TUNG CHUNG EAST NATURAL TERRAIN STUDY AREA GROUND MOVEMENT AND GROUNDWATER MONITORING EQUIPMENT AND PRELIMINARY RESULTS

GEO REPORT No. 142

N.C. Evans & J.S. Lam

GEOTECHNICAL ENGINEERING OFFICE

CIVIL ENGINEERING DEPARTMENT

THE GOVERNMENT OF THE HONG KONG SPECIAL ADMINISTRATIVE REGION

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PREFACE

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

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R.K.S. Chan
Head, Geotechnical Engineering Office
December 2003

FOREWORD

This report describes a monitoring programme on an area of natural terrain with a history of instability near Tung Chung, on Lantau Island. The purpose of the monitoring programme is to gather data on the initiation and movement of landslides on the natural terrain, with particular reference to rainfall and groundwater conditions. Experience has been gained with a variety of techniques and monitoring equipment, and the information in this report might be of use to others planning similar work. The site continues to be monitored. The purpose of this report is to document the results obtained to date and the monitoring techniques used.

The report was prepared by Mr N.C. Evans and Mr J.S. Lam of Special Projects Division. The early equipment development and site work was carried out by Dr H.W. Sun. Most of the routine data collection was carried out by technical officers from Special Projects Division, primarily Mr C.W. Fung and Mr C.K. Lee.

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ABSTRACT

An area of natural terrain above the North Lantau Expressway, east of Tung Chung on Lantau Island, has been monitored since the summer of 1999. The site is being studied to collect time-stamped data on ground movements, groundwater and rainfall. The objective of this work is to improve understanding of the factors affecting stability in this type of terrain, and to assist with the development of landslip warning algorithms and natural terrain hazard assessment methodologies.

Monitoring at the site is continuing. This report documents the work carried out and the data obtained up to the end of 2001. A possible ground model for the site is discussed. The monitoring techniques used are described and assessed, and some preliminary observations regarding rainfall, groundwater and pore pressures at the site are presented.

CONTENTS

1. INTRODUCTION

An area of natural terrain above the North Lantau Expressway, east of Tung Chung on Lantau Island, has been monitored since the summer of 1999. The site, which is referred to as Tung Chung East (see Figure 1), is being studied to collect time-stamped data on ground movements, groundwater and rainfall. The site comprises approximately 2.5 ha of terrain, with slopes of 30º to 40º in weathered volcanic rocks.

The natural terrain in the study area was first investigated as part of a larger area under Consultancy Agreement No. CE 42/98 (Halcrow Asia Ltd, 2000), which developed and evaluated methods of hazard and risk assessment. Although site work under CE 42/98 ended in the summer of 1999, Special Projects Division continued to monitor the site at Tung Chung East because movement was observed after heavy rainfall associated with Typhoon Sam (20-23 August 1999). Fresh shallow slab-slide type movement and longer run-out debris avalanches occurred within an area approximately 100 m by 100 m. A site visit by staff of SP Division the following week confirmed this movement, and signs of previous similar movements were also noted. Plate 1 is an overview of the site at this time.

An area of about 2.5 ha was identified for further study. The site is well-positioned to be used for the gathering of detailed data on ground conditions, groundwater and the initiation of ground movements. Additional instrumentation has been installed and monitoring is continuing to investigate the relationship between rainfall, groundwater and ground movement in this type of terrain. Improved understanding of these phenomena will assist in the development of landslip warning algorithms and natural terrain hazard assessment methodology.

Significant further movement has not yet occurred at the site. Nevertheless, it is considered timely to document the work carried out and the data obtained. A possible ground model based on the available data is discussed. The monitoring techniques used are described and assessed, and some preliminary observations regarding rainfall, groundwater and pore pressures at the site are presented.

2. SITE INVESTIGATION AND GROUND MODEL

Appendix A contains details of the ground and site investigations carried out in the area. Drawing GCSP 34/10 shows the locations of all the ground investigation stations at the site. Appendix B contains a summary of laboratory test results. A short description of the investigation work in and around the site follows.

Boreholes were first sunk in the area in the late 1970s and early 1980s as part of the preliminary studies for the North Lantau Expressway. Additional boreholes along the North Lantau Expressway alignment were sunk in the early 1990s. Between March and June 1999 a variety of investigation techniques were used in the study area under Agreement CE 42/98. These included seismic reflection traverses and resistivity soundings, trial pits and trenches and shallow boreholes, together with dynamic probing (a varient on the GCO Probe/SPT).

Following the decision to continue monitoring the site after Typhoon Sam in August 1999, additional site-specific topographic surveys and investigation were carried out. These included, during the 1999-2000 dry season, surface mapping, installation of surface survey markers and raingauges, sinking of portable sampler holes to depths of about 6 m below ground level (bgl), installation of jet-fill tensiometers and experimental movement detectors, and laboratory testing for index properties. During the dry season of 2000-2001, additional trial pits were sunk, and proprietary logging piezometer/tensiometers were installed by Geotechnical Observations Ltd of Imperial College, UK. The instrumentation at the site has been installed in clusters to investigate both the disturbed and undisturbed ground. The logs of the 1999-2000 portable sampler holes and the 2000-2001 trial pits are contained in Appendix A.

Using the available data, an interpretation has been made of the probable elevation of the top of Grade III material at the site. This interpretation is based on borehole and trial pit data, sesimics, surface observations, and geomorphological theory. As with any ground model, this interpretation is subject to uncertainties and simplifications and is partly a matter of judgement. It should be reviewed if additional data become available.

Figure 2 shows the locations of the boreholes and trial pits at the site, together with the locations of outcrops of Grade III bedrock. Table 1 summarises the borehole data. Figure 3 shows the location of the seismic lines, and Figures 4 to 11 show the ground profiles interpreted by the geophysical contractor (EGS, 1999). Figure 12 interprets the location of the top of the Grade III material. Figure 13 shows the interpreted thickness of regolith across the site. The regolith comprises weathered rock (Grade IV and V), residual soil, colluvium and, at the base of the slope, debris flow deposits. The available data might support an interpretation of the level of the top of the Grade V material across the site if this was required. Mapping the base of the colluvium would be considerably more difficult. Note that there are often uncertainties when logging these materials as discriminating between residual soil and weathered colluvium can be difficult. The following observations are also relevant:

(i) The log of borehole D122 is not consistent with other information in the area. This borehole was sunk in 1978 at the top of the ridge in the southern part of the site and records over 16 m of colluvium. This is inconsistent with the other data and is considered unlikely. The log shows that the material in question is a sandy silt, with no record of any lithic clasts. It is considered more probable that this material is actually residual soil or Grade V weathered rock.

(ii) The interpretation of the seismic records presented in Figures 4 to 11 was carried out in 1999 by the geophysical contractor (EGS). The contractor used empirical relationships between soil type/weathering state and seismic velocities derived from general Hong Kong data, with limited verification in the boreholes at the site. Interpretation of the data from the lower part of the site was complicated by partial ground saturation.

(iii) The available data suggest that the elevation of the top of the Grade III material forms an approximately planar

> surface across the site, sloping generally to the north west, but not influenced greatly by the detailed surface topography. Hence the regolith thickness is more a function of the detailed surface topography than the topography of the top of the Grade III. This is in broad agreement with the geomorphological model proposed by Hansen (1984), which is discussed further in Section 4.

Figures 14 to 19 show a range of interpreted cross-sections through the site.

3. GEOLOGY

Published information (GEO, 1995) indicates that the sloping terrain at the site is underlain by rocks belonging to the Jurassic Lantau Volcanic Group. This unit comprises a complex sequence of rhyolitic lavas, rhyolitic tuffs and tuffaceous sedimentary rocks. Hydrothermal and dynamic processes have produced rocks with complex textures and field relations. Between the extrusive flows there are numerous thin beds of tuffaceous mudstone and siltstone, although these are noted to be less common in the northern part of Lantau (where the site is located). It is also noted that the siltstone outcrops tend to form prominent ridges and positive features.

The flatter ground at the base of the sloping terrain is shown as being underlain by the East Lantau Rhyodacite, a complex of feldsparphyric rhyolite/porphyritic granite dykes of similar age to the Lantau Volcanic Group. The contact between the two units is thought to be faulted. Superficial deposits (colluvium and alluvium) are recorded on some valley floors and sides.

Geotechnical Area Studies Programme VI (GEO, 1988) makes the following observations concerning the materials thought to be present at, or close to, the site:

(1) Undifferentiated volcanics. These rocks usually produce a thin (< 1 m) soil horizon followed downward, especially on lower slopes (as at the site), by yellowish brown sandy completely weathered material over less weathered, strongly jointed rock below about 11 m. On steep, high slopes considerable rock is exposed, with thin soil and thin weathering. The stability of the weathered material may be suspect, especially during or immediately after prolonged heavy rainfall. Failures are quite common. Rapid surface runoff is common. Deep weathering and close jointing should be anticipated near structural geological lineaments.

(2) Colluvium. This can occur as independent deposits of a unique age such that one deposit overlies another. Older deposits may be subject to severe weathering and may be completely decomposed to a mottled, coloured sandy silt or clayey silt similar to the insitu residual soils. The depth of such weathering may be 10 m or more. Colluvium may be susceptible to failure when wet. It may contain voids.

(3) Feldspar porphyry dyke swarm. These rocks generally weather faster than volcanic rocks but slower than granitic rocks. Develops a thick reddish soil. Weathering depths are generally in the range 7-15 m. Surface hydrology can be affected by these rocks,

with drainage networks aligning with the strike of the dykes. Subsurface hydrology will be affected by the variable rockhead.

Borehole data broadly confirms this interpretation, with "granite porphyry" (feldsparphyric rhyolite) logged at the base of the slope and "tuff/banded lava" logged beneath the slope. Borehole D122 unexpectedly logs "quartz porphyry" further up the slope than might be expected. This suggests either an inlier of the rhyolite dyke swarm (which is possible), or an error in logging (this borehole was sunk in 1978 and the log is fairly crude). Borehole TRL 130, at the base of the slope, appears to intercept a contact between the two formations.

Surface data also confirm the above interpretation, although exposures are limited. Weathered tuff can be seen in the backscarps of the various failures on the slope, and feldsparphyric rhyolite was noted in a streamcourse outcrop at the base of the slope. Outcrops of Grade II and III tuff are present in the perennial streamcourses (see Figure 2). The tuff appears to be metamorphosed in places, exhibiting a sheared/mylonitised appearance and a grey-green colour. This possible metamorphism might result from the later intrusion of the feldsparphyric rhyolite.

4. GEOMORPHOLOGY AND GROUND MOVEMENTS

Hansen (1984) proposed a geomorphological model for terrain evolution in Hong Kong. To simplify, Hansen's model envisages that deep weathering profiles were probably established before the last ice age. Sea level lowering during and after the ice age stimulated the reactivation of streamcourse erosion, forming concave slopes and stripping weathered material. This model envisages that landforms associated with the upper, convex parts of slopes tend to be older and to have deeper (relict) weathering profiles than those associated with lower, concave slopes. An appreciation of Hansen's model can assist with the interpretation and understanding of ground conditions at a site.

The site at Tung Chung East slopes to the north west and comprises part of the lower slopes of a significant hill that rises to 529 mPD. The elevation of the upper slope boundary is about 120 m. The slopes terminate at an elevation of about 15 m at the crest of the cut slopes overlooking the North Lantau Expressway.

The site comprises the interfluve between two perennial streams. At the base of the site, and probably originating from the perennial streams, there are two conspicuous debris fans. These were identified from aerial photographs and from trial pits and trenches during the 1999 studies (Halcrow Asia Ltd, 2000). The age of these fans is not known. This study concentrates on the ground conditions in the interfluve. The generation and movement of these debris flows, and the formation of the debris fans, does not form part of this study.

Figure 20 shows an interpretation of the geomorphological features at the site, including regolith thickness. Much of the site, with the exception of the ridge crests, is mantled with a thin (0.5 m to 1.5 m) layer of colluvium. There are conspicuous concave slope breaks (from 25º-30º to 35º-45º) along the upper parts of the slopes rising from the boundary perennial streams. One interpretation of these slope breaks is that they represent reactivated erosion fronts associated with the streamcourses.

The western part of the interfluve comprises a conspicuous convex ridge. To the east and west of this ridge there are bowl-shaped gullies with ephemeral watercourses. The most conspicuous gully is just to the east of this ridge. The slopes to the east of this gully also show a conspicuous concave slope break (from 25º-30º to 35º-40º).

The eastern part of the interfluve comprises a long gently concave slope with weathering depths generally in the range of 4 m to 8 m. The slope gradient decreases from 30º-35º at the top to 20º-25º at the bottom. This slope is also drained by ephemeral watercourses.

The greatest thickness of weathered rock above Grade III (perhaps 25 m) is found in the ridge in the western part of the site. This ridge, which has a distinctively convex topography, may represent a relict landform (after Hansen, 1984). Elsewhere on the site, the thickness of weathered rock is interpreted to be considerably less, reducing to below 2 m in places. This suggests dissection of a previously-existing surface, with weathering levels determined at an earlier stage in the evolution of the area. The borehole data indicate a relatively sharp transition between Grade V and Grade III, with Grade IV material either absent or limited in thickness.

There are two distinct areas and modes of slope failure in the interfluve.

In the western part of the site there are/have been a number of slump-type failures in the bowl-shaped gullies each side of the ridge. These failures were of the high-mobility type, with the failed material disintegrating completely and running out for significant distances. Slope gradients at the back scarps of these failures are 30º-40º. The largest of these failures has been instrumented and is identified on Figure 20 as area (1). Regolith thickness in the vicinity of these failures varies from 4 m to 12 m.

Investigation in this area has been focussed on the slip identified as area (1). Plate 2 shows the backscarp of this failure. Trial pit TP1 and portable sampler hole A6 were sunk in the failed mass and found colluvium to 2.6 m and 3.1 m respectively. It was not clear whether there was a single failure plane at the base of the colluvium, or multiple failures within it. It is also not clear whether the colluvium involved in the failure derived entirely from the recent movements or, possibly more likely, also resulted from gradual infilling of the gully. Grade V tuff is exposed in the backscarp (which is up to about 2 m high) beneath thin colluvium. Degraded scarps up to about 0.5 m in height are visible upslope, indicating earlier movement.

In the eastern half of the site a large area of the gently concave slope appears to be subject to slab-slide type failure of limited mobility, with the failed material remaining on the slope. The area affected slopes at 25º-35º, with a regolith thickness of about 3 m to 6 m. The failed area contains many minor scarps and tension cracks. The unstable area is identified on Figure 20 as area (2) and has been instrumented. The back scarps are about 1 m high and expose thin colluvium over Grade V tuff. Degraded minor scarps are again visible upslope. Plate 3 shows part of the recent backscarp.

The precise depth and nature of the failure surface or surfaces in this area is not clear. However, the following observations were made in the portable sampler holes and trial pits.

(i) A zone of possible kaolin enrichment was noted in Grade V material at a depth of 5.3 m bgl to 5.5 m bgl in portable sampler hole A2. At the same location an infilled pipe was seen at 2.2 m bgl in Grade V material.

(ii) Pipes, both infilled and open, were seen at multiple levels from 0.5 m to 1.3 m in colluvium in TP4, where an infilled tension crack at 1.0 m bgl was also noted.

(iii) A 0.2 m thick layer of very soft silty clay was seen at 2.0 m bgl between possible residual soil and Grade V material in TP6.

(iv) Buried soil profiles were seen at 0.7 m bgl and 0.4 m bgl respectively in colluvium in TP 2 and TP 3.

The above observations, particularly the infilled pipes, can be interpreted as suggesting vigorous groundwater movement constrained in a relatively thin regolith, with multiple failure surfaces down to depths of about 2 m bgl in colluvium and residual soil.

The history of ground movement at the site has been interpreted mainly from aerial photograph interpretation, supplemented by ground observation of relict scarps, and is shown on Figure 21, superimposed on the site topography.

To summarise, significant movement appears to have occurred as follows:

(i) Before 1963 (data unknown); a variety of movement types, ranging from minor surface failures to possible slab-slide low-mobility events.

(ii) Between November 1984 and December 1986; one slump-type high mobility failure, and possible reactivation of the area of low-mobility slab-slides.

(iii) Between April 1992 and 11 November 1992; three minor high-mobility surface failures.

(iv) Between 22 and 27 August 1999 (Typhoon Sam); moderate-sized high-mobility slump type failures, and major reactivation of the area of low-mobility slab-sliding (see Plates 1, 2 and 3).

(v) Between 6 and 8 July 2001; one minor surface failure (see Plate 4).

In addition, multiple failures were observed close to the west of the site between 1 and 11 November 1993, but movement was not observed within the site.

An analysis of debris avalanche susceptibility using the methodology proposed by

Evans & King (1998) indicates that all the failures within the site originate within areas defined as having "High" susceptibility. This methodology is based on 1:20,000 scale terrain units defined by geological class and slope angle, for which average Hong Kong-wide debris avalanche frequencies have been calculated. Figure 22 shows the susceptibility map derived for the site.

5. SOIL PROPERTIES

The following information is derived from field observations at the surface and in trial pits, and from laboratory testing of samples from the trial pits and portable sampler holes. The laboratory test results are summarised in Appendix B.

The weathered bedrock is characterised by the presence of relict structures (stained joints). As noted above the transition from Grade V to Grade III is generally abrupt. Test data are only available for Grade V material, which is a variably clayey SILT of low-intermediate compressibility (LL 30-45). Clay content is generally 5-40%, averaging 18%.

Residual soil is characterised by an absence of both relict structures and transported clasts. Misidentification of weathered clast-free colluvium as residual soil is always a possibility. Generally less than 0.5 m thick, residual soil was not recorded at all locations. A maximum thickness of more than 2 m was recorded at portable sampler hole G3P on the crest of the ridge in the western part of the site. This tends to support the hypothesis that erosion and mass movement has had less effect in this part of the site than elsewhere.

The residual soil sampled is a clayey SILT of intermediate compressibility (LL35-50). Clay content is generally 25-40%, averaging 34%.

Colluvium is generally ubiquitous on sideslopes and in declivities across the site, and is generally 0.5 m to 1.5 m thick, with a maximum observed thickness of 3.1 m at portable sampler hole A6 (a recently-failed slump).

The colluvium is variable across the site with respect to clast content, although it is consistently matrix-supported. Clasts range in size from pebbles to boulders, with no discernible pattern. The clasts comprised Grade III to Grade V tuffs, varying from rounded to subangular, again with no apparent pattern.

The colluvium matrix is silty CLAY/clayey SILT of intermediate-high compressibility (LL 40-60). Clay content is generally 20-50%, averaging 36%.

6. MONITORING

6.1 General

Figures 23 and 24 show the locations of the movement detectors, piezometers, tensiometers, and raingauges that have been monitored, and the location of the disturbed terrain. Table 2 lists the response zones for the below-ground equipment, and identifies whether they are placed in disturbed or undisturbed terrain. A brief description of the monitoring and data recording programme follows.

6.2 Rainfall

Two Casella tipping-bucket raingauges with internal data loggers were installed during the winter of 1999/2000. The raingauges (which tip every 0.5 mm of rainfall) are located at the upper and lower margins of the site, at elevations of about 95 mPD and 10 mPD respectively. The raingauges record rainfall every five minutes. In addition raingauge N17 (which is part of the GEO network of automatic raingauges) is located approximately 2 km to the southwest of the site, in Tung Chung. This raingauge (also a 0.5 mm tipping bucket type) was installed in 1984 and transmits data to the GEO every five minutes.

6.3 Groundwater

(1) Non-recording open standpipes. In the spring of 1999 Halcrow buckets were installed in open standpipes at 26 locations along the ridge forming the southern part of the site. The standpipes were installed to depths of between about 1 m and 5 m in holes formed by dynamic probing. Readings of maximum water levels in these installations have been taken during the regular monitoring visits. Standpipes and piezometers without Halcrow buckets (one of each) were also installed in two boreholes at the base of the site (TCE1 and TCE2) at this time. These were dipped during the monitoring visits.

(2) Non-recording tensiometers. Standard jet-fill tensiometers were installed at ten locations on the site in the winter of 1999/2000, to depths of between 0.5 m and 2.0 m. Readings were taken during the monitoring visits.

(3) Recording open standpipe transducers. “Diver” logging transducers were installed in open standpipes at seven locations on the site in May 2000. The standpipes were installed in holes formed by portable sampler triple-tube coring to depths of about 6 m. The “Diver” comprises a sealed stainless steel housing containing a pressure sensor, datalogger and power source. It is 20 mm in diameter and can be installed directly in a borehole or standpipe, suspended from the surface by a wire. The internal memory can store 48,000 measurements. The data recording interval was initially set at 2 hours, but this was reduced to 1 hour in November 2000. Data can be downloading to a PC in the field via a readout unit.

(4) Recording standpipe piezometer. In the winter of 1999/2000 an existing 19 mm piezometer with a tip at about 14 m depth in borehole TRL 129 was flushed and found to be working. The original Halcrow buckets were also functioning. The piezometer was subsequently dipped and the Halcrow buckets recorded during the monitoring visits. From spring to autumn of 2001 a Geotechnical Observations Ltd 8 mm diameter recording transducer was installed at the base of the standpipe. The transducer connects to a surface data logger through a flexible, watertight electrical cable. The surface data logger is housed in a water-resistant box with a battery power supply and a sealed RS232 socket. The equipment can record up to 1800 items of time-stamped data at intervals as small as one second. For this investigation the data recording interval was set at 1 hour, giving about 10 weeks between data downloads. These data are discussed further in Geotechnical Observations Ltd (2001).

(5) Shallow recording piezometer/tensiometers. Geotechnical Observations Ltd

have also developed a piezometer which can measure pore pressures continuously over the range +65 kPa to -100 kPa. The piezometer is designed to be used at shallow depths above the natural water table. Ten were installed at the site between spring and autumn 2001. The piezometer head incorporates inlet and outlet flushing ports, connected to the surface by tubing and opened by a hydraulic valve. The head also includes a miniature pressure sensor connected to the surface by a waterproof hydraulic cable. The porous tip comprises ceramic material with an air entry value of about 1 bar. The piezometer heads can be removed from the installation for routine maintenance and calibration. A data logger unit and power supply is housed in a water-resistant box at the surface, and incorporates a sealed RS232 socket. The logger can record up to 1800 data items at intervals as small as one second. For this investigation the data recording interval was set at 1 hour, giving about 10 weeks between data downloads. These data are discussed further in Geotechnical Observations Ltd (2001).

6.4 Ground Movement

(1) Modified recording open standpipe transducers. Three of the portable sampler holes immediately upslope from the failed areas were equipped with a modified variant of the open standpipe transducers, in an attempt to gain time-stamped data on occurrence and magnitude of any further movement. The installations comprised a sealed standpipe (no holes or slots) with a pulley at the surface. The logging tranducers (“Divers”) were installed as normal just above the base of the standpipe, suspended from a wire. The wire was taken over the pulley to a ground anchor downslope in the failed areas. The tranducers were set up to record any changes in the head of water in the standpipes. In the event of movement downslope at the installation location, the transducer would be pulled up the hole, and, if the standpipe retained its integrity, would record velocity as well as time of movement. Maintenance during each monitoring visit comprised checking that the standpipes were full of water, and downloading the transducer memory. Figure 25 gives details of these installations.

These assemblies were designed to record significant movements. The data loggers were set to record whenever the water head changed by more than 2 cm. The devices are not suitable for measuring minor movement, as sag/movement of the lines caused by wind and vegetation can occur. No significant movements have been recorded to date. Occasional false indications were recorded, and were attributed to cows (there is a small herd living in the area) walking into and through the lines. On these occasions a “fail-safe” weak link in the line at the head of the assemblies broke, preventing damage to the installations.

The standpipes were checked for water level during the monitoring visits and topped-up when necessary. The assembly appears to be relatively robust and trouble-free but, of course, no gross movements occurred and the performance of the system as a whole cannot be evaluated.

(2) Surface markers. Thirteen monitoring points (M1 to M13) and nine control points (L1 to L9, located in areas thought unlikely to move) were installed at the site in early December 1999. The locations are shown on Drawing GCSP 34/10. The monitoring and control points comprise conspicuous target markers designed to be visible on low-level aerial photographs. Four aerial photographic surveys were carried out between December 1999

and September 2001. Ground surveys of the markers were carried out at the same time as the first two aerial surveys, and in spring 2002. All the surveys were carried out by Survey Division of the CED. Survey Division also liaised with Lands Department who assisted with producing photogrammetric plots from the aerial photographs. The ground surveys and the photogrammetric analyses showed that there has been no significant movement of the target markers, i.e. minor differences in position were within the limits of accurate measurement and showed no clear trend.

(3) Digital terrain modelling. The photographic equipment used by Survey Division during the aerial surveys permits digitisation of the data. Digital terrain models (DTMs) can be generated from the aerial photographs. An attempt was made to use this technique for monitoring possible changes in slope morphology. However, it soon became clear that the vegetation on the slope was confusing the picture sufficiently to render the results invalid, i.e. the DTM was modelling the top of the vegetation, not the ground surface. The technique was not therefore pursued.

7. DISCUSSION

7.1 Ground Movement and Rainfall

Three episodes of movement in the study area have been recorded with a temporal accuracy sufficient to assign them to individual rainstorms with some confidence, as follows:

(i) Movement between 4/92 and 11/92, assumed to result from the storm of 18-19 July, 1992 (multiple high-mobility shallow failures).

(ii) Movement between 22 and 27 August 1999, assumed to result from Typhoon Sam on the same dates (reactivation of shallow slab-slide failure and deeper, high-mobility slumping).

(iii) Movement between 6 and 8 July 2001, assumed to result from the rainstorm on the same dates (single high-mobility shallow failure).

Table 3 shows a selection of rainfall data from these storms, also from all other major storms known to have affected the site since 1992. Plots of the rainfall profiles are in Appendix C. Note particularly the storm of 4-6 November 1993 which was extremely severe but which did not apparently cause any movement at the site. Note also that prior to April 2000 the rainfall parameters are taken from raingauge N17, which is located about 3 km to the southwest of the site. There is therefore some uncertainty over the actual rainfall at the site for the storms before this date.

All the three rainstorms associated with failures are typified by an initial period of moderate intensity rainfall (averaging between 7.5 and 9 mm/hr) contributing between 60 and 150 mm. This initial rainfall was then followed immediately by more intense rainfall (40 mm per hour or more) contributing between 90 and 330 mm.

The four rainstorms which did not cause failures are more difficult to categorise. The storm of 22-24 April 2000 comprised very intense but short duration rainfall (200 mm in three hours) with no significant antecedent rainfall. Note that total runoff would have been high, and infiltration relatively low. The storm of 24-28 June 2001 comprised relatively steady but moderate rainfall that never exceeded 35 mm per hour for a total of nearly 300 mm in approximately three days. The storm of 10-13 June 2001 comprised approximately 75 mm of steady antecedent rainfall averaging about 9 mm per hour, followed by approximately 120 mm in two hours. It is perhaps surprising that this rainstorm did not cause any failures. The storm of 5 November 1993 is the most difficult to explain. This storm (data from N17, not from the site) comprised steady rainfall averaging 12 mm per hour and totalling 320 mm, followed by intense rain (420 mm in 6 hours). It is very surprising that this storm did not cause failures at the site, although many failures were recorded on Lantau in general and in the Tung Chung area in particular.

It is clear from the above that there is, at this site, no simple correlation between the normal measures of rainfall and ground movement.

7.2 Groundwater

7.2.1 Surface Observations

Figure 26 summarises surface water observations made in January 2000 (dry season) and June 2001 (during the wet season, but following a dry spell). There appears to be a permanent groundwater system at the site. The perennial streams to the north and south of the site are flowing year-round, although the southern stream dries in its lower reaches in the winter where it passes through the relatively thick debris lobe. There is also a permanent spring at an elevation of about 19 mPD at the base of the slope, and the low-relief alluvial terrain below this point is permanently wet.

It can be seen that the two streams are permanently flowing where they are cut into the top of the Grade III rock. One interpretation of this observation is that the top of the Grade III forms a low-permeability boundary on top of which residual groundwater flow occurs from the hill behind the site. Hence the water flowing in the streams could be derived from seepage from the regolith higher up the stream courses. The southern stream dries in its lower reaches where the top of the Grade III becomes depressed below ground level (the stream is cut in highly variable and probably permeable debris flow deposits in this area). Seepage from the base of the regolith was observed at one point in the northern streambed in June 2001 (see Figure 26). The permanent spring at the base of the slope occurs where the regolith is about 5 m thick, but thickens upslope to about 8-10 m.

Hence a model of the permanent groundwater flow at the site could envisage permanent seepage on the top of the Grade III, derived from local regolith (during wet periods) and from upslope storage (during both wet and dry periods). This groundwater flow becomes constrained towards the toe of the slope where the regolith thins. Flow would be mainly in weathered and open joints in the Grade IV (where present) and V material, and would therefore be expected to be variable, depending largely on the inherited rock structure.

7.2.2 Deep Groundwater

Borehole TRL 129 at the crest of the ridge in the southern part of the site contains a standpipe piezometer with the tip at about 14 m bgl straddling the Grade III/IV boundary. Data is recorded with a logging transducer (see Section 6.3). The piezometer is dry most of the time, responding during rainstorms. It is therefore not possible to calculate the absolute rise in the base groundwater. The highest recorded water level was about 11 m bgl, a rise of about 3 m above the (dry) piezometer tip. Note that permanent or transient groundwater seepage at the Grade III-IV interface, as discussed above, might not register in this piezometer as it could take place below the piezometer tip.

The rainstorm of 24-28 June 2001 produced peak levels noticeably above the general trend. It is interesting to note that this storm was a little unusual in that it produced almost 300 mm of rain in 24 hours, but the intensity never exceeded about 30 mm/hour. Hence the relative infiltration could be expected to be quite high when compared with higher intensity rainfall.

Peak water levels were generally reached between 10 and 15 hours after cessation of significant rainfall (14 to 18 hours after peak hourly intensity). The storm of 10-13 June 2001 was an exception, with peak values 30 hours after cessation of significant rainfall, and 33 hours after peak hourly rainfall. It should be noted that this was the first significant storm of 2001, with low estimated base flows prior to the event. There are no data from TRL 129 for the first (only) storm of 2000, so a comparison cannot be made.

7.2.3 Shallow Groundwater (Halcrow buckets)

These are installed in open slotted standpipes in probe holes to depths of about 6 m bgl along the ridge line in the south of the site, and on the debris fan at the slope toe. The top 0.25 m is sealed. The buckets record approximate equilibrium water levels over the interval sampled, rather than water pressures at a given level. The levels recorded are the maxima since the previous reading. These were the only groundwater monitoring devices in place during Typhoon Sam.

Data were available throughout the entire period from ten stations (some stations became unusable over time). Data from these stations were compared with rainfall parameters.

Regular monitoring of these stations enabled most readings to be assigned to a given storm. The exception was the period 24 June - 16 July 2001 during which there were three distinct storms but only one set of readings. In this case the readings were compared with the rainfall maxima from all the storms during this period, rather than just one storm.

Typhoon Sam produced the highest recorded levels. Five of the ten stations recorded water at, or close to, surface (0.25 m) during Typhoon Sam. The staff who carried out these readings were under the impression that some of these stations may have been flowing (i.e. artesian). The stations recording water at or close to the surface during Typhoon Sam (P19, 27, 29, 31 and 35) are located at elevations above 60 mpd in regolith of 6 m to 8 m thickness.

It is, of course, not possible to assess the lag between rainfall and water level rise for these data.

7.2.4 Shallow Groundwater (Divers)

These seven stations comprise transducers with built-in data loggers in open slotted standpipes. They were installed in portable sampler holes to depths of about 7 m bgl, with the top 0.5 m sealed. The data (head of water converted to a depth bgl or level mPD) represent approximate equilibrium water levels in the response zone. Data were recorded at two hour intervals in the wet season of 2000 and one hour intervals in the wet season of 2001.

All the standpipes were dry between rainstorms, hence maximum groundwater rise is not known. The maximum measured rise was just over 5 m.

As a general observation it can be noted that peak readings increase, and response times shorten, with increasing elevation. Those stations with shorter response times also appear to react to short-duration rainfall, and vice-versa.

7.2.5 Shallow Groundwater (Imperial College piezometer/tensiometer)

The data obtained by Geotechnical Observations Ltd during the summer of 2001 are described and discussed in a separate report (Geotechnical Observations Ltd, 2001). Plots of suction/pore pressure against rainfall are also contained in Appendix C.

As a general observation it should be noted that at shallow depths (about 1 m) pore pressures during rainstorms occasionally approach, or even exceed, full hydrostatic. This suggests that seepage pressures and/or a degree of confinement are present, in addition to complete, or almost complete, saturation of the surface layer. This observation is in agreement with possible observation of flowing (artesian) standpipe piezometers after Typhoon Sam (see Section 7.2.3).

7.2.6 Soil Suction

Suction at the site was monitored using two different types of equipment: conventional Jetfill tensiometers and the Geotechnical Observation Ltd (Imperial College) shallow piezometer/tensiometers, which can measure both positive and negative pressures. Suction measurements (and positive pressures in the case of the piezometer/tensiometers) are plotted against rainfall in Appendix C. The following observations can be made.

(i) Suction at the depths measured (1 to 3 m bgl) responds rapidly to rainfall (this is demonstrated only by the piezometer/tensiometers, as they provide continuous data). The response is more obvious in the shallowest tensiometers, and is also fastest and greatest in the areas disturbed by ground movements.

(ii) The suction values and trends recorded by the Jetfill tensiometers are generally consistent with those recorded by the logging shallow piezometer/tensiometers.

(iii) Suction during the wet season was often destroyed during rainstorms, recovering to values of about -20 to -40 kPa. Suction recovered rapidly during the dry season approaching -100 kPa at shallow depths (off-scale).

(iv) In general, at depths of 1-2 m bgl, suctions are low (and often destroyed) during the wet season, but recover rapidly to high values during dry periods. In contrast, at depths of 2-3 m bgl, suctions tend to remain higher during the wet season, respond less to rainfall, and do not recover as rapidly or to such high values during the dry season.

7.3 Monitoring Techniques

(1) Movement. The adapted Divers have not yet been subjected to a full trial as they have not been involved in any ground movement at the site. However, the technique has the potential to record time and (possibly) rate of movement. The need to incorporate a long and vulnerable trip wire probably restricts use of this technique to remote areas with little human (or animal) activity. Better ways of recording movement might become available soon. A cheap differential GPS receiver with data logger triggered by movement would be ideal. The more traditional marker posts used at the site are simple and reliable, but labour intensive in that they require regular surveying. Also, they are limited in that they cannot produce data on time or rate of movement. The attempts to use digital aerial photography to monitor movement at Tung Chung East were not successful, due mainly to interaction with vegetation.

(2) Groundwater and soil suction. The Imperial College piezometer/tensiometers are relatively easy to install (hand auger) and provide high-quality data at shallow depths. However, they are at present only available as a turnkey service from Geotechnical Observations Ltd, and this service is not cheap. The total cost of obtaining about eight months of data from ten locations (plus one 8 mm transducer as discussed below) was about HK$300,000. The Imperial College 8 mm diameter transducer also has considerable potential as it can be inserted into a 17 mm standard standpipe piezometer. The Diver transducers are robust and reliable but suffer from having a diameter of 20 mm. This means that they cannot be inserted into a standard 17 mm standpipe piezometer. However, it is noted that there has been a recent trend towards using 25 mm diameter standpipe piezometers, and the Divers can be used in these. The traditional Halcrow buckets are reliable, but monitoring is resource-intensive, requiring regular inspection. Standard manual piezometers are not very useful for work such as this as they do not catch peak water levels.

8. CONCLUSIONS

The work carried out at Tung Chung East has shown that groundwater conditions here are complex. Pore pressures at shallow depths at this site (about 1 m bgl) cycled rapidly and repeatedly from positive to negative under the influence of rainstorms during the wet season. At the end of the wet season soil suctions rose rapidly to the limit of measurement (about -100 kPa).

In contrast, at slightly greater depths (2-3 m bgl) suctions tended to remain at higher levels during the wet season, with the generation of positive pore pressures during rainstorms being usually (not always) somewhat more subdued. At the end of the wet season, suctions developed somewhat slower, and did not reach such high values.

There also appears to be a deeper permanent groundwater regime at the site, with groundwater flow taking place at the Grade III/Grade IV boundary. During the wet season rises of up to 3 m were recorded in this deeper groundwater.

There are no clear and unambiguous correlations between any particular rainfall duration and groundwater response or ground movement. This is unsurprising as there is an almost infinite number of combinations of rainfall depth/duration/pattern. As a very general observation, rapid groundwater responses tend to occur at shallow depth and/or where the regolith is thin, and are associated with intense short-period rainfall. In contrast, slower groundwater responses tend to occur at greater depth and/or in thicker regolith, and are associated with longer-duration rainfall.

9. REFERENCES

EGS (Asia) Ltd (1999). Natural Terrain Hazard and Risk Area Studies, Tung Chung East (TCE), Lantau. Geophysical Survey. Contract No. GE/97/12, Works Order No. GE/97/12.25. Job Number HK 139199. For Geotechnical Engineering Office, Hong Kong.

Evans, N.C. (1997). Preliminary Assessment of the Influence of Rainfall on Natural Terrain Landslide Initiation (Discussion Note DN 1/97). Geotechnical Engineering Office, Civil Engineering Department, Hong Kong, 28 p.

Evans, N.C. & King, J.P (1998). Debris Avalanche Susceptibility (Technical Note TN 1/98). Geotechnical Engineering Office, Civil Engineering Department, Hong Kong, 96 p.

GEO (1987). Geotechnical Area Studies Programme - North Lantau. Geotechnical Control Office, Hong Kong, 58 p.

Geotechnical Observations Ltd (2001). Shallow Pore Pressure Measurements in a Natural Terrain Slope, Tung Chung, Lantau Island, Hong Kong. For Geotechnical Engineering Office, Hong Kong, 9 p plus apps.

Halcrow Asia Ltd (2000). Agreement CE 42/98. Natural Terrain Hazard and Risk Area Studies, Mount Johnston North and Tung Chung East, Final Report. For Geotechnical Engineering Office, Hong Kong, 50 p.

Hansen, A. (1984) Engineering geomorphology: the application of an evolutionary model of Hong Kong's terrain. Zeitschrift fur Geomorphologie N.F. Suppl-Bd. 51, pp 39-50.

LIST OF TABLES

Table 1 - Summary of Borehole Data

			Top (mPD/m bgl)					
BH	Date	Superfical Thickness	Grade V	Grade IV	Grade III	Grade II	TD	Comments
EL 81	March 91	4.95 (al/col)	NP	+1.05/4.95	+0.60/5.40	-2.00/8.00	-19.1/25.1	Top 3.00 m is alluvium (1.95 m of colluvium). Bedrock is feldsparphyric rhyolite.
TRL 102	April 82	NP	Surface (+16.4)	+13.4/3.00	+11.4/5.00	+8.60/7.78	-3.74/20.1	Bedrock is granite porphyry (felsparphyric rhyolite).
TRL 127	May 82	6.30 (col/res)	+18.2 (6.30)	NP	NP	NP	+14.2/10.4	Top 4.35 m is col (0.95 m of res). Bedrock logged as tuff.
TRL 128	April 82	1.50 (col)	+31.9 (1.50)	+15.6 (17.8)	+10.6 (22.8)	+4.64 (28.7)	+3.31/30.1	Bedrock is granite porphyry to +28.4 (4.95) then f-m banded lava.
TRL 129	April 82	NP	Surface (+48.9)	NP	+35.0/13.9	+19.6/29.3	+13.8/35.1	Bedrock is tuff/fine-grained banded lava. Piezo at 17 m in Grade III (now operational).
TRL 130	April 82	3.00 (col)	+13.9 (3.00)	Grade IV/III +9.00/7.85		+1.45/15.4	+0.35/16.5	Bedrock is fine-grained banded lava to +1.45, then granite porphry (feldsparphyic rhyolite).
TRL 302	April 82	4.00 (res)	+12.6/4.00	NP	NP	NP	+6.61/10.0	Bedrock is fine-grained granite porphyry (feldsparphyric rhyolite).
D122	Nov 78	16.0 (col??)	+25.0/16.0	+15.5/25.5	+14.0/27.0	+11.1/29.9	+8.7/32.3	Bedrock is "medium grained quartz porphyry".
D123	Nov 78	8.00 (col??)	+28.0/8.00	+24.0/12.00	+17.3/18.7	+15.6/20.4	+12.2/23.8	Bedrock is "porphyry"
TCE1	Apr 99	4.92 (DF)	+14.8/4.92	+14.7/5.02	NP	NP	+4.18/15.5	Bedrock is "tuff". Standpipe at +14.8/5.00, piezo at +5.18/14.5
TCE2	Apr 99	5.27 (DF)	+9.93/5.27	NP	NP	NP	+2.80/12.6	Bedrock is "tuff". Standpipe at +12.2/3.00, piezo at +10.0/5.20

Legend:
al = Alluvium
col = Colluvium
res = Residual soil
DF = Debris flow deposits
TD = Total depth
NP = Not present

Table 2 - Groundwater Monitoring Equipment Response Zones

Location	Type	Ground Conditions	Response Zone (m bgl)
A1	Automatic recording standpipe transducer (Diver)	Undisturbed	0.50-2.38
A2	"	Disturbed	0.50-6.99
A3	"	Disturbed	0.50-5.64
A4	"	Disturbed	0.50-7.21
A5	"	Disturbed	0.50-6.23
A6	"	Disturbed	0.50-5.16
A7	"	Undisturbed	0.50-4.65
P01-S	With Halcrow bucket piezometer (manual)	Debris flow	0.25-2.16
P02-S	"	Debris flow	0.25-2.21
P05-S	"	Debris flow	0.25-1.90
P07-S	"	Debris flow	0.25-2.22
P08-S	"	Debris flow	0.25-1.01
P09-S	"	Debris flow	0.25-1.33
P10-S	"	Debris flow	0.25-1.00
P11-S	"	Undisturbed	0.25-5.03
P13-S	"	Undisturbed	0.25-2.80
P15-S	"	Undisturbed	0.25-5.99
P17-S	"	Undisturbed	0.25-4.97
P19-S	"	Undisturbed	0.25-3.77
P21-S	"	Undisturbed	0.25-6.30
P23-S	"	Undisturbed	0.25-5.04
P25-S	"	Undisturbed	0.25-5.12
P27-S	"	Undisturbed	0.25-4.09
P29-S	"	Undisturbed	0.25-2.27
P31-S	"	Undisturbed	0.25-1.32
P33-S	"	Undisturbed	0.25-2.16
P34-S	"	Undisturbed	0.25-2.19
P35-S	"	Undisturbed	0.25-2.22
P36-S	"	Undisturbed	0.25-3.27
P38-S	"	Undisturbed	0.25-1.62
P39-S	"	Undisturbed	0.25-1.51
P41-S	"	Undisturbed	0.25-3.68
P43-S	"	Undisturbed	0.25-3.96
T1	Jetfill tensiometer (manual)	Undisturbed	0.50
T2	"	Undisturbed	1.20
T3	"	Disturbed	1.50
T4	"	Disturbed	2.00
T5	"	Disturbed	1.50
T6	"	Disturbed	2.00
T7	"	Undisturbed	0.94
T8	"	Undisturbed	1.70
T9	"	Disturbed	1.50
T10	"	Disturbed	1.57
SP1	Automatic recording piezometer/tensiometer	Undisturbed	2.50
SP2	"	Disturbed	3.00
SP3	"	Undisturbed	2.00
SP4	"	Disturbed	2.73
SP5	"	Disturbed	1.53
SP6	"	Disturbed	3.00
SP7	"	Undisturbed	2.62
SP8	"	Undisturbed	1.00
SP9	"	Disturbed	3.00
SP10	"	Disturbed	1.15
SP11 (TRL 129)	Automatic recording piezometer	Undisturbed	16.6

Table 3 - Rainfall Data for Major Storms

Rolling Rainfall (mm)	Raingauge N17			TCE Site Raingauges										
				A	A	B	A	B	A	B	A	B	A	B
	18-19 July 1992	4-6 November 1993	22-27 August 1999	23-24 April 2000	11-12 June 2001		24-28 June 2001		6-8 July 2001		15-16 July 2001		29 August - 8 September 2001	
5 min	12.5	17	6	18.5	20	21	9		9.5	7.5	10.5	11.5	12	13.5
10 min	25	31.5	11.5	32	32	34	14.5	16.5	14.5	11.5	20	20	20.5	22.5
15 min	36	45	16.5	40.5	43	48	18	17.5	21	18.5	27	28	26	27
30 min	64.5	76	28	71	69.5	77.5	25	28	32	27	49	49	36	35
1 hr	115	114	54.5	120	106	112	37	38.5	59.5	52	81	81	54.5	58
2 hr	213.5	190.5	95.5	187	124	128.5	44.5	46	96	87.5	115.5	114.5	80.5	80
4 hr	312.5	285	130.5	200.5	153	156	79.5	87.5	134.5	128	151.5	150.5	139.5	123.5
6 hr	356	422.5	150	207	175.5	177	89.5	99	159.5	155	168.5	166.5	179.5	165.5
8 hr	377	488	167.5	207	188	184	116	123.5	173	171	181.5	180.5	199.5	187
12 hr	423.5	579	205	214.5	207	198	159.5	161.5	208	196.5	183.5	182	211.5	199
18 hr	454	649	263.5	244.5	209.5	198	167	169	251.5	240	187	186	216.5	204.5
24 hr	454	745	310.5	245	232.5	232	168.5	170.5	254.5	242.5	187.5	186	231.5	219.5
36 hr	455.5	774.5	364	247.5	268.5	255.5	218	199.5	269	251.5	187.5	186	235	223.5
48 hr	455.5	775	424	247.5	271	255.5	249	221	271.5	258.5	191	188.5	280	268
72 hr	455.5	777	466	249	293.5	256	286	257	285.5	267	250	259.5	348.5	342.5

LIST OF FIGURES

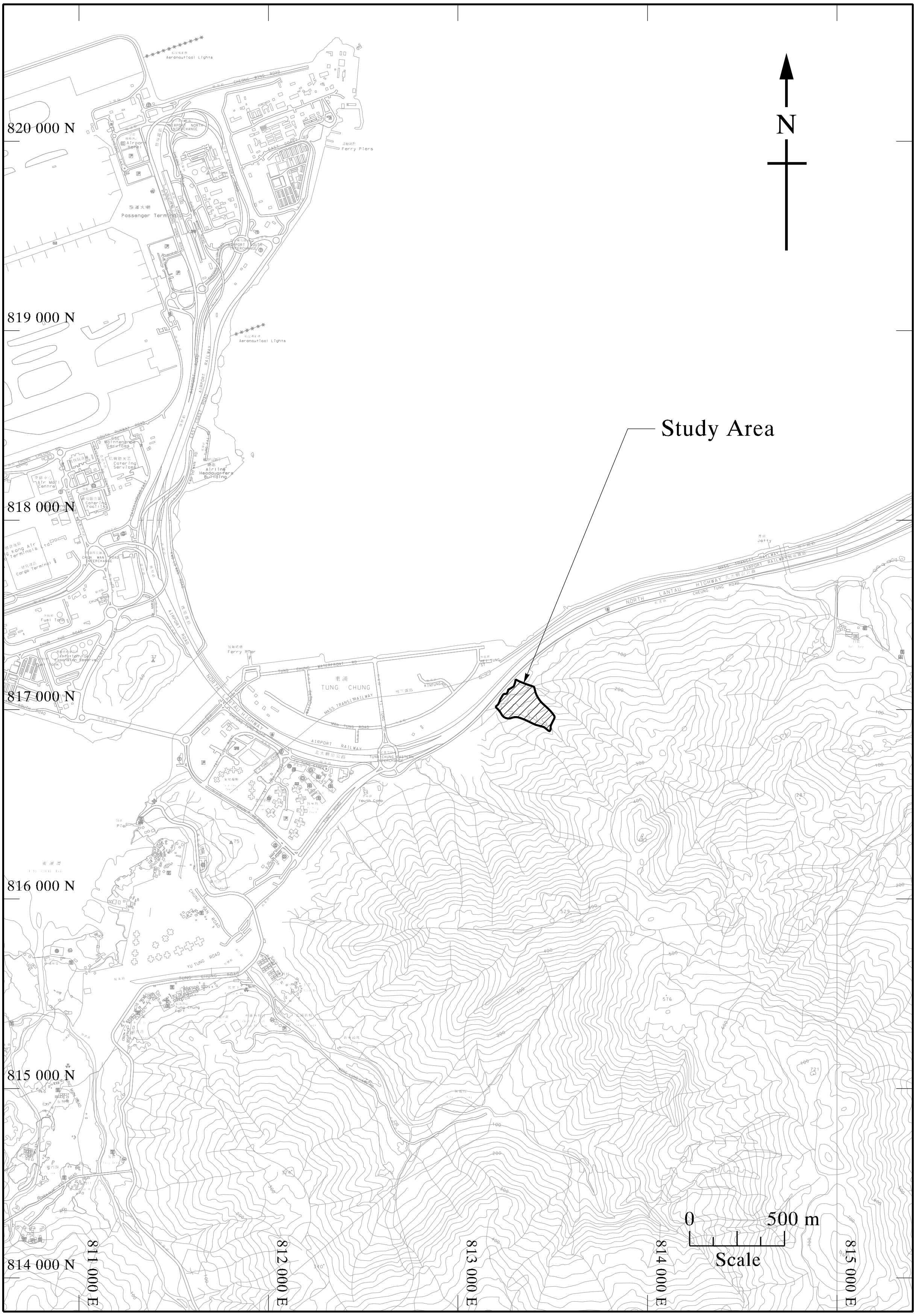


Figure 1 - Tung Chung East Location Map

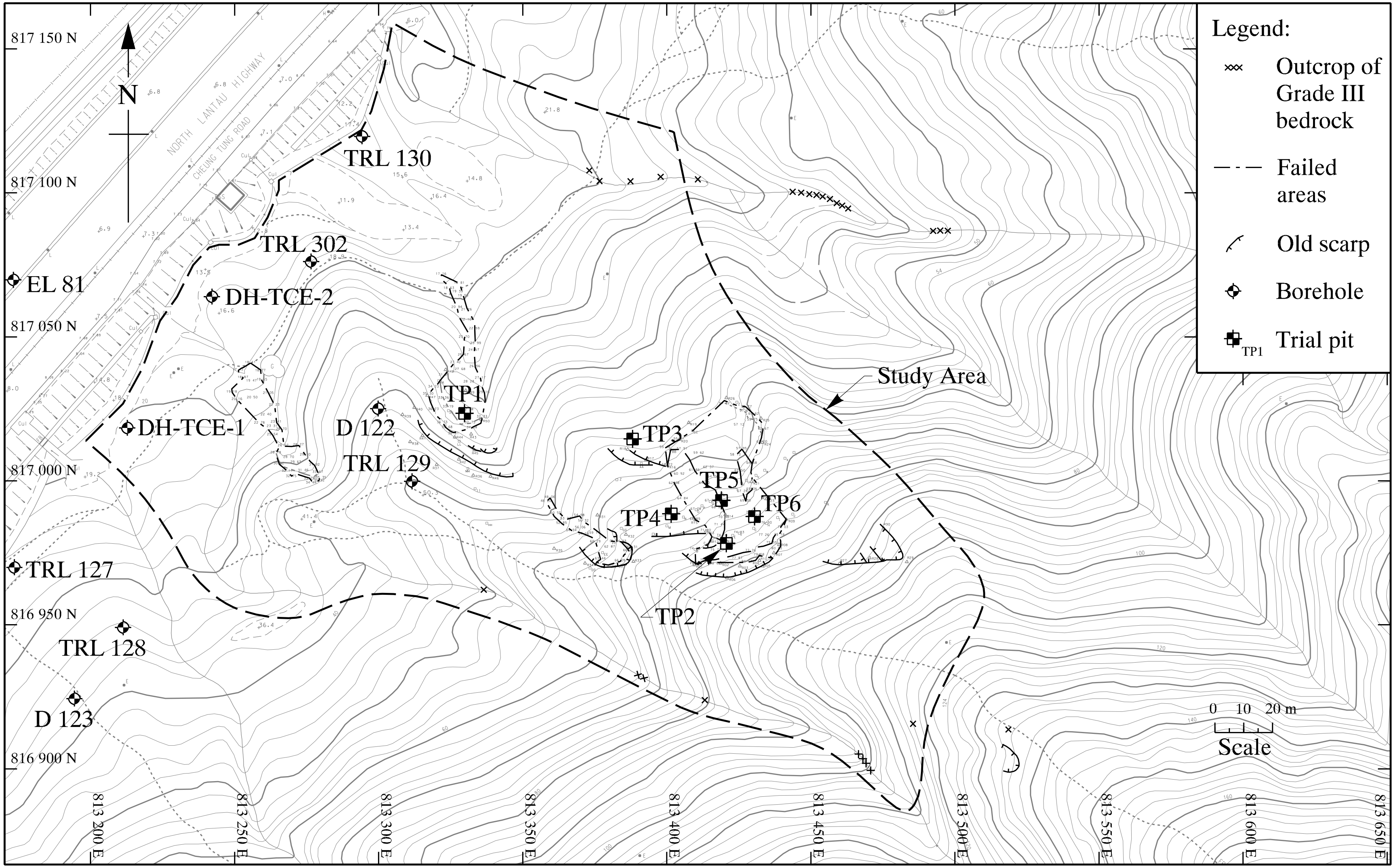


Figure 2 - Boreholes, Trial Pits and Outcrops of Grade III Bedrock

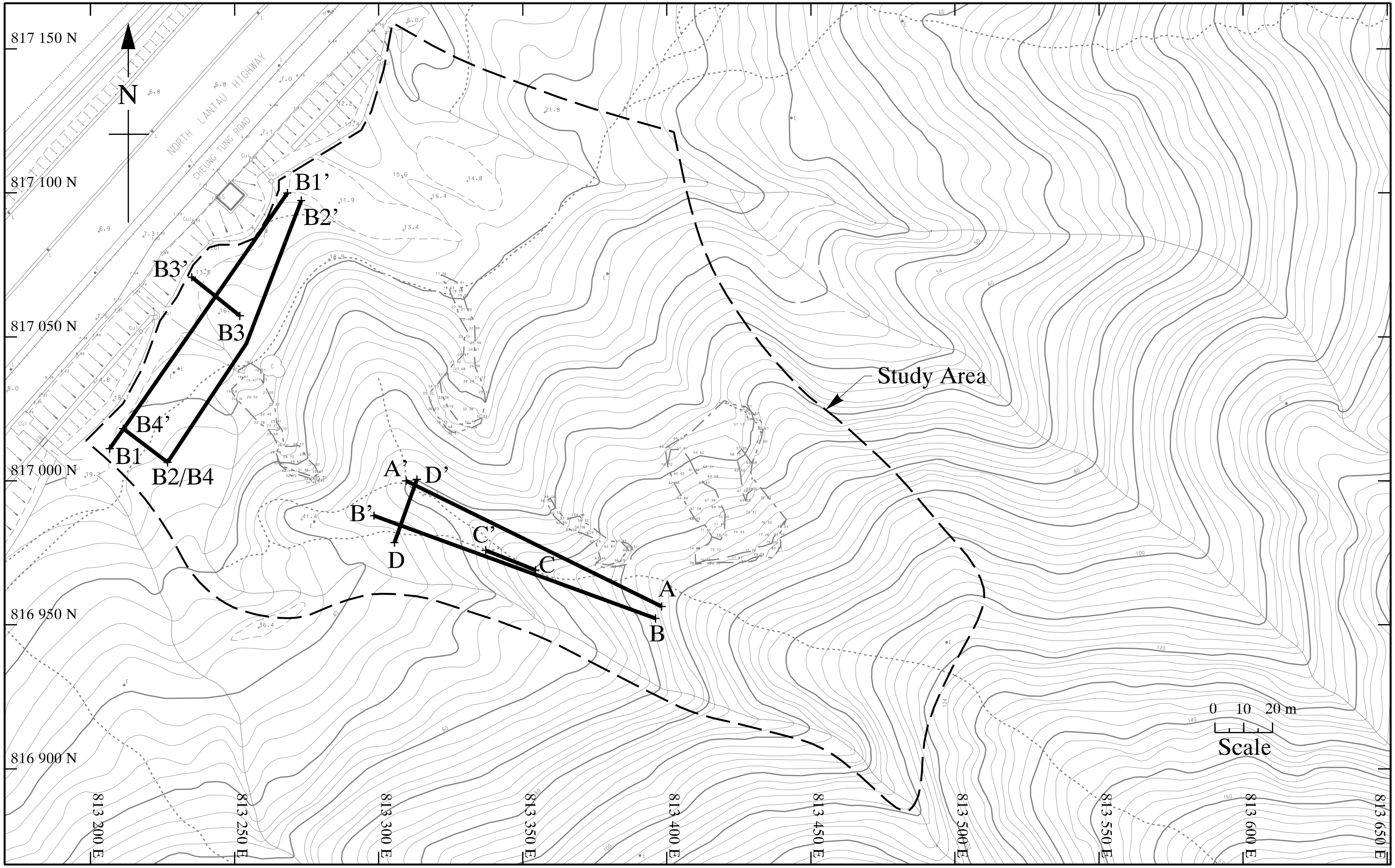
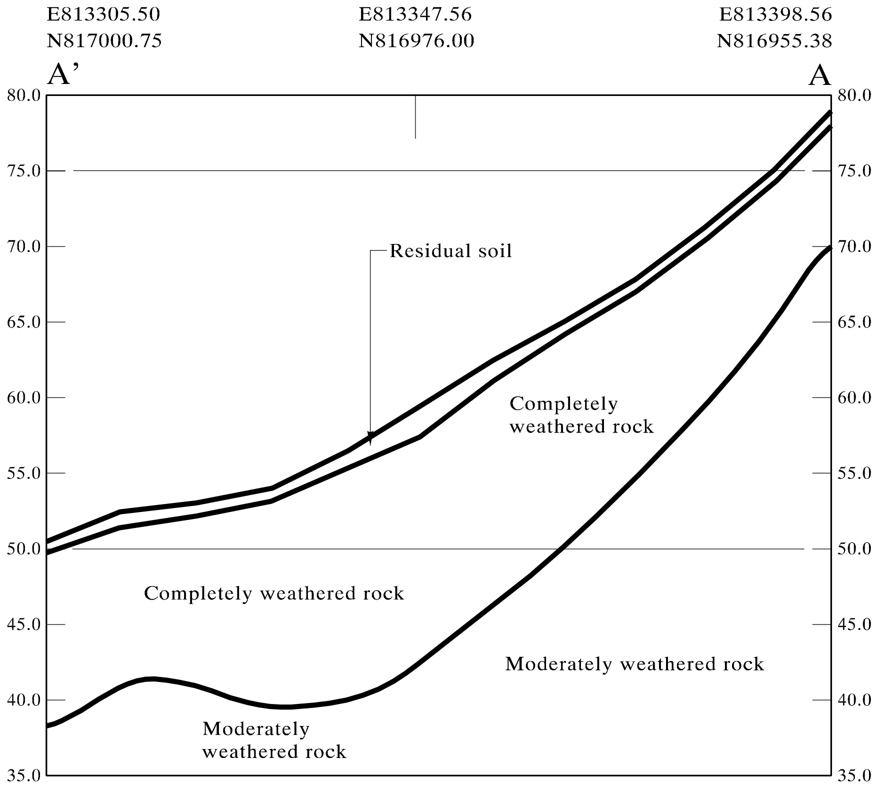
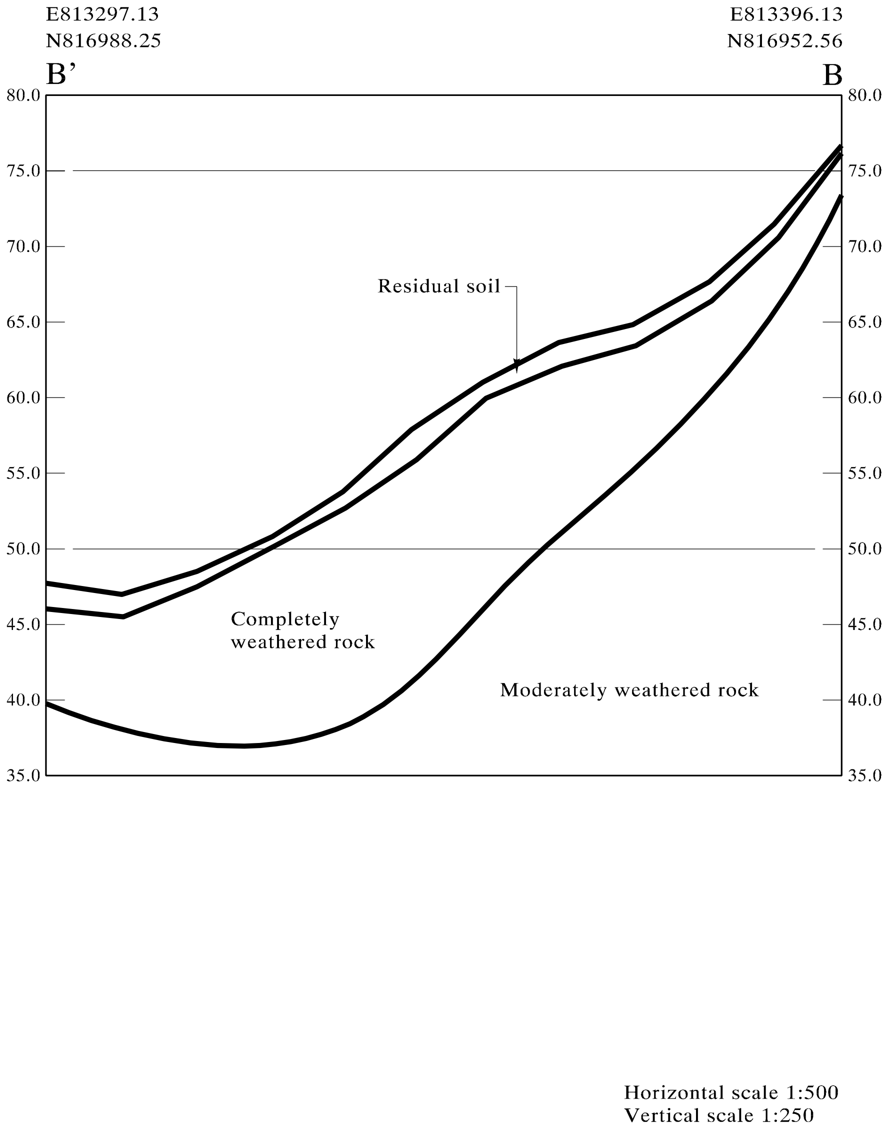


Figure 3 - Seismic Line Locations



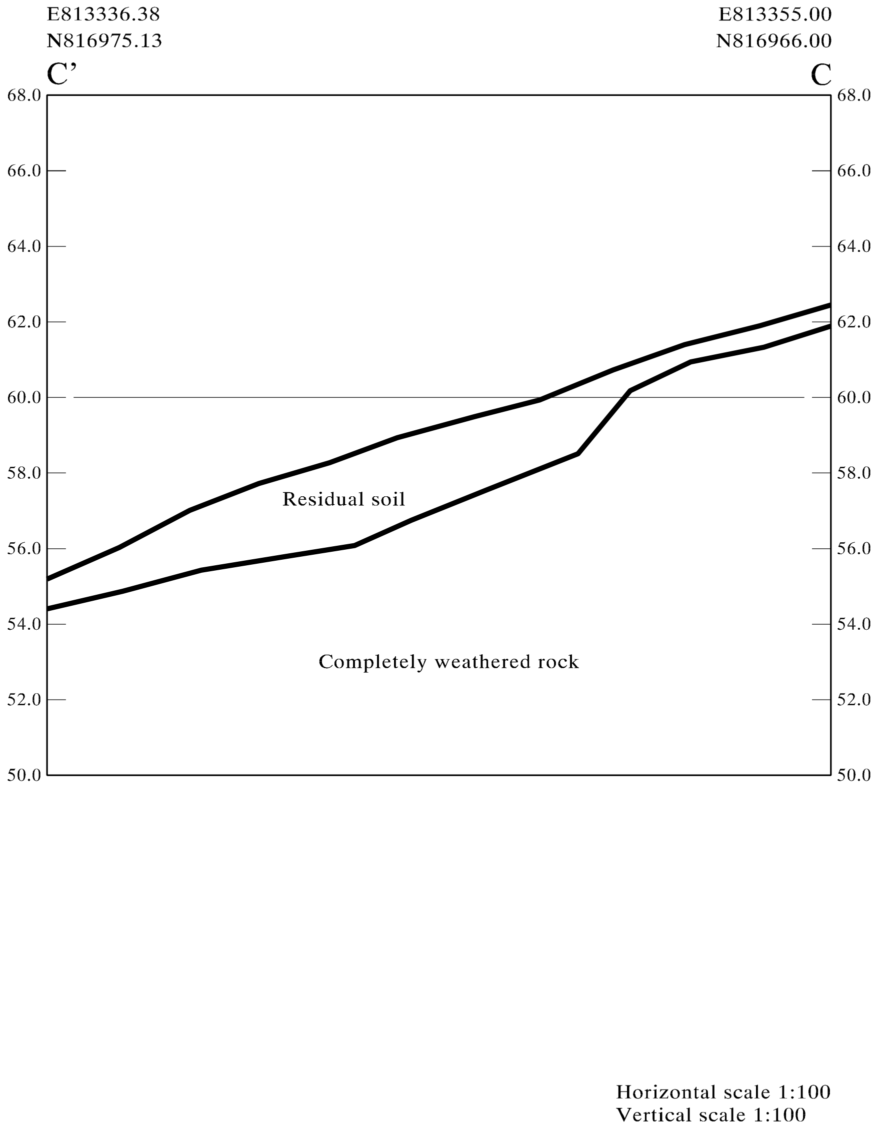
Note: After EGS (1999).

Figure 4 - Seismic Profile A'-A



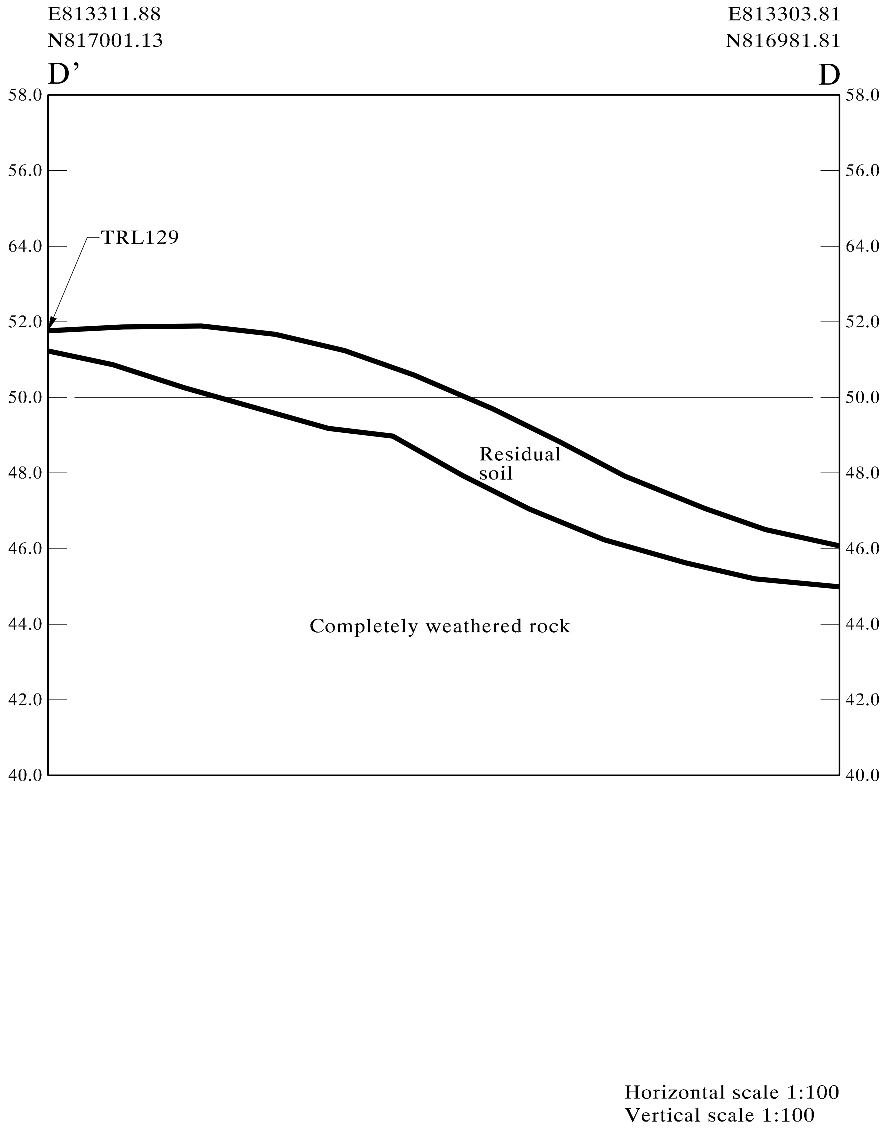
Note: After EGS (1999).

Figure 5 - Seismic Profile B'-B



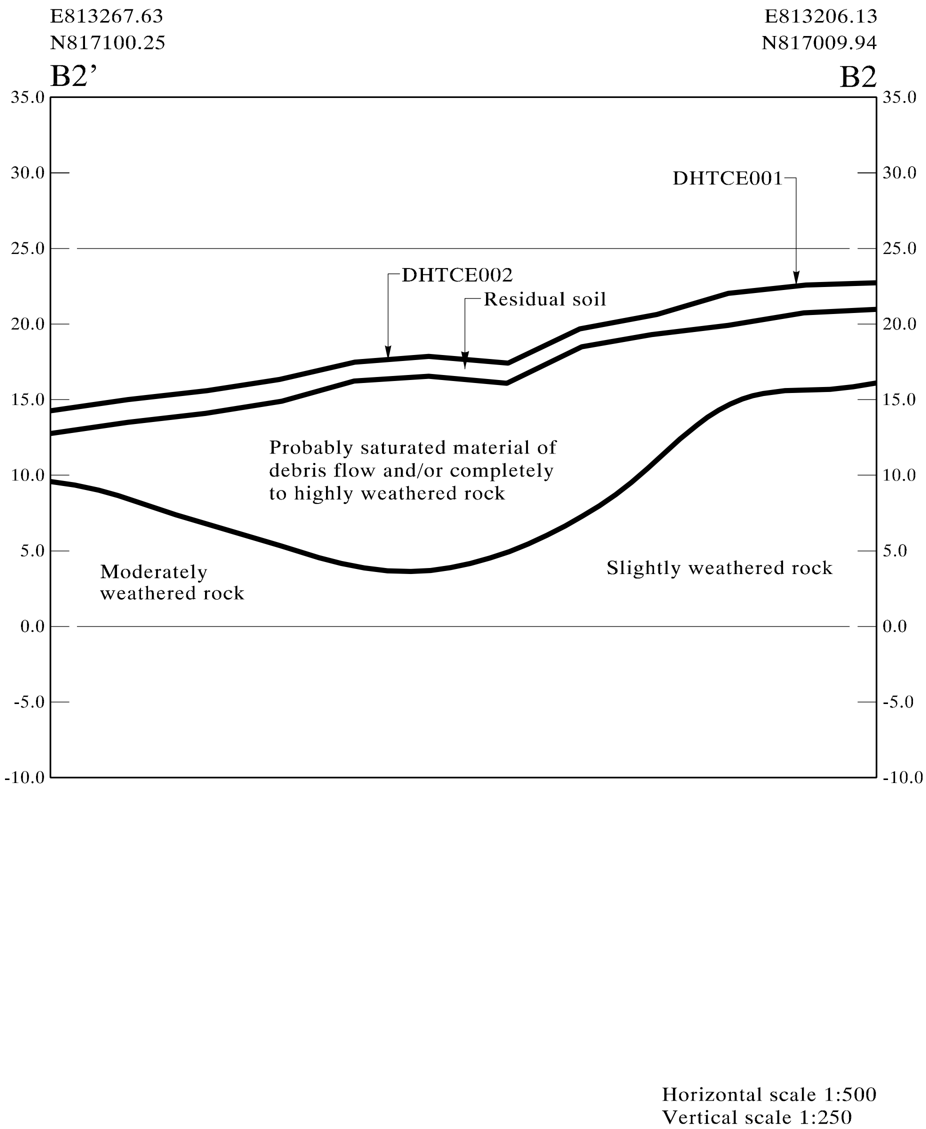
Note: After EGS (1999).

Figure 6 - Seismic Profile C'-C



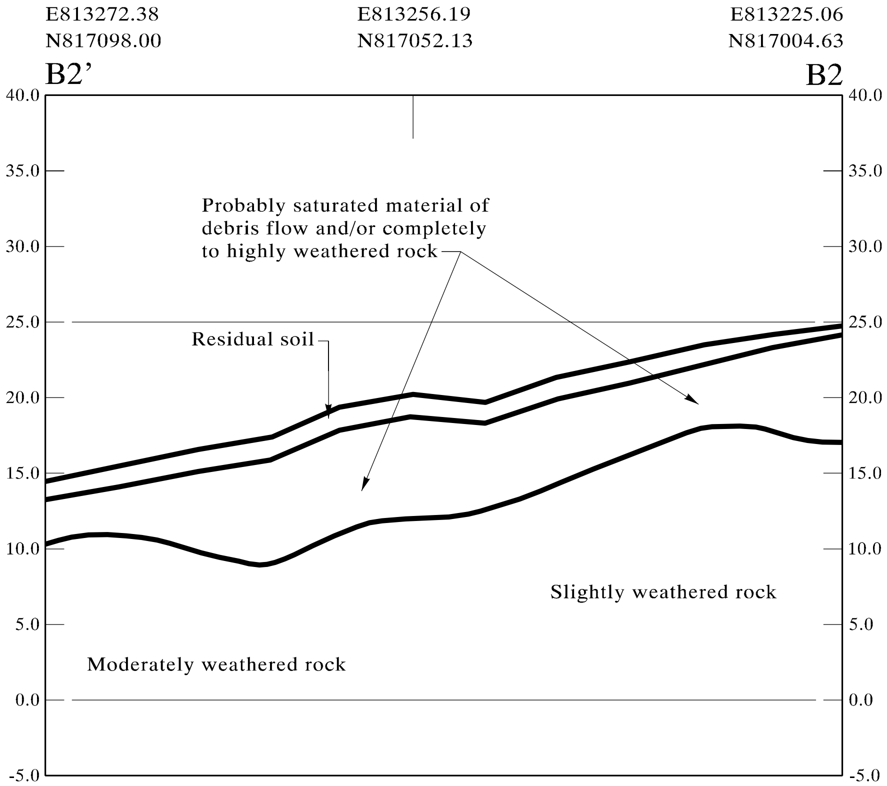
Note: After EGS (1999).

Figure 7 - Seismic Profile D'-D



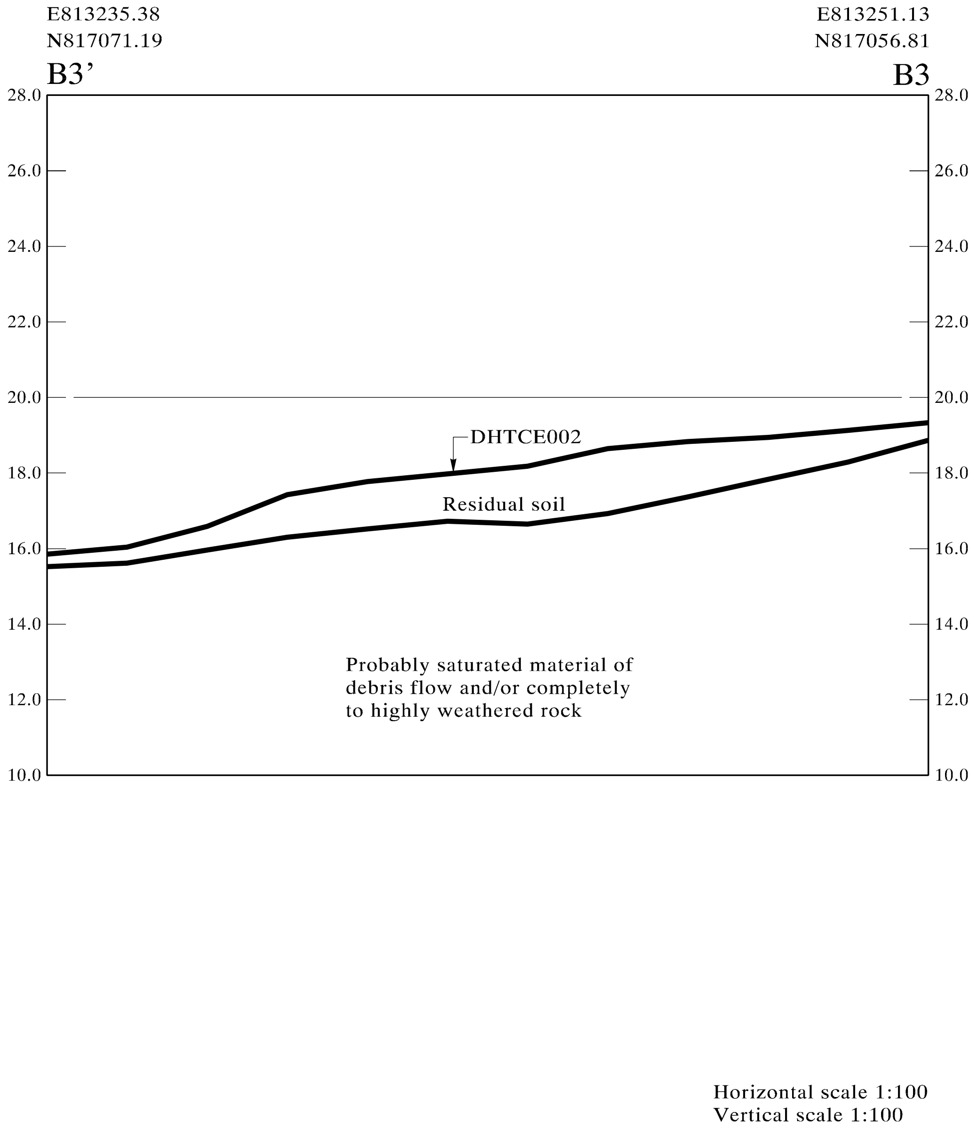
Note: After EGS (1999).

Figure 8 - Seismic Profile B1'-B1



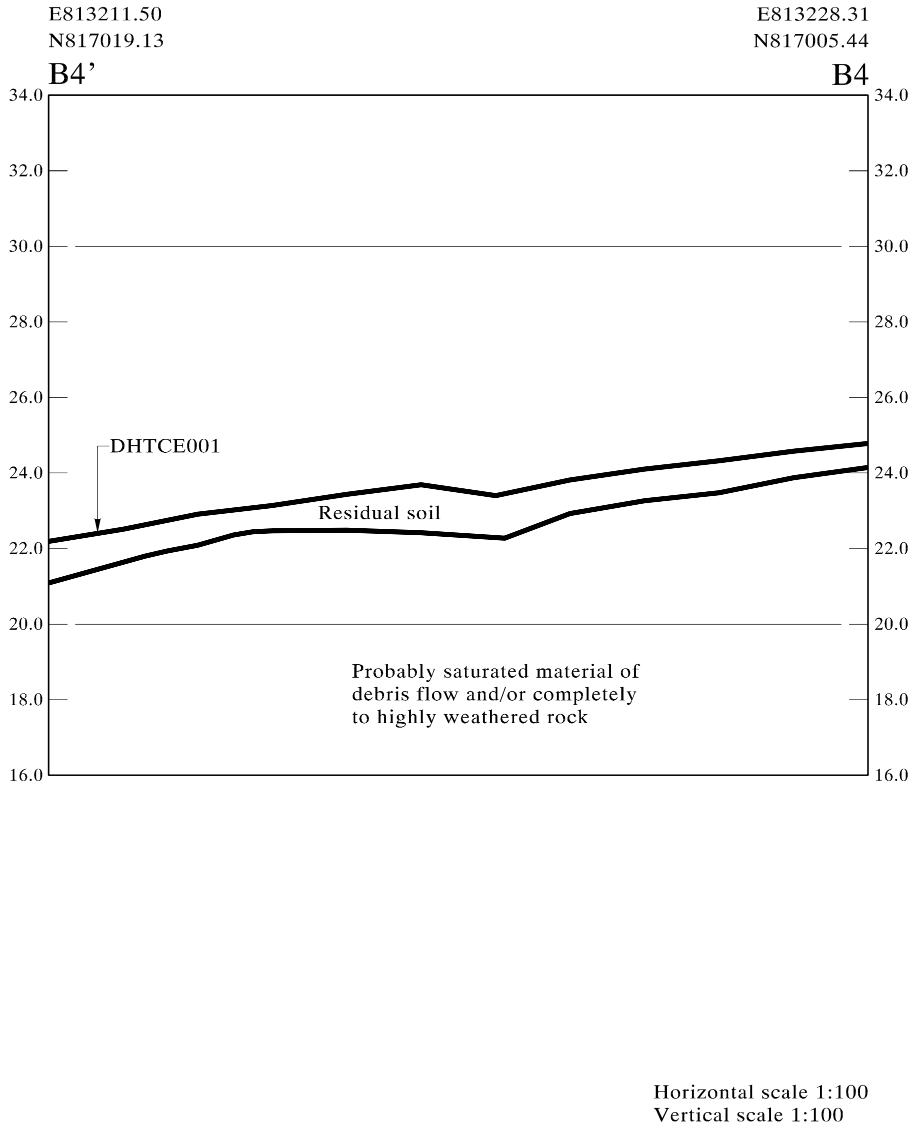
Note: After EGS (1999).

Figure 9 - Seismic Profile B2'-B2



Note: After EGS (1999).

Figure 10 - Seismic Profile B3'-B3



Note: After EGS (1999).

Figure 11 - Seismic Profile B4'-B4

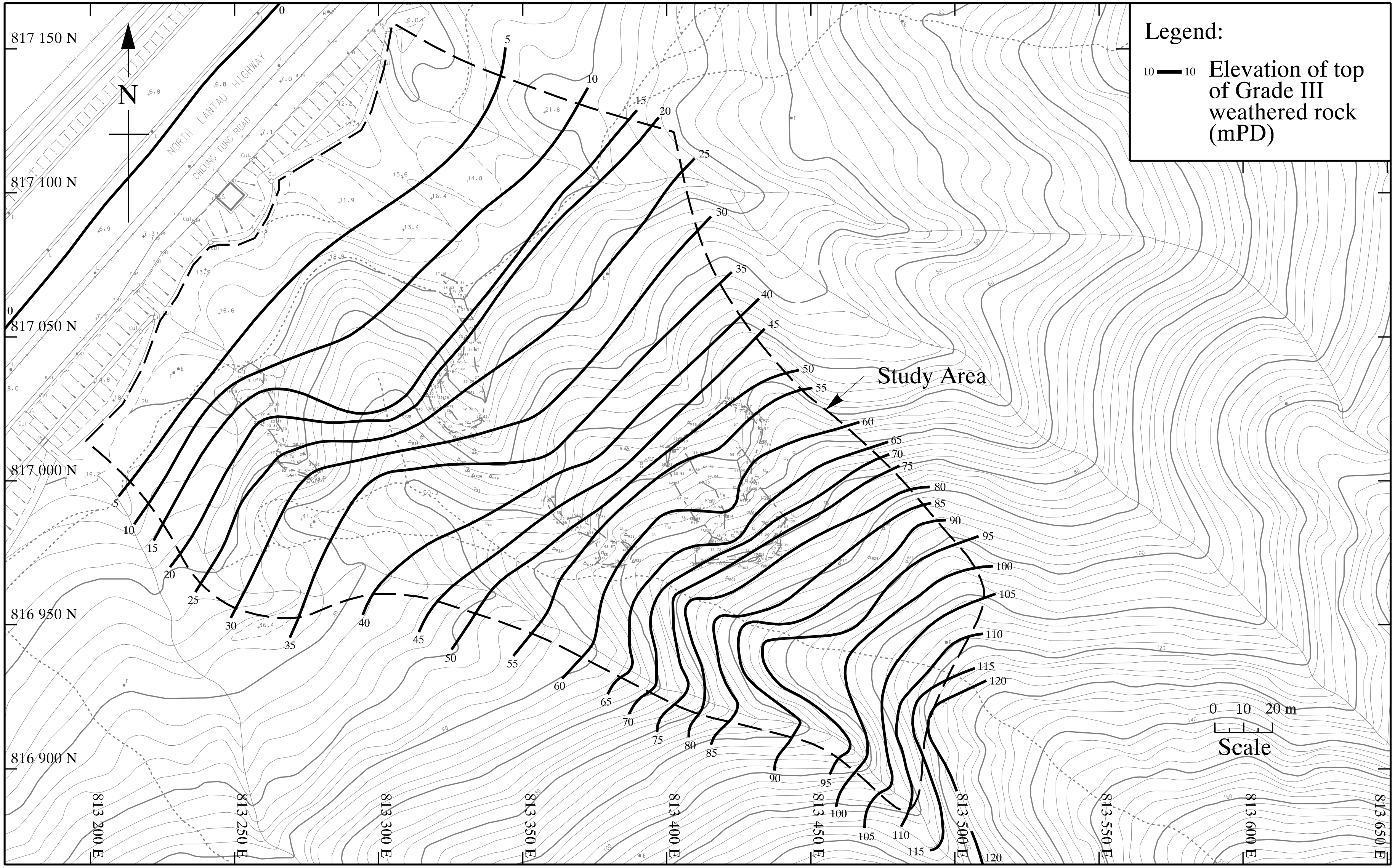


Figure 12 - Top of Grade III Weathered Rock

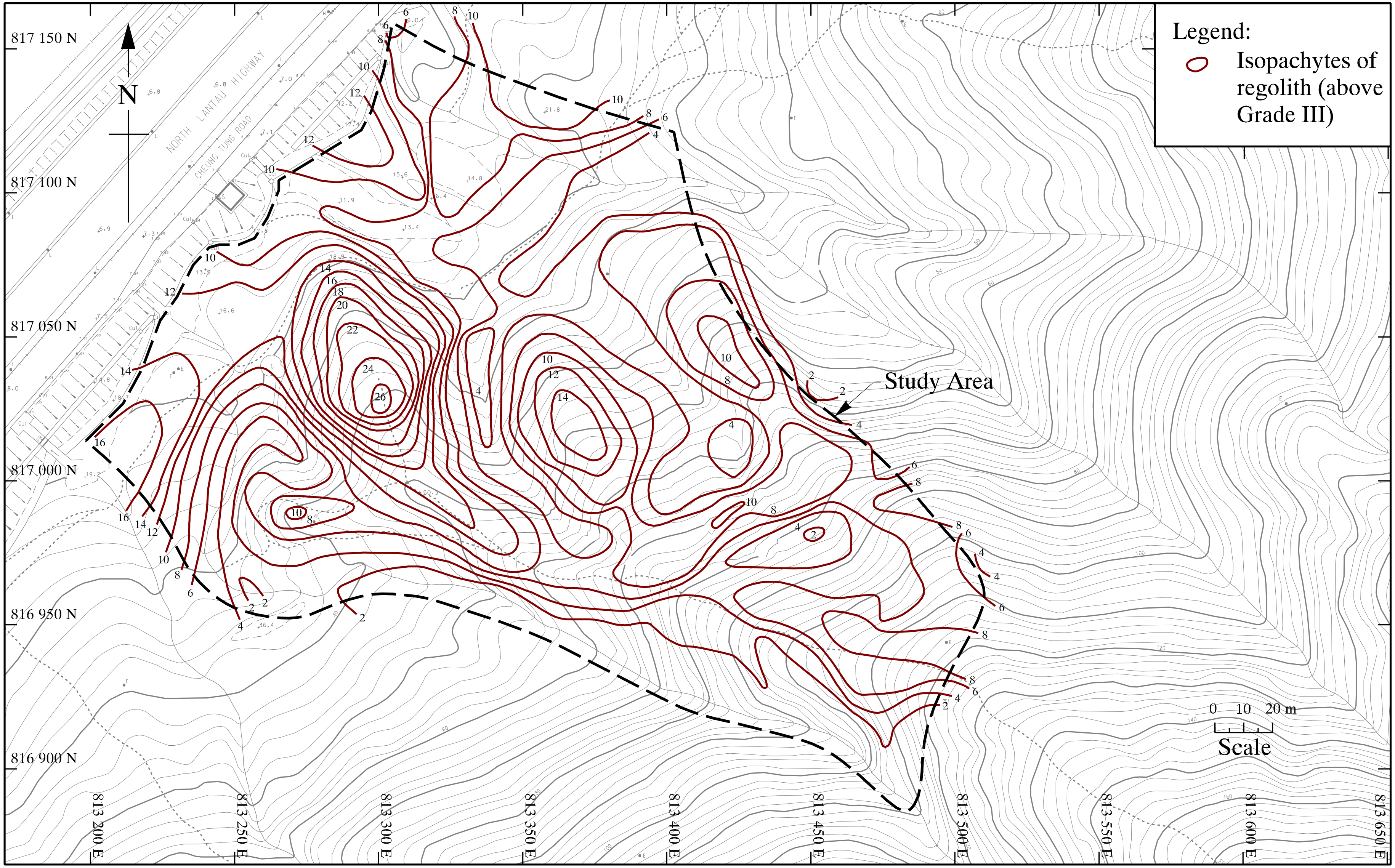


Figure 13 - Isopachytes of Regolith (above Grade III)

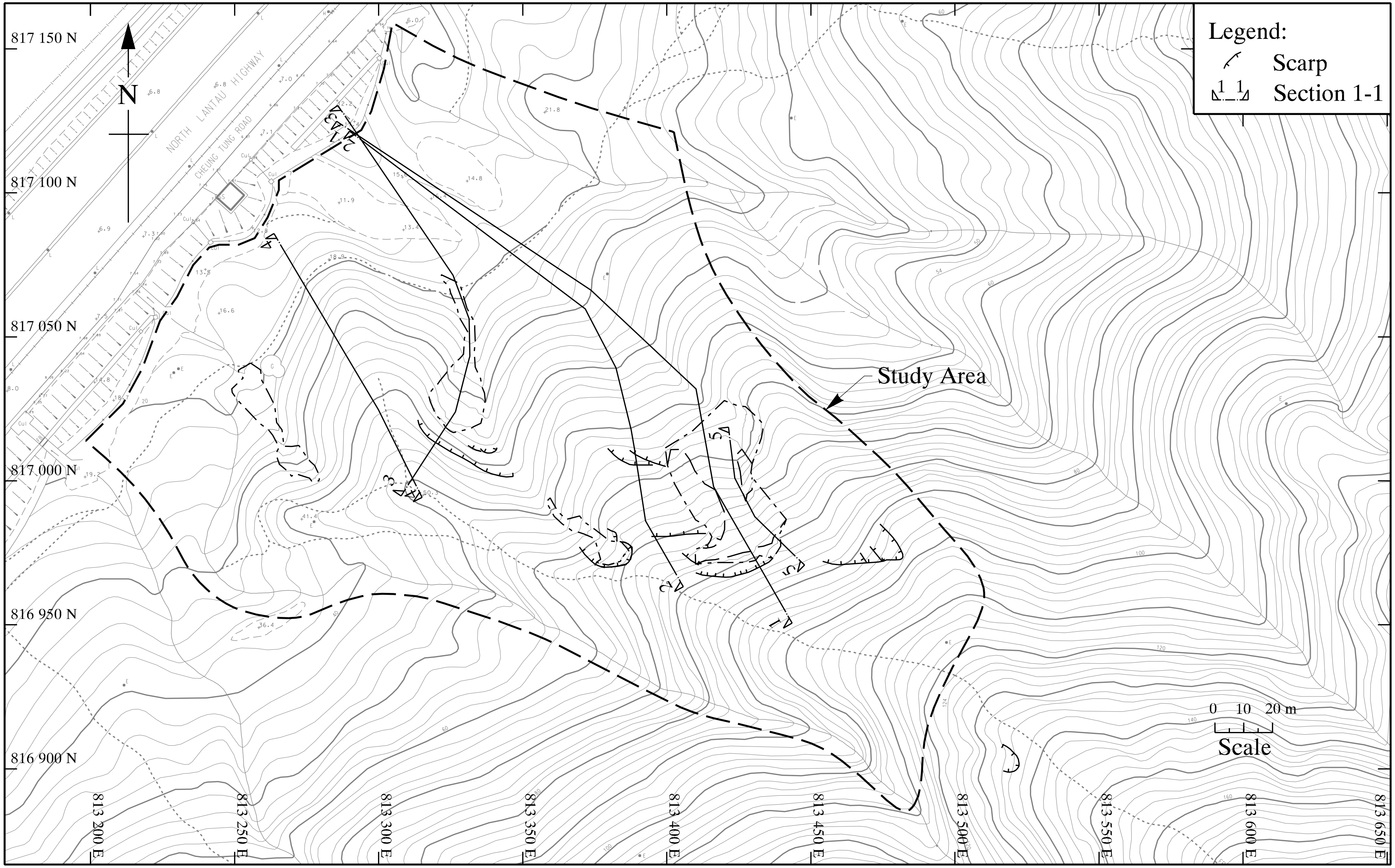


Figure 14 - Cross-section Locations

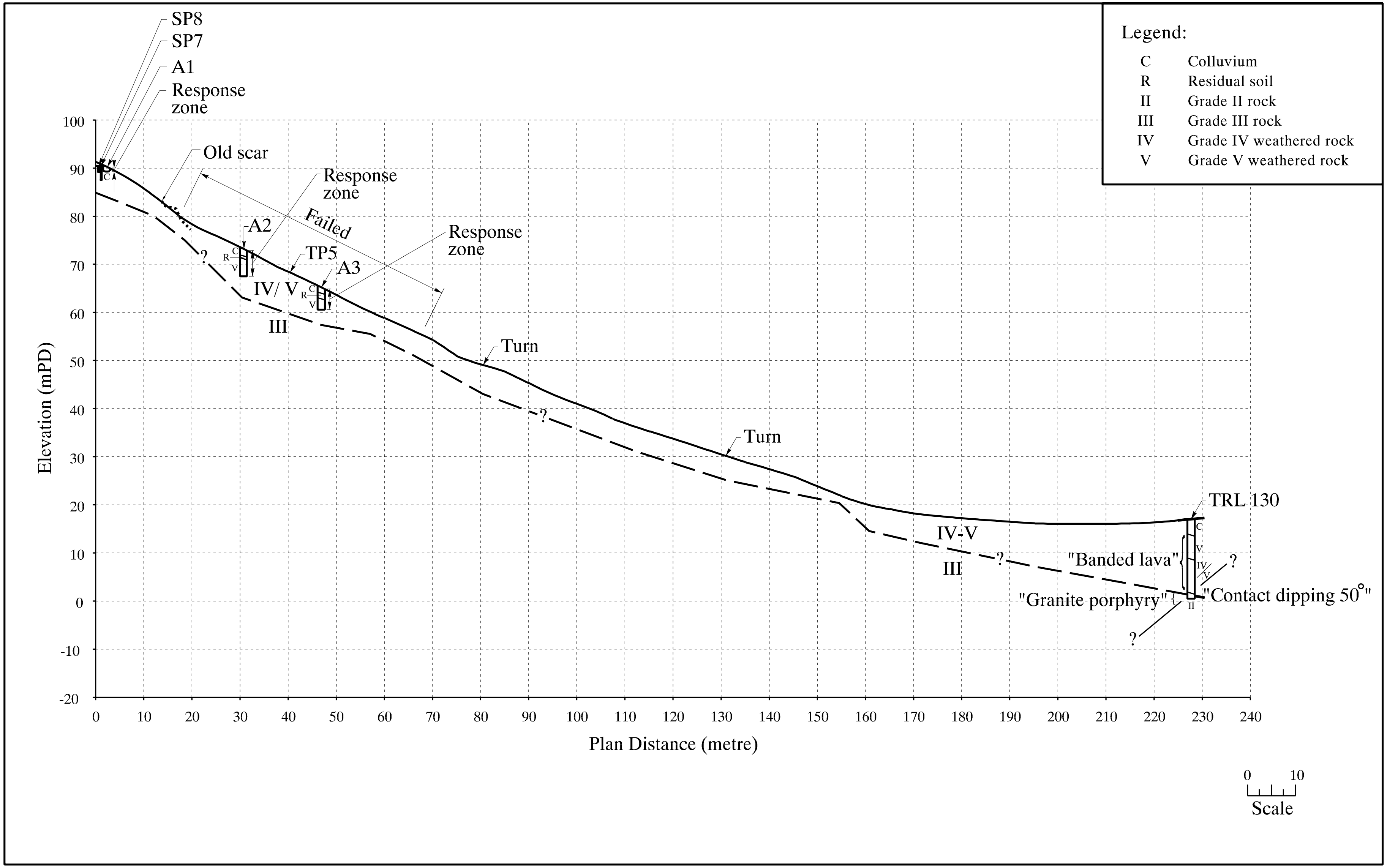


Figure 15 - Cross-section 1-1

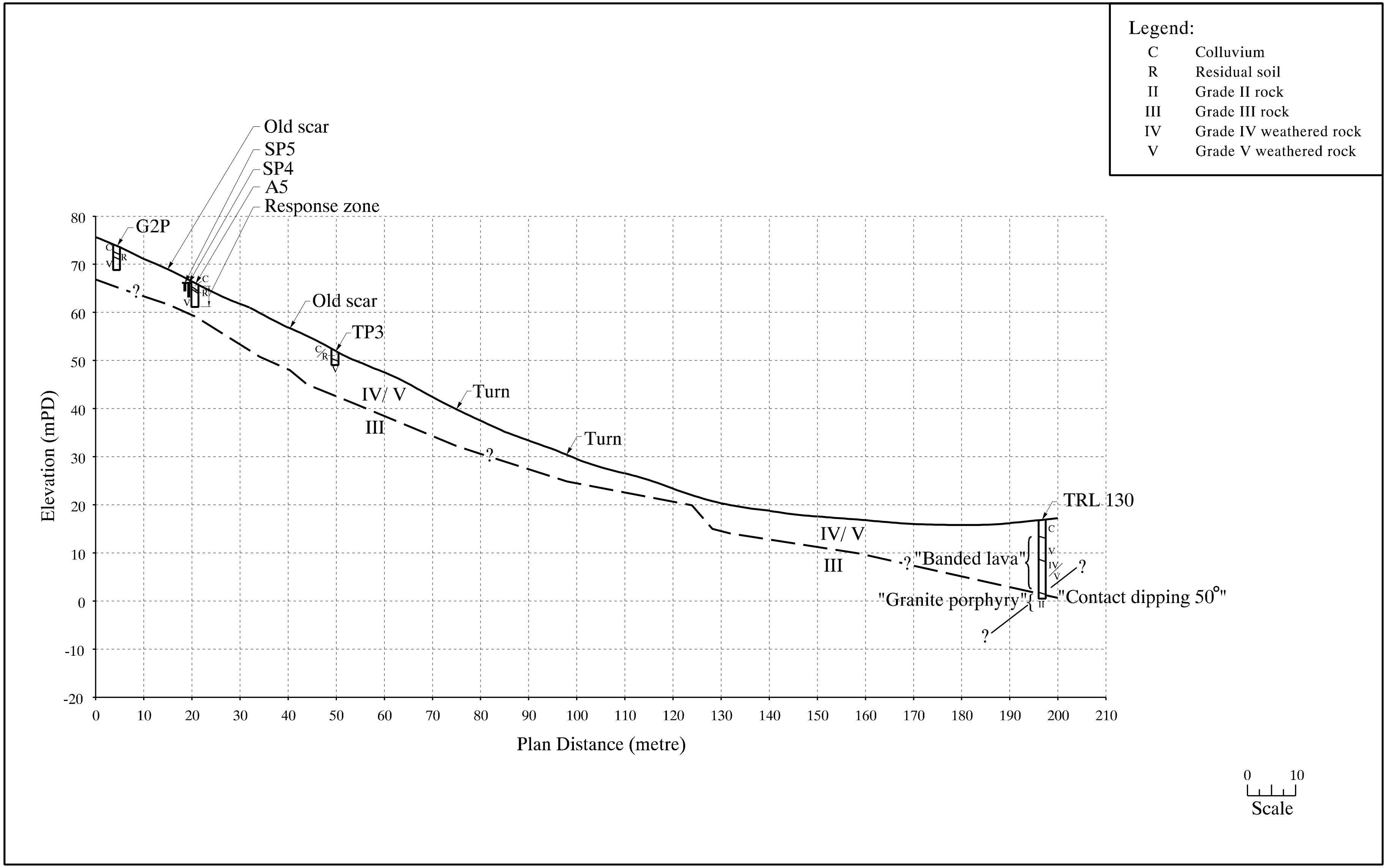


Figure 16 - Cross-section 2-2

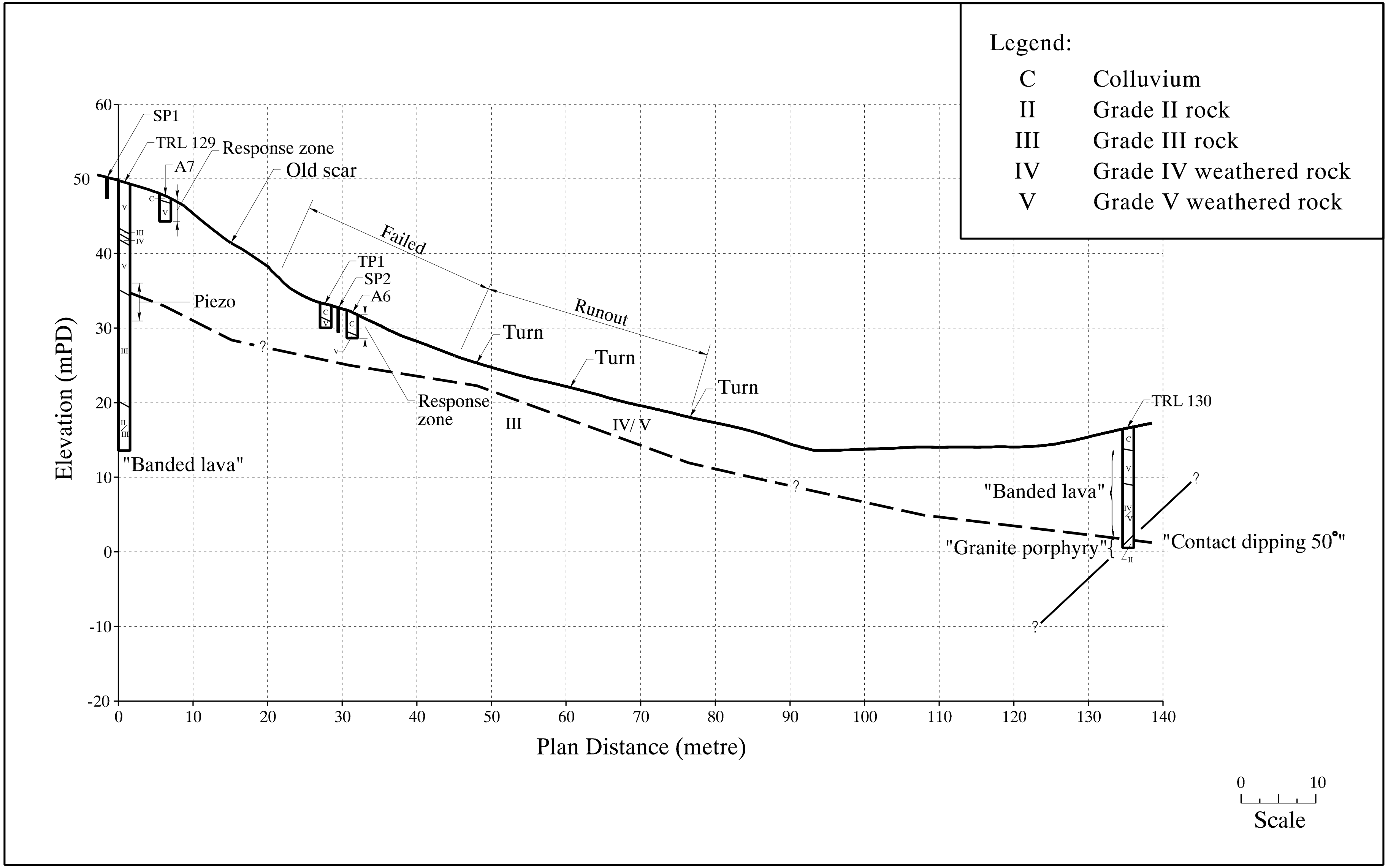


Figure 17 - Cross-section 3-3

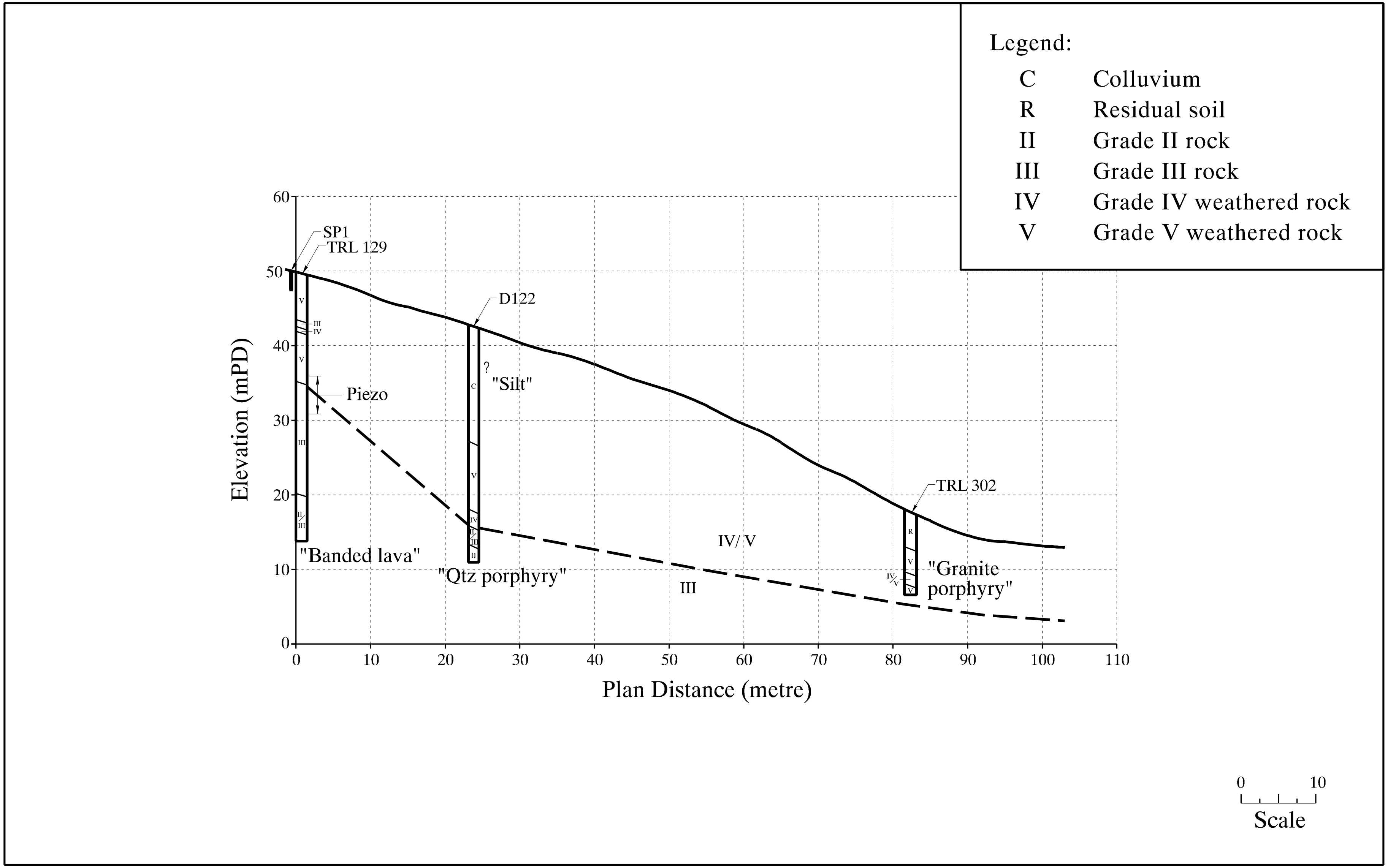


Figure 18 - Cross-section 4-4

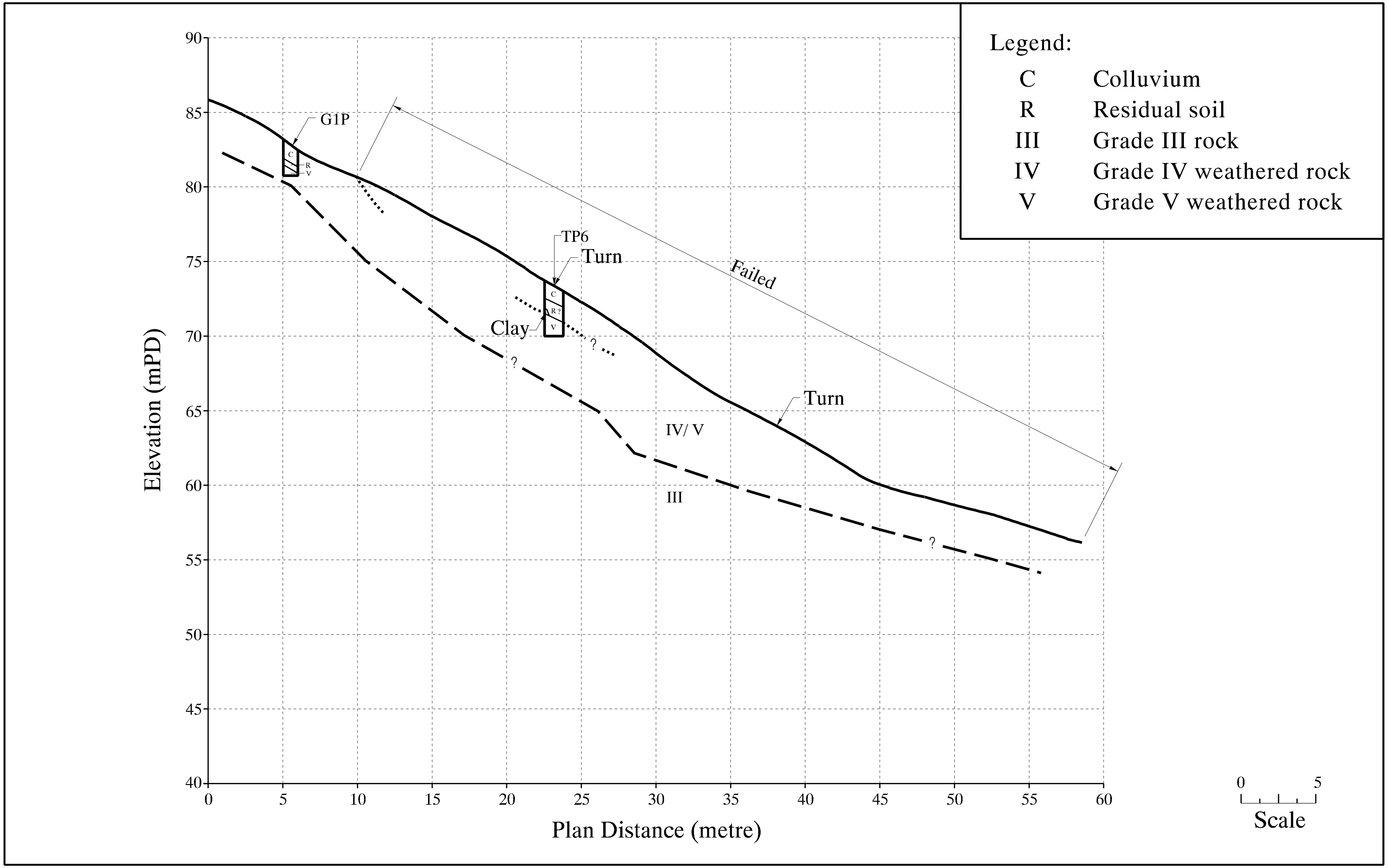


Figure 19 - Cross-section 5-5

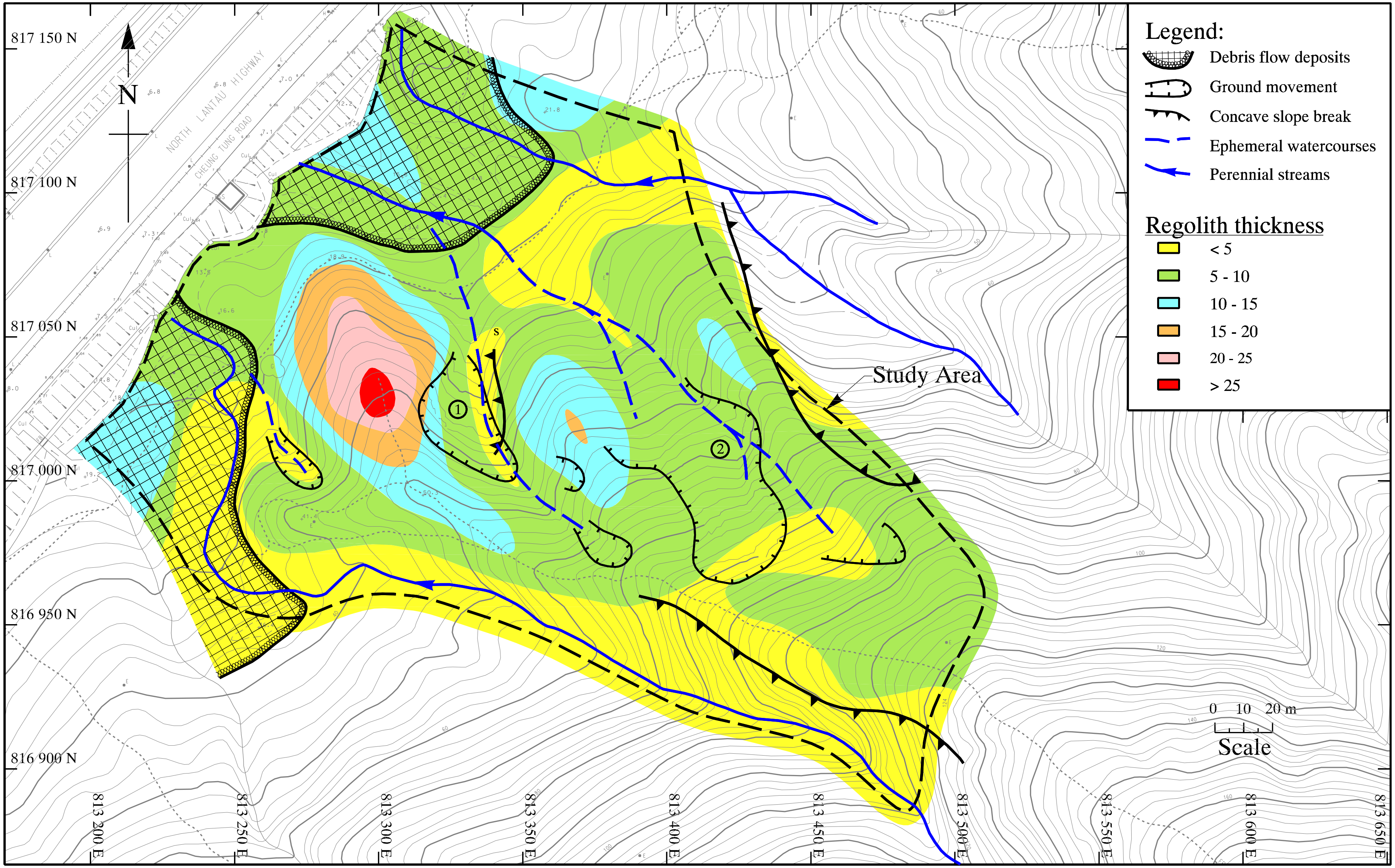


Figure 20 - Geomorphology

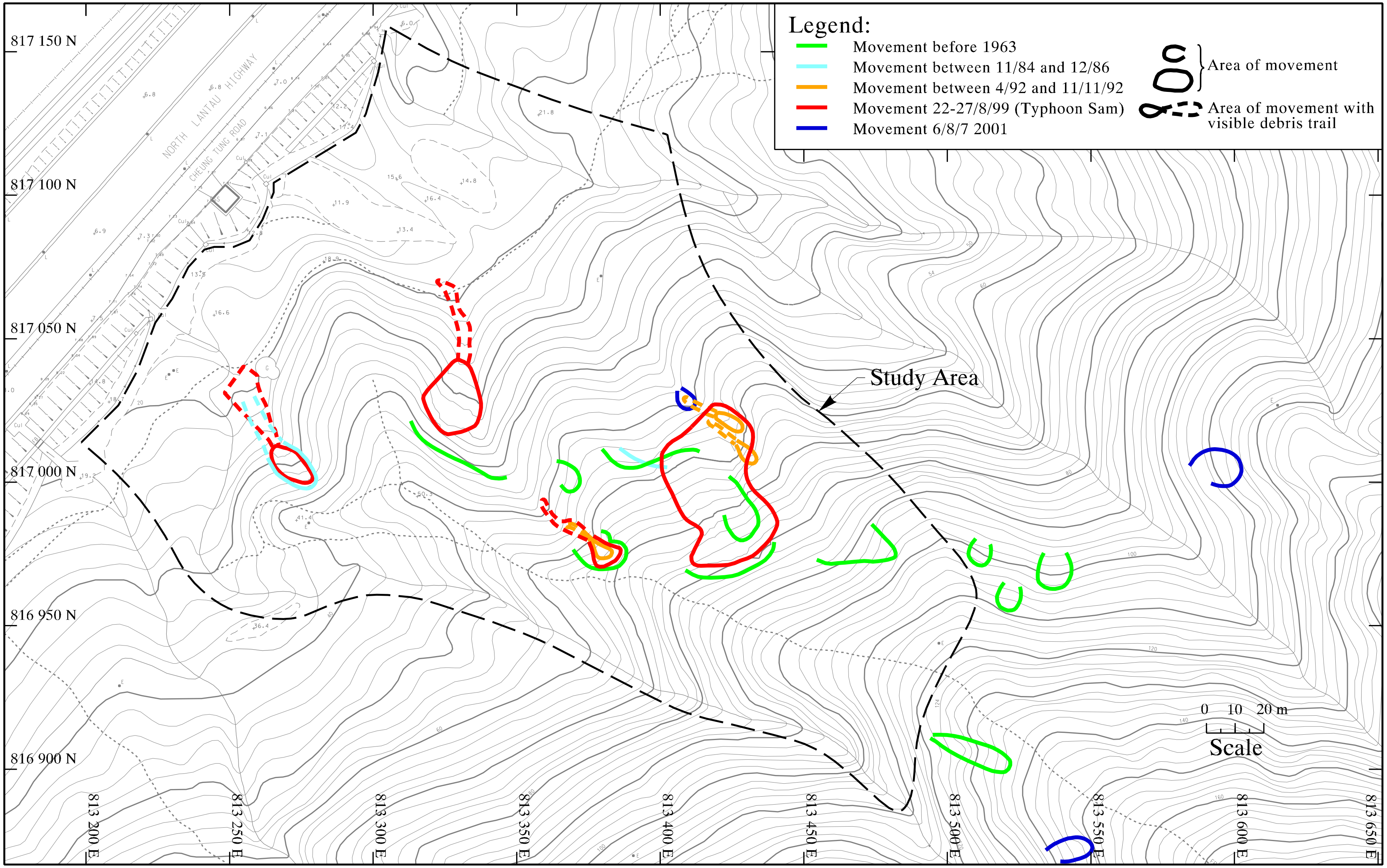


Figure 21 - Movement History

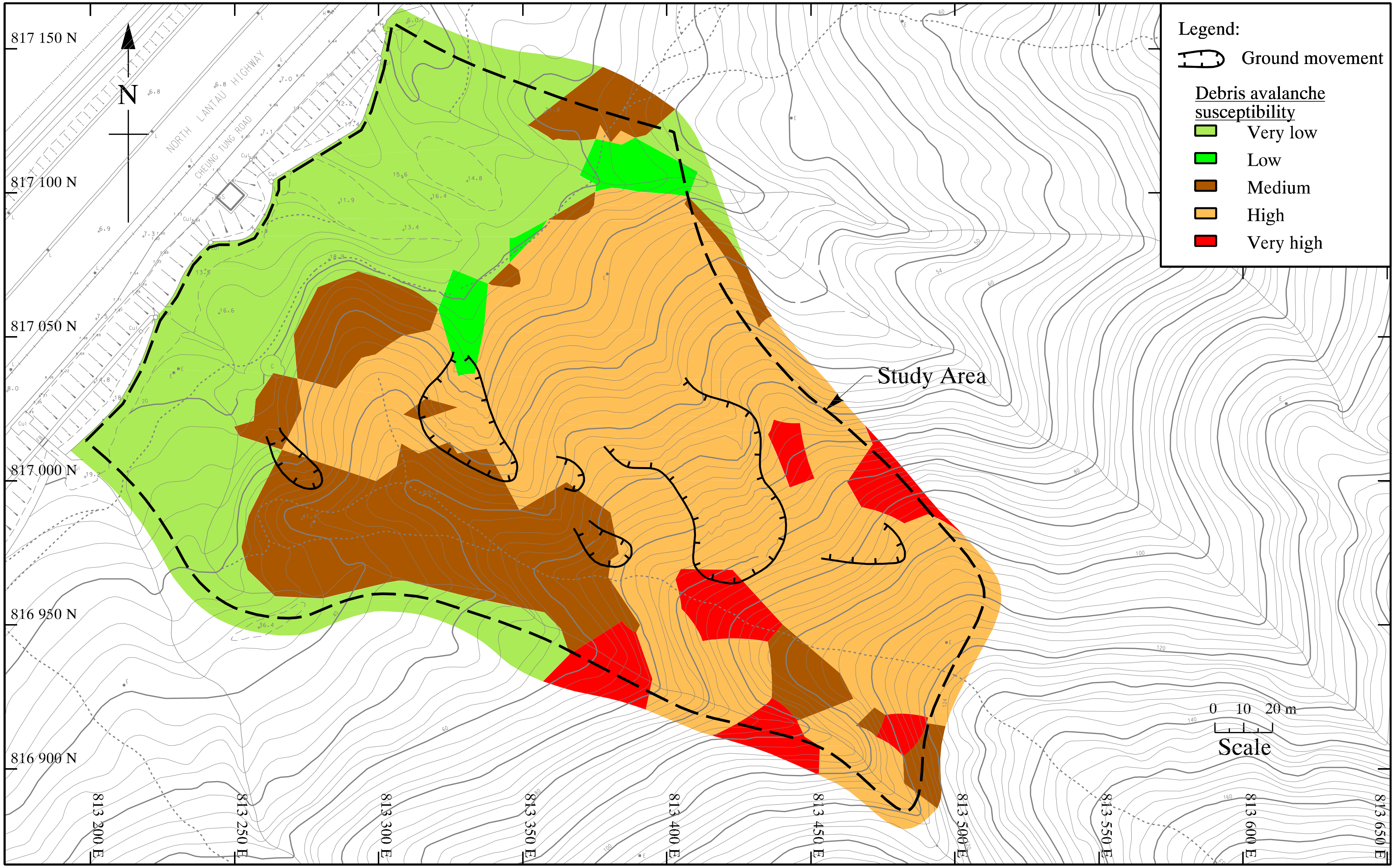


Figure 22 - Debris Avalanche Susceptibility

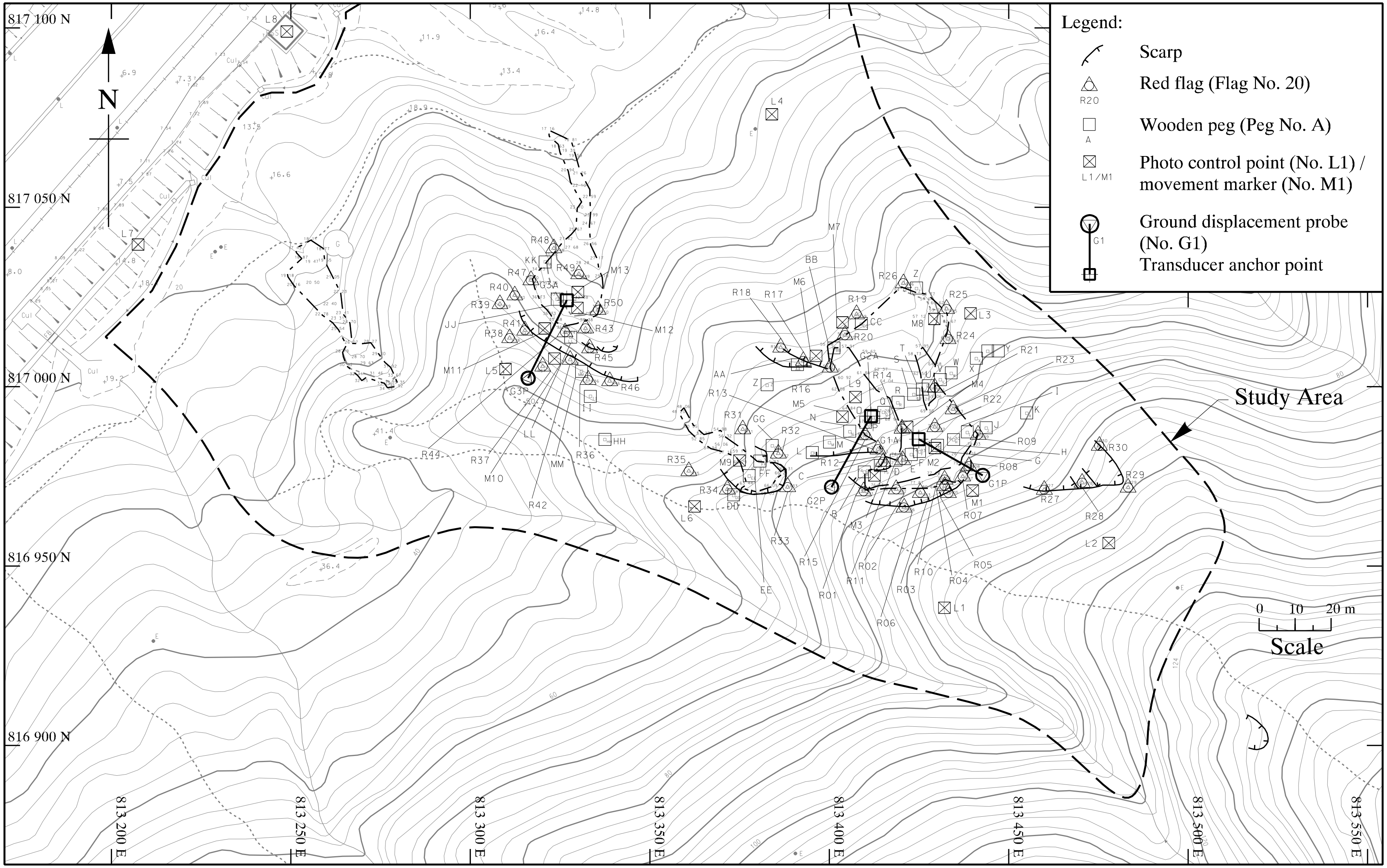


Figure 23 - Movement Detector Locations

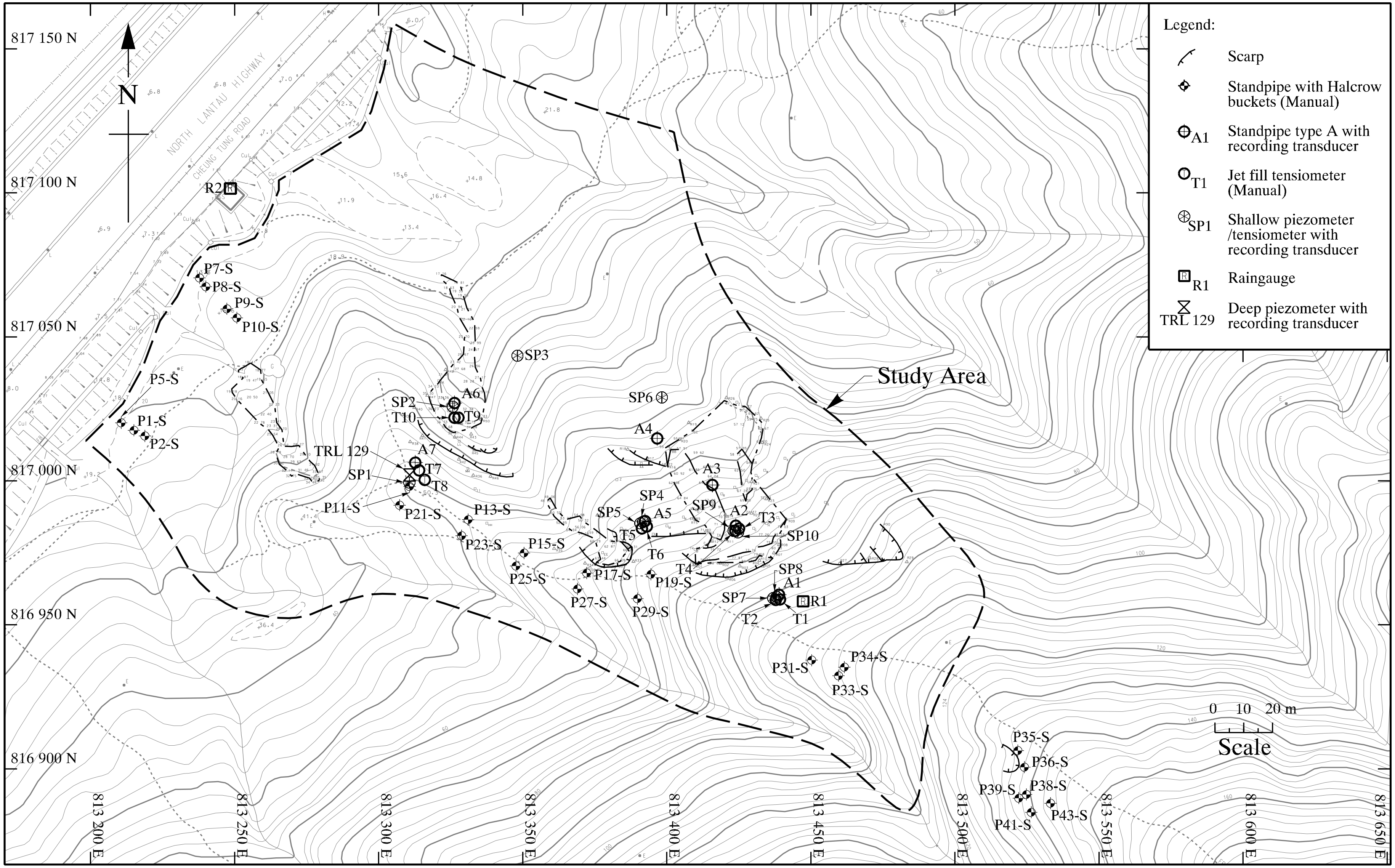


Figure 24 - Piezometer, Tensiometer and Raingauge Locations

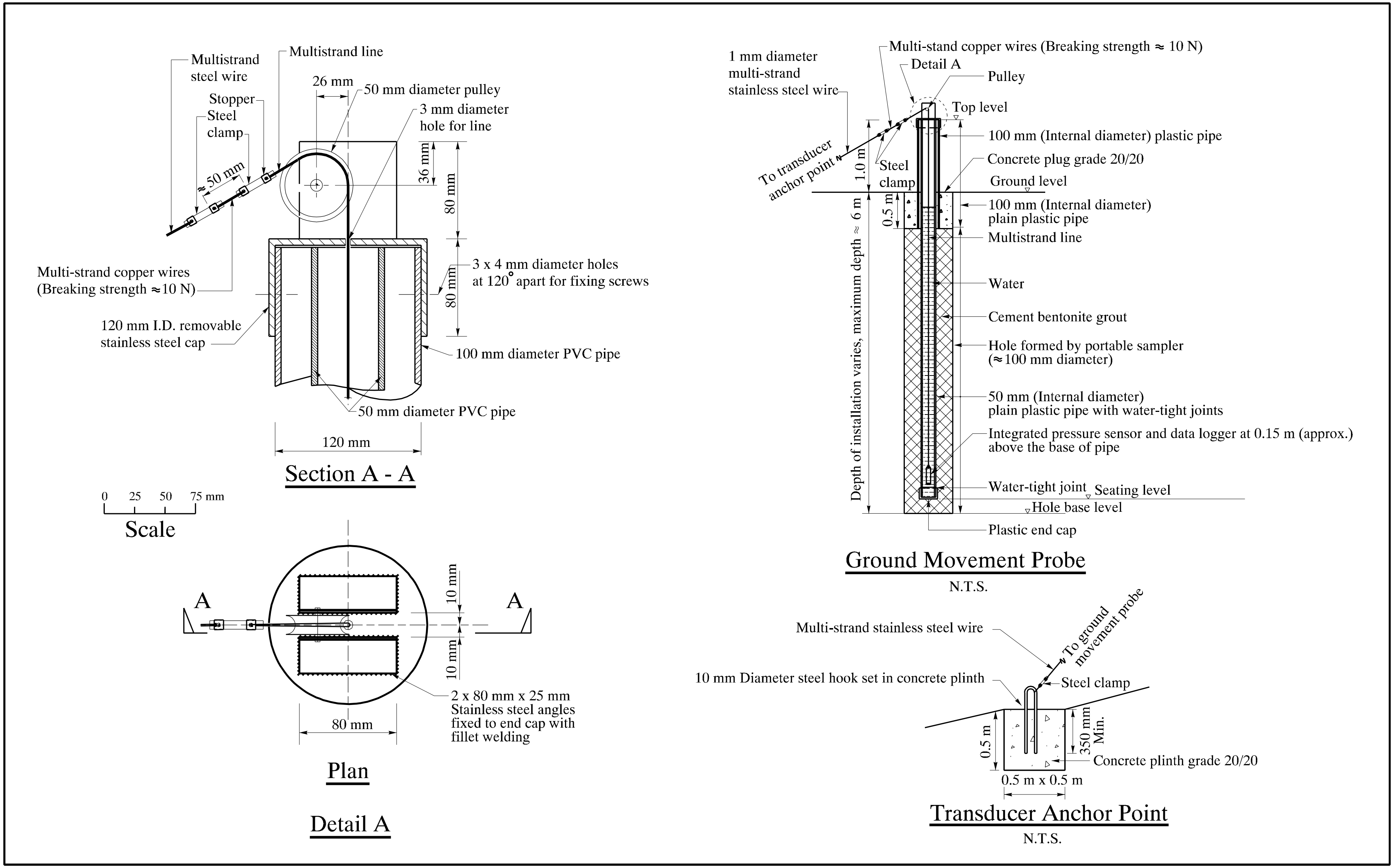


Figure 25 - Ground Movement Detector

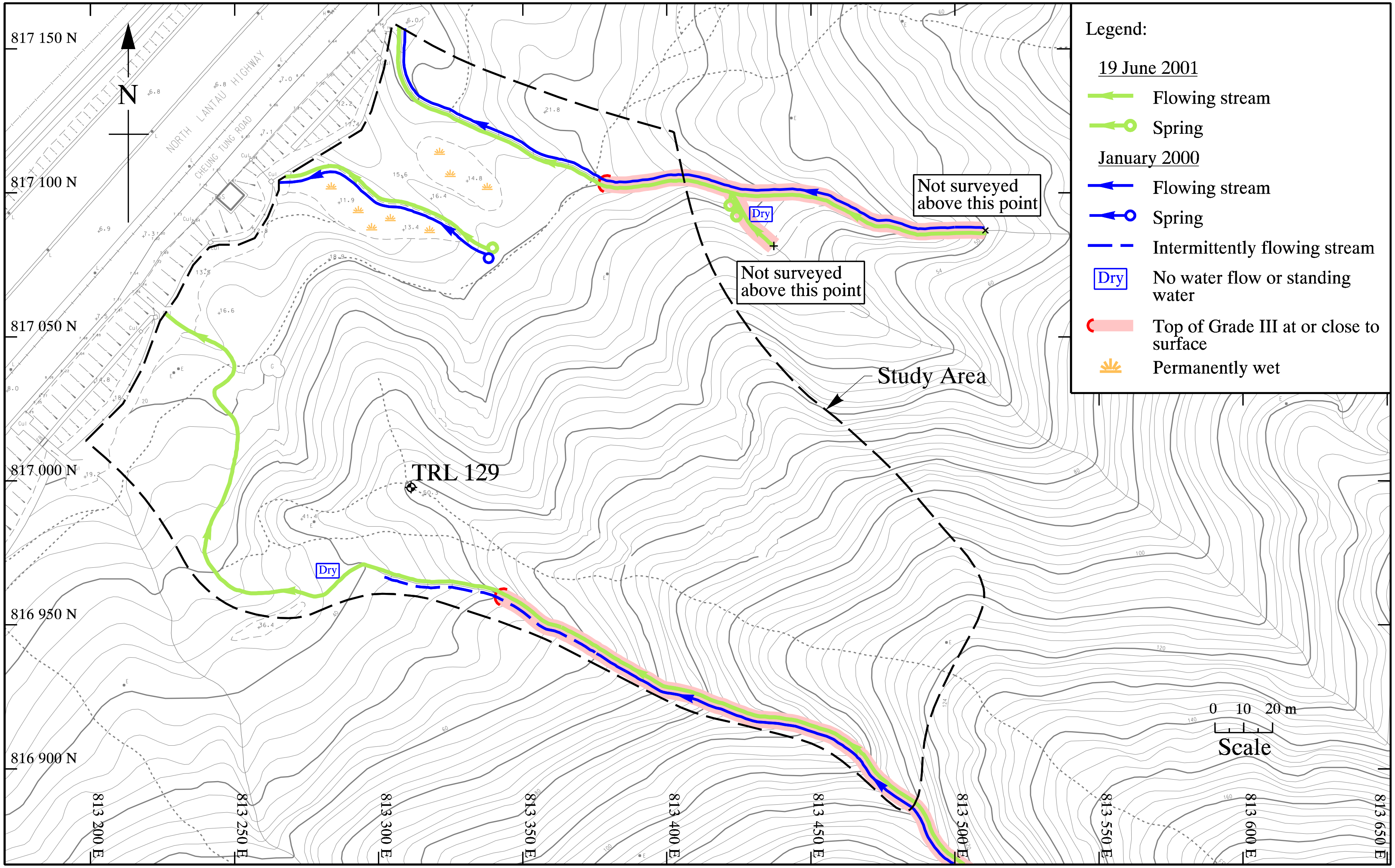


Figure 26 - Surface Water Observations

LIST OF PLATES

Plate 1 - PS 1027-S Overview of the Site, 24 September 1999

Plate 2 - SP 99027/13 Area 1, September 1999

Plate 3 - SP 99027/06 Area 2, September 1999

Plate 4 - SP 0103522 Minor Failure, July 2001

APPENDIX A

SUMMARY OF SITE INVESTIGATIONS, PORTABLE SAMPLER LOGS AND TRIAL PIT LOGS

A variety of investigations have been carried out in and around the site. Early work comprised boreholes associated with the planning and construction of the North Lantau Expressway. Later work (1999 and on) was focussed on investigating and developing techniques for natural terrain hazard and risk analysis, and on instrumentation of the unstable areas. A summary of the work carried out at the site follows.

November 1978
Two boreholes (D122 and D123) for Development & Airport Division, PWD. North Lautau Land SI. Contract PWD 682/77 (Gammon)

April-May 1982
Five boreholes (TRL 127 - 130, TRL 302) for North Lautau and Replacement Airport Division, Truck Road Phase 1 SI (Bachy-Soletanche) PWD. TRL 129 contains a deep standpipe piezometer that was tested in 2000, found to be working, and re-commissioned.

March 1991
One borehole (EL 81) for Highways Department. NLE SI Phase 1 Contract HY/90/23 (GCE)

March 1999 to June 1999
Agreement CE 42/98 ("Natural Terrain Hazard and Risk Area Studies, Tung Chung East and Mount Johnston North") looked in detail at two contrasting areas of natural terrain in order to test and evaluate a number of techniques for hazard and risk assessment. The following works were carried out in or close to the site now being monitored.

April 1999 - geophysical survey (four seismic reflection traverses and three resistivity soundings). These surveys broadly confirmed the rockhead levels interpreted from the boreholes. WO GE/97/12.25 (EGS)

April - May 1999 - two boreholes (TCE1 and TCE 2) and three trial trenches in the debris flow deposits at the base of the site, intended to investigate their thickness and characteristics. WO GE/97/15.63 (Enpack)

April- May 1999 - dynamic probing with installation of Halcrow bucket piezometers at locations along the ridge in the southern part of the site. (Bachy-Soletanche, for Halcrow, Job No. W653 under CE 42/98.)

29 September 1999
Walkover survey by GEO, confirming the location and nature of ground movements.

October - December 1999
Surface survey markers installed. These comprised lines of pegs across the failed areas, and a number of aerial survey target markers.

January 2000
Surface mapping by GEO to confirm the interpreted geology, and to investigate surface water flows during the dry season.

Winter/spring 1999/2000
Additional investigations carried out by GEO as follows:

Portable sampler - ten triple tube cores to 6.05m maximum depth. WO GE/99/07.18 (Vibro). Samples were logged in detail and tested for index properties. Detailed test results are kept in file GCSP 2/D9/38-4. A summary of the results is contained in Appendix B. Recording transducers were installed in standpipes in seven of these holes to give time-stamped data on the potentiometric surface within the regolith. Similar transducers were installed in the remaining three location using a modified set-up to record any ground movements. This installation comprised a sealed and flooded tube to total depth with the transducer suspended just off the bottom on a line passing over a pulley at ground level to a fixed point further up slope. Any downslope displacement of the instrumented location would result in the transducer being pulled up the hole, recording the time and extent of head loss (and movement). Although a promising idea, movement has not, to date, been recorded. Problems have also been encountered with cows walking through the lines and giving false readings.

Standard push-in type dial gauge tensiometers were installed at ten locations.

Two Casella tipping-bucket raingauges with built-in data loggers were installed on the site at elevations of about 10m and 95m.

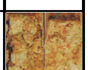
Winter/spring 2000/2001
Six trial pits were sunk by GEO to investigate the nature of the failures. WO GE/99/07.43 (Vibro) Disturbed samples were taken and tested for basic indices. a/a. Ten logging piezometers/tensiometers were installed at depths of 1.5 m to 2.5 m. These were proprietary instruments installed and maintained by Dr Andrew Ridley of Imperial College, London. Dr Ridley also installed a logging transducer in the deep standpipe piezometer in borehole TRL 129.

GEO / Special Projects Natural Terrain Landslide Studies	LOCATION Tung Chung East	HOLE NUMBER A1
CONTRACTOR : **Vibro (H.K.) LTD.**	DATUM LEVEL **+90.75 mPD**	SHEET NO. : **1** OF **1**
WORKS ORDER NO. : GE/99/07.18	DRILLING COMMENCED **19/04/2000**	EASTING : 813438.89 NORTHING : 816960.45
METHOD : Mazier / Portable Sampler	DRILLING COMPLETED : **19/04/2000**	LOGGED BY : N.C.Evans DATE LOGGED : 17/07/2000

SAMPLES RECOVERY %	SAMPLES TYPE	Sample Photo	Depth (m)	REDUCED LEVEL (m)	DESCRIPTION	PSD % GRAVEL	PSD % SAND	PSD % SILT	PSD % CLAY	PL	LL	PI
			0.00	90.75								
76%	M		0.23	90.52	Very soft, dark brown, dark greyish brown, sandy clayey SILT with organic matter and roots. (TOPSOIL)							
					Soft, orangish brown, sandy clayey SILT with roots.							
	●		0.50	90.25								
60%	M				Soft to firm, orangish brown, intact, sandy clayey gravelly SILT. Gravel is fine to medium, subangular to subrounded, of highly to completely decomposed, coarse ash tuff. Some fine roots. (COLLUVIUM)	9	19	32	40	23	54	31
	●		1.00	89.75								

CODES : M=Mazier sample
● =Small disturbed sample
PSD=particle size determination
PI=plasticity index
PL=plastic limit
LL=liquid limit

GEO / Special Projects **Natural Terrain Landslide Studies**	***LOCATION*** **Tung Chung East**	***HOLE NUMBER*** **A2**
CONTRACTOR : **Vibro (H.K.) LTD.**	DATUM LEVEL **+73.67 mPD**	SHEET NO. : **1** OF **3**
WORKS ORDER NO. : GE/99/07.18	DRILLING COMMENCED **22/04/2000**	EASTING : 813424.07
		NORTHING : 816984.31
METHOD : Mazier / Portable Sampler	DRILLING COMPLETED : **24/04/2000**	LOGGED BY : N.C.Evans
		DATE LOGGED : 17/07/2000

SAMPLES RECOVERY %	SAMPLES TYPE	Sample Photo	Depth (m)	REDUCED LEVEL (m)	DESCRIPTION	PSD % GRAVEL	PSD % SAND	PSD % SILT	PSD % CLAY	PL	LL	PI
			0.00	73.67								
74%	M				Soft, reddish brown, intact, clayey, slightly gravelly SILT with abundant roots. Gravel is fine to medium, subangular to subrounded, highly decomposed, volcanics. (COLLUVIUM?)							
	●		0.55	73.12	Soft, pale grey, very sandy silty CLAY. Sand is fine to medium, subangular to subrounded.							
42%	M		0.56	73.11	Soft to firm, reddish brown, intact, slightly clayey, slightly gravelly SILT. Gravel is fine to medium, subangular to subrounded, highly weathered, volcanics. Occasional roots. (COLLUVIUM?)	15	18	33	34	23	46	23
	●		1.10	72.57								
71%	M				Soft to firm, reddish brown mottled yellow, intact, clayey sandy SILT. Sand is fine to medium, subangular. (RESIDUAL SOIL?)	4	20	37	39	24	51	27
	●		1.65	72.02								
100%	M		1.68	71.99	Soft, white mottled reddish brown, intact, slightly sandy SILT. Extremely weak, reddish brown mottled yellowish brown, banded pale grey, completely decomposed, coarse ash TUFF. (Soft to firm sandy clayey SILT)							
	●		2.20	71.47		4	32	35	29	24	42	18
100%	M				Soft, dark brown mottled yellowish brown, slightly sandy clayey SILT with some roots. (INFILLED PIPE?)							
	●				Extremely weak, reddish brown mottled yellowish brown and pale grey, completely decomposed, coarse ash TUFF. (Soft to firm sandy clayey SILT)							

CODES : M=Mazier sample; ● =Small disturbed sample; PSD=particle size determination; PI=plasticity index; PL=plastic limit; LL=liquid limit

GEO / Special Projects Natural Terrain Landslide Studies	LOCATION Tung Chung East	HOLE NUMBER A2
CONTRACTOR : Vibro (H.K.) LTD.	DATUM LEVEL +73.67 mPD	SHEET NO. : 2 OF 3
WORKS ORDER NO. : GE/99/07.18	DRILLING COMMENCED 22/04/2000	EASTING : 813424.07 NORTHING : 816984.31
METHOD : Mazier / Portable Sampler	DRILLING COMPLETED 24/04/2000	LOGGED BY : N.C.Evans DATE LOGGED : 17/07/2000

SAMPLES RECOVERY %	TYPE	Sample Photo	Depth (m) 3.00	REDUCED LEVEL (m) 70.67	DESCRIPTION	GRAVEL	SAND	SILT	CLAY	PL	LL	PI
70%	M											
	•		3.30	70.37								
92%	M				Extremely weak, reddish brown mottled yellowish brown and pale grey completely decomposed, coarse ash TUFF. (Firm sandy clayey SILT)	10	39	45	6			
	•		3.85	69.82								
100%	M				Extremely to very weak, pale grey mottled reddish brown, completely decomposed, coarse ash TUFF with very close to closely spaced joints, smooth planar, extremely narrow, some surface staining. (Firm sandy clayey SILT)							
	•		4.40	69.27								
90%	M				Extremely to very weak, pale grey mottled reddish brown, completely decomposed, coarse ash TUFF with possible steeply dipping fabric and occasional closely spaced joints above 4.55m, smooth planar, extremely narrow, some surface staining. (Firm sandy clayey SILT)							
	•		4.95	68.72								
90%	M				Extremely to very weak, pale grey mottled reddish brown, completely decomposed, coarse ash TUFF with occasional steeply dipping joints, smooth undulating, extremely narrow, some staining. (Firm sandy clayey SILT)							
			5.30	68.37	Extremely weak, pale grey mottled white and dark reddish brown, completely decomposed, coarse ash TUFF with occasional smooth planar joints, extremely narrow. Possible kaolinised zone? (Soft to firm sandy clayey SILT)	17	41	32	10	28	45	17
	•		5.50	68.17								

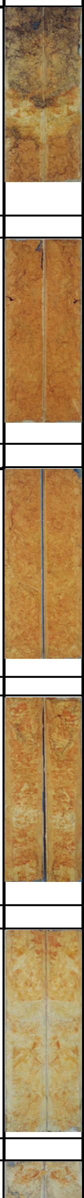
CODES : M=Mazier sample
• =Small disturbed sample
PSD=particle size determination
PI=plasticity index
PL=plastic limit
LL=liquid limit

GEO / Special Projects **Natural Terrain Landslide Studies**	***LOCATION*** **Tung Chung East**	***HOLE NUMBER*** **A2**
CONTRACTOR : **Vibro (H.K.) LTD.**	DATUM LEVEL **+73.67 mPD**	SHEET NO. : **3** OF **3**
WORKS ORDER NO. : GE/99/07.18	DRILLING COMMENCED **22/04/2000**	EASTING : 813424.07 NORTHING : 816984.31
METHOD : Mazier / Portable Sampler	DRILLING COMPLETED : **24/04/2000**	LOGGED BY : N.C.Evans DATE LOGGED : 17/07/2000

SAMPLES RECOVERY %	SAMPLES TYPE	Sample Photo	Depth (m)	REDUCED LEVEL (m)	DESCRIPTION	PSD % GRAVEL	PSD % SAND	PSD % SILT	PSD % CLAY	PL	LL	PI
			5.50	68.17								
90%	M		5.65	68.02	Extremely weak, pale grey mottled reddish brown, yellowish brown and white, completely decomposed, coarse ash TUFF with conspicuous steeply-dipping joint, rough planar, narrow, with kaolin(?) and manganese infill. (Soft to firm sandy clayey SILT)							
	●		6.05	67.62	Extremely to very weak, pale grey mottled reddish brown, completely decomposed, coarse ash TUFF. (Firm sandy clayey SILT)							

CODES : M=Mazier sample
● =Small disturbed sample
PSD=particle size determination
PL=plastic limit
LL=liquid limit
PI=plasticity index

GEO / Special Projects	LOCATION	HOLE NUMBER
Natural Terrain Landslide Studies	Tung Chung East	A3
CONTRACTOR : Vibro (H.K.) LTD.	DATUM LEVEL +65.08 mPD	SHEET NO. : 1 OF 2
WORKS ORDER NO. : GE/99/07.18	DRILLING COMMENCED 25/04/2000	EASTING : 813415.80
		NORTHING : 816998.56
METHOD : Mazier / Portable Sampler	DRILLING COMPLETED : 25/04/2000	LOGGED BY : N.C.Evans
		DATE LOGGED : 17/07/2000



SAMPLES RECOVERY %	TYPE	Depth (m)	REDUCED LEVEL (m)	DESCRIPTION	PSD % GRAVEL	SAND	SILT	CLAY	PL	LL	PI
		0.00	65.08								
80%	M	0.20	64.88	Very soft to soft, pale yellowish brown to dark brown, sandy clayey SILT with organic matter and roots. (TOPSOIL)							
				Soft to firm, reddish brown, sandy SILT with fine to coarse gravel of highly to completely decomposed, coarse ash tuff. Some roots. (COLLUVIUM?)							
	●	0.55	64.53								
86%	M			Firm to stiff, reddish brown, structureless sandy SILT with some fine to medium gravel, subrounded of highly decomposed, coarse ash tuff. Occasional roots. (COLLUVIUM?)	9	17	28	46	25	56	31
	●	1.10	63.98								
88%	M	1.22	63.86	Firm to stiff, structureless sandy SILT with some fine subangular gravel. (COLLUVIUM)							
		1.29	63.79	Gradational boundary							
				Yellowish brown mottled reddish brown, firm, intact, sandy SILT with occasional roots. (RESIDUAL SOIL?)							
	●	1.65	63.43								
86%	M			Firm, mottled reddish brown, yellowish brown and yellowish grey, intact, sandy SILT with occasional roots above 1.75m. (RESIDUAL SOIL)	1	31	34	34	21	44	23
	●	2.20	62.88								
94%	M			Extremely weak, mottled and banded pale reddish brown, pale yellowish brown, yellowish grey, completely decomposed, coarse ash TUFF. Very thinly spaced joints, smooth planar, extremely narrow, stained. (Firm sandy SILT)							
	●	2.75	62.33								

CODES :	
M=Mazier sample	PSD=particle size determination PI=plasticity index
● =Small disturbed sample	PL=plastic limit LL=liquid limit

GEO / Special Projects Natural Terrain Landslide Studies	LOCATION Tung Chung East	HOLE NUMBER A3
CONTRACTOR : Vibro (H.K.) LTD.	DATUM LEVEL +65.08 mPD	SHEET NO. : 2 OF 2
WORKS ORDER NO. : GE/99/07.18	DRILLING COMMENCED 25/04/2000	EASTING : 813415.80 NORTHING : 816998.56
METHOD : Mazier / Portable Sampler	DRILLING COMPLETED : 25/04/2000	LOGGED BY : N.C.Evans DATE LOGGED : 17/07/2000

SAMPLES RECOVERY %	TYPE	Sample	Depth (m)	REDUCED LEVEL (m)	DESCRIPTION	PSD % GRAVEL	SAND	SILT	CLAY	PL	LL	PI
			3.00	62.08								
60%	M				3.04m - manganese stain on joints							
	●											
80%	M				Extremely weak, pale greenish grey mottled reddish brown, completely decomposed, coarse ash TUFF with very thinly spaced smooth planar joints, extremely narrow, stained. (Firm sandy SILT)	4	51	33	12	19	35	16
	●		3.85	61.23								
46%	M				Extremely weak, pale greenish grey mottled reddish brown, completely decomposed, coarse ash TUFF with very thinly spaced smooth planar joints, extremely narrow, stained, trace manganese. (Firm sandy SILT)							
	●		4.40	60.68								

CODES : M=Mazier sample; ● =Small disturbed sample; PSD=particle size determination; PL=plastic limit; LL=liquid limit; PI=plasticity index

GEO / Special Projects Natural Terrain Landslide Studies	***LOCATION*** Tung Chung East	***HOLE NUMBER*** A4
CONTRACTOR : **Vibro (H.K.) LTD.**	DATUM LEVEL **+53.43 mPD**	SHEET NO. : **1** OF **3**
WORKS ORDER NO. : GE/99/07.18	DRILLING COMMENCED **26/04/2000**	EASTING : 813396.71
		NORTHING : 817014.76
METHOD : Mazier / Portable Sampler	DRILLING COMPLETED : **26/04/2000**	LOGGED BY : N.C.Evans
		DATE LOGGED : 17/07/2000

SAMPLES RECOVERY %	SAMPLES TYPE	Sample Photo	Depth (m)	REDUCED LEVEL (m)	***DESCRIPTION***	PSD % GRAVEL	PSD % SAND	PSD % SILT	PSD % CLAY	PL	LL	PI
			0.00	53.43								
80%	M		0.25	53.18	Very soft, dark grey, sandy clayey SILT with organic matter and roots. (TOPSOIL)							
			0.55	52.88	Soft, reddish brown, structureless sandy clayey SILT. Some roots.							
	●											
62%	M		1.10	52.33	Soft to firm, reddish brown mottled yellowish brown, structureless sandy clayey SILT with occasional fine to medium subrounded to subangular gravel, and some roots. (COLLUVIUM?)							
	●											
70%	M		1.65	51.78	Soft to firm, reddish brown mottled yellowish brown, structureless sandy clayey SILT with occasional fine to medium subangular gravel of highly to completely decomposed, coarse ash tuff. (COLLUVIUM)	1	23	43	33	22	50	28
	●											
90%	M		1.72	51.71	Soft to firm, reddish brown, structureless sandy clayey SILT. (COLLUVIUM?)							
			2.20	51.23	Extremely weak, pale greenish grey mottled reddish brown, completely decomposed, coarse ash TUFF with very closely spaced joints, smooth planar, extremely narrow, stained. (Firm sandy SILT)							
	●											
90%	M		2.75	50.68	Extremely weak, pale greenish grey mottled reddish brown, completely decomposed, coarse ash TUFF with occasional smooth planar extremely narrow joints, stained. (Firm sandy SILT)	3	54	33	10	18	28	10
	●											
												

CODES : M=Mazier sample; ● =Small disturbed sample; PSD=particle size determination; PI=plasticity index; PL=plastic limit; LL=liquid limit

GEO / Special Projects Natural Terrain Landslide Studies	LOCATION Tung Chung East	HOLE NUMBER A4
CONTRACTOR : Vibro (H.K.) LTD.	DATUM LEVEL +53.43 mPD	SHEET NO. : 2 OF 3
WORKS ORDER NO. : GE/99/07.18	DRILLING COMMENCED 26/04/2000	EASTING : 813396.71 NORTHING : 817014.76
METHOD : Mazier / Portable Sampler	DRILLING COMPLETED : 26/04/2000	LOGGED BY : N.C.Evans DATE LOGGED : 17/07/2000

SAMPLES RECOVERY %	SAMPLES TYPE	Sample Photo	Depth (m)	REDUCED LEVEL (m)	DESCRIPTION	PSD % GRAVEL	PSD % SAND	PSD % SILT	PSD % CLAY	PL	LL	PI
			3.00	50.43								
90%	M				Extremely weak, pale greenish grey mottled reddish brown, completely decomposed, coarse ash TUFF with closely spcaed smooth planar joints, extremely narrow, stained. (Firm sandy SILT) 2.83m-2.87m Possible kaolin joint infill							
	●		3.30	50.13								
90%	M				Extremely weak, pale greenish grey mottled reddish brown, completely decomposed, coarse ash TUFF. Possible sub-horizontal mylonitic fabric. Closely spaced smooth planar joints, extremely narrow, stained (trace manganese). (Firm sandy SILT)							
	●		3.85	49.58								
50%	M				Extremely weak, pale greenish grey mottled reddish brown, completely decomposed, coarse ash TUFF with occasional very closely spaced joints, rough undulating, extremely narrow, stained. (Firm sandy SILT)							
	●		4.40	49.03								
60%	M				Extremely weak to weak, pale greenish grey mottled reddish brown, completely decomposed, coarse ash TUFF with occasional rough planar joints, extremely narrow, stained (trace manganese). (Firm to stiff sandy SILT)							
	●		4.95	48.48								
85%	M				Extremely weak to weak, pale greenish grey mottled reddish brown, completely decomposed, coarse ash TUFF with closely spaced smooth planar joints, extremely narrow, stained (trace manganese). (Firm to stiff sandy SILT)	10	61	25	4	18	28	10
	●		5.50	47.93								

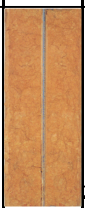
CODES : M=Mazier sample; ● =Small disturbed sample; PSD=particle size determination; PL=plastic limit; LL=liquid limit; PI=plasticity index

GEO / Special Projects **Natural Terrain Landslide Studies**	***LOCATION*** **Tung Chung East**	***HOLE NUMBER*** **A4**
CONTRACTOR : **Vibro (H.K.) LTD.**	DATUM LEVEL **+53.43 mPD**	SHEET NO. : **3** OF **3**
WORKS ORDER NO. : GE/99/07.18	DRILLING COMMENCED **26/04/2000**	EASTING : 813396.71 NORTHING : 817014.76
METHOD : Mazier / Portable Sampler	DRILLING COMPLETED : **26/04/2000**	LOGGED BY : N.C.Evans DATE LOGGED : 17/07/2000

SAMPLES: RECOVERY %	SAMPLES: TYPE	Sample Photo	Depth (m)	REDUCED LEVEL (m)	***DESCRIPTION***	PSD %: GRAVEL	PSD %: SAND	PSD %: SILT	PSD %: CLAY	PL	LL	PI
			5.50	47.93								
60%	M				Extremely weak to weak, pale greenish grey mottled reddish brown (and yellowish brown below 5.70m), completely decomposed, coarse ash TUFF with occasional smooth planar joints, extremely narrow, stained, trace manganese. (Firm to stiff sandy SILT) 5.52m - 5.62m Grey green firm to stiff clayey silt. (POSSIBLE WEATHERED LITHIC BOMB)							
	⬬		6.05	47.38								

CODES : M=Mazier sample
⬬ =Small disturbed sample
PSD=particle size determination
PL=plastic limit
LL=liquid limit
PI=plasticity index

GEO / Special Projects **Natural Terrain Landslide Studies**	***LOCATION*** **Tung Chung East**	***HOLE NUMBER*** **A5**
CONTRACTOR : **Vibro (H.K.) LTD.**	DATUM LEVEL **+66.11 mPD**	SHEET NO. : **1** OF **2**
WORKS ORDER NO. : GE/99/07.18	DRILLING COMMENCED **27/04/2000**	EASTING : 813392.43
		NORTHING : 816986.03
METHOD : Mazier / Portable Sampler	DRILLING COMPLETED : **28/04/2000**	LOGGED BY : N.C.Evans
		DATE LOGGED : 19/07/2000

SAMPLES RECOVERY %	SAMPLES TYPE	Sample Photo	Depth (m)	REDUCED LEVEL (m)	***DESCRIPTION***	PSD % GRAVEL	PSD % SAND	PSD % SILT	PSD % CLAY	PL	LL	PI
			0.00	66.11								
86%	M		0.17 0.55	65.94 65.56	Soft, dark grey mottled yellowish brown clayey SILT with roots. (TOPSOIL) Soft, pale reddish brown, clayey SILT with some fine angular gravel and roots. (COLLUVIUM?)							
	•											
92%	M		0.99 1.00	65.12 65.11	Soft to firm, pale reddish brown mottled yellowish brown clayey SILT with occasional coarse sand and fine subangular gravel. Some roots. (COLLUVIUM?) Gradational boundary	1	18	36	45	21	47	26
	•											
90%	M		1.10 1.65	65.01 64.46	Soft to firm, pale reddish brown mottled yellowish brown, clayey SILT with occasional coarse sand and fine subangular gravel. Possible relict texture. (RESIDUAL SOIL?) Extremely weak, pale reddish brown mottled yellowish brown, completely decomposed, coarse ash TUFF with occasional sub vertical smooth undulating relict joints, tight. Occasional roots above 1.15m. (Soft to firm sandy SILT)	1	21	37	41	20	43	23
	•											
72%	M		2.20	63.91	Extremely weak, pale reddish brown mottled and banded pale yellowish brown and pale greenish grey, completely decomposed, coarse ash TUFF. (Soft to firm sandy SILT)							
	•											
91%	M		2.75	63.36	Extremely weak, pale reddish brown mottled and banded pale yellowish brown and pale greenish grey, completely decomposed, coarse ash TUFF. (Firm sandy SILT) 2.45m-2.52m Possible mylonitic texture.	1	22	43	34	23	42	19
	•											
90%	M				Extremely weak, pale yellowish brown mottled reddish brown and greenish grey, completely decomposed, coarse ash TUFF with very closely spaced joints, smooth planar, extremely narrow, stained, kaolin infill. (Firm sandy SILT)							

CODES : M=Mazier sample
• =Small disturbed sample
PSD=particle size determination
PL=plastic limit
LL=liquid limit
PI=plasticity index

GEO / Special Projects Natural Terrain Landslide Studies		LOCATION Tung Chung East	HOLE NUMBER A5
CONTRACTOR : **Vibro (H.K.) LTD.**		DATUM LEVEL **+66.11 mPD**	SHEET NO. : **2** OF **2**
WORKS ORDER NO. : GE/99/07.18	DRILLING COMMENCED **27/04/2000**		EASTING : 813392.43 NORTHING : 816986.03
METHOD : Mazier / Portable Sampler	DRILLING COMPLETED : **28/04/2000**		LOGGED BY : N.C.Evans DATE LOGGED : 19/07/2000

SAMPLES RECOVERY %	SAMPLES TYPE	Sample Photo	Depth (m)	REDUCED LEVEL (m)	DESCRIPTION	PSD % GRAVEL	PSD % SAND	PSD % SILT	PSD % CLAY	PL	LL	PI
			3.00	63.11	Extremely weak, very pale greenish grey, completely decomposed, coarse ash TUFF with very closely spaced joints, smooth planar, extremely narrow, stained. (manganese) (Soft clayey SILT)							
	●		3.30	62.81		0	38	50	12	18	31	13
			3.44	62.67	Gradational boundary							
88%	M		3.47	62.64	Extremely weak, yellowish brown mottled and banded reddish brown, dark red and pale greenish grey, completely decomposed, coarse ash TUFF with very closely spaced joints, smooth planar, very to extremely narrow, kaolin infill. (Firm clayey sandy SILT)							
	●		3.85	62.26								
			3.96	62.15						2	48	2
86%	M		4.15	61.96	Extremely weak, pale brown mottled yellowish brown and reddish brown, completely decomposed, coarse ash TUFF. (Soft clayey SILT)							
	●		4.40	61.71	Extremely weak, very pale greenish grey, completely decomposed, coarse ash TUFF with closely spaced joints, subvertical, smooth planar, extremely narrow, stained, trace kaolin infill. (Soft to firm sandy clayey SILT)	6	47	36	11	19	33	14
90%	M		4.74	61.37	Extremely weak, pale yellowish brown mottled greenish grey completely decomposed coarse ash TUFF with closely spaced joints, subvertical, smooth planar, extremely narrow, stained, trace kaolin infill. (Soft to firm sandy clayey SILT)							
	●		4.95	61.16	Extremely weak, pale greenish grey mottled reddish brown and yellowish brown, completely decomposed, coarse ash TUFF with closely spaced joints, smooth planar, extremely narrow, stained. (Soft to firm sandy clayey SILT)							
					Weak, greenish grey, completely decomposed, coarse ash TUFF. (Firm to stiff sandy SILT)							

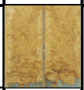
CODES : M=Mazier sample; ● =Small disturbed sample; PSD=particle size determination; PL=plastic limit; LL=liquid limit; PI=plasticity index

GEO / Special Projects Natural Terrain Landslide Studies	LOCATION Tung Chung East	HOLE NUMBER A6
CONTRACTOR : Vibro (H.K.) LTD.	DATUM LEVEL +32.54 mPD	SHEET NO. : 1 OF 2
WORKS ORDER NO. : GE/99/07.18	DRILLING COMMENCED 05/05/2000	EASTING : 813326.30 NORTHING : 817027.02
METHOD : Mazier / Portable Sampler	DRILLING COMPLETED : 05/05/2000	LOGGED BY : N.C.Evans DATE LOGGED : 19/07/2000

SAMPLES: RECOVERY %	SAMPLES	Sample Photo	Depth (m)	REDUCED LEVEL (m)	DESCRIPTION	PSD %: GRAVEL	PSD %: SAND	PSD %: SILT	PSD %: CLAY	PL	LL	PI
		0.015	0.00	32.54	32.525							
92%	M		0.02	32.52	Very soft, dark brown to grey, clayey SILT with organic matter. (TOPSOIL)							
			0.26	32.28	Thin, pale reddish brown sandy clayey SILT. (WASHOUT?)							
					Very soft, pale brown mottled reddish brown sandy clayey SILT with abundant roots. (COLLUVIUM?) (INTERMIXED WITH TOPSOIL)							
	●		0.55	31.99								
88%	M				Very soft, pale reddish brown, sandy clayey SILT with occasional fine to medium subrounded gravel and occasional pockets of loose, pale greenish grey, silty fine sand. Occasional roots. (COLLUVIUM?)	2	34	40	24	22	41	19
	●		1.10	31.44	Very soft, reddish brown, sandy clayey SILT with fine to coarse, subangular to subrounded gravel of extremely weak, completely decomposed, coarse ash TUFF. (COLLUVIUM)							
86%	M		1.25	31.29	Extremely weak, pale greenish grey mottled reddish brown, completely decomposed, coarse ash TUFF. (Soft sandy SILT) (BOULDER?)	2	36	44	18	21	38	17
	●		1.65	30.89	Soft, pale reddish brown sandy clayey SILT with fine to medium subangular to subrounded gravel of completely decomposed, coarse ash tuff. (COLLUVIUM?)							
90%	M				Very weak, pale greenish grey mottled reddish brown, completely decomposed, coarse ash TUFF with very closely spaced rough planar joints, extremely narrow to very narrow, trace manganese infill. Disturbed. (Firm sandy SILT) (BOULDER?)							
	●		2.20	30.34								
88%	M		2.28	30.26	Soft, pale reddish brown, sandy clayey SILT with fine to medium subangular to subrounded gravel of completely decomposed, coarse ash tuff. (COLLUVIUM?)							
			2.35	30.19	Very weak, pale greenish grey, completely decomposed, coarse ash TUFF. (COBBLE?)							

CODES : M=Mazier sample; ● =Small disturbed sample; PSD=particle size determination; PI=plasticity index; PL=plastic limit; LL=liquid limit

GEO / Special Projects **Natural Terrain Landslide Studies**	***LOCATION*** **Tung Chung East**	***HOLE NUMBER*** **A6**
CONTRACTOR : **Vibro (H.K.) LTD.**	DATUM LEVEL **+32.54 mPD**	SHEET NO. : **2** OF **2**
WORKS ORDER NO. : GE/99/07.18	DRILLING COMMENCED **05/05/2000**	EASTING : 813326.30 NORTHING : 817027.02
METHOD : Mazier / Portable Sampler	DRILLING COMPLETED : **05/05/2000**	LOGGED BY : N.C.Evans DATE LOGGED : 19/07/2000

SAMPLES RECO-VERY %	SAMPLES TYPE	Sample Photo	Depth (m)	REDUCED LEVEL (m)	***DESCRIPTION***	PSD % GRAVEL	PSD % SAND	PSD % SILT	PSD % CLAY	PL	LL	PI
			2.50	30.04								
					Soft, pale reddish brown, sandy clayey SILT with fine to medium subangular to subrounded gravel of completely decomposed, coarse ash tuff. (COLLUVIUM?)	4	40	34	22	23	44	21
	•		2.75	29.79								
86%	M				Soft, pale yellowish brown mottled reddish brown, sandy clayey SILT with some fine to medium subrounded gravel of highly decomposed, coarse ash tuff. (COLLUVIUM)							
			3.07	29.47	Extremely weak, pale greenish grey mottled yellowish brown, completely decomposed, coarse ash TUFF. (Firm sandy SILT)							
	•		3.30	29.24								
92%	M				Extremely weak, pale greenish grey mottled yellowish brown and reddish brown, completely decomposed, coarse ash TUFF with very closely spaced joints, smooth planar, extremely narrow, trace kaolin infill, trace manganese. Conspicuous subvertical joint stained back about 10mm into rock mass. (Firm sandy SILT)	8	50	30	12			
	•		3.85	28.69								

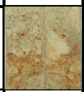
CODES : M=Mazier sample; • =Small disturbed sample; PSD=particle size determination; PL=plastic limit; LL=liquid limit; PI=plasticity index

GEO / Special Projects Natural Terrain Landslide Studies	LOCATION Tung Chung East	HOLE NUMBER A7
CONTRACTOR : **Vibro (H.K.) LTD.**	DATUM LEVEL **+47.45 mPD**	SHEET NO. : **1** OF **2**
WORKS ORDER NO. : GE/99/07.18	DRILLING COMMENCED **03/05/2000**	EASTING : 813312.71 NORTHING : 817006.32
METHOD : Mazier / Portable Sampler	DRILLING COMPLETED : **04/05/2000**	LOGGED BY : N.C.Evans DATE LOGGED : 19/07/2000

SAMPLES RECOVERY %	TYPE	Depth (m)	REDUCED LEVEL (m)	DESCRIPTION	GRAVEL	SAND	SILT	CLAY	PL	LL	PI
		0.00	47.45								
90%	M	0.10	47.35	Soft, dark brown mottled dark grey, sandy clayey SILT with organic matter and abundant roots. (TOPSOIL)							
		0.24	47.21	Soft, greenish grey mottled yellowish brown, sandy clayey SILT with roots and some fine to medium subangular to subrounded gravel of highly decomposed, coarse ash tuff. (COLLUVIUM)							
	●	0.55	46.90								
90%	M			Soft to firm, reddish brown mottled yellowish brown, sandy SILT with some fine to medium subangular to subrounded gravel of highly decomposed, coarse ash tuff. Occasional roots. (COLLUVIUM)	2	33	52	13	19	33	14
	●	1.10	46.35	Extremely weak, pale reddish brown mottled pale yellowish brown, completely decomposed, coarse ash TUFF with possible mylonitic/eutaxitic texture and occasional rough planar joints extremely narrow, stained. Occasional roots. (Soft sandy SILT)							
90%	M								20	36	16
	●	1.65	45.80	Extremely weak, pale greenish grey mottled yellowish brown, completely decomposed, coarse ash TUFF with closely spaced joints, rough planar, tight to extremely narrow, stained. (Soft to firm sandy SILT)							
92%	M			Very to extremely weak, pale greenish grey mottled yellowish brown, completely decomposed, coarse ash TUFF. Mylonitic/eutaxitic fabric dipping around 45°. Very closely spaced joints, smooth to rough planar, tight to extremely narrow, stained. (Firm to stiff sandy SILT)							
	●	2.20	45.25								
92%	M			Very to extremely weak, pale greenish grey mottled pinkish grey and yellowish brown, completely decomposed, coarse ash TUFF with mylonitic/eutaxitic fabric dipping around 45°. (Firm to stiff sandy SILT)							

CODES : M=Mazier sample; ● =Small disturbed sample; PSD=particle size determination; PI=plasticity index; PL=plastic limit; LL=liquid limit

GEO / Special Projects Natural Terrain Landslide Studies	LOCATION Tung Chung East	HOLE NUMBER A7
CONTRACTOR : **Vibro (H.K.) LTD.**	DATUM LEVEL **+47.45 mPD**	SHEET NO. : **2** OF **2**
WORKS ORDER NO. : GE/99/07.18	DRILLING COMMENCED **03/05/2000**	EASTING : 813312.71 NORTHING : 817006.32
METHOD : Mazier / Portable Sampler	DRILLING COMPLETED : **04/05/2000**	LOGGED BY : N.C.Evans DATE LOGGED : 19/07/2000

SAMPLES: RECOVERY %	SAMPLES: TYPE	Sample Photo	Depth (m)	REDUCED LEVEL (m)	DESCRIPTION	PSD %: GRAVEL	PSD %: SAND	PSD %: SILT	PSD %: CLAY	PL	LL	PI
			2.50	44.95								
					Extremely to very weak, pale greenish grey mottled pinkish grey and yellowish brown, completely decomposed, coarse ash TUFF with very closely spaced joints, smooth to rough planar, tight to extremely narrow, stained. (Firm to stiff sandy SILT)							
	⬬		2.75	44.70								
92%	M		2.78	44.67	Soft, pale brown, homogeneous clayey SILT.							
			2.82	44.63	Extremely to very weak, pale greenish grey mottled pinkish grey and yellowish brown, completely decomposed, coarse ash TUFF with very closely spaced joints, smooth to rough planar, tight to extremely narrow, stained. (Firm to stiff sandy SILT)							
	⬬		3.30	44.15								

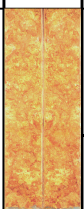
CODES : M=Mazier sample
⬬ =Small disturbed sample
PSD=particle size determination
PI=plasticity index
PL=plastic limit
LL=liquid limit

GEO / Special Projects Natural Terrain Landslide Studies	LOCATION Tung Chung East	HOLE NUMBER G1P
CONTRACTOR : Vibro (H.K.) LTD.	DATUM LEVEL +83.56 mPD	SHEET NO. : 1 OF 1
WORKS ORDER NO. : GE/99/07.18	DRILLING COMMENCED 21/04/2000	EASTING : 813442.75 NORTHING : 816975.27
METHOD : Mazier / Portable Sampler	DRILLING COMPLETED : 21/04/2000	LOGGED BY : N.C.Evans DATE LOGGED : 17/07/2000

SAMPLES RECOVERY %	SAMPLES TYPE	Sample Photo	Depth (m)	REDUCED LEVEL (m)	DESCRIPTION	PSD % GRAVEL	PSD % SAND	PSD % SILT	PSD % CLAY	PL	LL	PI
			0.00	83.56								
90%	M		0.19	83.37	Soft to firm, dark brown / grey, sandy clayey SILT with organic matter and roots. (TOPSOIL)							
					Soft to firm, reddish brown, structureless sandy SILT with abundant roots.							
	•		0.55	83.01								
92%	M				Soft to firm, reddish brown, structureless sandy SILT with occasional roots above 0.8m and some fine to medium, subrounded to angular gravel of highly to completely decomposed, coarse ash tuff. (COLLUVIUM)	8	20	27	45	24	51	27
	•		1.10	82.46								
74%	M		1.12	82.44	Very soft to soft, dark brownish grey, sandy clayey SILT with roots. (BURIED TOPSOIL?)							
			1.28	82.28								
			1.32	82.24	Soft to firm, reddish brown, structureless sandy SILT with some fine to medium subrounded to angular gravel. (COLLUVIUM)							
			1.60	81.96	Gradational boundary							
	•					4	34	52	10	19	31	12
93%	M		1.72	81.84	Firm, reddish brown mottled yellowish brown and pale grey, sandy SILT. (RESIDUAL SOIL?)							
			1.84	81.72						23	38	15
	•		2.00	81.56	Extremely weak, pale grey mottled reddish brown, completely decomposed, coarse ash TUFF with occasional smooth planar joints, tight. (Firm sandy SILT)							
					Firm to stiff, dark reddish brown, structureless sandy clayey SILT with occasional subangular fine to medium gravel of highly decomposed, coarse ash tuff. (RESIDUAL SOIL / SHEARED ZONE?)							
					Extremely weak to weak, pale grey mottled reddish brown, completely decomposed, coarse ash TUFF with occasional smooth planar joints, tight. (Firm to stiff sandy SILT)							

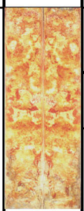
CODES : M=Mazier sample; • =Small disturbed sample; PSD=particle size determination; PI=plasticity index; PL=plastic limit; LL=liquid limit

GEO / Special Projects **Natural Terrain Landslide Studies**	***LOCATION*** **Tung Chung East**	***HOLE NUMBER*** **G2P**
CONTRACTOR : **Vibro (H.K.) LTD.**	DATUM LEVEL **+74.06 mPD**	SHEET NO. : **1** OF **2**
WORKS ORDER NO. : GE/99/07.18	DRILLING COMMENCED **29/04/2000**	EASTING : 813400.61
		NORTHING : 816972.02
METHOD : Mazier / Portable Sampler	DRILLING COMPLETED : **29/04/2000**	LOGGED BY : N.C.Evans
		DATE LOGGED : 19/07/2000

SAMPLES RECOVERY %	SAMPLES TYPE	Sample Photo	Depth (m)	REDUCED LEVEL (m)	***DESCRIPTION***	PSD % GRAVEL	PSD % SAND	PSD % SILT	PSD % CLAY	PL	LL	PI
			0.00	74.06								
68%	M		0.14 0.18	73.92 73.88	Very soft, dark grey, clayey sandy SILT with organic matter and roots. (TOPSOIL) Gradational boundary Very soft, pale reddish brown, clayey sandy SILT with roots.							
	•		0.55	73.51								
88%	M				Soft to firm, reddish brown mottled yellowish brown, clayey sandy SILT, structureless, with occasional fine to medium gravel of highly decomposed, coarse ash tuff. Some roots. (COLLUVIUM?)	1	14	33	52	24	50	26
	•		1.10	72.96								
90%	M				Firm, reddish brown mottled yellowish brown, clayey sandy SILT, structureless, with occasional fine to medium, subangular gravel of completely decomposed, coarse ash tuff. (COLLUVIUM? / RESIDUAL SOIL?)	12	22	36	30	23	47	24
	•		1.65	72.41								
90%	M				Firm, reddish brown mottled yellowish brown, sandy clayey SILT with occasional fine to medium subangular gravel of highly decomposed, coarse ash tuff. Trace relict joints. (RESIDUAL SOIL?)							
	•		2.20	71.86								
90%	M				Extremely weak, reddish brown mottled yellowish brown, completely decomposed, coarse ash TUFF with occasional joints, smooth planar, tight. (Firm sandy SILT)	2	23	49	26	21	40	19
	•		2.75	71.31	Extremely weak, reddish brown mottled yellowish brown, completely decomposed, coarse ash TUFF. (Firm sandy SILT)							
			2.90	71.16								

CODES : M=Mazier sample   • =Small disturbed sample   PSD=particle size determination   PL=plastic limit   LL=liquid limit   PI=plasticity index

GEO / Special Projects	*LOCATION*	*HOLE NUMBER*
Natural Terrain Landslide Studies	**Tung Chung East**	**G2P**
CONTRACTOR : **Vibro (H.K.) LTD.**	DATUM LEVEL **+74.06 mPD**	SHEET NO. : **2** OF **2**
WORKS ORDER NO. : GE/99/07.18	DRILLING COMMENCED **29/04/2000**	EASTING : 813400.61
		NORTHING : 816972.02
METHOD : Mazier / Portable Sampler	DRILLING COMPLETED : **29/04/2000**	LOGGED BY : N.C.Evans
		DATE LOGGED : 19/07/2000

SAMPLES RECOVERY %	SAMPLES TYPE	Sample Photo	Depth (m) 3.00	REDUCED LEVEL (m) 71.06	*DESCRIPTION*	PSD % GRAVEL	PSD % SAND	PSD % SILT	PSD % CLAY	PL	LL	PI
92%	M		3.05	71.01	Very weak, pale greenish grey, completely decomposed, coarse ash TUFF with very closely spaced joints, smooth planar, stained, tight. (Stiff sandy SILT)							
	•		3.30	70.76								
92%	M				Extremely weak, pale greenish grey mottled yellowish brown and pinkish grey, completely decomposed, coarse ash Tuff with closely spaced joints, undulating smooth, extremely narrow, stained. (Firm sandy SILT)	4	24	50	22	22	39	17
	•		3.85	70.21	Extremely weak, mottled and banded pale greenish grey, reddish brown and yellowish brown, completely decomposed, coarse ash TUFF with occasional joints, smooth planar, extremely narrow, stained. (Firm sandy, occasionally clayey, SILT)							
92%	M		4.15	69.91	Extremely weak, mottled reddish brown, yellowish brown and pale greenish grey, completely decomposed, coarse ash TUFF with closely spaced joints, smooth planar, extremely narrow, stained. (Firm sandy SILT)							
	•		4.40	69.66								
92%	M				Very weak, pale greenish grey mottled reddish brown, completely decomposed, coarse ash TUFF with very closely spaced joints, smooth planar, stained, tight. (Firm to stiff sandy SILT)							
	•		4.95	69.11	Very to extremely weak, pale greenish grey mottled yellowish brown, completely decomposed, coarse ash TUFF with very closely spaced joints, smooth planar, stained, tight. (Firm to stiff sandy SILT)							

CODES : M=Mazier sample; • =Small disturbed sample; PSD=particle size determination; PL=plastic limit; LL=liquid limit; PI=plasticity index

GEO / Special Projects	LOCATION	HOLE NUMBER
Natural Terrain Landslide Studies	Tung Chung East	G3P
CONTRACTOR : Vibro (H.K.) LTD.	DATUM LEVEL +48.14 mPD	SHEET NO. : 1 OF 2
WORKS ORDER NO. : GE/99/07.18	DRILLING COMMENCED 03/05/2000	EASTING : 813316.09
		NORTHING : 817002.37
METHOD : Mazier / Portable Sampler	DRILLING COMPLETED : 03/05/2000	LOGGED BY : N.C.Evans
		DATE LOGGED : 19/07/2000

SAMPLES RECOVERY %	TYPE	Depth (m)	REDUCED LEVEL (m)	DESCRIPTION	PSD % GRAVEL	SAND	SILT	CLAY	PL	LL	PI
		0.00	48.14								
		0.09	48.05	Soft, brown mottled dark grey, sandy clayey SILT with organic matter and roots. (TOPSOIL)							
90%	M			Soft, reddish brown, structureless sandy SILT with occasional roots. (COLLUVIUM?) (RESIDUAL SOIL?)							
	•	0.55	47.59								
92%	M			Soft, reddish brown mottled yellowish brown, sandy SILT, structureless, with occasional roots. (RESIDUAL SOIL?)	2	21	37	40	24	51	27
	•	1.10	47.04								
92%	M			Soft, reddish brown mottled yellowish brown, structureless sandy SILT. (RESIDUAL SOIL)							
	•	1.65	46.49								
90%	M			Soft to firm, yellowish brown mottled reddish brown, sandy SILT, structureless. (RESIDUAL SOIL)	2	28	37	33	25	47	22
	•	2.20	45.94								
92%	M			Firm, yellowish brown mottled reddish brown, structureless sandy SILT. (RESIDUAL SOIL)	1	22	40	33	26	48	22
	•	2.75	45.39								
		2.88	45.26	Soft to firm, yellowish brown mottled reddish brown, sandy SILT. (RESIDUAL SOIL)							
		2.92	45.22	Gradational boundary							

CODES : M=Mazier sample; • =Small disturbed sample; PSD=particle size determination; PL=plastic limit; LL=liquid limit; PI=plasticity index

GEO / Special Projects Natural Terrain Landslide Studies	***LOCATION*** **Tung Chung East**	***HOLE NUMBER*** **G3P**
CONTRACTOR : **Vibro (H.K.) LTD.**	DATUM LEVEL **+48.14 mPD**	SHEET NO. : **2** OF **2**
WORKS ORDER NO. : GE/99/07.18	DRILLING COMMENCED **03/05/2000**	EASTING : 813316.09 / NORTHING : 817002.37
METHOD : Mazier / Portable Sampler	DRILLING COMPLETED : **03/05/2000**	LOGGED BY : N.C.Evans / DATE LOGGED : 19/07/2000

SAMPLES: RECO-VERY %	SAMPLES: TYPE	Sample Photo	Depth (m)	REDUCED LEVEL (m)	DESCRIPTION	PSD %: GRAVEL	PSD %: SAND	PSD %: SILT	PSD %: CLAY	PL	LL	PI
			3.00	45.14								
92%	M				Very to extremely weak, pale greenish grey mottled yellowish brown, completely decomposed, coarse ash TUFF with very closely spaced joints, smooth planar, extremely narrow, stained. (Firm to stiff sandy SILT)							
	●		3.30	44.84								
86%	M				Extremely weak, pale greenish grey, completely decomposed, coarse ash TUFF with very closely spaced joints, smooth planar, tight to extremely narrow, trace kaolin. (Firm sandy SILT)	2	44	50	4			
	●		3.85	44.29								
84%	M				Very to extremely weak, pale greenish grey mottled yellowish brown, completely decomposed, coarse ash TUFF with very closely spaced joints, smooth planar, tight to extremely narrow, stained. (Firm to stiff sandy SILT)							
	●		4.40	43.74								
72%	M				Very to extremely weak, pale greenish grey mottled yellowish brown and pinkish grey, completely decomposed, coarse ash TUFF with very closely spaced joints, smooth planar, tight to extremely narrow, stained. (Firm to stiff sandy SILT)							
	●		4.95	43.19								

CODES : M=Mazier sample; ● =Small disturbed sample; PSD=particle size determination; PL=plastic limit; LL=liquid limit; PI=plasticity index

VIBRO	VIBRO (H.K.) LTD. SITE INVESTIGATION DEPARTMENT	TRIAL PIT No.: TP 1
	TRIAL PIT RECORD	SHEET 1 OF 1

PROJECT	Natural Terrain Landslide Studies Tung Chung East Study Area Term Contract Ground Investigation - Phase 2			CONTRACT No.	GE/99/07
STARTED ON	31/01/2001	CO-ORDINATES	E 813328.18	WORKS ORDER No.	GE/99/07.43
COMPLETED ON	01/02/2001		N 817024.37	LOGGED BY	SWY
				DATE	03/02/2001
BACKFILLED ON	09/02/2001	GROUND LEVEL	+32.90 mPD	CHECKED BY	AWH
				DATE	07/02/2001

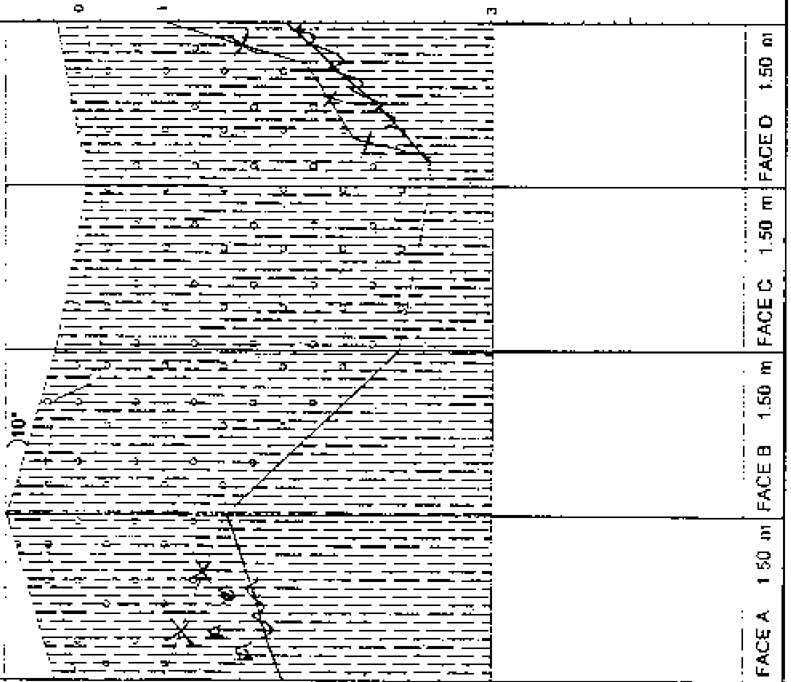
GRADE: >

DESCRIPTION

DEPTH (m)	DESCRIPTION
0.45	Firm, dark grey (N4), spotted and mottled light grey, slightly sandy SILT with occasional subangular to subrounded fine to coarse gravel (HDT, MDT) and some rootlets. (TOPSOIL)
1.00	Firm, brown (7.5YR 5/4), spotted and mottled light grey, slightly sandy SILT with some subangular to subrounded fine to coarse gravel (HDT, MDT) and occasional rootlets. (COLLUVIUM)
3.10	Extremely weak, locally very weak, light grey, dappled brown, completely decomposed fine ash crystal TUFF. (Sandy SILT)

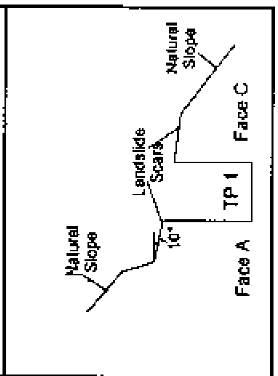
End of Trial Pit at 3.10m.

SKETCH

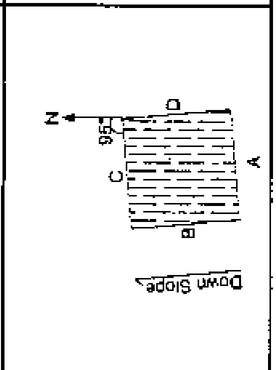


DEPTH (m): 0.50, 1.00, 1.50, 2.00, 2.50, 3.00, 4.00

CROSS SECTION



PLAN



REMARKS

1. Trial pit was dry during excavation.
2. Timber shoring over the full height.
3. Stable.
4. Average depth 2.85m.

SYMBOLS

- Small disturbed sample
- Large disturbed sample
- Undisturbed horizontal sample
- Undisturbed vertical sample
- Block sample
- In situ density test
- Water seepage
- Water sample

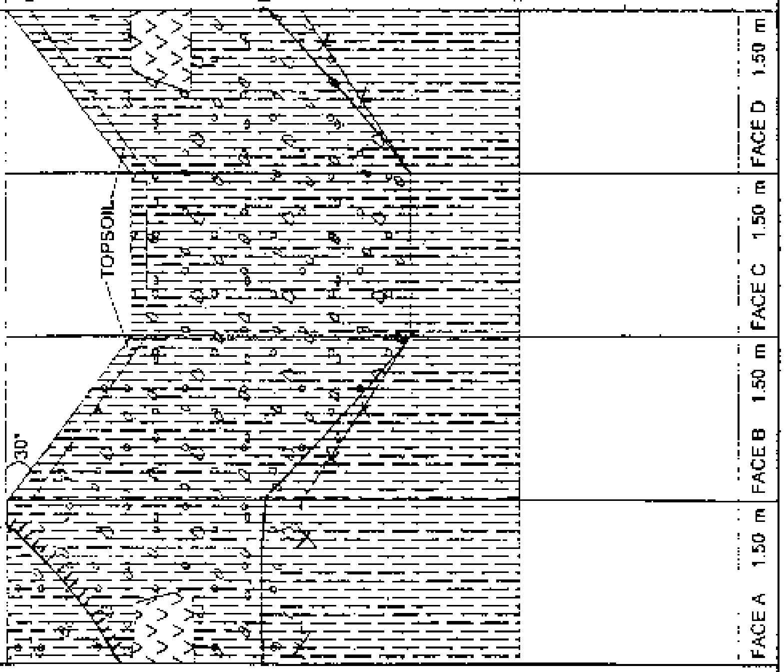
VIBRO	VIBRO (H.K.) LTD. SITE INVESTIGATION DEPARTMENT			TRIAL PIT No.: TP 2
	TRIAL PIT RECORD			SHEET 1 OF 1
PROJECT	Natural Terrain Landslide Studies Tung Chung East Study Area Term Contract Ground Investigation - Phase 2		CONTRACT No.	GE/99/07
STARTED ON 30/01/2001	CO-ORDINATES	E 813419.46	WORKS ORDER No.	GE/99/07.43
COMPLETED ON 31/01/2001		N 816977.33	LOGGED BY / DATE	SWY / 02/02/2001
BACKFILLED ON 09/02/2001	GROUND LEVEL	+75.48 mPD	CHECKED BY / DATE	AWH / 05/02/2001

GRADE: V

DESCRIPTION

Depth (m)	Description
0.00 – 0.15	Firm, dark grey (N4) and dark brown (7.5YR 3/4), slightly sandy SILT with occasional subangular to subrounded fine to coarse gravel (HDT, MDT), some rootlets. (TOPSOIL)
0.15 – 1.80	Soft, brown (7.5YR 5/4), mottled light grey, dappled dark grey and black, slightly sandy SILT with occasional angular to subrounded fine to coarse gravel (MDT) and occasional subangular to subrounded cobbles (MDT) and angular boulders (MDT, sized up to 600mm) and occasional rootlets. (COLLUVIUM) Reddish brown. (Soft silty CLAY/clayey SILT)
1.80 – 3.30	Extremely weak, light grey, dappled brown, completely decomposed fine ash crystal TUFF. (Slightly sandy SILT) Yellow brown mottled pale blue grey.
3.30	End of Trial Pit at 3.30m. Additional notes D Evans GEO

SKETCH



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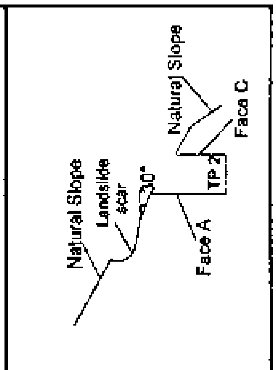

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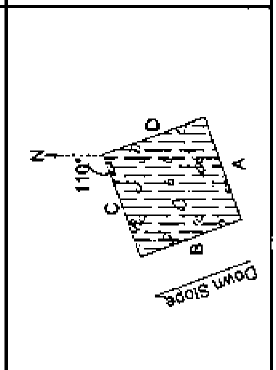


REMARKS

1. Trial pit was dry during excavation.
2. Timber shoring over the full height.
3. Unstable.
4. Average depth 2.90m.

SYMBOLS

- Small disturbed sample
- Large disturbed sample
- Undisturbed horizontal sample
- Undisturbed vertical sample
- Block sample
- In situ density test
- Water seepage
- Water sample

VIBRO (H.K.) LTD.

SITE INVESTIGATION DEPARTMENT

TRIAL PIT No.: TP 3

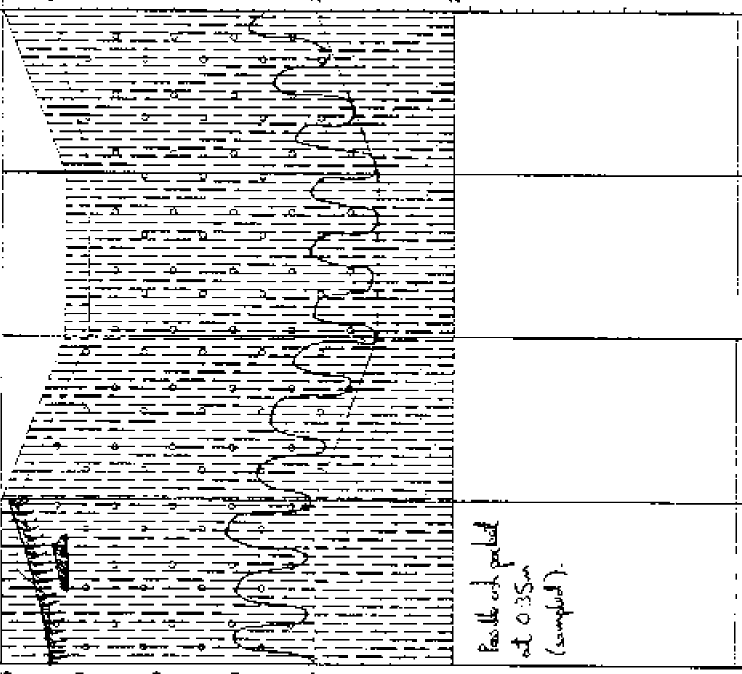
TRIAL PIT RECORD

SHEET 1 OF 1

PROJECT	Natural Terrain Landslide Studies Tung Chung East Study Area Term Contract Ground Investigation - Phase 2			CONTRACT No.	GE/99/07
STARTED ON	30/01/2001	CO-ORDINATES	E 813388.16	WORKS ORDER No.	GE/99/07.43
COMPLETED ON	31/01/2001		N 817014.14	LOGGED BY	SWY
				DATE	02/02/2001
BACKFILLED ON	09/02/2001	GROUND LEVEL	+52.96 mPD	CHECKED BY	AWH
				DATE	05/02/2001

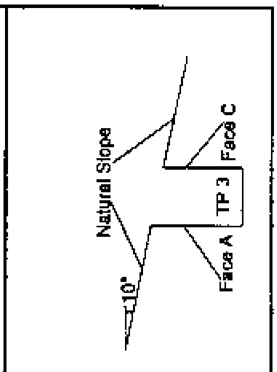
GRADE	DESCRIPTION	DEPTH (m)
	Firm, dark grey (N4) and dark brown (7.5YR 3/4), SILT with some rootlets. (TOPSOIL)	0.30
	Firm, brown (7.5YR 5/4), spotted and mottled light grey, SILT with occasional angular to subangular fine to medium gravel (HDT) and occasional rootlets. (COLLUVIUM) Red brown mottled yellow brown. No ground (pebbles) seen. (RESIDUAL SOIL?) Transitional boundary	2.00
V	Extremely weak, light grey and reddish brown, completely decomposed fine ash crystal TUFF. (Slightly sandy SILT) Pale red brown mottled pale yellow brown and pale blue grey. Occasional fine roots.	2.90
	End of Trial Pit at 2.90m.	
	Additional notes N Evans GEO	

SKETCH



SAMPLES & TESTS

CROSS SECTION



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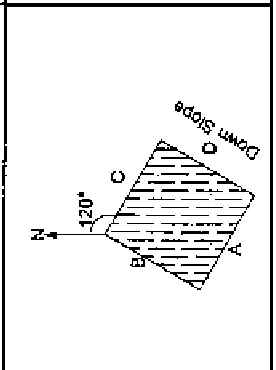


REMARKS

1. Trial pit was dry during excavation.
2. Timber shoring over the full height.
3. Stable.
4. Average depth 2.70m.

SYMBOLS

- Small disturbed sample
- Large disturbed sample
- Undisturbed horizontal sample
- Undisturbed vertical sample
- Block sample
- In situ density test
- Water seepage
- Water sample

VIBRO (H.K.) LTD.

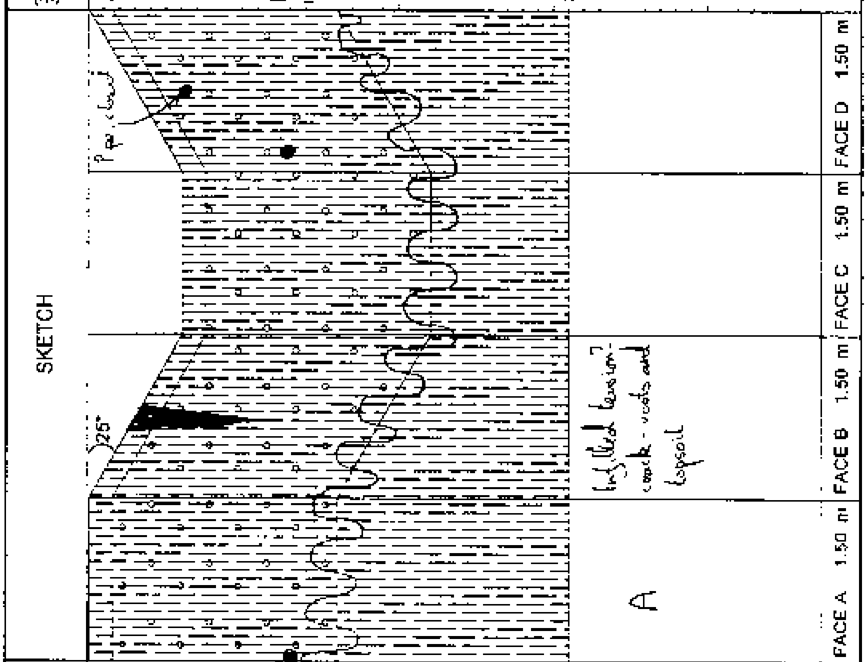
SITE INVESTIGATION DEPARTMENT

TRIAL PIT RECORD

TRIAL PIT No.: TP 4				SHEET 1 OF 1	
PROJECT	Natural Terrain Landslide Studies Tung Chung East Study Area Term Contract Ground Investigation - Phase 2			CONTRACT No.	GE/99/07
STARTED ON	30/01/2001	CO-ORDINATES	E 813401.40	WORKS ORDER No.	GE/99/07.43
COMPLETED ON	31/01/2001		N 816988.82	LOGGED BY	SWY
				DATE	02/02/2001
BACKFILLED ON	09/02/2001	GROUND LEVEL	+66.22 mPD	CHECKED BY	AWH
				DATE	05/02/2001

DEPTH (m)	DESCRIPTION	GRADE
0.15	Firm, dark grey (N4) and dark brown (7.5YR 3/4), SILT with some rootlets. (TOPSOIL)	
1.00	Stiff, brown (7.5YR 5/4), SILT with occasional angular to subangular fine to medium gravel (MDT) and occasional rootlets. (COLLUVIUM) Reddish brown occ mottled pale yellow brown. Possibly transitional to RESIDUAL soil. Transitional boundary	
3.10	Extremely weak, light grey, dappled reddish brown, completely decomposed fine ash crystal TUFF. (SILT) Pale yellow brown mottled reddish brown. Occasional close spaced tight relict joints. Occasional roots	V
	End of Trial Pit at 3.10m. Pipe at 1.3m on A face 4cm diameter, partially infilled with soft clay. Pebbles in colluvium subang - subround highly weathered volcanic, some with thin weathering rinds. Additional notes N. Evans GEO	

SKETCH



SAMPLES & TESTS — DEPTH (m): 0.00, 0.50, 1.00, 1.30, 1.50, 2.00, 2.50, 3.00, 4.00

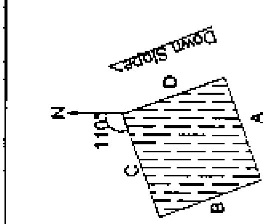
SYMBOLS

- • Small disturbed sample
- ↕ Large disturbed sample
- Undisturbed horizontal sample
- Undisturbed vertical sample
- Block sample
- In situ density test
- Water seepage
- ▲ Water sample

REMARKS

1. Trial pit was dry during excavation.
2. Timber shoring over the full height.
3. Stable.
4. Average depth 2.80m.

PLAN



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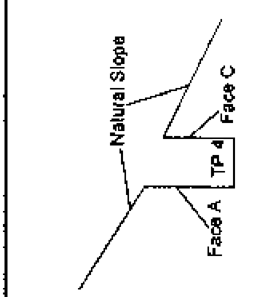


VIBRO (H.K.) LTD.
SITE INVESTIGATION DEPARTMENT

TRIAL PIT RECORD

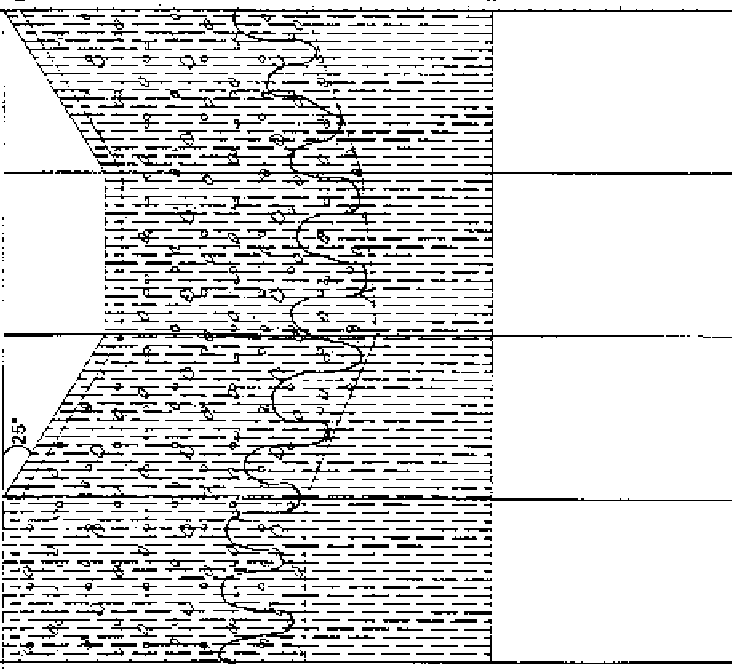
TRIAL PIT No.: TP 5
SHEET 1 OF 1

PROJECT	Natural Terrain Landslide Studies Tung Chung East Study Area Term Contract Ground Investigation - Phase 2			CONTRACT No.	GE/99/07
STARTED ON	31/01/2001	CO-ORDINATES	E 813418.94	WORKS ORDER No.	GE/99/07.43
COMPLETED ON	01/02/2001		N 816993.37	LOGGED BY	SWY
				DATE	02/02/2001
BACKFILLED ON	09/02/2001	GROUND LEVEL	+68.08 mPD	CHECKED BY	AWH
				DATE	05/02/2001

DEPTH (m)	GRADE	DESCRIPTION
0.10		Firm, dark grey (N4) and dark brown (7.5YR 3/4), SILT with some rootlets. (TOPSOIL)
1.95		Firm, brown (7.5YR 5/4), mottled light grey, slightly sandy SILT with occasional angular to subrounded fine to coarse gravel (HDT, MDT) and occasional angular cobbles (MDT) and occasional rootlets. (COLLUVIUM) Red-brown
		Approx. Col/Tuff boundary
3.15	V	Extremely weak, reddish brown and brown, dappled light grey, completely decomposed fine ash crystal TUFF. (SILT)
		End of Trial Pit at 3.15m.

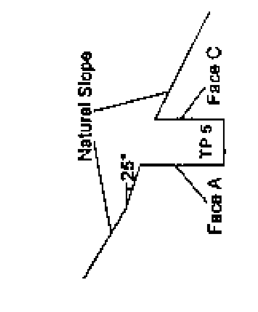
Additional notes

SKETCH



SAMPLES & TESTS

CROSS SECTION



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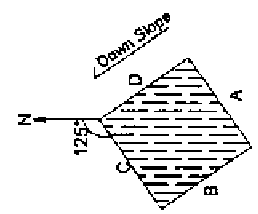


REMARKS

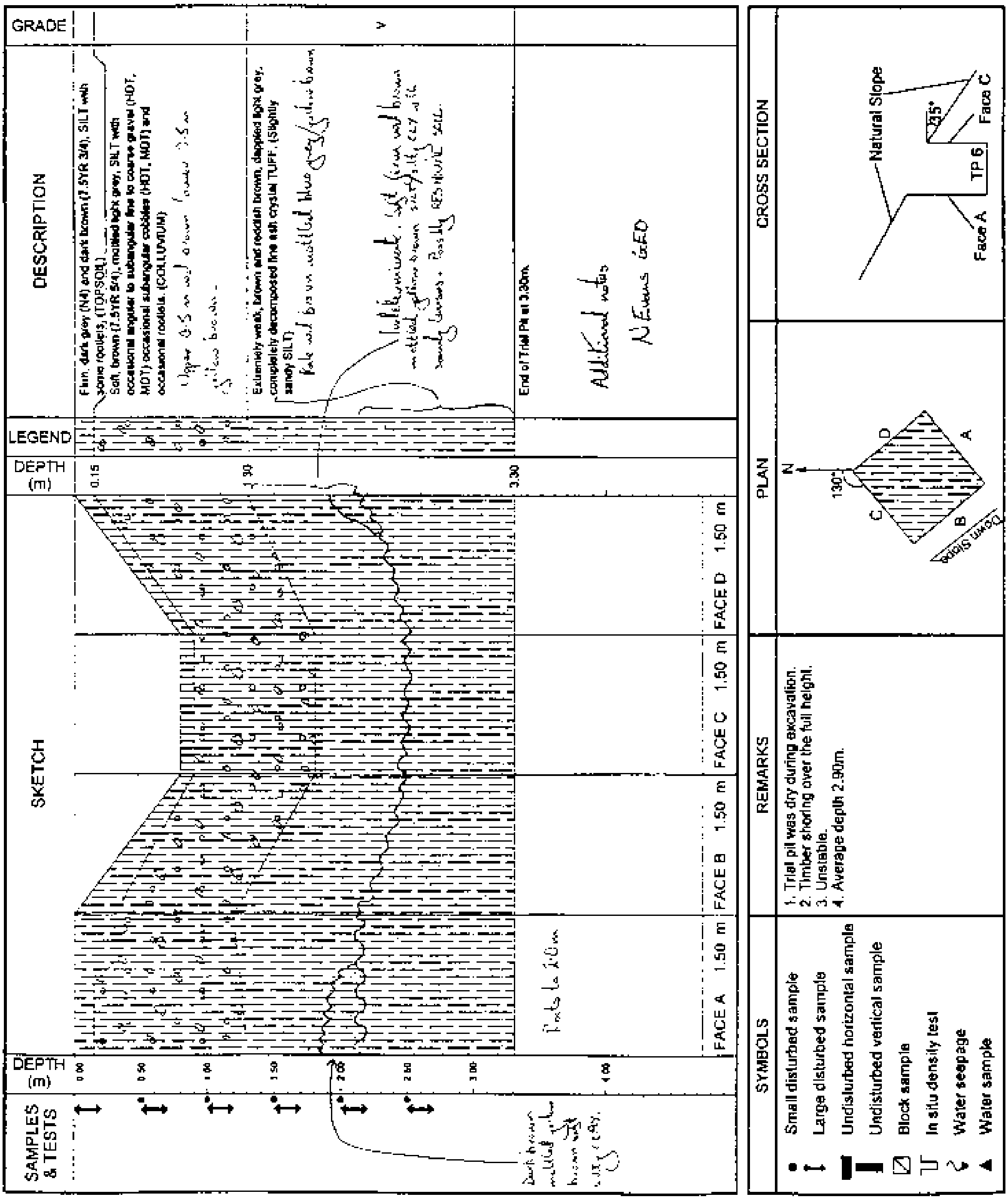
1. Trial pit was dry during excavation.
2. Timber shoring over the full height.
3. Stable.
4. Average depth 2.80m.

SYMBOLS

- Small disturbed sample
- Large disturbed sample
- Undisturbed horizontal sample
- Undisturbed vertical sample
- Block sample
- In situ density test
- Water seepage
- Water sample

VIBRO	VIBRO (H.K.) LTD. SITE INVESTIGATION DEPARTMENT	TRIAL PIT No.: TP 6
	TRIAL PIT RECORD	SHEET 1 OF 1

PROJECT	Natural Terrain Landslide Studies Tung Chung East Study Area Term Contract Ground Investigation - Phase 2			CONTRACT No.	GE/99/07
STARTED ON	31/01/2001	CO-ORDINATES	E 813430.37	WORKS ORDER No.	GE/99/07.43
COMPLETED ON	01/02/2001		N 816987.63	LOGGED BY	SWY
				DATE	02/02/2001
BACKFILLED ON	09/02/2001	GROUND LEVEL	+73.36 mPD	CHECKED BY	AWH
				DATE	05/02/2001



APPENDIX B

SUMMARY OF LABORATORY TEST RESULTS

Table B1 - Colluvium (Sheet 1 of 2)

Undisturbed Area

Location	Depth	Description	% gravel	% sand	% silt	% clay	LL (%)	PL (%)	PI (%)	LI	MC (%)
A1 (PS)	0.75	Sft-frm orng brn SILT	9	19	32	40	54	23	31		
G1P (PS)	0.85	Sft-frm rd brn SILT	8	20	27	45	51	24	27		
A5 (PS)	0.85	Sft-frm rd brn-yel brn SILT	1	18	36	45	47	21	26		
G2P (PS)	0.75	Sft-frm rd brn-yel brn SILT	1	14	33	52	50	24	26		

Relict Disturbed Area

Location	Depth	Description	% gravel	% sand	% silt	% clay	LL (%)	PL (%)	PI (%)	LI	MC (%)
A4 (PS)	1.3	Sft-frm rd brn-yel brn SILT	1	23	43	33	50	22	28		
TP3 (2/01)	0.5	Yel-rd yel CLAY	3	24	31	42	53	25	28	0.08	23
TP3 (2/01)	1	Rd yel-pl brn SILT	4	25	35	36	52	26	26	0.03	22
TP3 (2/01)	1.5	Rd yel-yel CLAY	2	24	30	44	54	26	28	0.07	24
TP3 (2/01)	2	Rd yel-yel-wh CLAY	2	23	34	41	39	23	16	0.29	23
TP4 (2/01)	0.5	Rd yel-brn yel CLAY	2	23	33	42	54	27	27	0.02	24
TP4 (2/01)	1	Rd yel-yel CLAY	0	16	39	45	54	27	27	0.02	25
TP4 (2/01)	1.5	Rd yel-yel-brn CLAY	0	16	35	49	56	28	28	0.01	26

Table B1 - Colluvium (Sheet 2 of 2)

Recent Disturbed Area

Location	Depth	Description	% gravel	% sand	% silt	% clay	LL (%)	PL (%)	PI (%)	LI	MC (%)
A2 (PS)	0.75	Sft-frm rd brn SILT	15	18	33	34	46	23	23		
A3 (PS)	0.75	Frm-stf rd brn SILT	9	17	28	46	56	25	31		
A6 (PS)	0.85	V sft rd brn SILT	2	34	40	24	41	22	19		
A6 (PS)	1.5	Sft rd brn SILT	2	36	44	18	38	21	17		
A6 (PS)	2.8	Sft yel brn-rd brn SILT	4	40	34	22	44	23	21		
TP1 (2/01)	0.5	Yel-gy SILT	7	36	25	32	43	22	21	0.33	22
TP1 (2/01)	1	Yel-brn SILT	7	40	33	20	39	23	16	0.39	22
TP2 (2/01)	0.5	Rd-yel CLAY	3	24	33	40	54	26	28	0.06	24
TP2 (2/01)	1	Rd-yel-pl brn SILT	13	24	37	26	47	25	22	0.33	24
TP2 (2/01)	1.5	Rd-yel SILT	18	24	36	22	43	23	20	0.54	23
TP5 (2/01)	0.5	Brn yel-gy CLAY	0	23	35	42	52	27	25	-0.02	24
TP5 (2/01)	1	Rd yel CLAY	4	16	33	47	60	28	32	0	24
TP5 (2/01)	1.5	Rd yel-yel SILT	0	20	40	40	53	26	27	-0.02	23
TP6 (2/01)	0.5	Brn yel-gyCLAY	1	24	32	43	52	26	26	-0.01	23
TP6 (2/01)	1	Brn yel-rd CLAY	1	24	32	43	55	28	27	-0.1	21

Table B2 - Residual Soil

Undisturbed Area

Location	Depth	Description	% gravel	% sand	% silt	% clay	LL (%)	PL (%)	PI (%)	LI	MC (%)
G2P (PS)	1.6	Sft-frm rd brn-yel brn SILT	12	22	36	30	47	23	24		
G3P (PS)	1.75	Sft rd brn-yel brn SILT	2	21	37	40	51	24	27		
G3P (PS)	1.95	Sft-frm yel brn-rd brn SILT	2	28	37	33	47	25	22		
G3P (PS)	2.45	Frm yl brn-rd brn SILT	1	22	40	33	48	26	22		

269

Recent Disturbed Area

Location	Depth	Description	% gravel	% sand	% silt	% clay	LL (%)	PL (%)	PI (%)	LI	MC (%)
A2 (PS)	1.25	Sft-frm rd brn SILT	4	20	37	39	51	24	27		
A3 (PS)	1.95	Frm rd brn-yel brn-yl gy SILT	1	31	34	34	44	21	23		
TP6 (2/01)	1.5	Rd yel-yel rd SILT	2	22	42	34	46	26	20	0	23
TP6 (2/01)	2	Rd yel-yel rd SILT	3	25	46	26	43	27	16	0	22

Table B3 - Grade V (Sheet 1 of 2)

Undisturbed Area

Location	Depth	Description	% gravel	% sand	% silt	% clay	LL (%)	PL (%)	PI (%)	LI	MC (%)
A7 (PS)	0.85	Ex wk rd brn-yel brn cs ash TUFF	2	33	52	13	33	19	14		
A7 (PS)	1.6	Ex wk pl grn gy-yel brn cs ash TUFF					36	20	16		
G1P (PS)	1.7	Ex wk pl gy-rd brn cs ash TUFF	4	34	52	10	31	19	12		
G1P (PS)	1.85	Frm-stf dk rd brn SILT sheared?					38	23	15		
A5 (PS)	1.35	Ex wk pl rd brn-yel brn cs ash TUFF	1	21	37	41	43	20	23		
A5 (PS)	2.45	Ex wk pl rd brn-yel brn cs ash TUFF	1	22	43	34	42	23	19		
A5 (PS)	3.4	Ex wk pl grn gy cs ash TUFF	0	38	50	12	31	18	13		
A5 (PS)	4.4	Ex wk pl yl brn-grn gy cs ash TUFF, tr kaolin	6	47	36	11	33	19	14		
G2P (PS)	2.45	Ex wk rd brn-yel brn cs ash TUFF	2	23	49	26	40	21	19		
G2P (PS)	3.55	Ex wk pl grn gy-rd brn-yel brn cs ash TUFF	4	24	50	22	39	22	17		
G3P (PS)	3.55	Ex wk grn gy cs ash TUFF, trace kaolin	2	44	50	4					
TCE5(HAP)	1	Brn-yel SILT									29
TCE5(HAP)	2	Brn-yel SILT									27

Relict Disturbed Area

Location	Depth	Description	% gravel	% sand	% silt	% clay	LL (%)	PL (%)	PI (%)	LI	MC (%)
A4 (PS)	2.2-2.7	Ex wk pl grn gy-rd brn cs ash TUFF	3	54	33	10	28	18	10		
A4 (PS)	5.0-5.5	Ex wk pl grn gy-rd brn cs ash TUFF	10	61	25	4	28	18	10		
TP3 (2/01)	2.5	Yel-rd-wh SILT	7	44	31	18	54	26	28	0.12	19
TP4 (2/01)	2	Pl brn-rd SILT	0	18	47	35	44	25	19	-0.1	20
TP4 (2/01)	2.5	Pl brn-rd SILT	0	20	53	27	39	23	16	-0.08	19

Table B3 - Grade V (Sheet 2 of 2)

Recent Disturbed Area

Location	Depth	Description	% gravel	% sand	% silt	% clay	LL (%)	PL (%)	PI (%)	LI	MC (%)
A2 (PS)	2.2	Ex wk rd brn - yl brn cs ash TUFF	4	32	35	29	42	24	18		
A2 (PS)	3.85	Ex wk rd brn-yl brn-pl gy cs ash TUFF, w/ inf. pipe	10	39	45	6					
A2 (PS)	5.5	Ex wk pl gy-wh-dk rd brn cs ash TUF, poss kaolin	17	41	32	10	45	28	17		
A3 (PS)	3.6	Ex wk pl grn gy-rd brn cs ash TUFF	4	51	33	12	35	19	16		
TP1 (2/01)	1.5	Yel-brn SAND	24	42	26	8	36	24	12	0.97	18
TP1 (2/01)	2	Yel-brn SAND	18	52	23	7	33	25	8	0.82	17
TP1 (2/01)	2.5	Yel-brn SAND	18	49	27	6	33	24	9	0.75	17
TP2 (2/01)	2	Yel-wh SILT	14	35	33	18	43	25	18	0.37	21
TP2 (2/01)	2.5	Yel-rd yel SILT	13	34	35	18	40	23	17	0.49	20
TCE2(HAP)	1	Brn yel SILT									18
TCE2(HAP)	2	Brn yel SILT									16
TCE2(HAP)	3	Brn yel SILT									11
TP5 (2/01)	2	Rd brn-yel SILT	0	20	40	40	52	25	27	0.03	23
TP5 (2/01)	2.5	Brn-rd SILT	0	23	50	27	41	23	18	-0.07	19
TP6 (2/01)	2.5	Brn yel-wh rd SILT	3	24	46	27	44	25	19	0.06	22

Table B4 - Topsoil

Relict Disturbed Area

Location	Depth	Description	% gravel	% sand	% silt	% clay	LL (%)	PL (%)	PI (%)	LI	MC (%)
TP1 (2/01)	0	Yel-brn-gy SILT	24	26	28	22	45	24	21	0.42	19
TP3 (2/01)	0	Rd yel-yel gy CLAY	0	20	39	41	49	25	24	-0.01	23
TP4 (2/01)	0	Rd yel-brn yel CLAY	2	16	35	47	53	26	27	-0.03	23
TP2 (2/01)	0	Brn-yel SILT	9	20	36	35	48	25	23	0.06	22
TP6 (2/01)	0	Rd yel-yel CLAY	10	21	32	37	48	26	22	0.11	24
TP5 (2/01)	0	Rd yel CLAY	6	18	34	42	51	27	24	-0.09	22

APPENDIX C

RAINFALL AND GROUNDWATER DURING RAINSTORMS

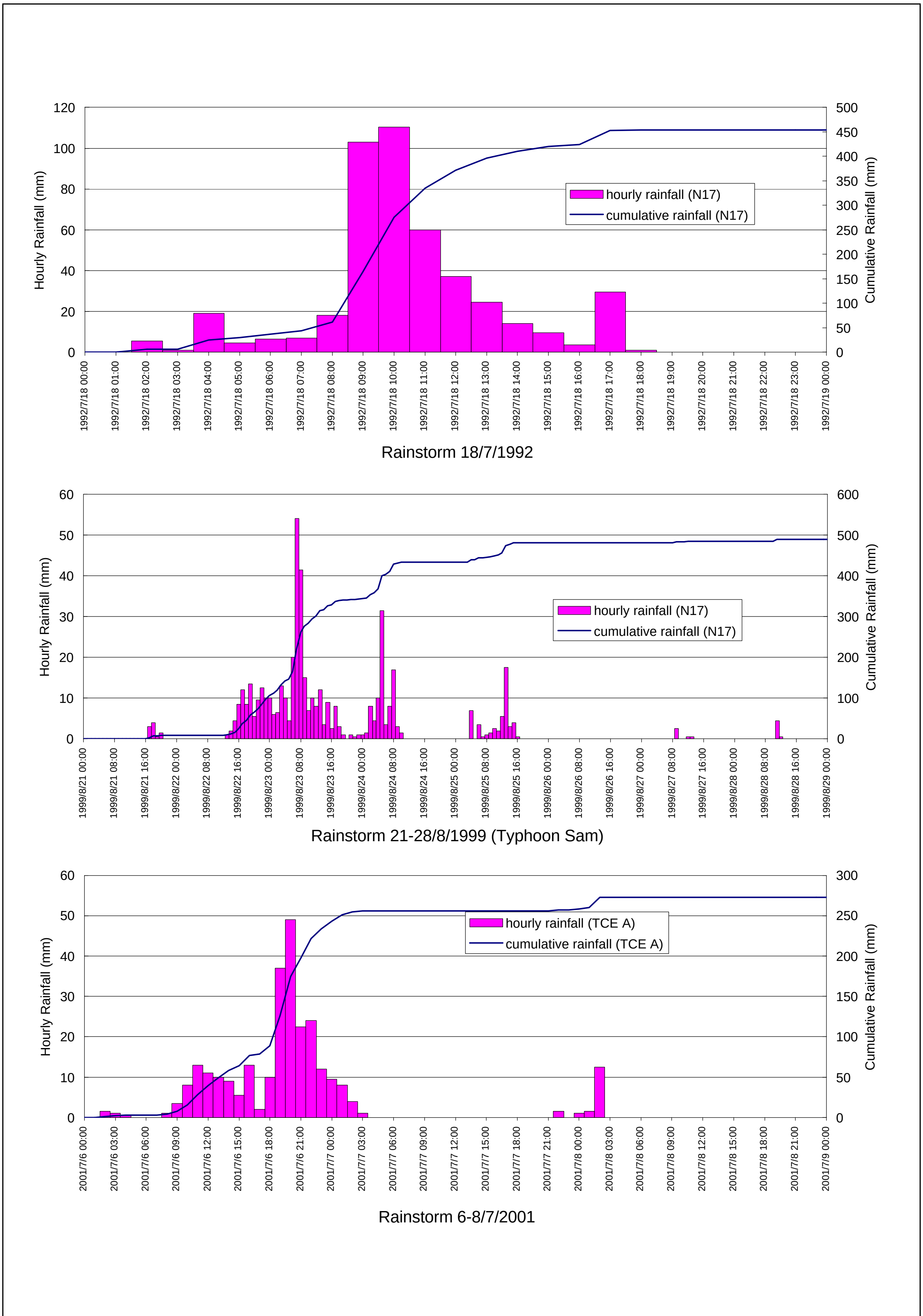


Figure C1 - Rainstorm Profiles (Sheet 1 of 3)

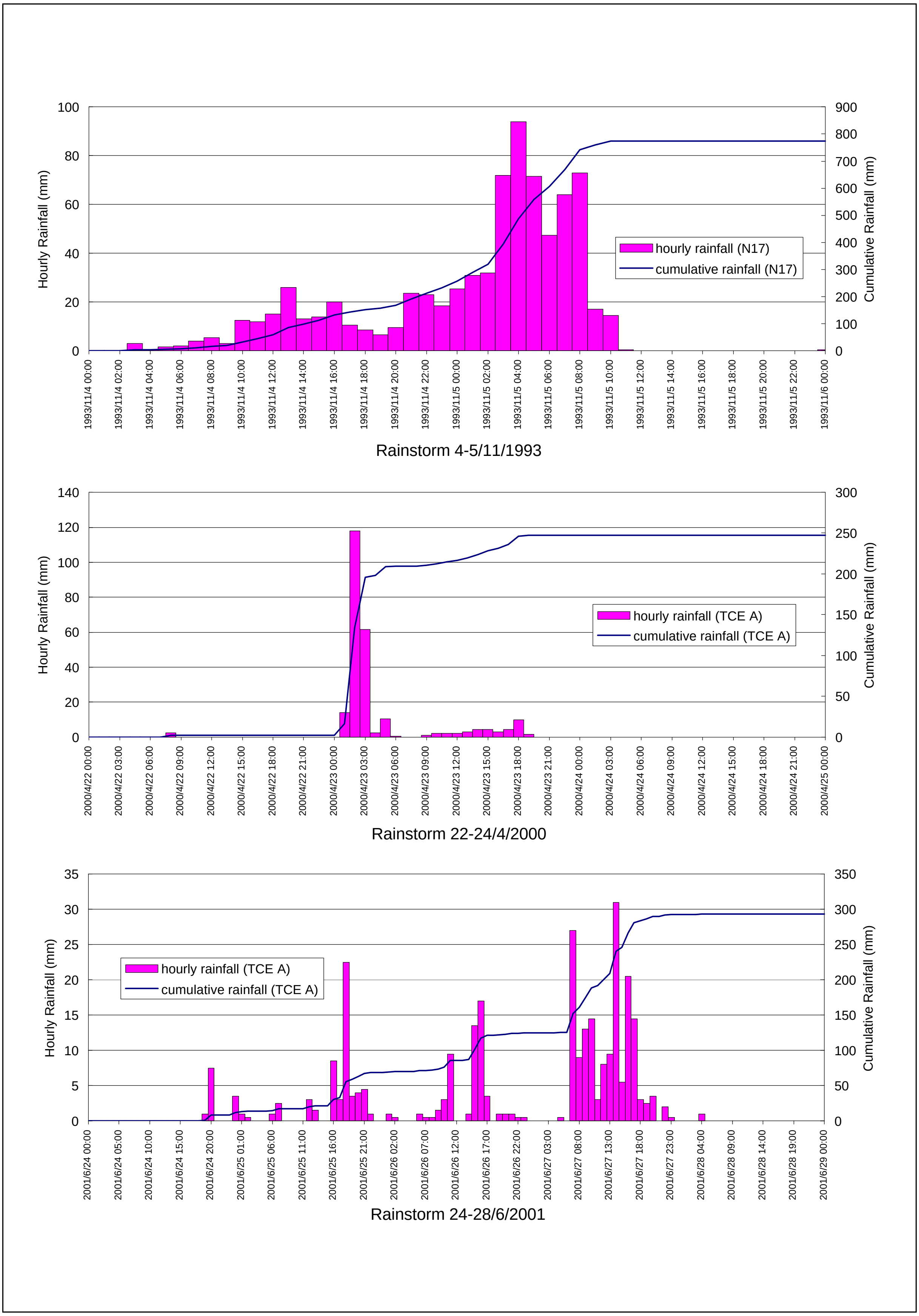


Figure C1 - Rainstorm Profiles (Sheet 2 of 3)

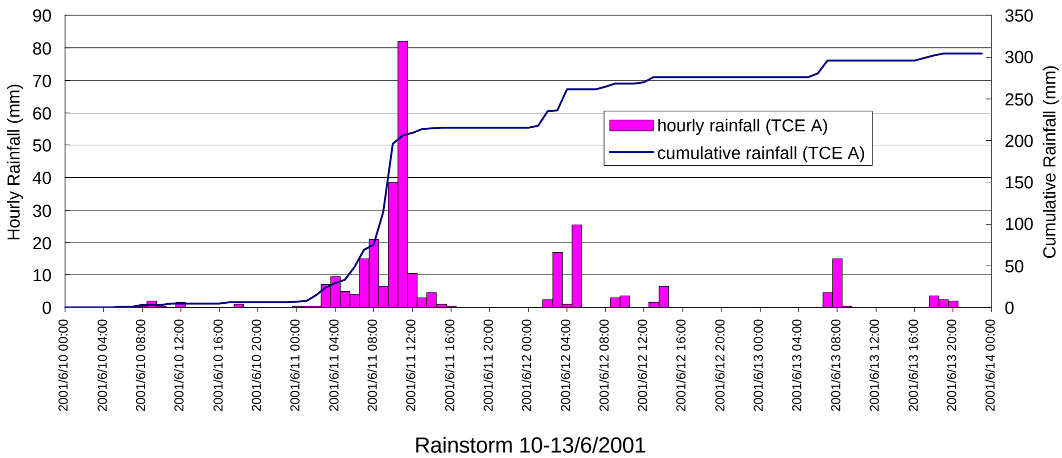


Figure C1 - Rainstorm Profiles (Sheet 3 of 3)

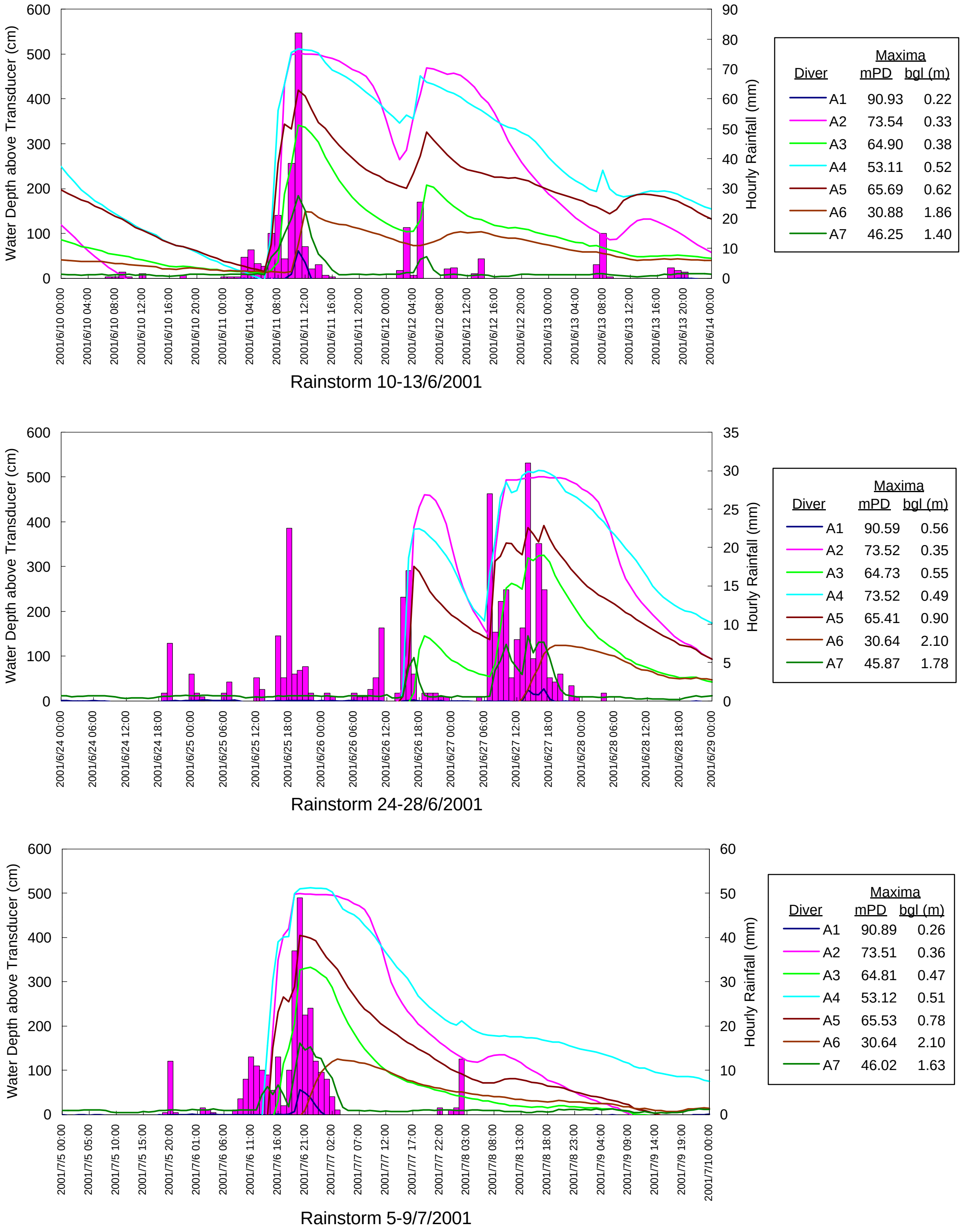
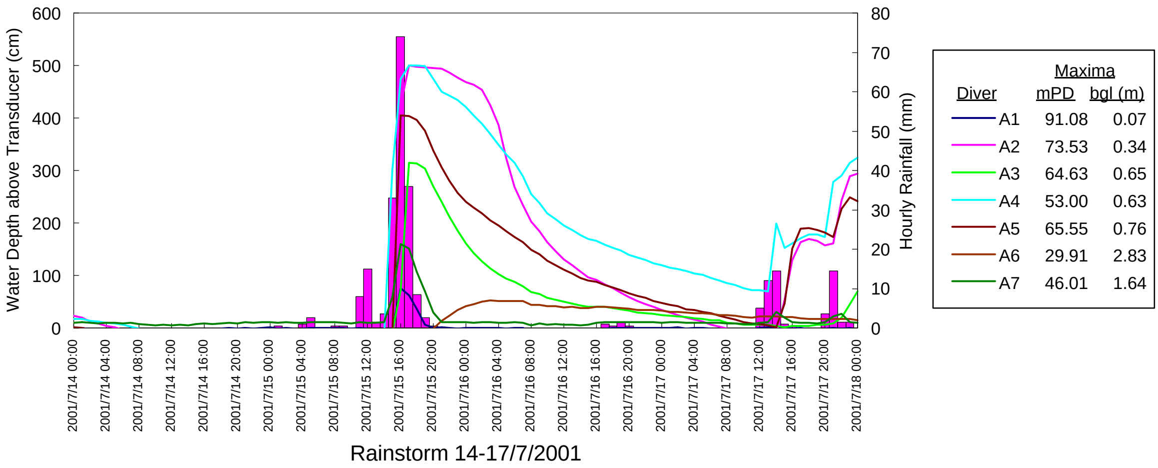


Figure C2 - Groundwater Response Measured by Divers During Rainstorms (Sheet 1 of 2)



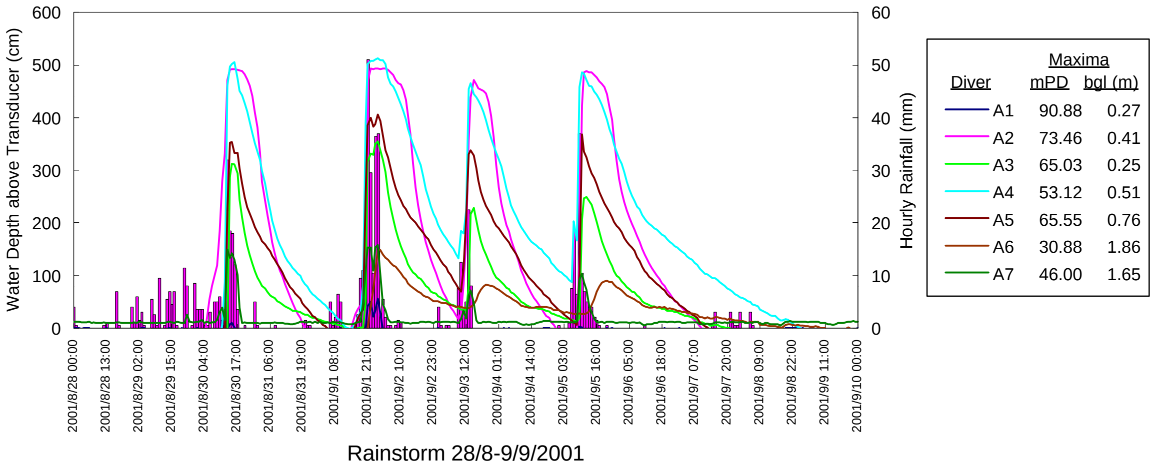


Figure C2 - Groundwater Response Measured by Divers During Rainstorms (Sheet 2 of 2)

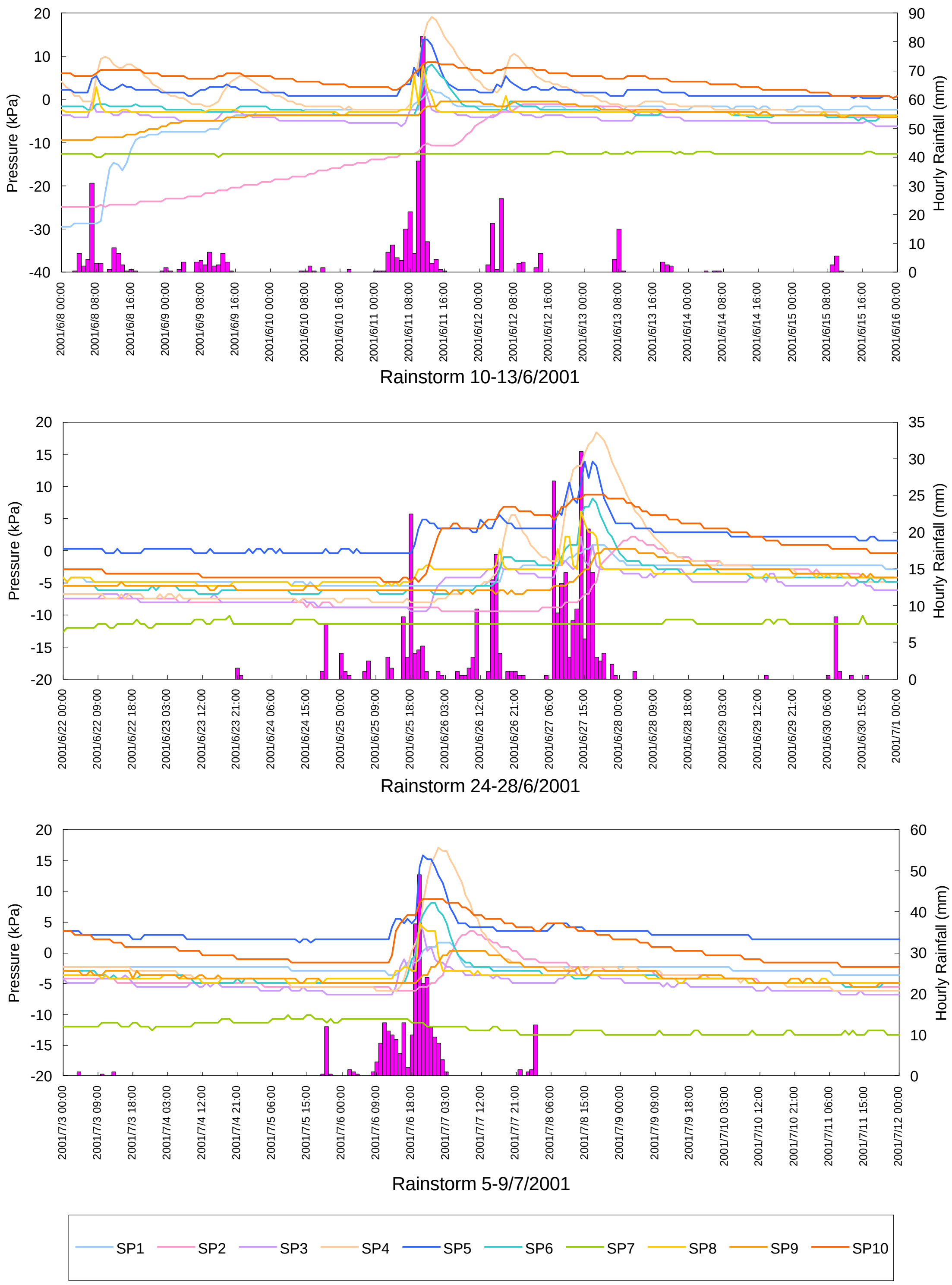


Figure C3 - Rainfall Profile and Pore Pressures Measured by Shallow Piezometers During Rainstorms (Sheet 1 of 2)

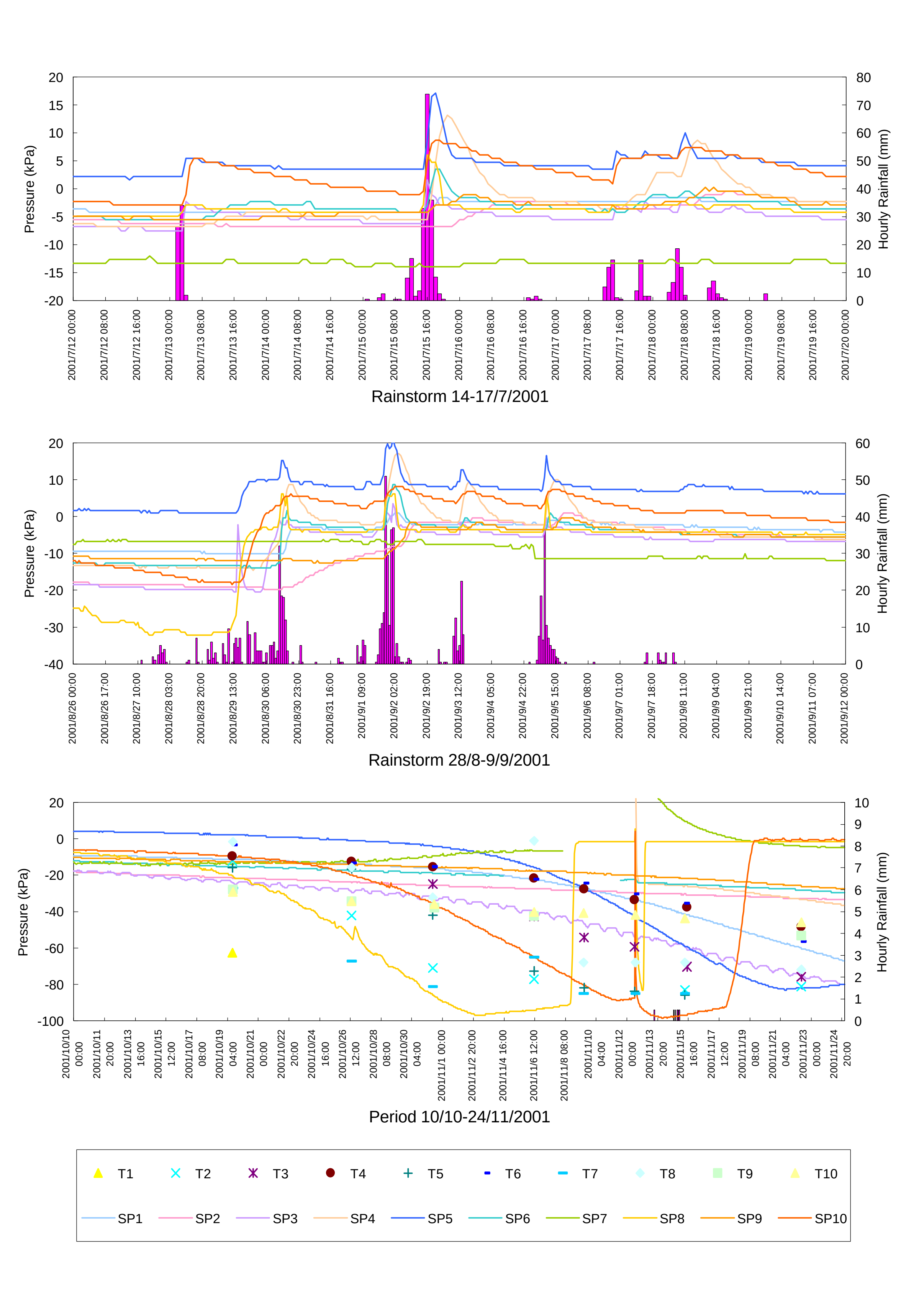


Figure C3 - Rainfall Profile and Pore Pressures Measured by Shallow Piezometers During Rainstorms (Sheet 2 of 2)

LIST OF DRAWINGS