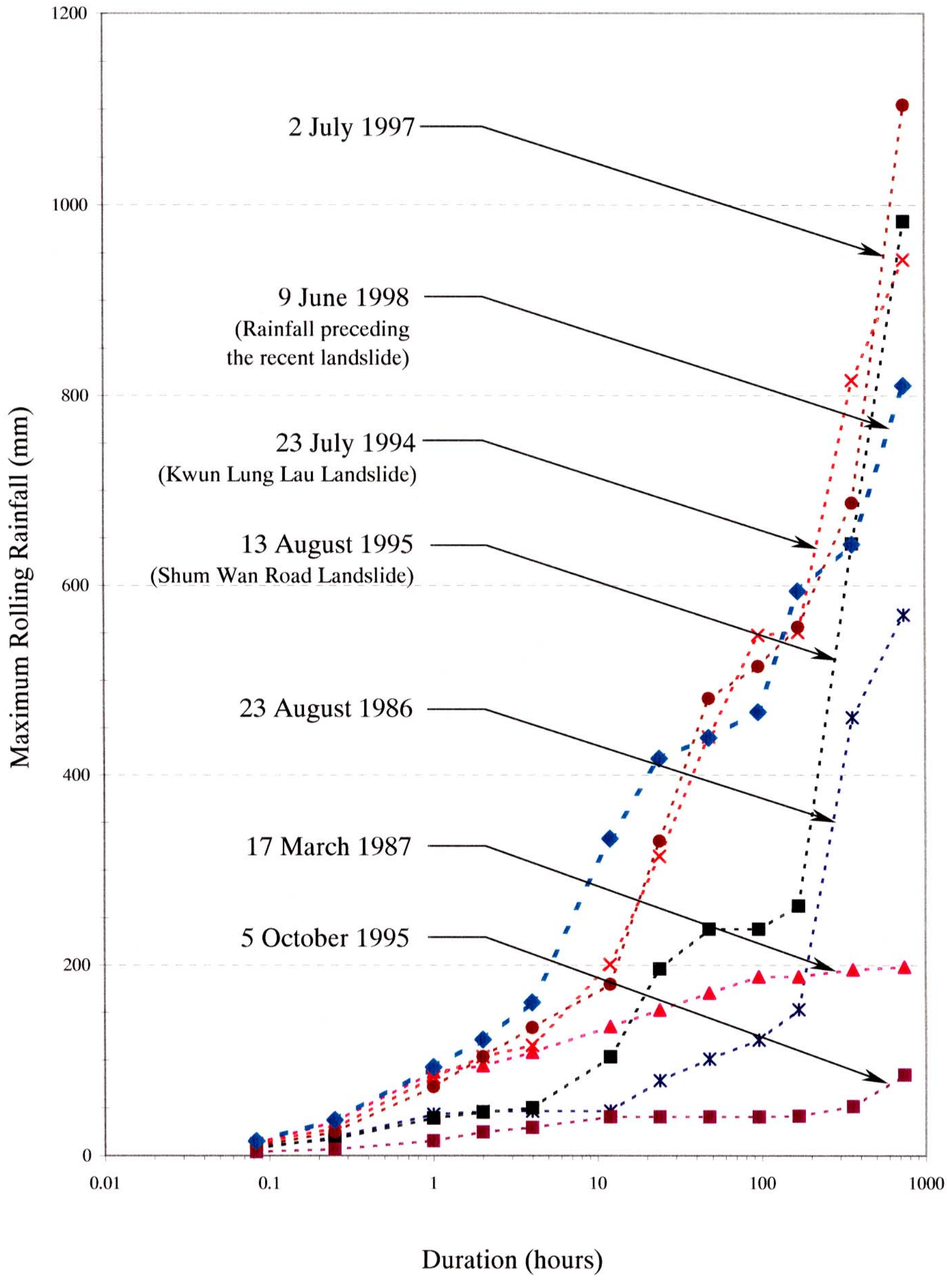


Figure 15 – Rainfall Recorded at GEO Raingauge No. N15



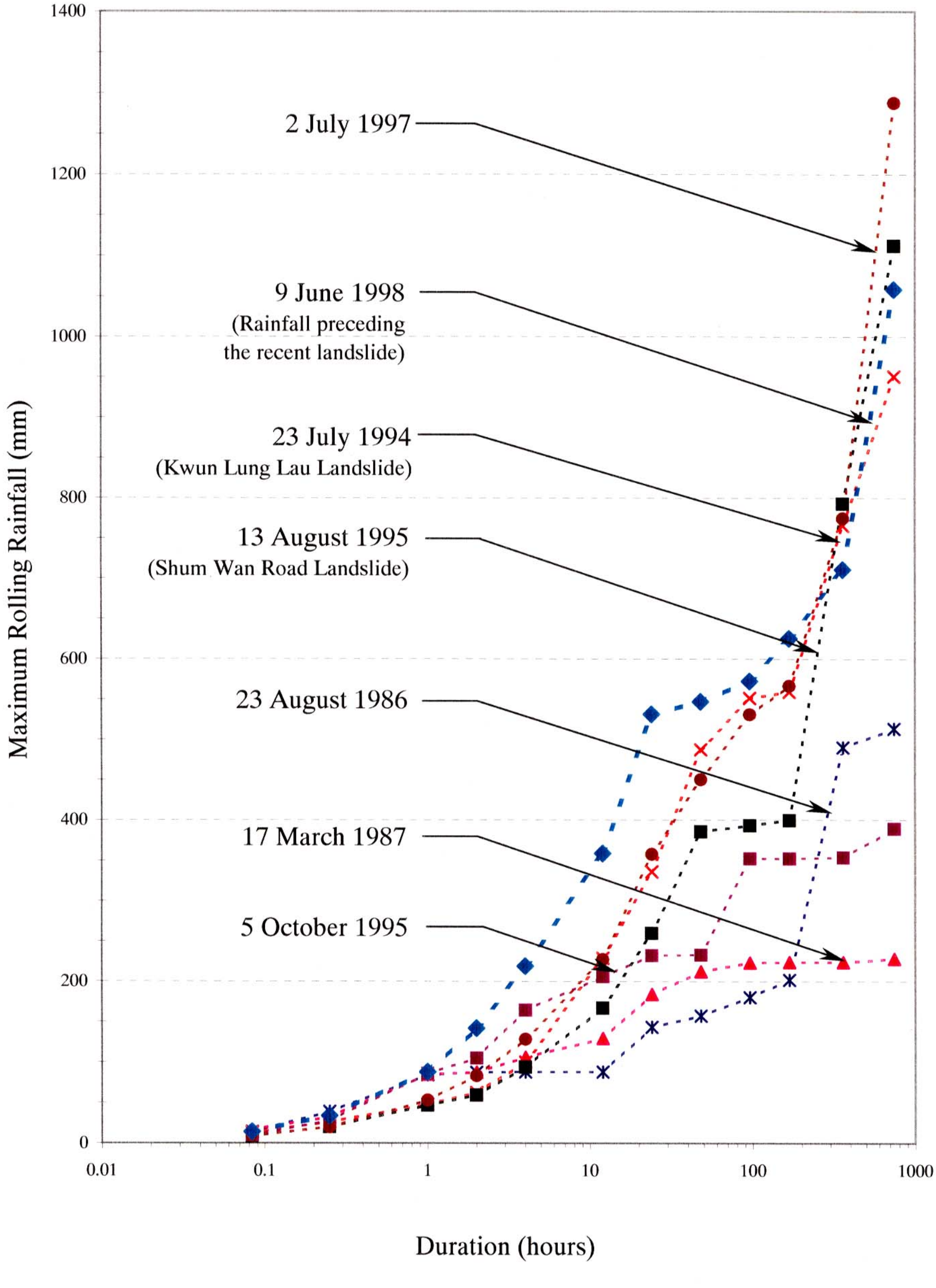
Note : Isohyets of rainfall for the period from 5:30 p.m. on 8 June 1998 until 5:30 p.m. on 9 June 1998

Figure 16 - Rainfall Distribution in the 24 hour Period Preceding the Landslide of 9 June 1998



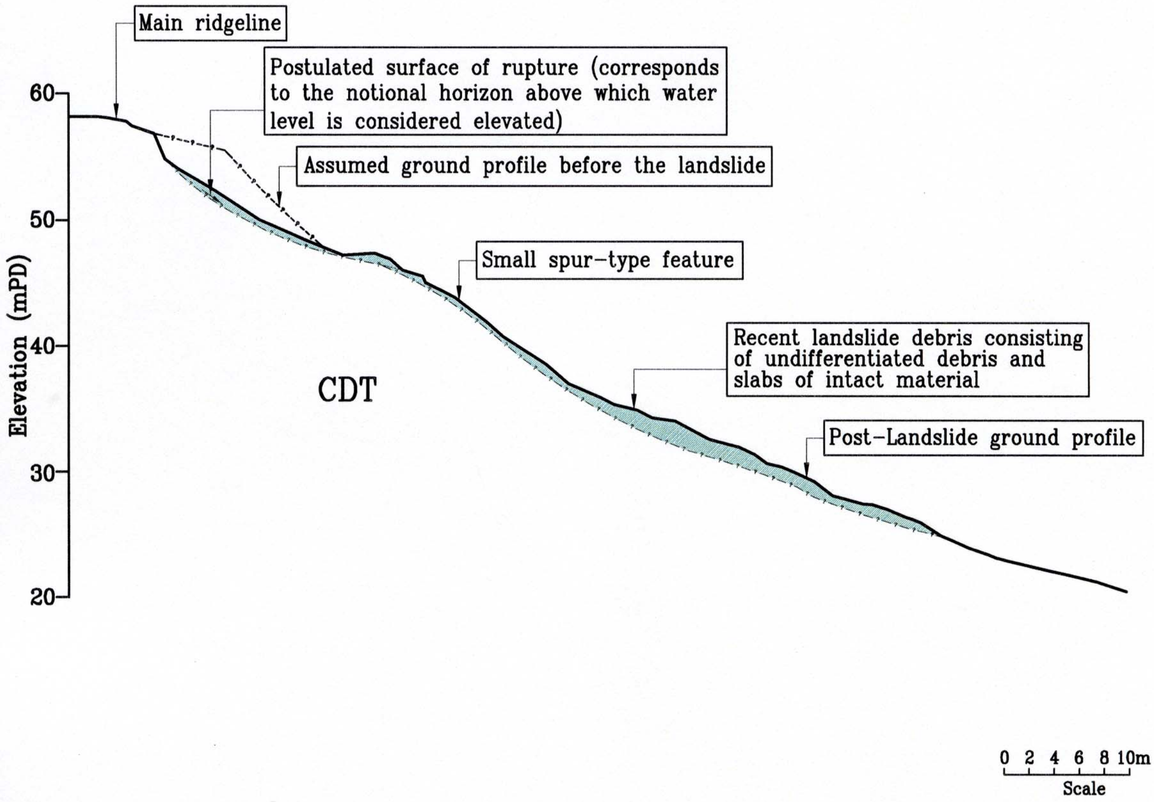
Note : Rainfall data are 5-minute statistics from GEO Raingauge No. N13

Figure 17 - Maximum Rolling Rainfall Preceding the Landslide of 9 June 1998 (and Selected Major Rainstorms to 2 July 1997) - GEO Raingauge No. N13



Note : Rainfall data are 5-minute statistics from GEO Raingauge No. N15

Figure 18 - Maximum Rolling Rainfall Preceding the Landslide of 9 June 1998 (and Selected Major Rainstorms to 2 July 1997) - GEO Raingauge No. N15



Section A – A through the Landslide Site

Material	Range of Parameters Considered in Analysis		
	Representative Saturated Mass Shear Strength		Unit Weight (kN/m^3)
	Effective Cohesion c' (kPa)	Effective Angle of Shearing Resistance (ø')	
Residual Soil / Completely Decomposed Tuff	0 – 8	30° – 40°	19

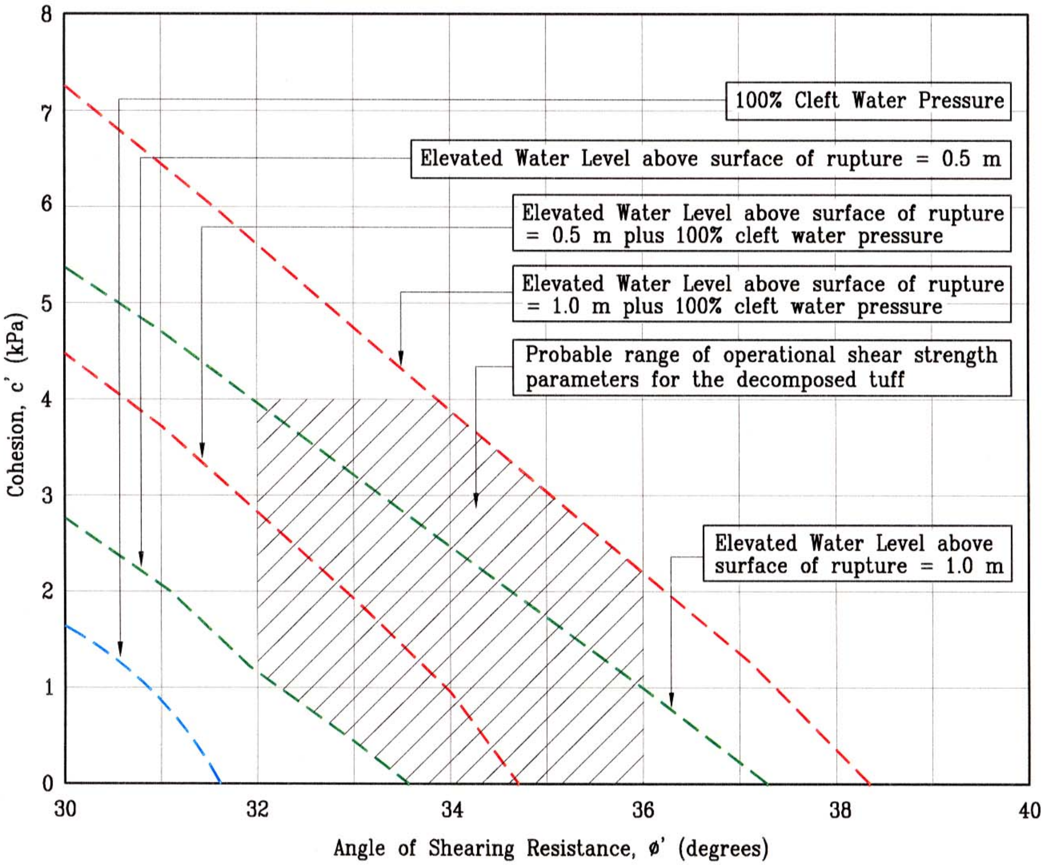
Legend: [shaded box] Recent landslide debris

CDT Completely Decomposed Tuff

Notes: (1) See Figure 7 for location of section.

(2) Information shown on this figure is based on topographic survey, geomorphological and engineering geological mapping, field observations and documentary evidence.

Figure 19 - Theoretical Stability Analysis



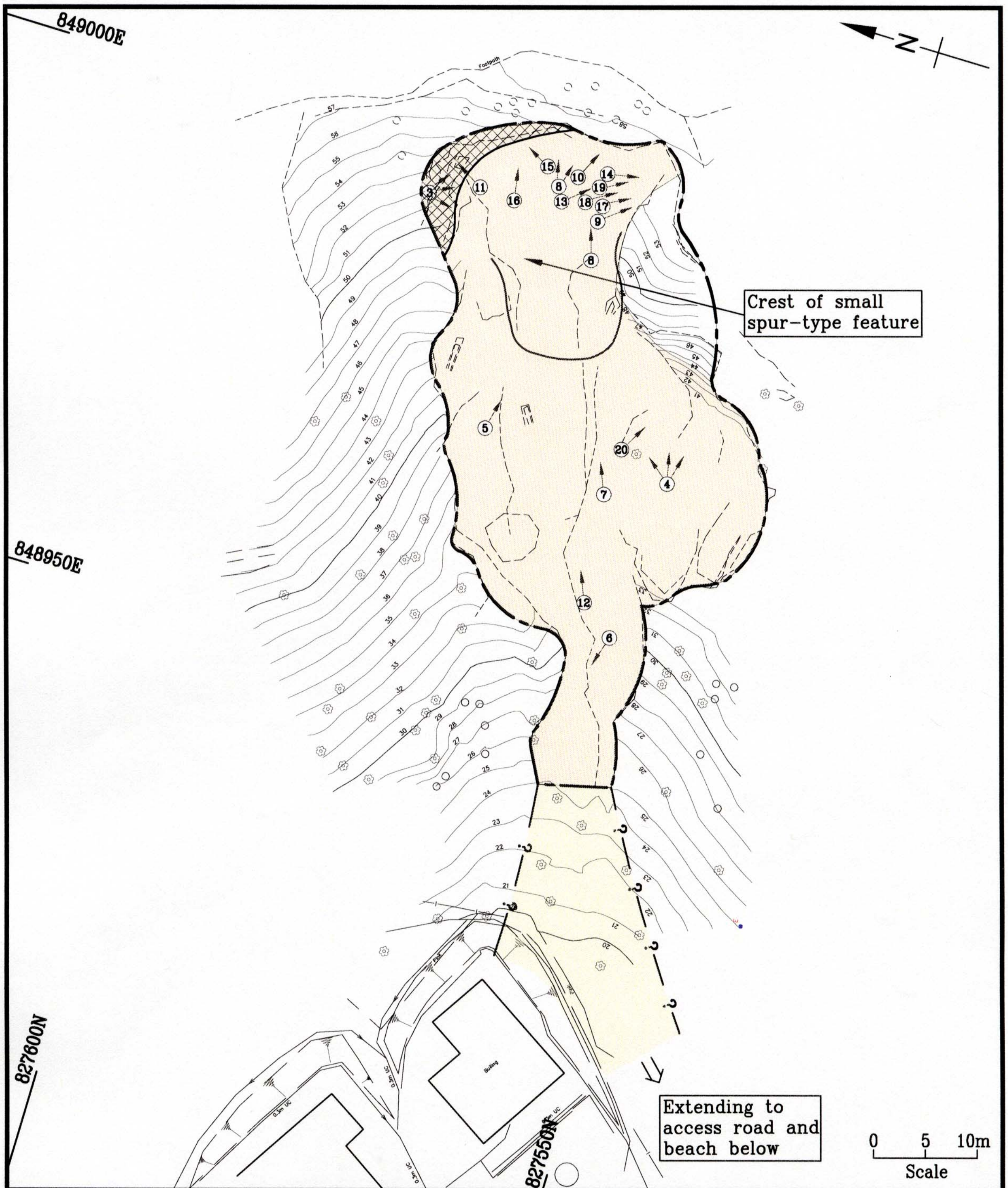
Legend: Factor of safety equal to unity (i.e. limiting equilibrium).

- - - Cleft Water Pressure

- - - Elevated Water Pressure

- - - Cleft Water Pressure Plus Elevated Water Pressure

Figure 20 - Results of Sensitivity Analyses



Legend:

- Undifferentiated landslide debris
- Post–landslide alluvial outwash
- Area of tension cracking
- ③ Approximate location from which Plate No. 3 was taken with general direction of view
- Outline of landslide scar
- — ?— Inferred limit of subsequent alluvial outwash
- Erosion channels within landslide debris
- 20 Contour in mPD

Note: Plate Nos. 1 and 2 were taken from a helicopter.

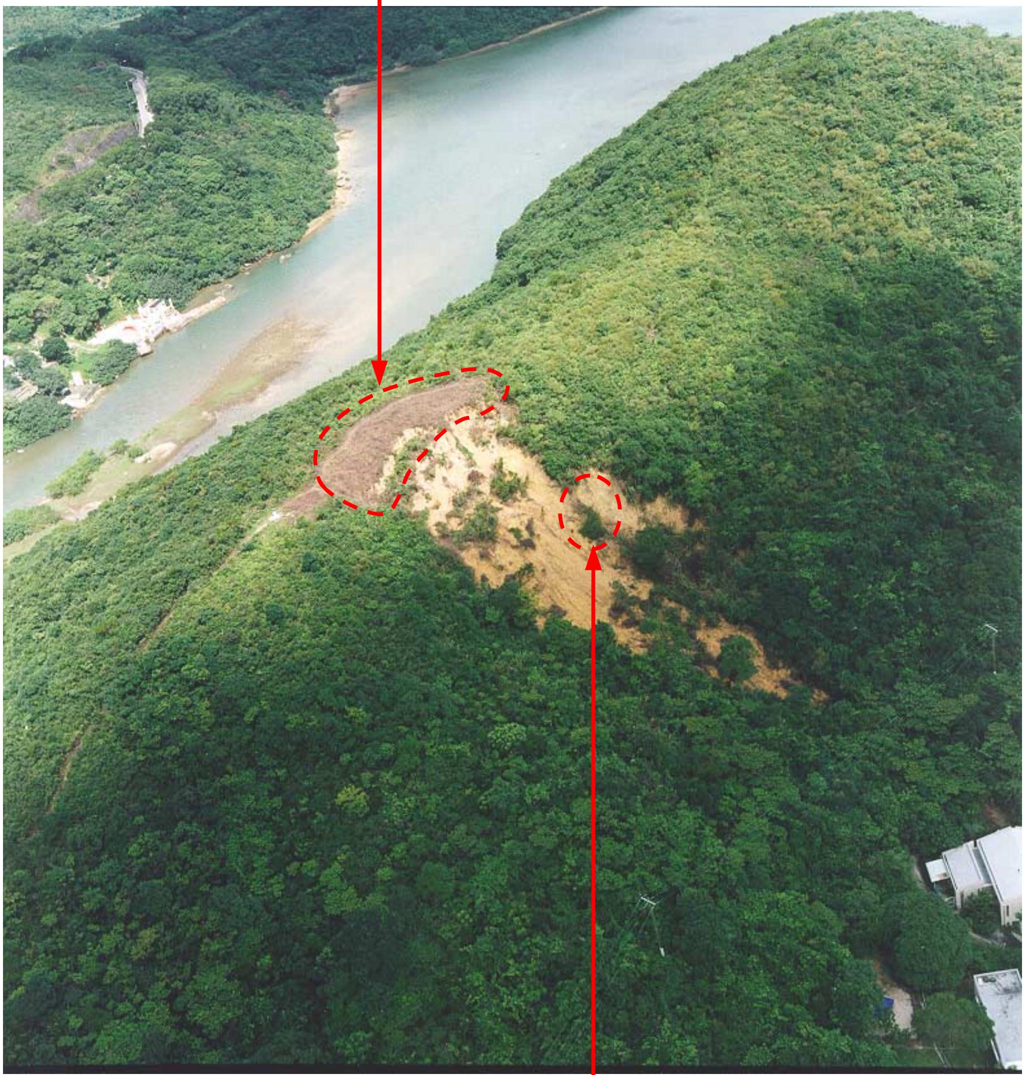
Figure 21 - Location Plan of Photographs Taken

LIST OF PLATES

Plate 1 – The Landslide of 9 June 1998 (Photograph taken on 29 June 1998)

Note: See Figure 21 for Location of Photograph.

Vegetation Clearance has been undertaken in the Area between the Main Ridgeline and the Head of the Landslide following the Incident on 9 June 1998



Material displaced at the Junction between the North-facing Slopes of the Southern Spur and the Small Spur-type Feature

Plate 2 – Oblique View of the Landslide of 9 June 1998
(Photograph taken on 29 June 1998)

Note: See Figure 21 for Location of Photograph.

Plate 3 – Erosion Channels within Debris at Base of Landslide. Flowing Water Evident (Photographs taken on 24 June 1998)

Note: See Figure 21 for Location of Photograph.

a)

b)

Plate 4 – Erosion Channels within Landslide Debris Immediately to the South of the Small Spur-type Feature (Photographs taken on 24 June 1998)

Note: See Figure 21 for Location of Photograph.

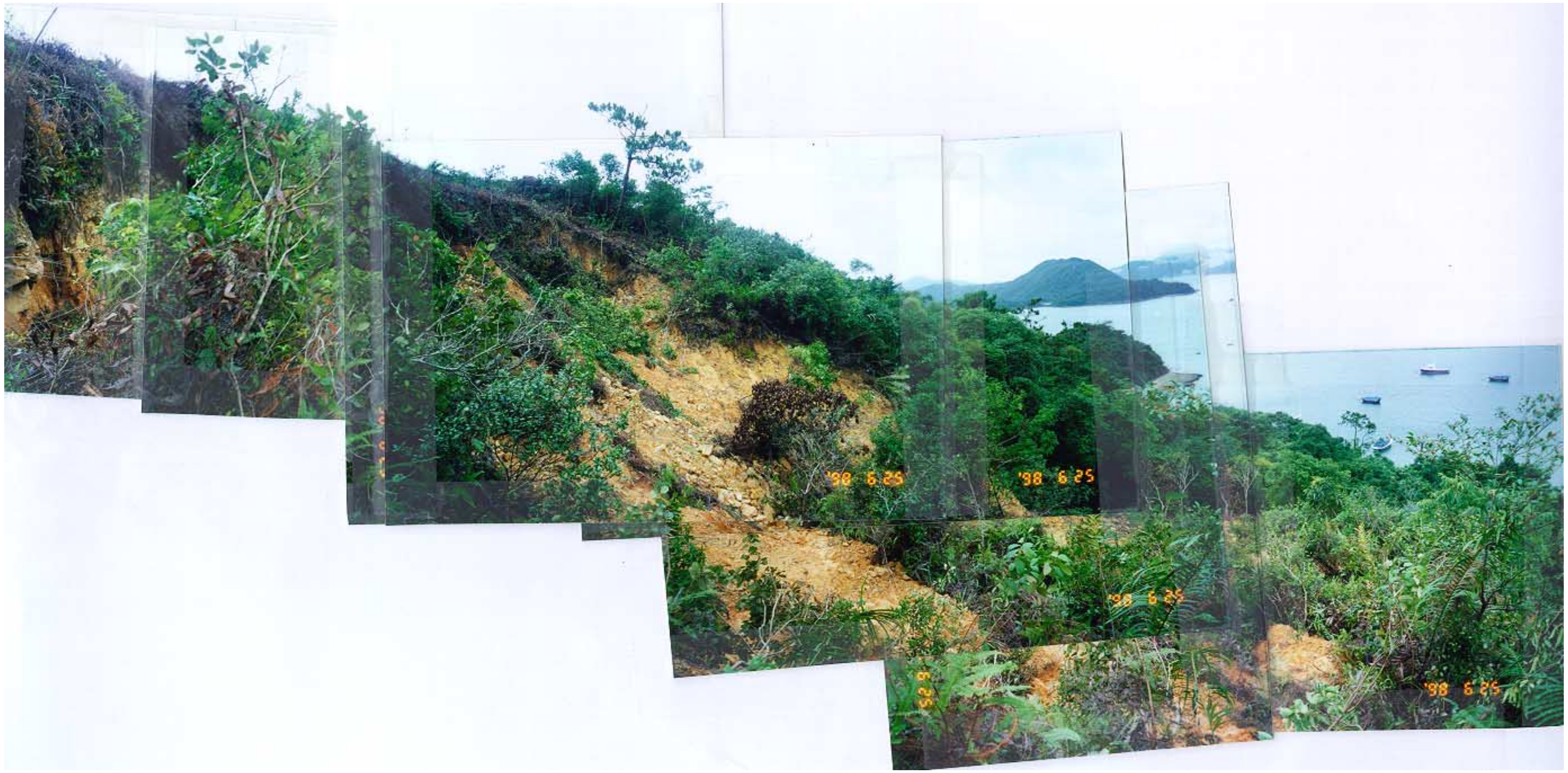


Plate 5 – General View of the Upper Landslide Backscarp and Top of the Small Spur-type Feature (Photographs taken on 25 June 1998)

Note : See Figure 21 for Locations of Photographs.

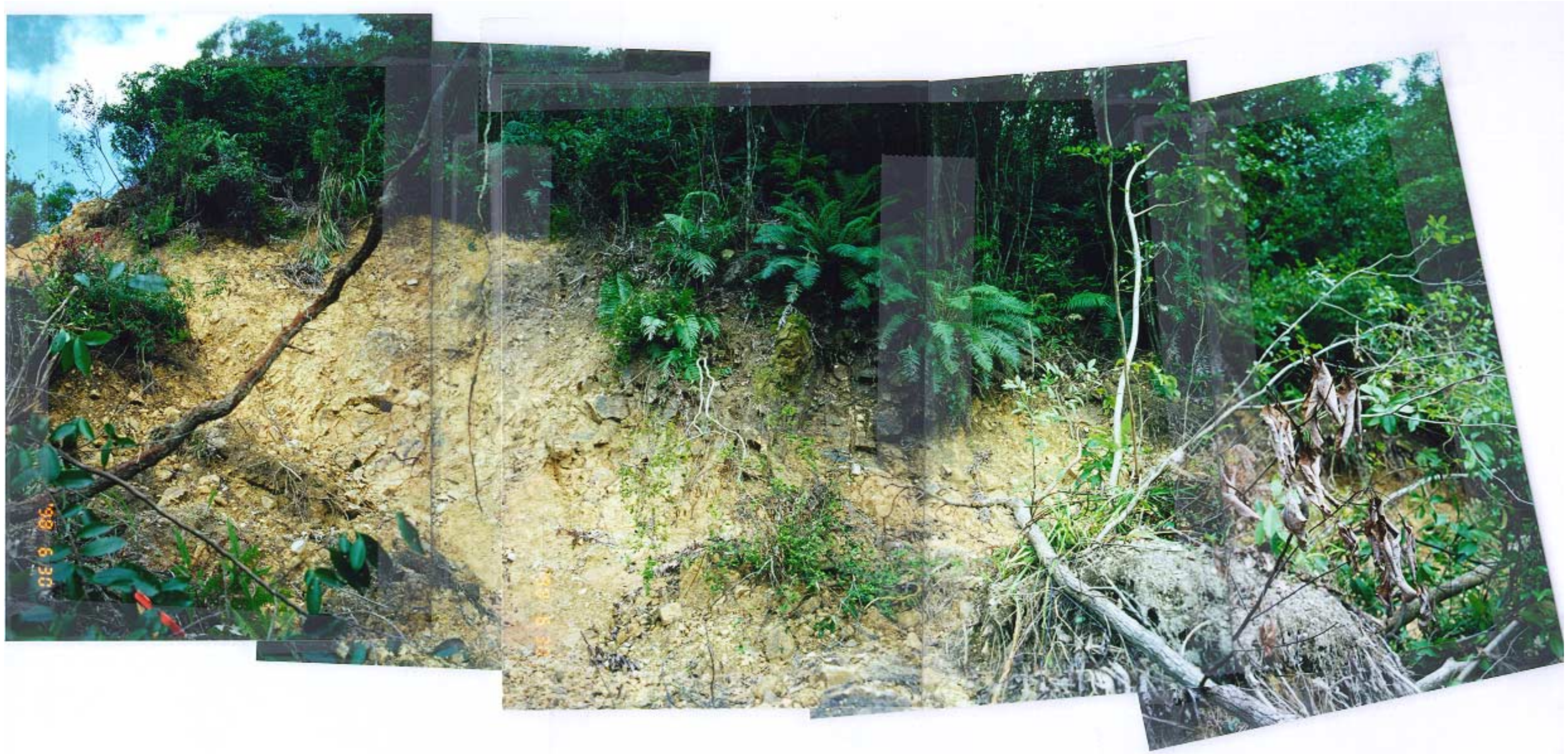


Plate 6 – General View of the Lower Landslide Backscarp
(Photographs taken on 30 June 1998)

Note : See Figure 21 for Locations of Photographs.

Plate 7 – General View of the Landslide Looking up to the Small Spur-type Feature from Below. Note the Rafts of Material in the Foreground as well as the Erosion Channels that have formed within the Landslide Debris (Photographs taken on 24 June 1998)

Note : See Figure 21 for Locations of Photographs.

Plate 8 – View of the Upper Landslide Backscarp showing Small Ridge-type Feature (defined by Vine) as well as Many Blocks of Rock in the Foreground (Photographs taken on 2 July 1998)

Note : See Figure 21 for Locations of Photographs.

Plate 9 – Probable Erosion Pipes, typically 5 mm in Diameter, Observed adjacent to the Southern Fault Plane of the Fault Zone in the Upper Landslide Backscarp (Photograph taken on 30 June 1998)

Note: See Figure 21 for Location of Photograph.

Plate 10 – Possible Erosion Pipe, approximately 50 mm in Diameter, Observed within the Fault Zone in the Upper Landslide Backscarp (Photograph taken on 30 June 1998)

Note: See Figure 21 for Location of Photograph.

a)

b)

Plate 11 – Remnants of Tension Cracking in the Northern Portion of the Upper Landslide Backscarp (Photographs taken on 25 June 1998)

Note: See Figure 21 for Location of Photograph.

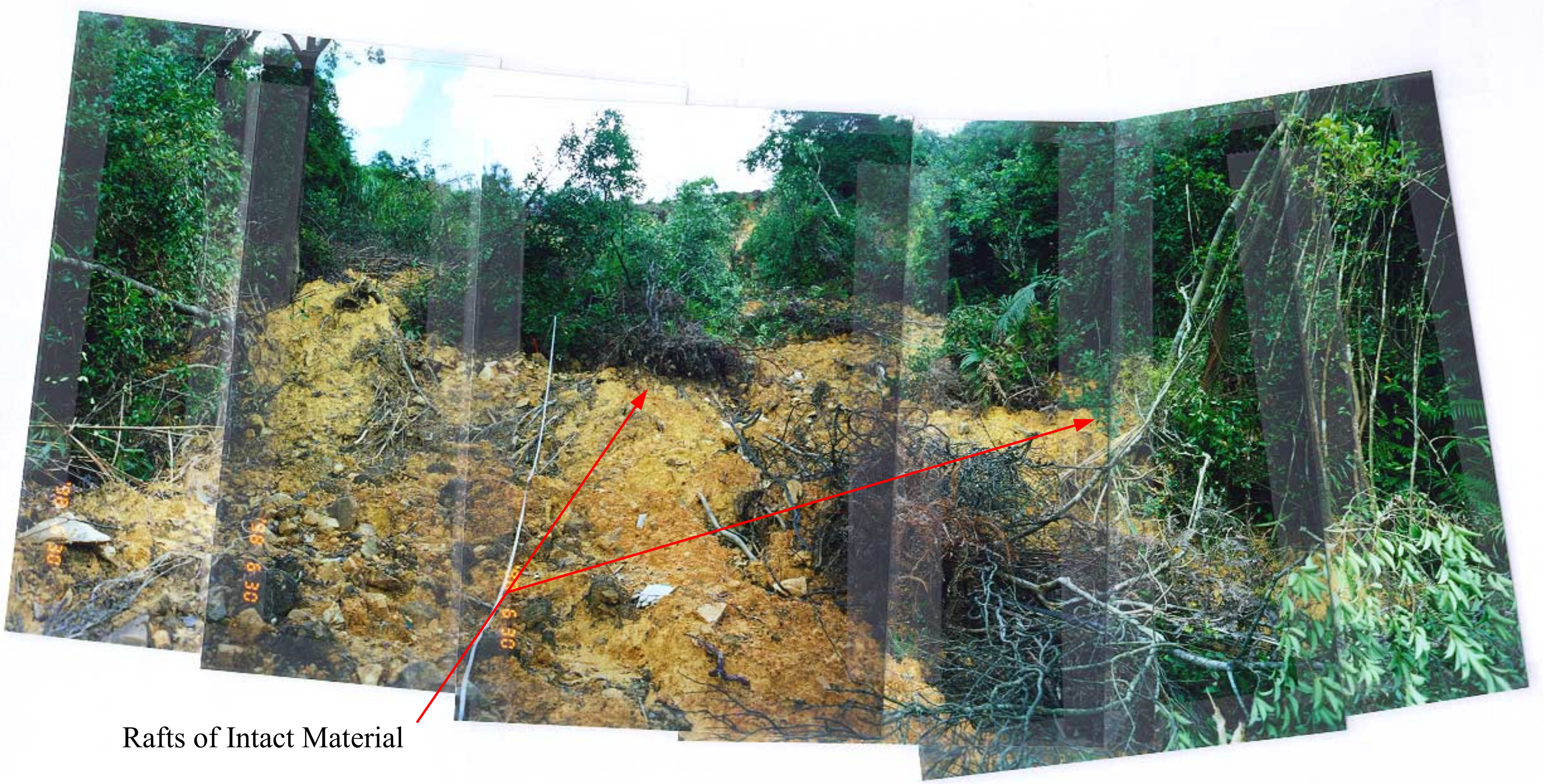


Plate 12 – General View of Debris Trail. Rafts of Intact Material Clearly Evident.
(Photographs taken on 30 June 1998)

Note : See Figure 21 for Locations of Photographs.

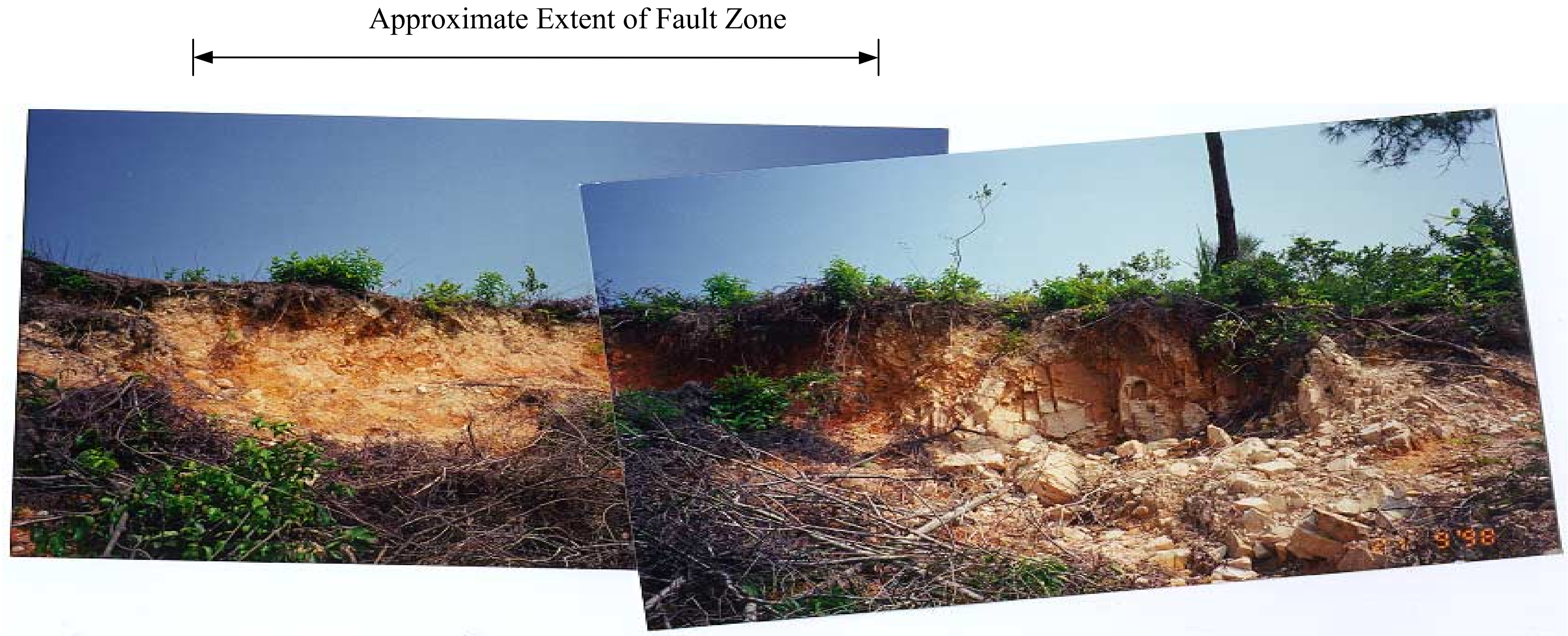


Plate 13 – Panoramic View of the Southern Fault Plane and Associated Fault Zone
(Photographs taken on 21 September 1998)

Note : See Figure 21 for Locations of Photographs.

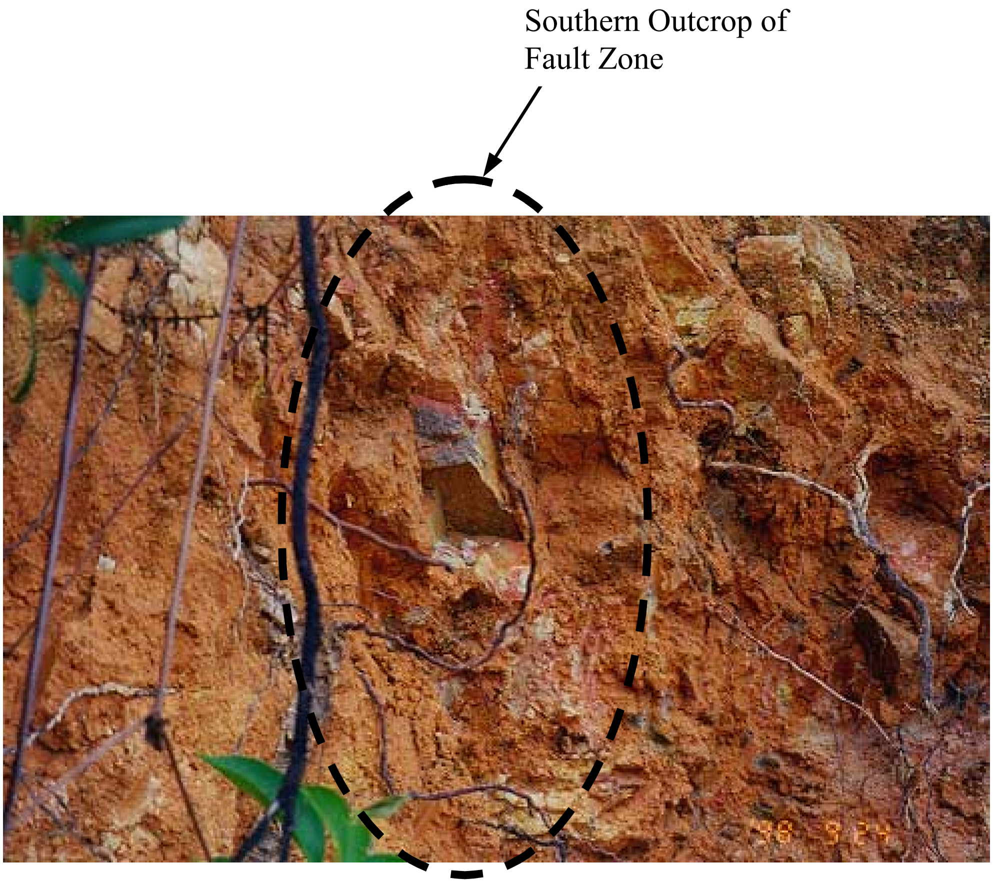


Plate 14 – Close-up Showing Southern Outcrop of the Fault Zone
(Photograph taken on 24 September 1998)

Note: See Figure 21 for Location of Photograph.

Plate 15 – Close-up Showing Slickensided Outcrop in the Northern Fault Plane
(Photograph taken on 24 September 1998)

Note: See Figure 21 for Location of Photograph.

Plate 16 – General View of the Northern Fault Plane
(Photograph taken on 24 September 1998)

Note: See Figure 21 for Location of Photograph.

Plate 17 – Open Nature of Joints in the Upper Landslide Backscarp below the Main Ridgeline (Photograph taken on 21 September 1998)

Note: See Figure 21 for Location of Photograph.

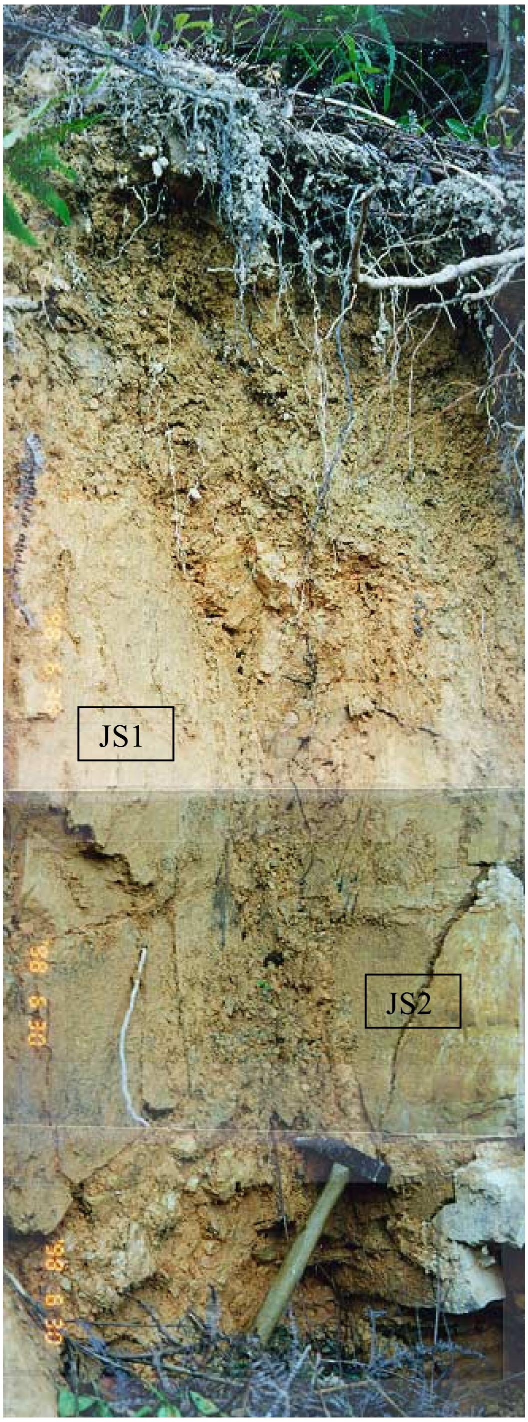


Plate 18 – Dominant West to West-Northwest (JS1) and North-Northeast (JS2) dipping Joint Sets in the Upper Landslide Backscarp (Photographs taken on 30 June 1998)

Note: See Figure 21 for Location of Photograph.

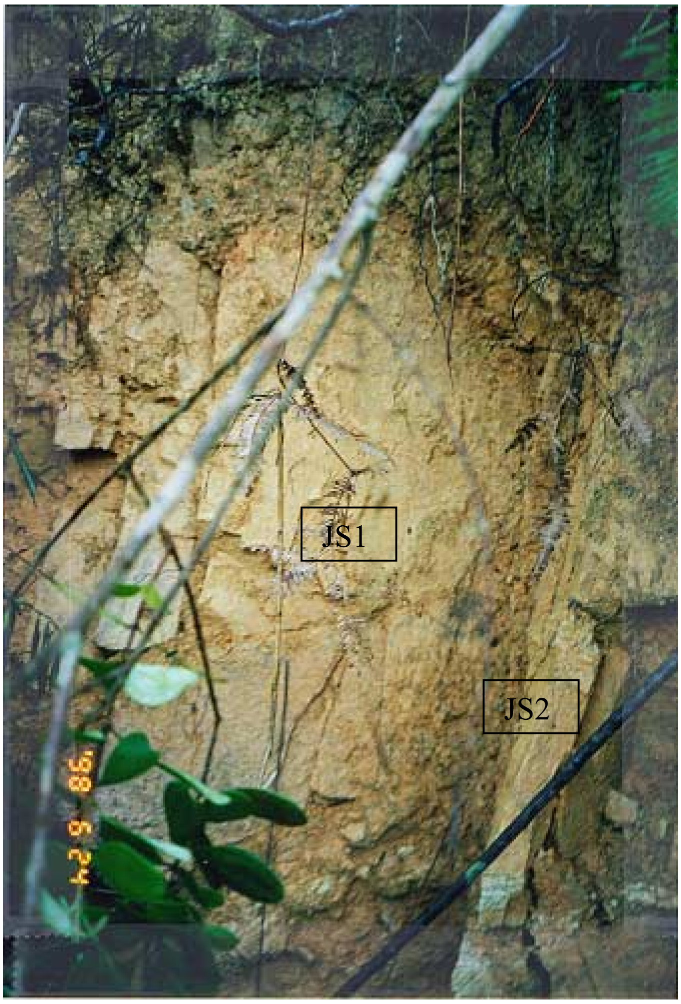


Plate 19 – Upper Landslide Backscarp Joint Planes – Dominant West to West-Northwest (JS1) and North-Northeast (JS2) dipping Joint Sets (Photograph taken on 24 June 1998)

Note: See Figure 21 for Location of Photograph.

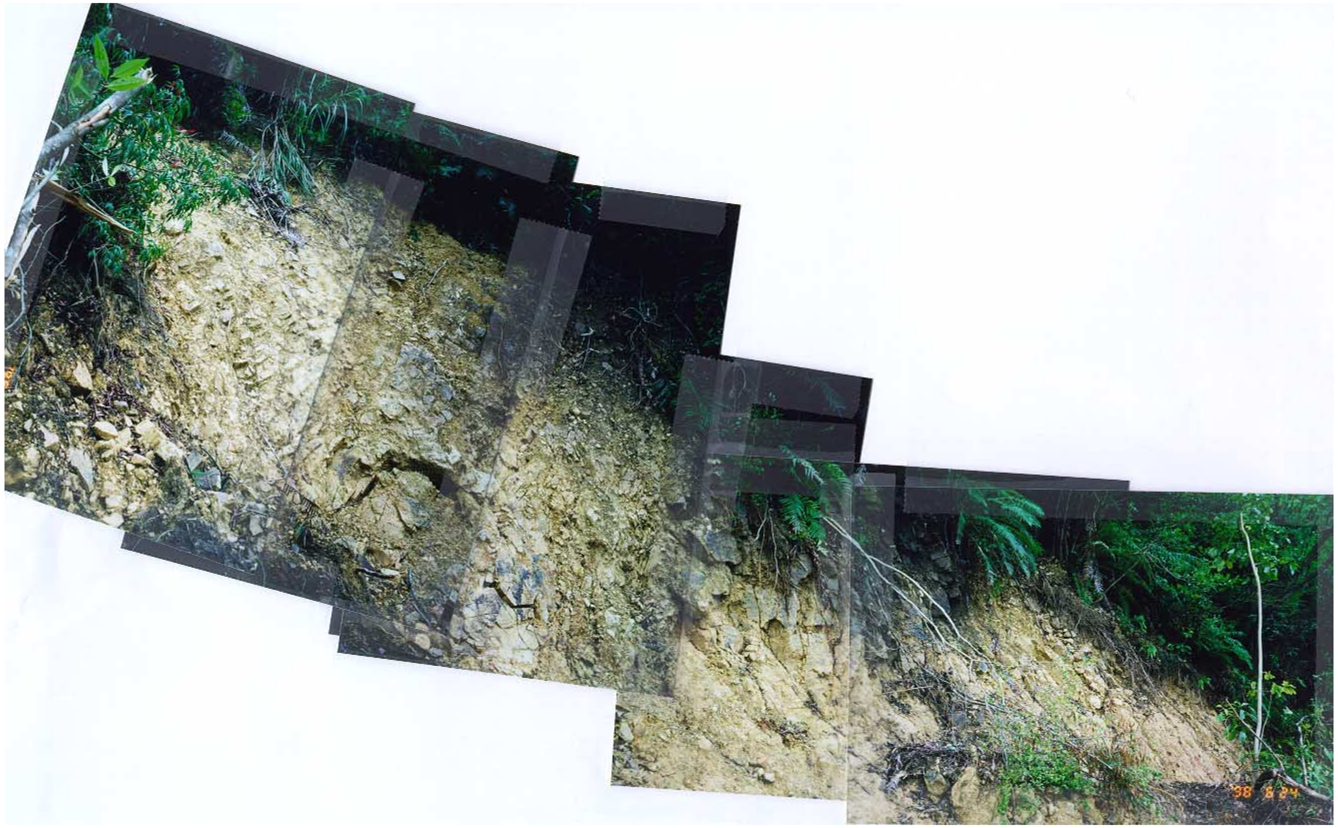


Plate 20 – Lower Landslide Backscarp – Dominant Westward dipping Joint Set Evident
(Photographs taken on 24 June 1998)

Note : See Figure 21 for Locations of Photographs.

APPENDIX A

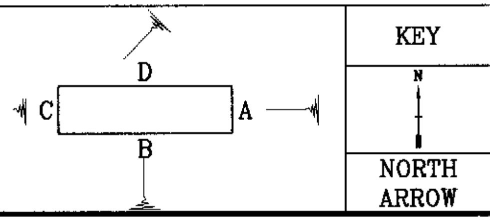
TRIAL PIT RECORD SHEETS

Fugro Scott Wilson Joint Venture **Agreement No. CE 74/97** **The 1998 Landslide Investigation Consultancy** **Detailed Study No. 7** **The Outward Bound School, Tai Mong Tsai, near Sai Kung**	TRIAL PIT RECORD TRIAL PIT No. 1 CO-ORDINATES 846991 E 827568 N GROUND LEVEL 47.05 mPD	Sheet 1 of 2 EXCAVATION DATE: from 24-07-98 BACKFILL DATE: 24-07-98 LOGGED BY: JH DATE: 24-07-98 CHECKED BY: GRT DATE: 24-07-98

Samples & tests	Depth (m)	FACE A: 0.50 m	FACE B: 1.50 m	FACE C: 0.50 m	FACE D: 1.50 m	Legend	Grade	Description
								Dry to moist, soft to firm, light yellowish buff brown, clayey slightly sandy SILT with coarse angular gravel and angular cobbles of tuffite, roots and branches (LANDSLIDE DEBRIS)
								Moist, soft, buff brown, clayey very sandy SILT (HILLWASH)
	1						III/IV	Weak, light grey stained brown, fine-grained, jointed, highly to moderately decomposed SILTSTONE (TUFFITE)
	2							Trial pit complete at 1.25m depth
	3							

SYMBOL	SAMPLES/TESTS/WATER
•	SMALL DISTURBED SAMPLE
↕	BULK DISTURBED SAMPLE
▬	UNDISTURBED SAMPLE HORI. (U100/U76)
⊓	UNDISTURBED SAMPLE VERT. (U100/U76)
⊠	BLOCK SAMPLE
˥ ˩	IN-SITU DENSITY TEST
▵	WATER SAMPLE
∿	SEEPAGE

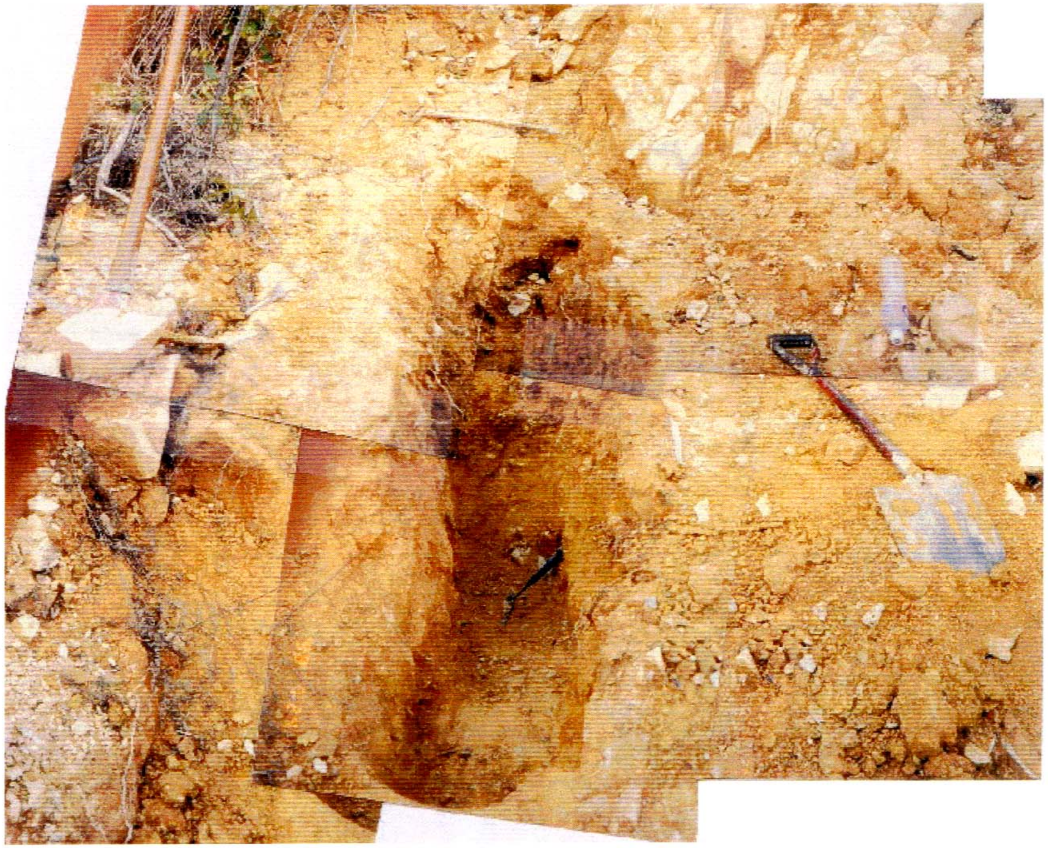
PLAN (NOT TO SCALE)



REMARKS

Pit sides stable. No water encountered

Fugro Scott Wilson Joint Venture Agreement No. CE 74/97 The 1998 Landslide Investigation Consultancy Detailed Study No. 7 The Outward Bound School, Tai Mong Tsai, near Sai Kung	TRIAL PIT RECORD		Sheet 2 of 2
	TRIAL PIT No. 1	EXCAVATION DATE: from 24-07-98 BACKFILL DATE: 24-07-98	
	CO-ORDINATES 848991 E 827568 N GROUND LEVEL 47.05 mPD	LOGGED BY: JH DATE: 24-07-98 CHECKED BY: GRT DATE: 24-07-98	



General View of Trial Pit

Fugro Scott Wilson Joint Venture
Agreement No. CE 74/97
The 1998 Landslide Investigation Consultancy
Detailed Study No. 7
The Outward Bound School, Tai Mong Tsai, near Sai Kung

TRIAL PIT RECORD

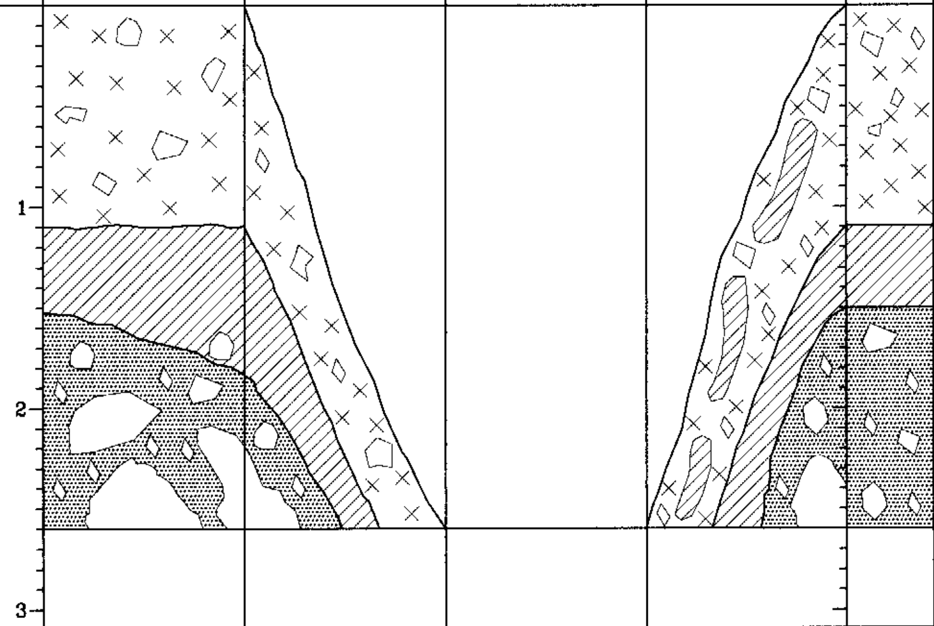
TRIAL PIT No. 2

Sheet 1 of 2

CO-ORDINATES 848982 E 827581 N
GROUND LEVEL 44.94 mPD

EXCAVATION DATE: from 14-09-98
BACKFILL DATE: 26-09-98
LOGGED BY: JH DATE: 17-09-98
CHECKED BY: GRT DATE: 17-09-98

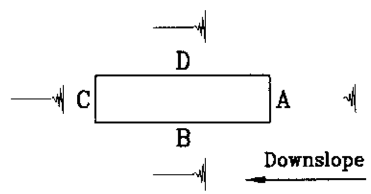
Samples & tests	Depth (m)	FACE A: 0.5 m	FACE B: 2.0 m	FACE C: 0.5 m	FACE D: 2.0 m	Legend	Grade	Description



Description
Moist, soft to firm, light buff brown, sandy SILT and CLAY with occasional angular gravel, cobbles and boulders of highly to moderately decomposed tuffite; and rafts of topsoil (LANDSLIDE DEBRIS)
Moist, soft to firm, dark grey, very silty slightly sandy organic CLAY with some roots and occasional cobbles (TOPSOIL)
Dry, dense, yellowish brown, clayey sandy SILT with some angular cobbles and boulders of highly to moderately decomposed tuffite (COLLUVIUM)
Trial pit complete at 2.60m depth

SYMBOL	SAMPLES/TESTS/WATER
•	SMALL DISTURBED SAMPLE
↕	BULK DISTURBED SAMPLE
▬	UNDISTURBED SAMPLE HORI. (U100/U76)
▯	UNDISTURBED SAMPLE VERT. (U100/U76)
⊠	BLOCK SAMPLE
⊔	IN-SITU DENSITY TEST
△	WATER SAMPLE
∿	SEEPAGE

PLAN (NOT TO SCALE)



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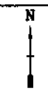


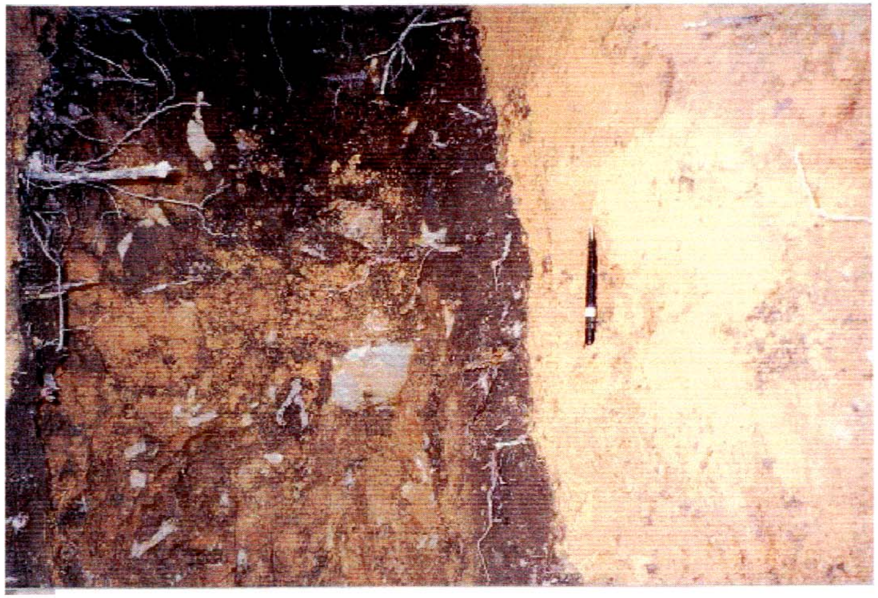
NORTH ARROW

REMARKS

Pit sides stable. No water encountered

Fugro Scott Wilson Joint Venture **Agreement No. CE 74/97** **The 1998 Landslide Investigation Consultancy** **Detailed Study No. 7** **The Outward Bound School, Tai Mong Tsai, near Sai Kung**	TRIAL PIT RECORD		Sheet 2 of 2
	TRIAL PIT No. 2	EXCAVATION DATE: from 14-09-98 BACKFILL DATE: 26-09-98	
	CO-ORDINATES 848982 E 827581 N GROUND LEVEL 44.94 mPD	LOGGED BY: JH DATE: 17-09-98 CHECKED BY: GRT DATE: 17-09-98	

General View of Trial Pit. Note layer of topsoil between recent landslide debris (above) and colluvium (below) in Face A.



Close-up of Face A. Note irregular interface between topsoil and colluvium. Recent landslide debris above topsoil on the right side of the photograph

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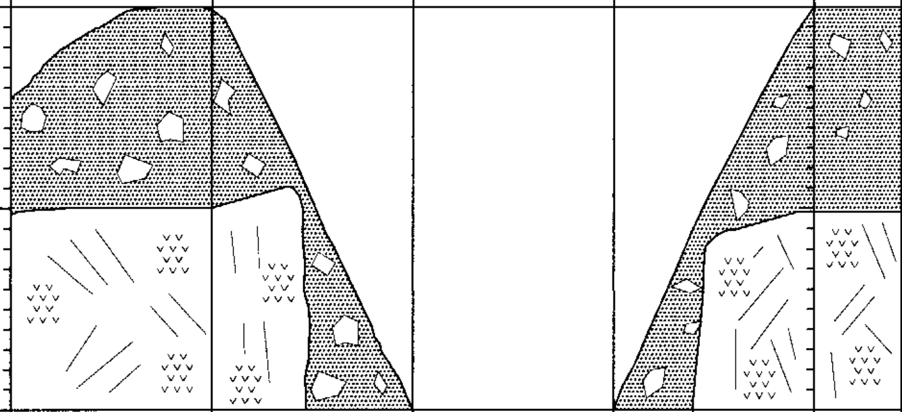
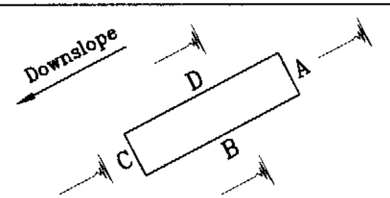
	TRIAL PIT No. 3	EXCAVATION DATE: from 12-09-98 BACKFILL DATE: 26-09-98	
	CO-ORDINATES 848979 E 827574 N GROUND LEVEL 39.99 mPD	LOGGED BY: JH DATE: 17-09-98 CHECKED BY: GRT DATE: 17-09-98	

Samples & tests	Depth (m)	FACE A: 0.5 m	FACE B: 3.0 m	FACE C: 0.5 m	FACE D: 3.0 m	Legend	Grade	Description
								Dry , dense, yellowish brown, clayey sandy SILT with many angular cobbles of highly to completely decomposed tuffite, and some roots (COLLUVIUM)
	1						V	Extremely weak, dry, greyish and orange brown, completely decomposed coarse ash crystal TUFF with some impersistent manganese-stained relict joints (Dry very dense silty fine to coarse SAND)
	2							Trial pit complete at 2.0m depth
	3							



SYMBOL	SAMPLES/TESTS/WATER
•	SMALL DISTURBED SAMPLE
↕	BULK DISTURBED SAMPLE
▬	UNDISTURBED SAMPLE HORI (U100/U76)
▯	UNDISTURBED SAMPLE VERT. (U100/U76)
[×]	BLOCK SAMPLE
⊔	IN SITU DENSITY TEST
▵	WATER SAMPLE
∿	SEEPAGE

PLAN (NOT TO SCALE)



KEY

NORTH ARROW

REMARKS

Pit sides stable. No water encountered

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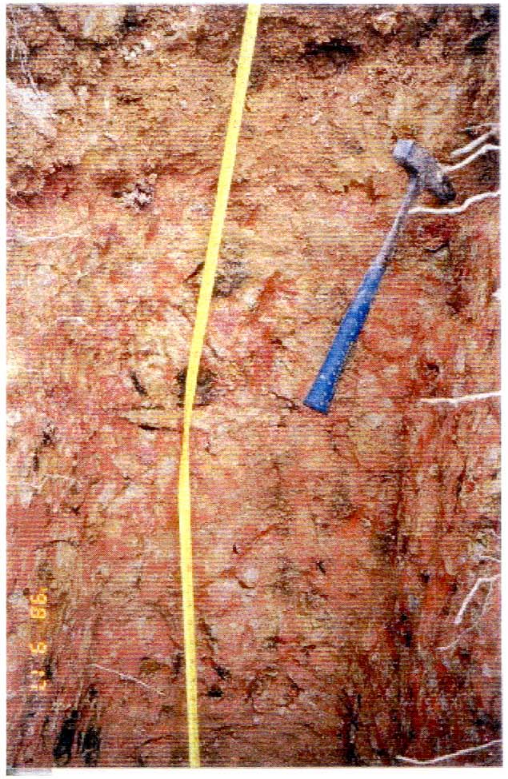
General View of Trial Pit



Close-up of Face A. Point of hammer indicates top of Completely Decomposed Tuff (CDT). Note presence of impersistent manganese-stained relict joints in CDT.

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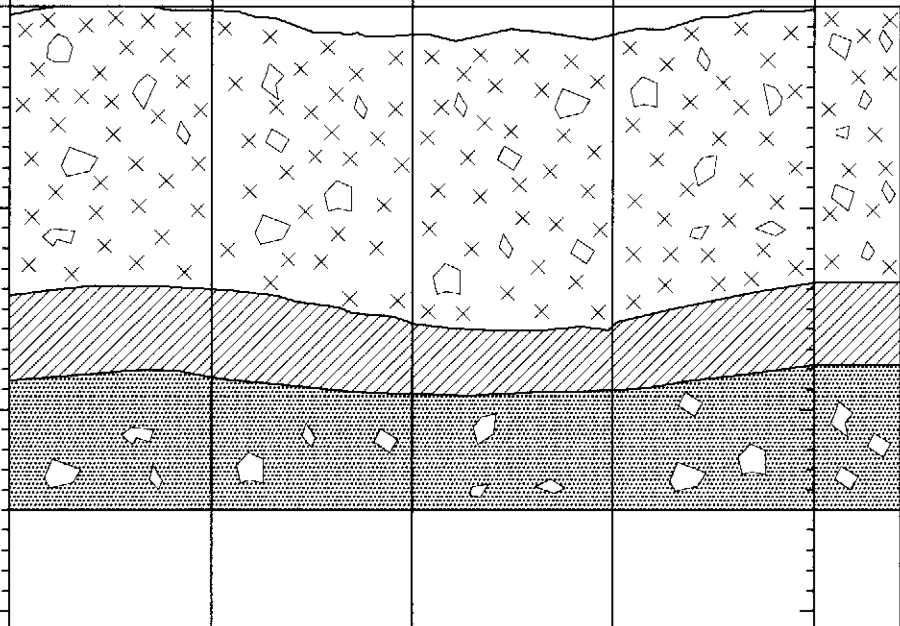
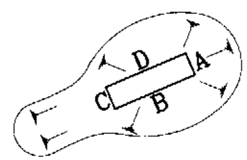
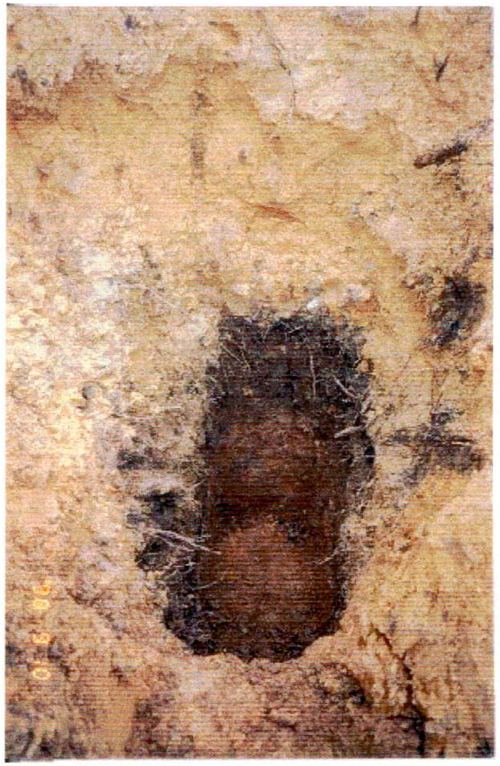
	TRIAL PIT No. 4	EXCAVATION DATE: from 8-09-98 BACKFILL DATE: 26-09-98	
	CO-ORDINATES 848968 E 827572 N GROUND LEVEL 34.42 mPD	LOGGED BY: JH DATE: 17-09-98 CHECKED BY: GRT DATE: 17-09-98	

Samples & tests	Depth (m)	FACE A: 0.50 m	FACE B: 1.50 m	FACE C: 0.50 m	FACE D: 1.50 m	Legend	Grade	Description
	1 2 3							Moist, soft to firm, light buff brown, sandy SILT and CLAY with occasional angular gravel, cobbles and boulders of moderately decomposed tuffite; and branches (LANDSLIDE DEBRIS)
								Moist, soft to firm, dark grey and brown, very silty slightly sandy organic CLAY with many roots and occasional cobbles (TOPSOIL)
								Dry, dense, dark yellowish brown, clayey sandy SILT with some angular cobbles and occasional boulders of slightly to moderately decomposed tuffite (COLLUVIUM)
								Trial pit complete at 2.50m depth

SYMBOL	SAMPLES/TESTS/WATER	PLAN (NOT TO SCALE)	KEY	REMARKS
•	SMALL DISTURBED SAMPLE		 NORTH ARROW	Pit sides battered back within soft landslide debris to prevent collapse. No water encountered
↕	BULK DISTURBED SAMPLE			
▬	UNDISTURBED SAMPLE HORI. (U100/U76)			
▯	UNDISTURBED SAMPLE VERT. (U100/U76)			
⊠	BLOCK SAMPLE			
⊔	IN-SITU DENSITY TEST			
▵	WATER SAMPLE			
∿	SEEPAGE			

Fugro Scott Wilson Joint Venture **Agreement No. CE 74/97**	TRIAL PIT RECORD		Sheet 2 of 2
The 1998 Landslide Investigation Consultancy **Detailed Study No. 7**	TRIAL PIT No. 4	EXCAVATION DATE: from 08-09-98 BACKFILL DATE: 26-09-98	
The Outward Bound School, Tai Mong Tsai, near Sai Kung	CO-ORDINATES 848968 E 827572 N GROUND LEVEL 34.42 mPD	LOGGED BY: JH DATE: 17-09-98 CHECKED BY: GRT DATE: 17-09-98	



General View of Trial Pit Note recent landslide debris above original ground surface

General View of Trial Pit. Note topsoil layer with roots above colluvium in Face A.