INVESTIGATION OF SOME SELECTED LANDSLIDES IN 2000 (VOLUME 2)

GEO REPORT No. 130

Halcrow China Limited

First published, November 2002

Prepared by:

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

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. A charge is made to cover the cost of printing.

The Geotechnical Engineering Office also publishes guidance documents as GEO Publications. These publications and the GEO Reports may be obtained from the Government's Information Services Department. Information on how to purchase these documents is given on the last page of this report.

R.K.S. Chan
Head, Geotechnical Engineering Office
November 2002

EXPLANATORY NOTE

This GEO Report consists of two Landslide Study Report carried out by the Landslip Investigation Division in 2001.

They are presented in two separate sections in this Report. Their titles are as follows:

SECTION 1: DETAILED STUDY OF THE 24 AUGUST 2000 LANDSLIDE ON FILL SLOPE NO. 15NE-B/FR123 BELOW SHEK O ROAD

Halcrow China Limited

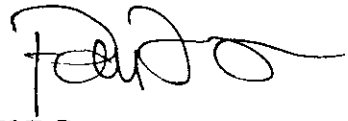
This report was originally produced in July 2001 as GEO Landslide Study Report No. LSR 5/2001

FOREWORD

This report presents the findings of a detailed study of a landslide (GEO Incident No. HK2000/08/04) which occurred on 24 August 2000 on a fill slope below Shek O Road opposite No. 18 Shek O Road. The landslide involved the collapse of a portion of Shek O Road and an associated concrete retaining wall. Shek O Road was subsequently closed, which cut off the sole access to Shek O Village and Big Wave Bay. The landslide debris travelled downslope into a stream course and its outwash was subsequently deposited onto the golf course of the Shek O Country Club. A taxi fell into the landslide scar, but no fatalities or injuries were reported as a result of the landslide.

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

The report was prepared as part of the Landslide Investigation Consultancy (LIC) for Kowloon and the New Territories in 2000 and the first quarter of 2001, for the Geotechnical Engineering Office (GEO), Civil Engineering Department (CED), under Agreement No. CE 2/2000. This is one of a series of reports produced during the consultancy by Halcrow China Limited.



X D Pan
Project Director
Halcrow China Limited

CONTENTS

1. INTRODUCTION

On the morning of 24 August 2000, a landslide (GEO Incident No. HK2000/08/04) occurred below the eastern side of Shek O Road, opposite No. 18 Shek O Road (Figure 1 and Plate 1). The landslide involved the northern portion of fill slope No. 15NE-B/FR123 and affected part of the road. Shek O Road was subsequently closed, which cut off the sole access to Shek O Village and Big Wave Bay. The landslide debris travelled downslope into a stream course and its outwash was subsequently deposited onto the golf course of the Shek O Country Club. A taxi fell into the landslide scar, but no fatalities or injuries were reported as a result of the landslide.

Following the landslide, Halcrow China Limited (HCL), the Landslide Investigation Consultants for Kowloon and the New Territories in 2000 and the First Quarter of 2001, carried out a detailed study of the failure for the Geotechnical Engineering Office (GEO), Civil Engineering Department (CED), under Agreement No. CE 2/2000. This is one of a series of reports produced during the consultancy by HCL.

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

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

(a) a review of relevant documents relating to the history of the site,

(b) site observations and measurements at the landslide site,

(c) aerial photograph interpretation (API),

(d) limited ground investigation,

(e) topographical survey,

(f) CCTV survey,

(g) analysis of rainfall records,

(h) interviews with eye-witnesses to the landslide, and

(i) diagnosis of the probable causes of the landslide.

2. THE SITE

2.1 Site Description

The landslide occurred at the northern portion of fill slope No. 15NE-B/FR123, located below the eastern side of a section of Shek O Road, opposite No. 18 Shek O Road (Figures 1 to 4 and Plates 1 and 2). At the location of the landslide, the slope traverses a natural drainage line which is not culverted below the embankment. The fill slope has a maximum height of about 16 m. It has a masonry toe wall with a maximum height of about 4 m below the location of the landslide (Figures 5 and 6). The fill embankment supports a section of Shek O Road and spurs of natural terrain bound the northern and southern ends of the slope. Prior to the landslide, there was a 3.6 m high (maximum) concrete retaining wall at the slope crest at the landslide location.

Based on API, site measurements and analysis, it is postulated that the failed portion of the fill slope below the concrete retaining wall had an inclination of about 27º to the horizontal (Figures 5 and 6). The portion of the fill slope to the south, unaffected by the landslide, is inclined at about 35°, near the crest, decreasing in inclination to almost horizontal behind the crest of the masonry toe wall. Before the landslide, the fill slope was covered with dense vegetation of trees and shrubs.

Shek O Road at the crest of the fill slope is about 9 m wide, with 400 mm wide and about 300 mm high concrete kerbs running along either side.

On the western side of Shek O Road, directly opposite the landslide, is an electricity transformer pillar (Hongkong Electric Company Limited (HEC) reference No. TP110, No. 18 Shek O Road), which partially occupies a relatively flat densely vegetated area.

At the southern end of slope No. 15NE-B/FR123, another natural drainage line is culverted beneath Shek O Road by a 1 m diameter concrete cross-road drain (Figure 3).

2.2 Maintenance Responsibility

According to the Slope Maintenance Responsibility Information System of the Lands Department, slope No. 15NE-B/FR123 has mixed maintenance responsibility (Figure 3). The part of the slope adjoining Shek O Road is maintained by the Highways Department (HyD), while the remaining portion of the slope falls within lot No. GL81. According to District Lands Office for Hong Kong South of the Lands Department, lot No. GL81 is effectively on unleased and unallocated Government land.

2.3 Site History

The history of the site was determined from a review of aerial photographs and available documentary information. Detailed observations from the API are presented in Appendix A. A summary of the key findings is given below.

A survey map covering Stanley and Cape D'Aguilar produced by the Ordnance Survey Office in 1895, provides the earliest record of a track following an alignment similar to that of the present day Shek O Road.

Aerial photographs taken in 1924 show that Big Wave Bay Road was being constructed but do not cover the area affected by the 2000 landslide. It is likely that the full length of Shek O Road, which is the sole vehicular access to Big Wave Bay, and the fill embankment affected by the 2000 landslide existed by that date. By 1945, dense vegetation had established on the fill embankment, which indicates that the embankment and Shek O Road had been constructed much earlier. The 1945 aerial photographs also show that the northern end of the fill embankment that supports Shek O Road and the masonry toe wall traverses a natural drainage line which runs between two low ridges. The drainage line drains a catchment about 80 m wide extending 200 m upslope.

Construction of an access road to a cut and fill platform for the property at No. 18 Shek O Road was in progress in 1949. The construction of the access road reduced the effective catchment above the 2000 landslide site to about 40 m width and 50 m upslope (Figure A1).

The 1949 aerial photographs show a small depression, about 10 m wide by 20 m long, on the western side of Shek O Road (see Figure 7 and Figure A2 of Appendix A), part of the depression is now occupied by the HEC transformer pillar which was constructed in 1991. The depression is bounded by the fill embankment of Shek O Road and the fill slope below the platform of No. 18 Shek O Road. The depression was possibly drained by cross-road drains exposed in the 2000 landslide scar and at the base of the masonry toe wall (see Section 3.4). In the 1963 aerial photographs, the depression appears to have been partially filled in, possibly by construction debris washed from the platform of the property at No. 18 Shek O Road, the construction of which was completed by 1963.

Between February 1963 and January 1979, there was no apparent change to slope No. 15NE-B/FR123, but the vegetation cover becomes denser.

A new retaining wall (i.e. the concrete wall that collapsed in the 2000 landslide) supporting the eastern side of Shek O Road, and a hard surface cover (Figure 2) on the northern portion of the fill slope below the retaining wall, are visible in the aerial photographs taken in September 1979. A small platform is visible below the base of the concrete retaining wall and a rectangular patch of new road surfacing (black-top) is visible on the eastern half of the road surface adjacent to the wall crest. It is likely that a landslide occurred in the original fill embankment above the masonry toe wall, at about the same location as the 2000 landslide, sometime during the wet season of 1979. The inferred 1979 landslide also affected the eastern lane of Shek O Road. No records have been found regarding either the 1979 landslide or the history and configuration of the concrete retaining wall.

Between 1979 and 1991, the hard surface below the concrete retaining wall was progressively vegetated and was completely obscured by vegetation by 1992, suggesting a deterioration of the hard surface through which the vegetation grew. Between 1992 and 1999, there were no apparent changes to the site although the vegetation cover becomes more

dense. The concrete retaining wall can be observed in aerial photographs taken up to, and including, September 1999.

2.4 Previous Studies and Assessments

Slope No. 15NE-B/FR123 was not registered in the 1977/78 Catalogue of Slopes. As-built drawings have not been identified for the slope or the crest concrete retaining wall.

The fill slope was identified in June 1996 under a project undertaken by the GEO entitled "Systematic Inspection of Features in the Territory" (SIFT). The project aimed to identify sizeable man-made slopes not included in the 1977/78 Catalogue of Slopes and to update information on registered slopes based on studies of aerial photographs and limited site inspections. The SIFT report indicated that the fill slope was formed before 1949, traversing a natural drainage line. The slope was categorised as a Class B1 feature, i.e. a fill feature assumed to "have been formed or substantially modified before 30 June 1978".

In 1994, the GEO initiated a project entitled "Systematic Identification and Registration of Slopes in the Territory" (SIRST), to update the 1977/78 Catalogue of Slopes and to prepare the New Catalogue of Slopes. The fill slope was registered in the New Catalogue of Slopes under SIRST as slope No. 15NE-B/FR123 in January 1997. The SIRST inspection report for slope No. 15NE-B/FR123, recorded that there were access problems "due to heavy vegetation – unable to determine slope height", and that inspection of the masonry toe wall was not possible. Neither SIFT nor SIRST identified the presence of the concrete retaining wall which collapsed in the 2000 landslide.

According to the Slope Information System, slope No. 15NE-B/FR123 was not ranked under the New Priority Classification System (NPCS) by the GEO, i.e. no NPCS score.

2.5 Maintenance Inspections by Highways Department

The HyD carried out Routine Maintenance Inspections on slope No. 15NE-B/FR123 on 11 January 1999 and 15 February 2000 and appointed geotechnical consultants to carry out an Engineer Inspection of the slope in September 1999. The HyD also resurfaced the section of Shek O Road above the crest of the slope in October 1999 (Figure 3). According to the HyD, the resurfacing was done for general maintenance purposes.

At the January 1999 Routine Maintenance Inspection, no maintenance works were identified as being necessary. Clearance of drainage channels and removal of surface debris and vegetation were recommended following the February 2000 Routine Maintenance Inspection. The recommended maintenance works are recorded as having been completed by 23 February 2000.

An Engineer Inspection (EI) of slope No. 15NE-B/FR123 was carried out by Maunsell Geotechnical Services Limited (MGS) in September 1999. The draft EI report recorded that the overall slope condition was "fair". Routine maintenance works were recommended which included:

(1) "Re-point deteriorated mortar joints on masonry (toe wall) face", and

(2) "Remove undesirable vegetation growth from (masonry toe) wall surface".

MGS also recommended the "Provision (of) a maintenance staircase to the feature for maintenance and inspection" and a "Low Priority Stability Assessment" be carried out.

The concrete retaining wall at the slope crest which collapsed in the 2000 landslide was not recorded in the draft EI Report.

2.6 Utilities and Services below Shek O Road

A number of cables, cable conduits and pipes buried below or running adjacent to Shek O Road were affected by the 2000 landslide (Figures 3 and 4 and Plates 3 and 4). Details of cables and conduits in the vicinity of the landslide are summarised in Table 2.

Hongkong Electric Company Limited (HEC) maintain a transformer pillar on the western side of Shek O Road opposite the location of the 2000 landslide. The transformer pillar was constructed in 1991. HEC also maintain a number of cables mostly below the western side of Shek O Road that were installed between March and May 2000. An extra high tension (EHT) high voltage cable runs below the eastern side of the road at the slope crest (Plate 3). The EHT high voltage cable was exposed by the landslide. HEC confirmed that the cable was not live and had not been used for several years. There were no records of when the cable was laid. A 6" diameter PVC pipe (Figures 3 and 4) crosses from the eastern to the western side beneath Shek O Road and acts as a conduit for two pilot cables to and from the transformer pillar.

Cavendish Construction Limited (HyD's maintenance agent for street lights) indicated that two street lighting cables pass beneath the eastern side of the road adjacent to the location of the collapsed concrete retaining wall (Figure 3). Both cables were exposed by the 2000 landslide.

Pacific Century Cyberworks Hongkong Telecom Limited (PCCW HKT) maintained six 107 mm diameter PVC cable conduits beneath Shek O Road (Figure 3), two of which were installed in 1973 while the rest were installed in 1989. All six conduits, which were confirmed by PCCW HKT to have friction-fit joints, were exposed and broken by the 2000 landslide (Plate 4).

Shek O Quarry Limited maintained a 100 mm diameter metal water pipe (Figure 3 and Plates 3 and 4) that runs along the top of the kerb, supported on a series of concrete bosses, on the eastern side of Shek O Road at the crest of the fill slope. According to the Lands Department, this water pipe was installed in the early 1990's to supply water to the casting basin at Shek O Quarry. The pipe was not damaged by the landslide. Pioneer Quarries Limited, who operate Shek O Quarry, confirmed in March 2001 that the water pipe was operational at the time of the landslide and remains in operation. Since the end of 2000,

Pioneer Quarries Limited no longer have maintenance responsibility for the pipe. The pipe is now under the maintenance responsibility of the Water Supplies Department.

Shek O Development Company Limited maintained an 80 mm diameter metal water pipe that runs across the crest of the fill slope (Figure 3 and Plate 4). It was confirmed by Shek O Development Company Limited in April 2001 that the pipe was not operational at the time of the 2000 landslide and had not been in use for some time.

3. THE LANDSLIDE

3.1 Sequence of Events Prior to the Landslide

The sequence of events prior to the time of the landslide has been established from accounts given by the driver of the taxi that fell into the failure scar and the police sergeant who attended the scene. The Hong Kong Police Force incident record has also been consulted.

Based on the account of the taxi driver, the landslide occurred rapidly and involved an initial sudden failure, at about 05:45 hours on 24 August 2000, when the taxi driver was driving on the eastern side of Shek O Road (i.e. towards Hong Kong) above the location of the landslide. The initial collapse probably involved failure of the fill slope and the crest concrete retaining wall. It is this initial failure that most likely caused his car to veer towards and strike the roadside kerb about 2 m to 3 m beyond the southern edge of the crown of the landslide scar that subsequently developed. On striking the kerb, the taxi became grounded and was unable to proceed. The driver then heard a loud noise and alighted from his car. It was still dark at the time of the incident and the taxi driver made few observations at the landslide site, although he noted that the rainfall was only light and did not notice any water on the road surface.

The police sergeant noted, upon arrival at the scene at 05:53 hours, that the landslide (initial stage) had already occurred. He noted that “there was not a lot of water on the road surface” but “there was much water coming out from underneath the road”.

The taxi remained on the road above the landslide until 06:14 hours, at which time there was a further and gradual collapse of a small portion of the crown of the landslide on which the rear of the taxi was resting. This gradual collapse caused the taxi to fall backwards into the landslide scar.

Based on the above witness accounts, the first stage of the landslide probably occurred at about 05:45 hours on 24 August 2000, just before the taxi collided with the roadside kerb.

3.2 Description of the Landslide

General views of the landslide are shown in Plates 1 to 4. Plans of the landslide are presented in Figures 2 to 4 and cross-sections through the landslide site are presented as Figures 5 and 6.

The landslide involved about 300 m^3 of debris from the northern end of slope No. 15NE-B/FR123, together with a concrete retaining wall which previously supported the eastern side of Shek O Road. The landslide debris travelled downslope into a natural stream course and the outwash material from the debris was subsequently deposited onto the golf course below (Figures 2 and 3).

During the inspection by FMSW at 12:15 hours on 24 August 2000, the landslide scar was estimated to be about 18 m wide, 12 m long and 8 m deep (Figure 4). The inclination of the main scarp was near vertical at the crown and varied between 70º and 25º along the flanks of the landslide scar downslope. The majority of the landslide debris comprised very loose, very wet, silty sand with much gravel and occasional cobbles. Fragments of concrete and asphalt from the road surface were also found in the debris (Plate 3). Fragments of chunam cover and concrete blocks, probably from a platform at the base of the concrete retaining wall as identified by API (see Section 2.3), were also found within the landslide debris during subsequent site inspections by HCL (see Section 3.4).

The landslide exposed a number of cables and cable conduits, including an EHT high voltage cable. FMSW noted that "a reasonable quantity of water was flowing from some of the conduits". FMSW also reported that there was "evidence of surface water flow" from the access road to No. 18 Shek O Road. The water appeared to follow a flowpath directly to the crown of the landslide scar at the location of the concrete wall prior to the landslide. Following a rainstorm on 20 October 2000, HCL observed water following the same flowpath towards the landslide scar (Plate 5). It was observed by HCL that the flowing water did not overtop the reinstated kerb which is about 200 mm high. The kerb either side of the 2000 landslide is about 300 mm high, and it is likely that the kerb line was continuous prior to the failure (see Section 3.4). None of the eye-witnesses noticed much water on the road surface, and it is therefore considered unlikely that surface water flow contributed to the first phase of the failure.

Despite the observation made by the police sergeant that there was "much water coming out from underneath the road" soon after the failure, no evidence of seepage from the main scarp was noted by FMSW during their inspection later that day.

A detailed inspection of the debris trail and the collapsed retaining wall was not possible by FMSW, since at the time of their inspection "soil continued to spall intermittently off the nearly vertical main scarp". During a later inspection by HCL on 29 August 2000, it was observed that much of the landslide debris had been washed away by intense rainfall. However, it could be observed that landslide debris had travelled along a natural drainage line below the masonry toe wall, and spread in two directions with the majority of the landslide debris deposited in the natural stream course (Figure 3). It is probable that a large volume of water was flowing down the natural stream course at the time of, and after, the landslide. This caused flooding of the area below and washed out fine-grained material, essentially sandy silt, from the landslide debris depositing it over a wide area of the golf course (Figure 2 and Plate 6).

The travel distance of the landslide debris was about 45 m beyond the masonry toe wall. The travel angle is estimated to be between 22º and 24º, which indicates that the debris was relatively mobile (Wong & Ho, 1996a). The debris is likely to have been partially channelised along the natural drainage line.

3.3 Consequences of the Landslide

Following the landslide, Shek O Road was closed, which cut off the sole access to Shek O Village and Big Wave Bay. The HyD carried out urgent repair work comprising the removal of loose debris and shotcreting of the landslide scar. Following the completion of the urgent repair work, no-fines concrete and rock fill were placed in the landslide scar to stabilise the failed slope. At the same time, the 350 mm diameter cross-road drain pipe, exposed in the main scarp of the landslide (see Section 3.4), was extended by installing a smaller diameter (300 mm) PVC pipe through the no-fines concrete. Shek O Road was re-opened in stages, from 25 August 2000 to 31 August 2000. Shek O Road was completely re-opened on 5 September 2000.

3.4 Observations Made Following the Landslide

Detailed inspections of the 2000 landslide site and the surrounding area were carried out by HCL between 29 August 2000 and 20 October 2000.

The concrete retaining wall at the slope crest, that had previously supported the eastern side of Shek O Road, was transported as an intact block about 40 m downslope within the natural drainage line (Plate 7). The wall was deposited on its rear face and had been rotated through about 90º with its northern side facing downslope (Figures 3 and 4). It was observed that some fill material remained attached to the collapsed wall and was partially embedded in the concrete. This suggests that the wall had probably been constructed as a mass concrete retaining wall directly onto the fill. It was observed that the upper 0.2 m of both ends of the concrete retaining wall were broken locally at the crest (Plate 7), which demonstrates that the roadside kerb was probably cast into the retaining wall forming a continuous upstand along the edge of the road. The concrete retaining wall was about 10 m long at the crest and 6.5 m long at the toe with a maximum height of 3.6 m. The wall was 0.5 m thick at the top and about 1.4 m at the base. The wall base was typically inclined at about 75º to 80º away from the front face (Figure 6). The front face of the wall, based on the right-angle between the top of the wall and the front face, was probably vertical prior to failure.

Four rows of plastic lined, 90 mm diameter weepholes in the collapsed concrete wall were mostly clear although a few weepholes were completely blocked with soil (probably landslide debris). There was no staining or other evidence of past seepage from the weepholes, although washing and scouring of the face of the wall during and following the landslide may have removed any such evidence. Discolouration was noted over the lower 1 m of the wall face, indicating that the lowest row of weepholes, located 0.4 m from the base of the wall, was probably buried prior to the landslide. The discolouration might indicate a deliberate embedment of the wall but this is considered unlikely because of the presence of the lower row of weepholes. The staining was probably the result of a build-up of vegetation and other debris in front of the wall since its construction.

Irregular-shaped fragments of up to 15 mm thick, with one flat surface and one rough surface, consisting primarily of coarse sand with a sparse cement mortar, were observed in the landslide debris above the toe masonry wall. These fragments are interpreted as being derived from the hard surface protection identified from API (Section 2.3). Rectangular

blocks of concrete, up to 1 m long with a square section of about 0.5 m x 0.5 m, were also observed in the debris above the toe masonry wall. These concrete blocks were probably derived from the platform, that was identified from API to be below the toe of the collapsed concrete retaining wall (see Section 2.3).

The masonry toe wall is about 34 m long and has a maximum height of 4 m at the northern end, below the location of the 2000 landslide, where it traverses the natural drainage line (Plate 8). The wall comprises dressed granite blocks with ribbon mortar pointing. The blocks are laid in uniform 0.4 m high horizontal courses with block widths varying between 0.1 m and 0.7 m. Three rows of 90 mm diameter vitrified clay pipe lined weepholes have been provided in the wall at 1.2 m vertical spacing and 2.5 m to 2.8 m horizontal spacing, staggered between rows. Weepholes in the masonry wall were probed to depths varying between 0.8 m near the wall crest to 1.7 m near the wall toe. Visual inspection of the internal condition of the weepholes with the aid of a torch, revealed that the linings were generally in fair order. The material at the rear of the weepholes is typically a moist, silty sand. There was no evidence of seepage from any of the weepholes.

Minor signs of distress were observed in the masonry toe wall, including minor loss of pointing and minor displacement (< 3 mm) of blocks, although one or two blocks appeared to have been dislodged from the northern end of the wall (Plate 9).

At the base of the masonry wall, near the northern end, there is a 350 mm outer diameter vitrified clay drainage pipe. Continuous heavy water flow was observed emerging from the drainage pipe during the post inspection by GEO's consultants Fugro Maunsell Scott Wilson Joint Venture (FMSW) on 24 August 2000 (Plate 9) but this flow steadily diminished with time and had reduced to a minor seepage by 11 September 2000 following a period of dry weather. Another 350 mm outer diameter cross-road drain pipe was exposed in the main scarp. It was observed to be dry and approximately 30% silted up at the time of the inspection by FMSW, seven hours after the landslide. No inlets for these drainage pipes could be found on site.

Some of the PCCW HKT's conduits (see Section 2.6), which were exposed and broken by the 2000 landslide, were observed to have water flowing from them into the landslide scar during the inspection by FMSW on 24 August 2000.

No surface drainage provision was found along the crest or the toe of fill slope No. 15NE-/FR123. However, two 650 mm wide U-channels of about 4 m in length, were observed to the north and south of the fill slope (Figure 3). The U-channels are part of a series of channels, at about 60 m to 70 m intervals, along both sides of Shek O Road. Surface runoff from Shek O Road is discharged onto the slope below through these U-channels. Two minor erosion gullies (Figure 3) of about 2 m width, are observed on the fill slope extending from near the slope crest to the slope toe. The origin of these erosion gullies is uncertain.

Adjacent to the electricity transformer pillar (see Section 2.6), on the western side of Shek O Road, is an almost flat area, approximately 3 m by 3 m in size, covered with recently deposited sand. The sand was angular and sharp and therefore probably construction debris. Ponded water, about 50 mm deep, was observed in this area on 24 August 2000 by FMSW and later by HCL on 20 October 2000 after a rainstorm (Plate 10).

The primary source of the ponded water was probably a 450 mm wide U-channel on the northern side of the access road to No. 18 Shek O Road (Figure 3). The U-channel directs surface runoff from the access road towards a baffle. The baffle directs surface water to flow over a fill slope, that forms the northern side of the access road, towards the almost flat area adjacent to the transformer pillar.

Cracks, up to 5 mm wide, were observed at intervals of between 6 m and 8 m in the concrete kerb on the western side of the road (Plate 11). Cracks up to 10 mm wide, with discoloured surfaces and recent concrete repairs to the transformer pillar foundation pad were also observed (Plate 12).

The 80 mm diameter metal water pipe, which was maintained by the Shek O Development Company (see Section 2.6), was broken during the landslide. No water was seen to be issuing from the pipe which was found to be severely corroded internally during the post-landslide inspection by HCL on 29 August 2000.

4. SUBSURFACE CONDITIONS

Sheet 15 of the Hong Kong Geological Survey 1:20 000 scale map series (GCO, 1986) indicates that the site is underlain by coarse-grained granite.

4.1 Ground Investigation

Ground investigation works, comprising three trial pits and 17 GCO probe tests were carried out on slope No. 15NE-B/FR123 between 28 September 2000 and 11 October 2000. A further four GCO probe tests were carried out on the western side of Shek O Road after a rainstorm on 23 October 2000. Results from GCO probe tests carried out nearest to the 2000 landslide are projected onto cross-section B – B through the landslide (Figure 6). Locations of the trial pits and GCO probe tests are presented on Figure 7, and trial pit logs are presented in Appendix B. Summaries of the GCO probe test results are presented in Tables C1 and C2 of Appendix C.

All three trial pits encountered fill material over their entire depth, with trial pit TP2 encountering slightly decomposed granite at about 2 m in the upslope face with the rockhead dipping about 36º downslope. The fill material is typically described as loose, yellowish brown slightly clayey/silty gravelly fine to coarse sand with occasional cobbles. The fill material was derived almost entirely from completely decomposed granite.

A total of 15 insitu density tests were undertaken by Public Works Regional Laboratories (PWRL), using the sand replacement method, at 0.5 m intervals within the trial pits. PWRL also carried out corresponding Proctor compaction tests in the laboratory on samples taken as part of the insitu density tests. Laboratory test results are presented in Table 4. The test results indicate that the degree of compaction of the fill is between 67.6% and 91.9% with a mean relative compaction of around 76%, indicating the loose nature of the fill material.

GCO probe tests from the initial ground investigation were carried out at 17 different locations on the fill slope, including tests that were carried out in each of the trial pits prior to excavation. Most of the tests were positioned as close to the landslide scar area as possible. The results indicated a typical probe value of less than 5 blows per 100 mm for up to about 7.5 m, confirming the nature and extent of the loose fill material. The results are summarised in Table C1 of Appendix C.

Soil classification and index tests were also carried out on bulk disturbed samples taken from the trial pits. The results are summarised in Table 4.

On 23 October 2000, after a rainstorm, four GCO probe tests were carried out on the western side of Shek O Road around the location of the electricity transformer pillar (Figure 7). A summary of the GCO probe test results is presented in Table C2 of Appendix C. The tests were carried out to verify the thickness and insitu density of the fill within that area. GCO probe test GC1 was carried out at the location where ponded water had been observed. Below the top 0.5 m of loose fill (between 0.5 m to 1.0 m below ground level), the probe fell under its own weight. The probe test results showed the loose nature of the fill up to 4.1 m below ground level where it met refusal. The other three GCO probe test results confirmed the loose nature of the fill and that the thickness (typically 2 m to 4 m) is less than that on the opposite side of Shek O Road. The GCO probe tests GC2 and GC3 carried out furthest west from Shek O Road met refusal at much shallower depths, probably indicating a decreasing fill thickness at higher elevations within the natural drainage line.

4.2 CCTV Survey

Since no inlets could be identified on site for the two 350 mm outer diameter clay drain-pipes observed at the site, CCTV surveys were carried out to examine the internal condition of the pipes, to try to locate the pipe inlets and to determine whether the pipes were operational prior to the 2000 landslide. Traces of the probable pipe alignments based on the survey are shown on Figures 4 and 5.

The 300 mm internal diameter vitrified clay pipe at the base of the masonry toe wall, with an outlet level of 25.57 mPD (Figure 6 and Plate 9), was surveyed to a length of about 20 m. Due to the pipe being inclined upwards from the point of entry at between 20º and 25º from the horizontal, it was not possible to push the CCTV equipment further at this point.

The survey revealed that the pipe was clear and comprised sections of approximately 0.7 m in length. Longitudinal cracks (Plate 13) of greater than 10 mm width were observed at the base of some pipe sections. Towards the end of the surveyed portion, the pipe was severely cracked and deformed (approximately ellipsoidal).

The upper pipe (approximately 2 m below Shek O Road, with an outlet level of 38.61 mPD) was surveyed to a total length of about 14 m. The first 6 m of the survey was within PVC pipe attached to the end of the old vitrified clay pipe as part of the urgent repair works for the 2000 landslide. The 300 mm internal diameter clay pipe section was severely cracked and much soil material was present in the pipe (Plate 14). The survey was terminated at about 14 m, at which point the pipe was blocked with soil and fragments of

broken clay pipe. The pipe appeared to have collapsed at that end, and it is unlikely to have been in working order prior to the August 2000 landslide.

A plot of the inferred alignment (Figure 4) of the two pipes indicates that the pipes might converge at a point on the western side of Shek O Road. These pipes could not be probed to a point further than underneath the Shek O Road surface. An inspection pit was excavated to a depth of 2.1 m, adjacent to the HEC transformer pillar, at the estimated position of the point of convergence for the pipes. No evidence of a catchpit or buried pipes was found.

It is likely that the upper pipe was not operational prior to the landslide. Although the survey of the lower pipe was incomplete, the water observed to be flowing from the pipe at the base of the masonry toe wall by FMSW during the inspection on 24 August 2000 (Plate 9), and subsequently by HCL on 29 August 2000, was probably groundwater infiltrating through the joints and cracks in the lower pipe.

5. RAINFALL ANALYSIS

The nearest GEO automatic raingauge No. H28 is located at Shek O Police Post, at the entrance to Shek O Country Club, about 350 m northeast of the landslide. The raingauge records and transmits rainfall data at 5-minute intervals via a telephone line to the GEO. These records have been analysed to determine the characteristics of the rainstorm preceding the landslide. For the purposes of this analysis, the landslide has been assumed to have occurred shortly before 5:45 hours on 24 August 2000 based on eye-witnesses accounts.

The daily rainfall recorded by the raingauge for one month preceding the landslide, together with the hourly rainfall, are presented in Figure 8. This shows that the rainstorm on 24 August 2000, was the most severe within the month, with a peak hourly rainfall of 126.5 mm recorded between 04:00 hours and 05:00 hours on 24 August 2000. Between 05:45 hours and 08:00 hours, subsequent to the landslide, a further 16.5 mm of rainfall was recorded. No further rainfall was recorded by raingauge No. H28 on 24 August 2000.

Isohyets of rainfall for the period between 00:00 hours and 05:45 hours on 24 August 2000 (Figure 9) indicate that the Shek O area experienced the heaviest rainfall in Hong Kong (over 300 mm). A Black Rainstorm Warning Signal was issued at 03:05 hours and lowered at 05:55 hours.

Table 3 presents the estimated return periods for the maximum rolling rainfall for various durations based on historical rainfall data at the Hong Kong Observatory (Lam & Leung, 1994). The 4-hour rolling rainfall (326.5 mm) was the most severe with a return period of about 250 years. This simplified method of rainfall analysis does not necessarily give the true return period for a particular site, as several contributory factors are not taken into account (Wong & Ho, 1996b). Nonetheless, it provides an indication of the relative severity of the various rainfall characteristics assessed.

Since GEO automatic raingauges Nos. H28, H26 and H29 (the latter two are the second and the third nearest raingauges to the landslide site) were installed after November 1999, no rainfall data are available for earlier major rainstorms. Raingauge

No. H14, which is located at Wo Hing House, Hing Wah Estate and is about 3.7 km northwest of the site, has been used for the rainfall analysis. Figure 10 compares data for the 24 August 2000 rainstorm recorded by raingauge Nos. H28 and H14, with that of other past major rainstorms recorded by raingauge No. H14. The 24 August 2000 rainstorm recorded by raingauge No. H28 was more severe than any previously significant rainstorms recorded by raingauge No. H14, between 2 and 8 hours duration, since installation of raingauge No. H14 in 1983. This comparison is however indicative only because other factors (especially possible regional influences) have not been accounted for.

6. DIAGNOSIS OF THE PROBABLE CAUSES OF THE LANDSLIDE

6.1 Mode and Sequence of the Landslide

The mode and sequence of failure is based on the eye-witness account, the Hong Kong Police Force incident report and post-failure inspections and investigations.

Based on the eye-witness account, it is likely that the landslide occurred rapidly and involved an initial sudden failure at about 05:45 hours on 24 August 2000. The crest concrete retaining wall was transported as an intact block about 40 m into the natural drainage line, and deposited on its rear face. This suggests that the wall most probably collapsed as a result of undermining caused by the failure of the fill slope below the wall.

A further collapse of a small portion of the crown of the landslide occurred some 30 minutes later and caused the taxi to fall into the landslide scar. Further minor collapses of the crown occurred over the following hours.

6.2 Probable Causes of the Landslide

The landslide occurred in a loose fill slope towards the end of an intense rainstorm, during which time the 4-hour maximum rolling rainfall had an estimated return period of about 250 years. The close correlation between the severe rainstorm and the landslide suggests that short duration intense rainfall most probably triggered the landslide.

The landslide was probably caused by failure of the loose fill below the crest concrete wall upon water ingress and saturation due to direct infiltration and subsurface seepage. Based on the loose state of the fill as revealed by insitu density tests and GCO probes, together with the high mobility of the landslide debris, the failure could well have involved liquefaction of the loose fill. Transient elevated groundwater pressures may also have developed in the fill behind the crest concrete retaining wall and contributed to the failure.

The probable sources of water ingress into the landslide site were:

(a) direct infiltration of rainfall into the fill slope through the vegetated slope surface and the deteriorated shotcrete surface cover below the concrete retaining wall,

(b) direct infiltration of ponded water on the western side of Shek O Road, followed by subsurface water flow through

fill material which is present to a depth of more than 3 m below the road surface, and

(c) water ingress into the fill behind the collapsed concrete retaining wall from the damaged upper cross-road drain (which had no apparent inlet or outlet) as well as through the cable conduits with friction-fit joints, some of which were observed to be discharging water on the day of the incident after the failure.

6.3 Discussion

It would appear that the August 2000 landslide occurred at about the same location of a previous failure of the fill embankment in 1979 and where the slope traverses a natural drainage line. It is likely that the concrete retaining wall at the crest was constructed as part of the urgent repair works carried out following the 1979 failure. The foundation of the wall was observed to be inadequate, indicating that the wall was probably not designed (i.e. with no geotechnical input) and little attention was paid to drainage, since no provision was made for re-instating the 350 mm outer diameter clay drainage pipe present at about 2 m beneath the road surface.

Although the fill slope was registered in the New Catalogue of Slopes, the presence of the crest concrete wall was not identified by the SIRST project or during the subsequent EI. The slope was classified as a 'B1' feature under the SIFT project but there was no NPCS score given to the slope.

Cross-road drains, which were probably installed in the early 1920's during the construction of the original fill embankment, were ineffective. The lower drain had no apparent inlet whilst the upper drain had no apparent inlet or outlet. Both pipes were found to be severely cracked which possibly contributed to the saturation of the ground mass and the subsequent failure of the fill slope below the road.

7. CONCLUSIONS

It is concluded that the 24 August 2000 landslide on fill slope No. 15NE-B/FR123 below Shek O Road was triggered by rainfall. The landslide probably involved liquefaction of the loose fill below the crest concrete retaining wall. The primary source of water ingress into the fill slope below the crest retaining wall was probably via direct infiltration through the vegetated slope surface and portions of the slope with dilapidated hard surface cover.

The development of transient elevated groundwater pressure in the fill material behind the concrete retaining wall as a result of subsurface seepage may also have contributed to the failure. Discharge of water through the cable conduits and the severely cracked cross-road drains into the landslide site were probable further sources of water ingress into the loose fill, and likely to be contributory factors to the failure.

8. REFERENCES

Geotechnical Control Office (1986). Hong Kong South and Lamma Island: Solid and Superficial Geology. Hong Kong Geological Survey, Map Series HGM 20, Sheet 15, 1:20 000 scale, Geotechnical Control Office, Hong Kong.

Lam, C.C. & Leung, Y.K. (1994). Extreme Rainfall Statistics and Design Rainstorm Profiles at Selected Locations in Hong Kong. Royal Observatory, Hong Kong, Technical Note No. 86, 89 p.

Wong, H.N. & Ho, K.K.S. (1996a). Travel distance of landslide debris. Proceedings of the Seventh International Symposium on Landslides, Trondheim, Norway, vol. 1, pp 417-422.

Wong, H.N. & Ho, K.K.S. (1996b). Thoughts on the Assessment and Interpretation of Return Periods of Rainfall. Discussion Note DN 2/96, Geotechnical Engineering Office, Hong Kong, 12 p.

LIST OF TABLES

Table 1 - Summary of Information Sources (Sheet 1 of 3)

Information Source	Reference	Principal Relevant Content
Published Reports and Documents	H.K. South & Lamma Island: Solid and superficial geology, Hong Kong Geological Survey Map Series HGM20, Sheet 15, 1:20 000 scale Geology of Hong Kong Island and Kowloon, Geological Memoir No. 2 Geotechnical Area Studies Programme Report I: Hong Kong and Kowloon	Background geological and geomorphological information of area.
Planning Division, GEO	Aerial Photographs 1924, 1945, 1949, 1963, 1967, 1978, 1979, 1980, 1981, 1982, 1983, 1984, 1986, 1987, 1988, 1990, 1991, 1992, 1993, 1994, 1995, 1996, 1997, 1998, 1999. SIFT Report for Slope No. 15NE-B/FR123	Site history and geomorphology of the feature and the surrounding area. Construction date, geometry and general condition.
Slope Safety Division, GEO	SIRST Report for Slope No. 15NE-B/FR123	Geometry, field observation and general condition of Slope No. 15NE-B/FR123.
Island Division, GEO	GCI 2/E1/2000 GCI 2/E1/2000-1	Incident Report No. HK2000/08/4 and details of the landslide.
Public Works Laboratories	(a) Insitu Density Tests results. (b) Laboratory test results	Details of laboratory test results of samples taken.

Table 1 - Summary of Information Sources (Sheet 2 of 3)

Information Source	Reference	Principal Relevant Content
Lands Department, and District Lands Office (DLO)	SIMAR Report Historical Survey Maps 1895 Map reference No. HE1-4 1905 Sheet No. 8 reference No. HD35	Registration status of Slope No. 15NE- B/FR123. Site History
DrilTech Ground Engineering Ltd.	"Stand-by" Ground Investigation on Landslide Sites Investigated under Agreement No. CE 2/2000. Works Order No. GI/SOR/28.531/001 Ground Investigation Report on Feature No. 15NE-B/FR123, Shek O Road, H.K.	Results and locations of GCO Probing, and location s of trial pits and inspection pit.
EGS (Asia) Ltd.	Job Number HK 158900 October 2000	Final report on CCTV of 2 No. drainage pipes.
Fugro Maunsell Scott Wilson JV	Landslip Incident Photographs, Initial Inspection Information, Incident Report	Detailed information and photographs of landslide debris, geometry and consequence on 24 August 2000.
Hong Kong Electric Co. Ltd.	Letter Reference D,P & IT/255/20/02 dated 14 October 2000 and 3 November 2000	Response to list of questions. Record photographs for recent cable installation. Foundation details for transformer pillar TP110.

Table 1 - Summary of Information Sources (Sheet 3 of 3)

Information Source	Reference	Principal Relevant Content
Highways Department	Slope Maintenance Records for slope No. 15NE-B/FR123 (HyD slope No. 11900FR01400) Letter Reference HH 66/184(S) dated 16 October 2000	Details of 1999 Engineer Inspection and Routine Maintenance Inspection by MGSL Consultant. Completed response to list of questions. Landslip and emergency repair works record photographs and recent excavation permits and road maintenance records.
Hong Kong Police Force (HKPF)		Police Incident Log No. 2000/09/04 Completed interview and response to list of questions.
Pacific Century Cyberworks HKT	Letter Reference OPS/ MP22257/ 2000/ SKO/ CKM dated 13 October 2000	Completed response to list of questions.
Hong Kong Observatory	Isohyets of rainfall	Rainfall distribution in Hong Kong from 00:00 Hours to 05:45 Hours on 24 August 2000.
Shek O Country Club		Photographs of the extent of debris deposition on Shek O Golf Course.

Table 2 - List of Government Departments and Utility Companies Contacted for Existing Utilities Information

Department	Reference	Utility Information Available
Water Supplies Department	Letter Reference (8) in WSD (HK) 674/3/94 Pt.4 TJ (15) dated 15 September 2000 Letter Reference (19) in WSD(HK)674/3/94 Pt. 4 TJ(15) dated 20 April 2001	No existing utility in the vicinity of landslide location. Confirmation of responsibility for the water supply pipe to Shek O Quarry.
Drainage Services Department	Letter Reference (101) in DSD HK14/13(10) dated 15 September 2000	No existing utility in the vicinity of landslide location.
Hong Kong Electric Co. Ltd.	Letter Reference D,P & IT/255/20/02 dated 14 October 2000 and 3 November 2000	Utility Plan and Details of existing utilities in the vicinity of failure location.
Pacific Century Cyberworks HKT	Letter Reference OPS/ MP22257/ 2000/ SKO/ CKM dated 13 October 2000	Utility Plan and Details of existing utilities in the vicinity of landslide location.
Cavendish Construction Limited	Letter Reference CCL/ 765/00/00 dated 4 October 2000	Utility Plan and Details of existing utilities in the vicinity of landslide location.
District Lands Officer/Lands Department	Utility information	Utility Plan
The Shek O Development Company Limited	Letter Reference MGB/35/106024041 dated 19 April 2001	Information on the 80 mm dia. metal water pipe

Table 3 - Maximum Rolling Rainfall at GEO Raingauge No. H28 and Estimated Return Periods for Different Durations Preceding the Landslide on 24 August 2000

Duration	Maximum Rolling Rainfall (mm)	End of Period (Hours)	Estimated Return Period (Years)
5 minutes	15.0	04:20 hours on 24 August 2000	4
15 minutes	40.0	04:30 hours on 24 August 2000	15
1 hour	126.5	05:05 hours on 24 August 2000	37
2 hours	195.5	05:35 hours on 24 August 2000	59
4 hours	326.5	05:45 hours on 24 August 2000	247
12 hours	346.5	05:45 hours on 24 August 2000	24
24 hours	347	05:45 hours on 24 August 2000	8
2 days	347.5	05:45 hours on 24 August 2000	4
4 days	347.5	05:45 hours on 24 August 2000	3
7 days	347.5	05:45 hours on 24 August 2000	2
15 days	356	05:45 hours on 24 August 2000	1
31 days	648.5	05:45 hours on 24 August 2000	2

Notes:
(1) Return periods were derived from Table 3 of Lam & Leung (1994).
(2) Maximum rolling rainfall was calculated from 5-minute data.
(3) The use of 5-minute data for durations between 4 hours and 31 days results in better data resolution, but may slightly over-estimate the return periods using Lam & Leung's (1994) data, which are based on hourly rainfall for these durations.

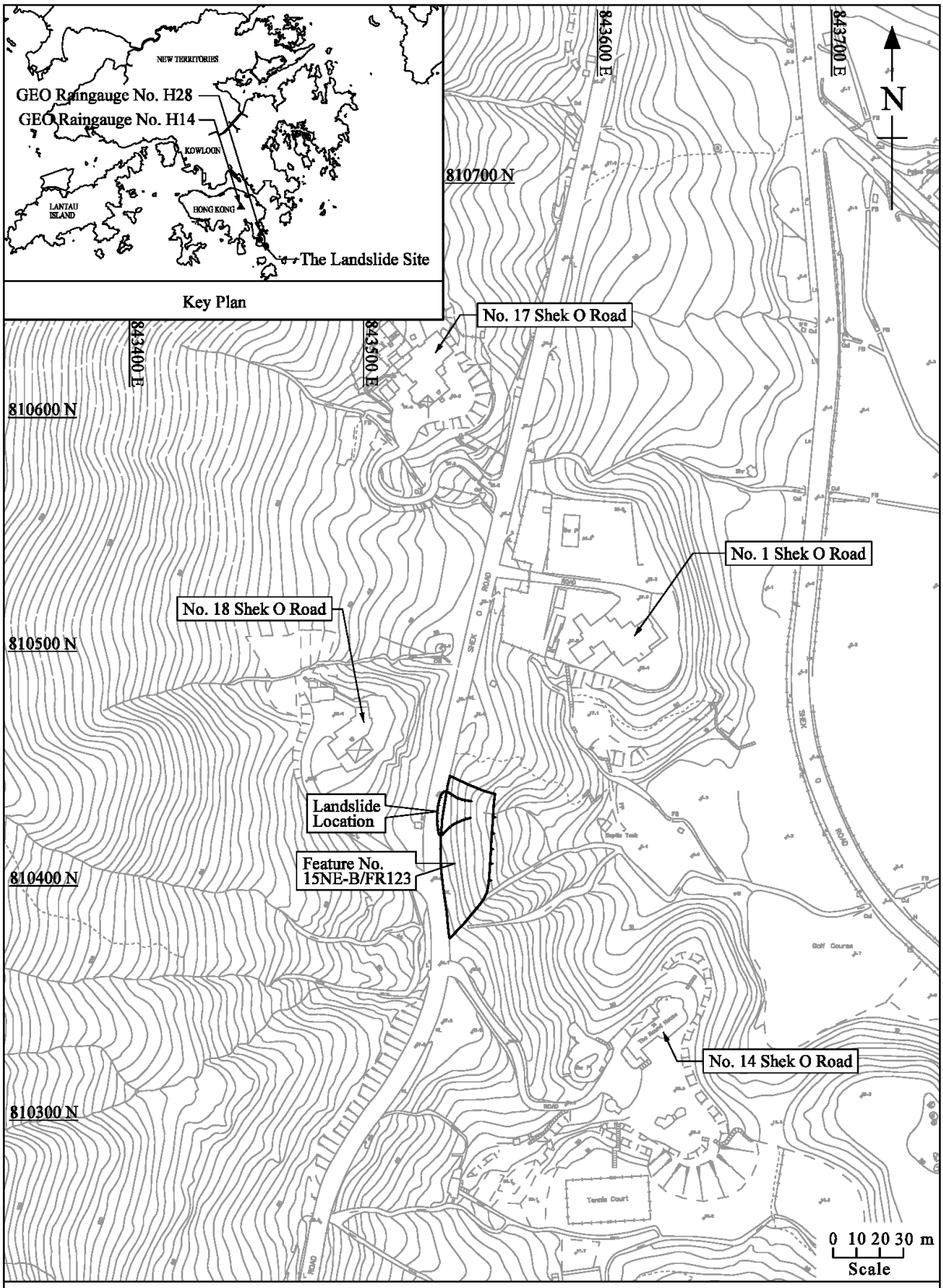
Table 4 - Summary of Laboratory Test Results (Sheet 1 of 2)

Laboratory Sample No.	Material Type	Sample Location	Depth below Ground Level (m)	Sample Type	Particle Size Distribution				Liquid Limit (%)	Plastic Limit (%)	Moisture Content (%)	Relative Compaction (%)
					Gravel (%)	Sand (%)	Silt (%)	Clay (%)				
NLSOR0004981/1 and NLSOR000528/1	FILL	TP1	0.5	Bulk	-	-	-	-	-	-	14	78.6
									54	27	-	-
NLSOR0004981/2 and NLSOR000528/2	FILL	TP1	1.0	Bulk	-	-	-	-	-	-	10	71.7
					18	55	12	15	54	-	-	-
NLSOR0004981/3 and NLSOR000528/3	FILL	TP1	1.5	Bulk	-	-	-	-	-	-	14	83.2
									48	28	-	-
NLSOR000507/1 and NLSOR000528/4	FILL	TP1	2.0	Bulk	-	-	-	-	-	-	16	77.5
					22	58	9	11	-	-	-	-
NLSOR000507/2 and NLSOR000528/5	FILL	TP1	2.5	Bulk	-	-	-	-	-	-	15	78
									54	27	-	-
NLSOR000507/3 and NLSOR000528/6	FILL	TP1	3.0	Bulk	-	-	-	-	-	-	17	80.9
					29	45	10	16	-	-	-	-
NLSOR000498/4 and NLSOR000529/1	FILL	TP2	0.5	Bulk	-	-	-	-	-	-	13	67.6
									47	27	-	-
NLSOR000498/5 and NLSOR000529/2	FILL	TP2	1.0	Bulk	-	-	-	-	-	-	11	76.9
					22	56	11	11	-	-	-	-

Table 4 - Summary of Laboratory Test Results (Sheet 2 of 2)

Laboratory Sample No.	Material Type	Sample Location	Depth below Ground Level (m)	Sample Type	Particle Size Distribution				Liquid Limit (%)	Plastic Limit (%)	Moisture Content (%)	Relative Compaction (%)
					Gravel (%)	Sand (%)	Silt (%)	Clay (%)				
NLSOR000498/6 and NLSOR000529/3	FILL	TP2	1.5	Bulk	-	-	-	-	-	-	16	76.3
									27	53	-	-
NLSOR000529/4	FILL	TP2	2.0	Bulk	22	54	10	14	-	-	-	-
NLSOR000529/5	FILL	TP2	2.5	Bulk	-	-	-	-	27	53	-	-
NLSOR000498/7 and NLSOR000530/1	FILL	TP3	0.5	Bulk	-	-	-	-	-	-	11	71.7
									27	63	-	-
NLSOR000498/8 and NLSOR000530/2	FILL	TP3	1.0	Bulk	-	-	-	-	-	-	13	69.6
					19	56	11	14	-	-	-	-
NLSOR000498/9 and NLSOR000530/3	FILL	TP3	1.5	Bulk	-	-	-	-	47	24	14	68.8
									-	-	-	-
NLSOR000507/4 and NLSOR000530/4	FILL	TP3	2.0	Bulk	-	-	-	-	-	-	15	76.3
					22	56	11	11	-	-	-	-
NLSOR000507/5 and NLSOR000530/5	FILL	TP3	2.5	Bulk	-	-	-	-	46	24	14	76.9
									-	-	-	-
NLSOR000507/6 and NLSOR000530/6	FILL	TP3	2.5	Bulk	-	-	-	-	-	-	14	91.9
					14	54	15	17	-	-	-	-

LIST OF FIGURES



Note : Base map is extracted from Survey Sheet Nos. 15NE-9B and 15NE-10A, scale 1:1000, dated November 1999.

Figure 1 - Site Location Plan

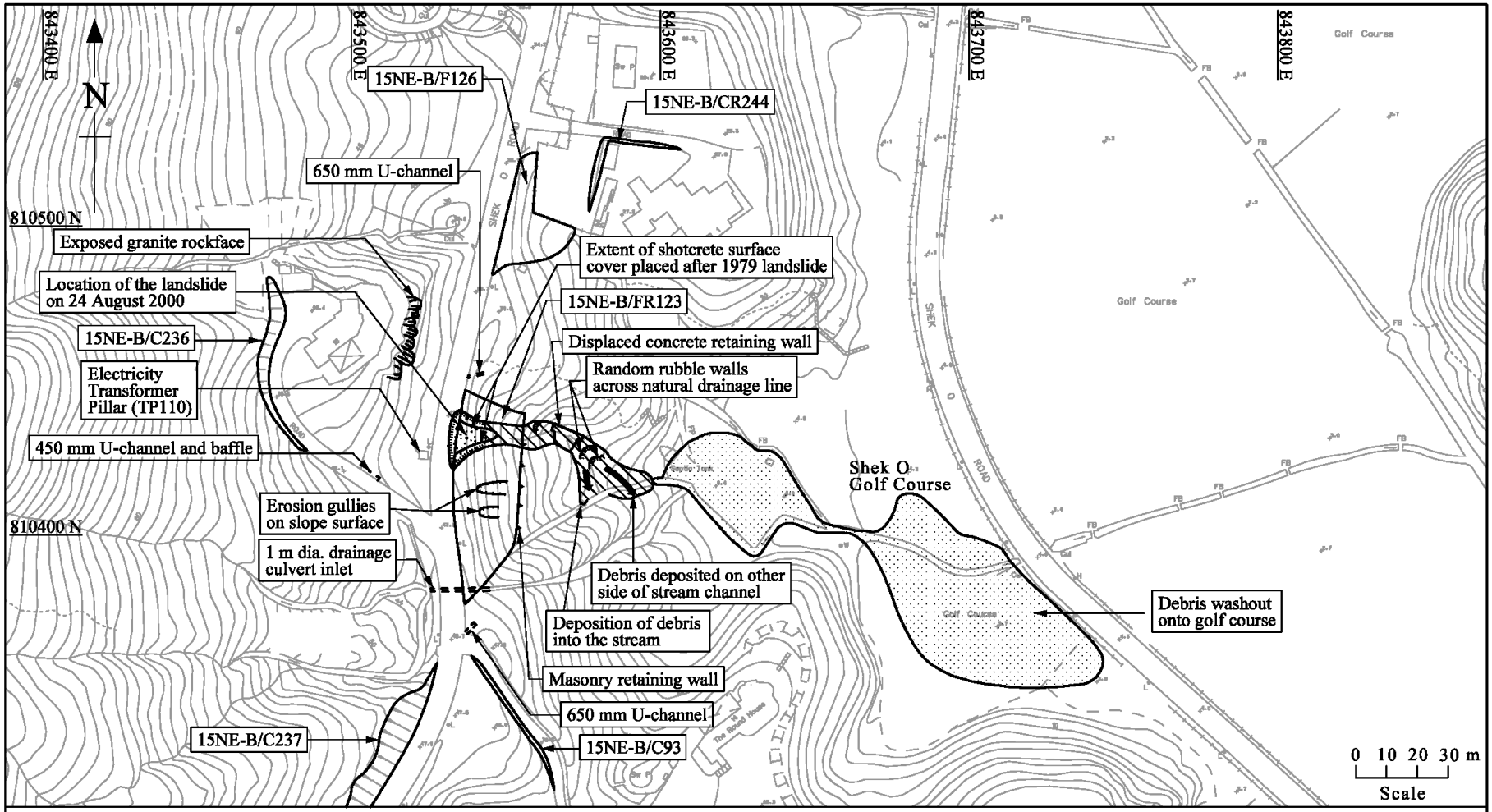


Figure 2 - Plan of the Landslide Site

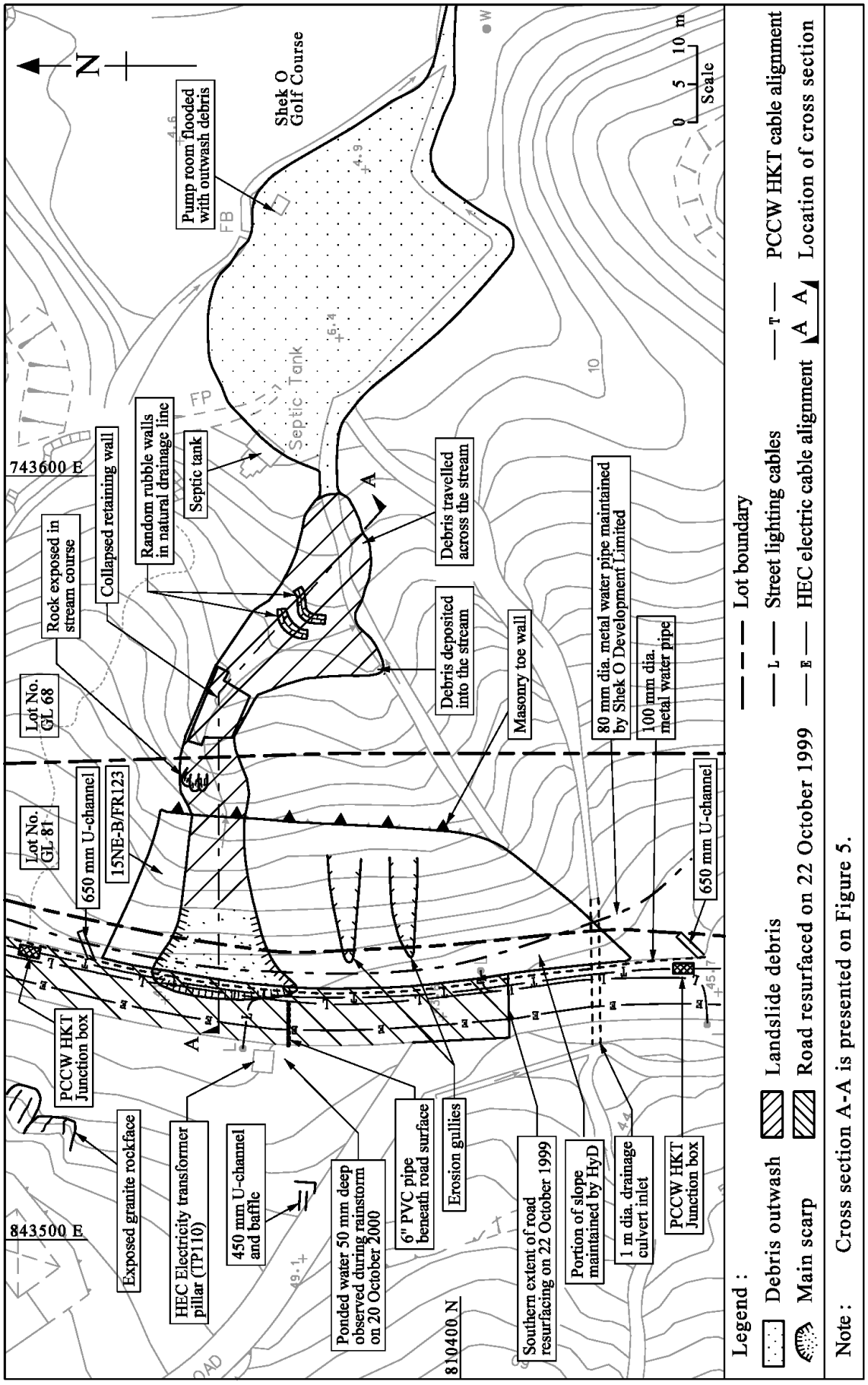


Figure 3 - Detailed Plan of the Landslide Site

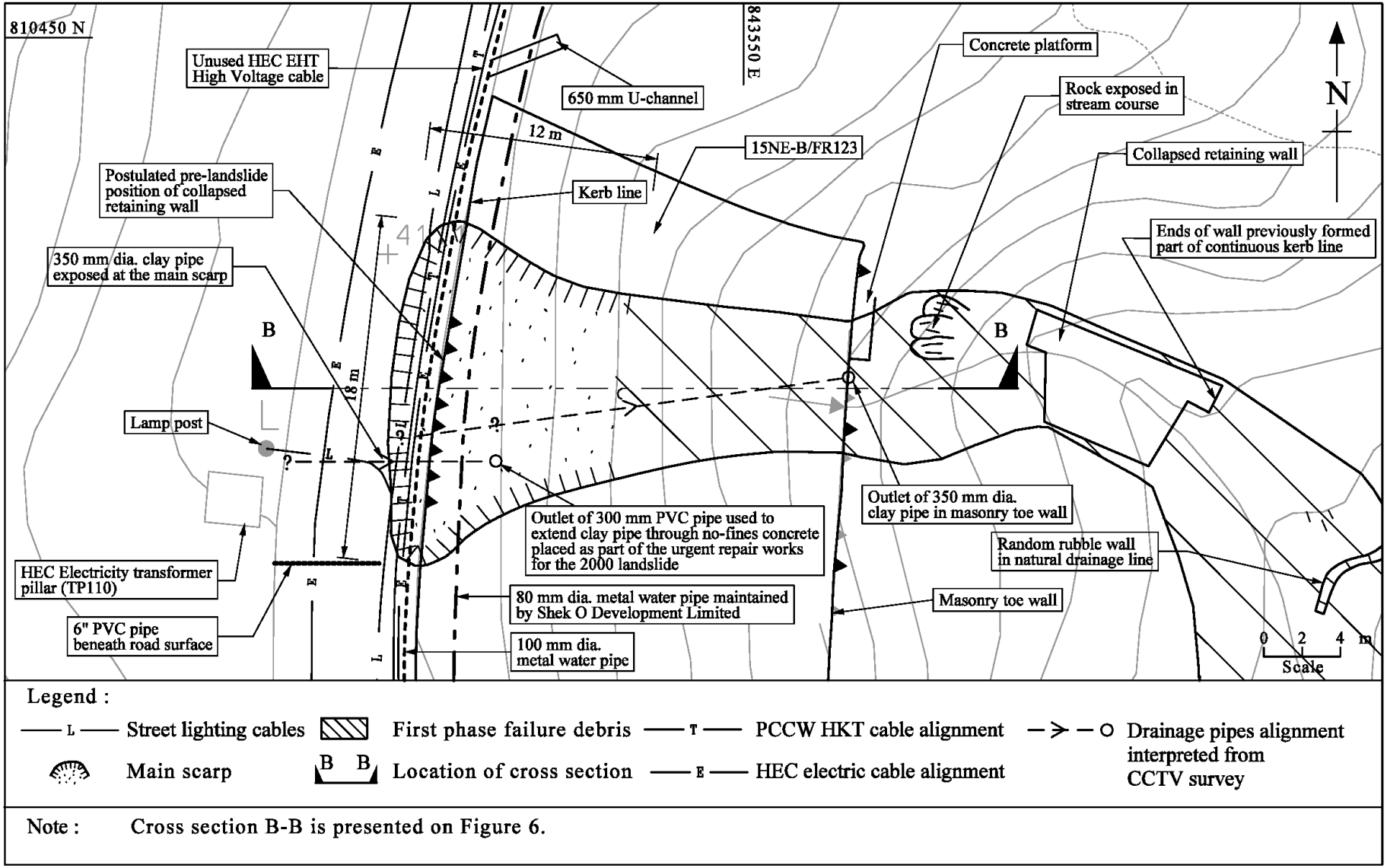


Figure 4 - Detailed Plan of the Landslide Scar

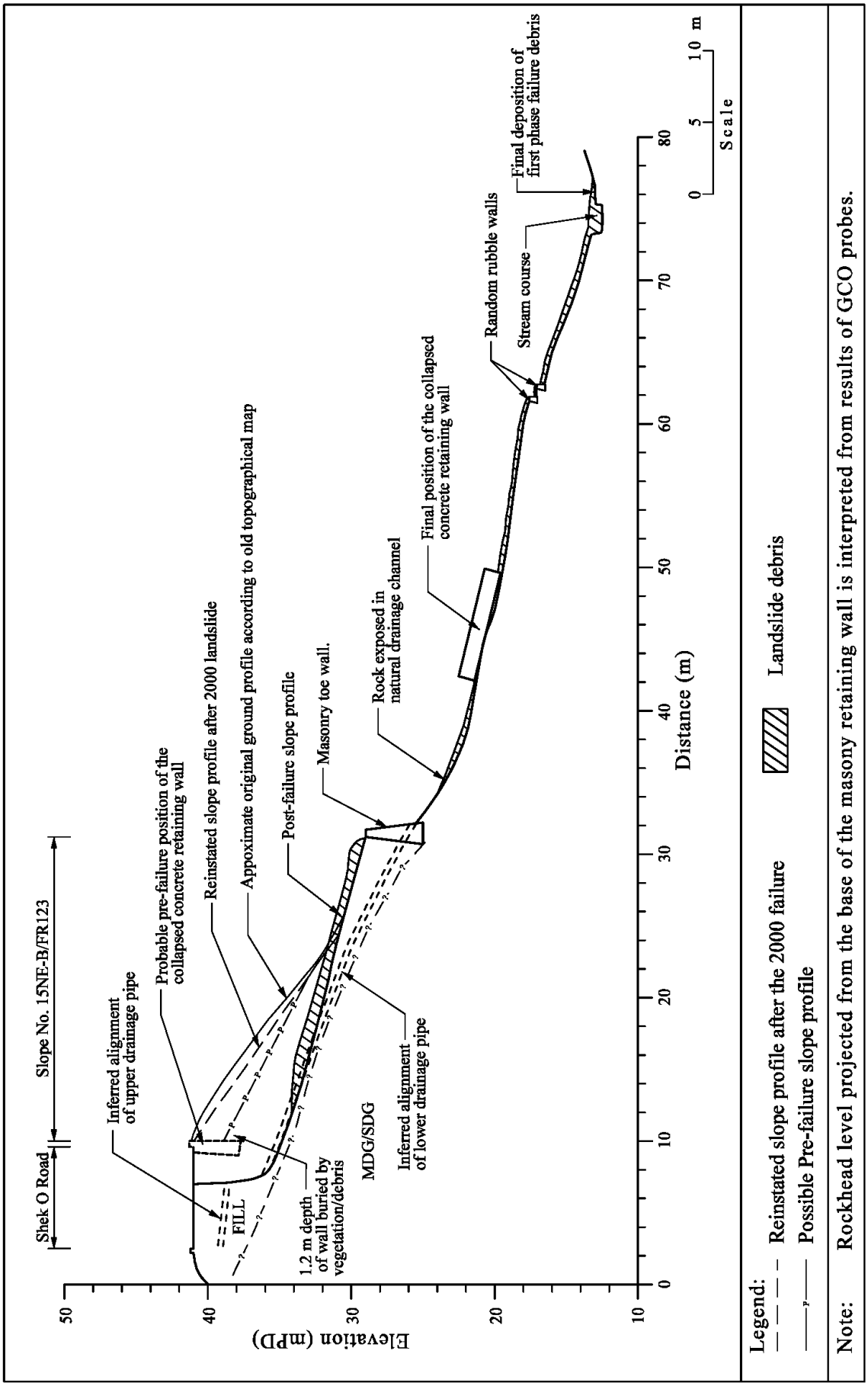


Figure 5 - Cross Section A - A through the Landslide

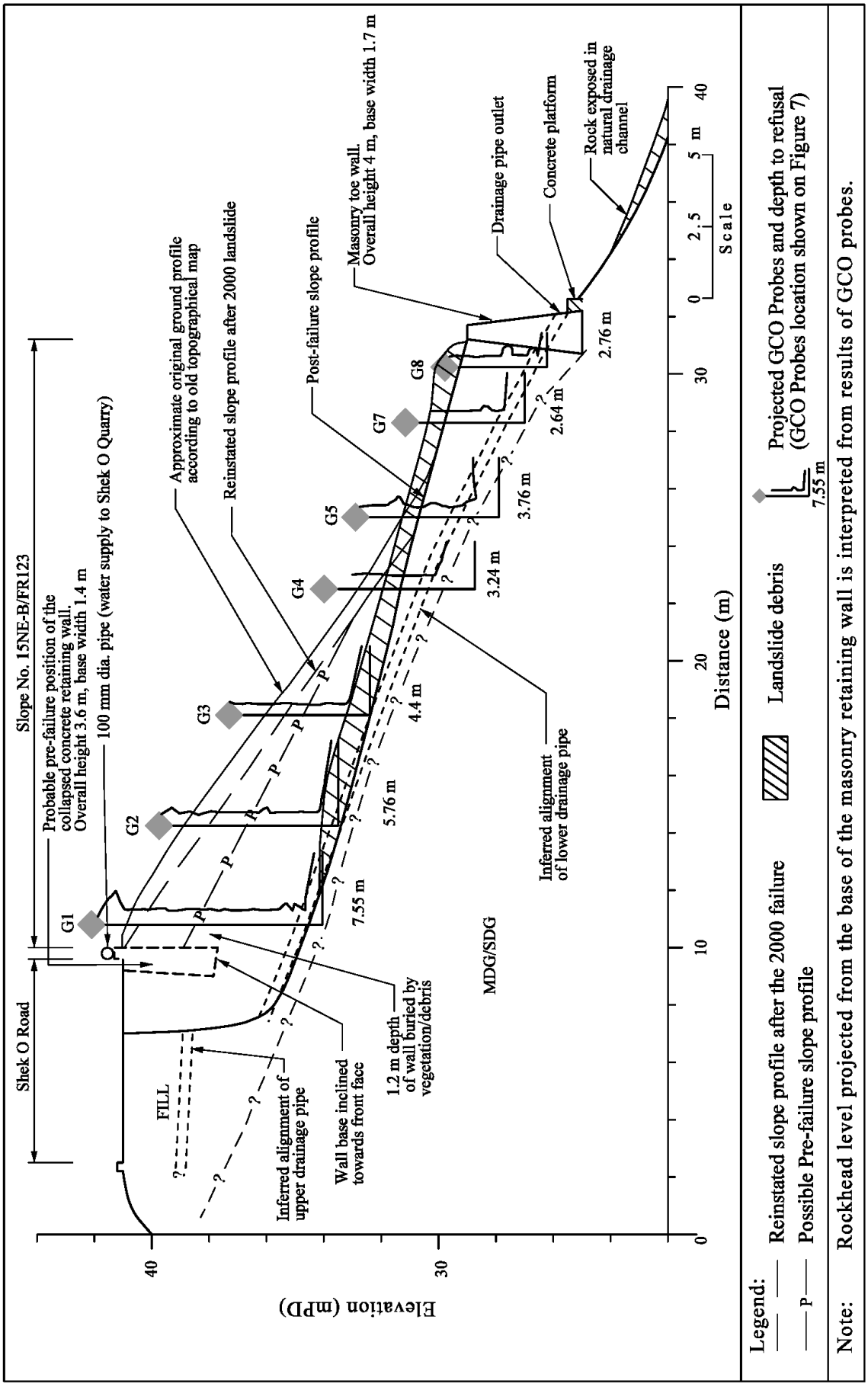


Figure 6 - Detailed Cross Section B-B through the Landslide

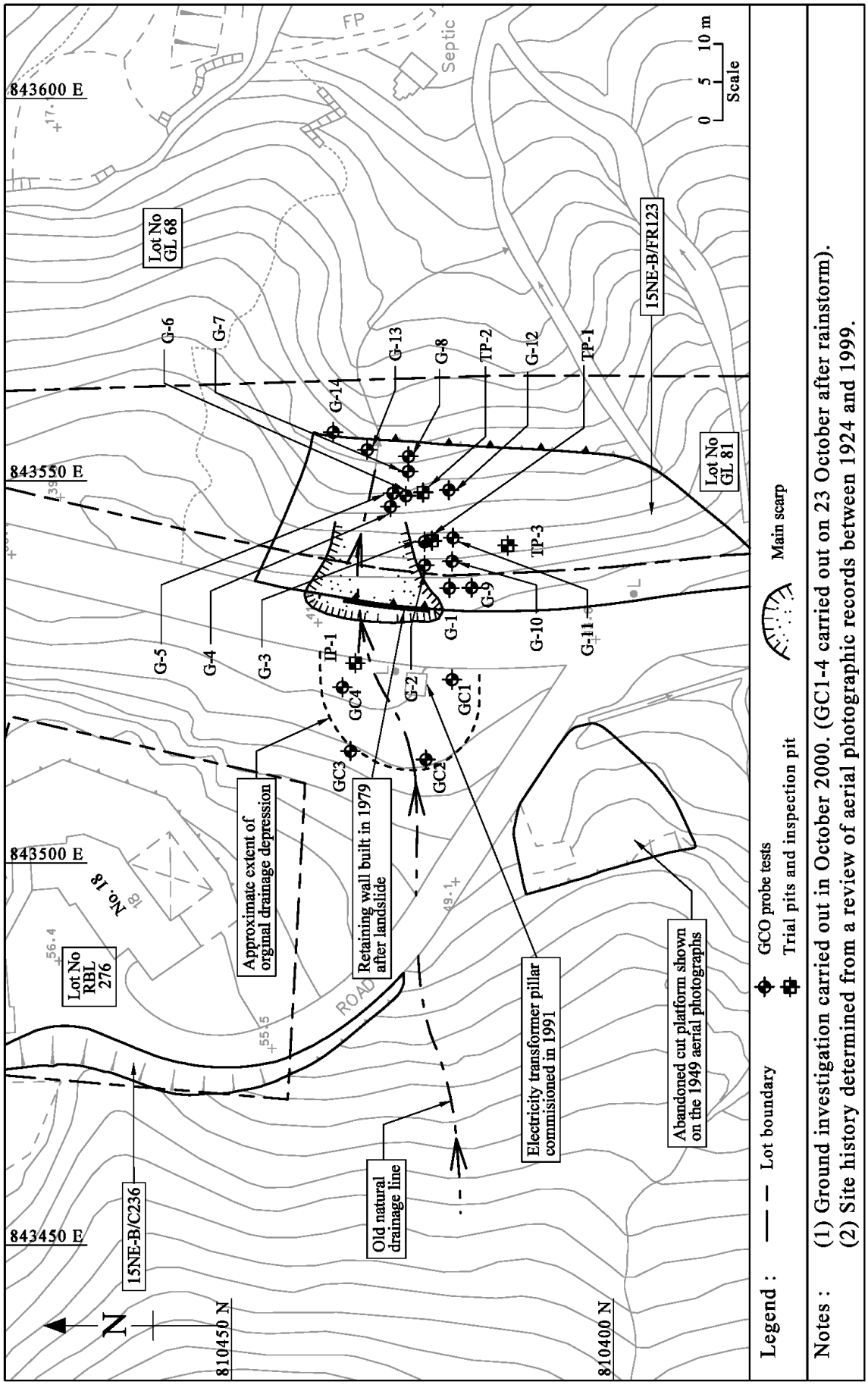
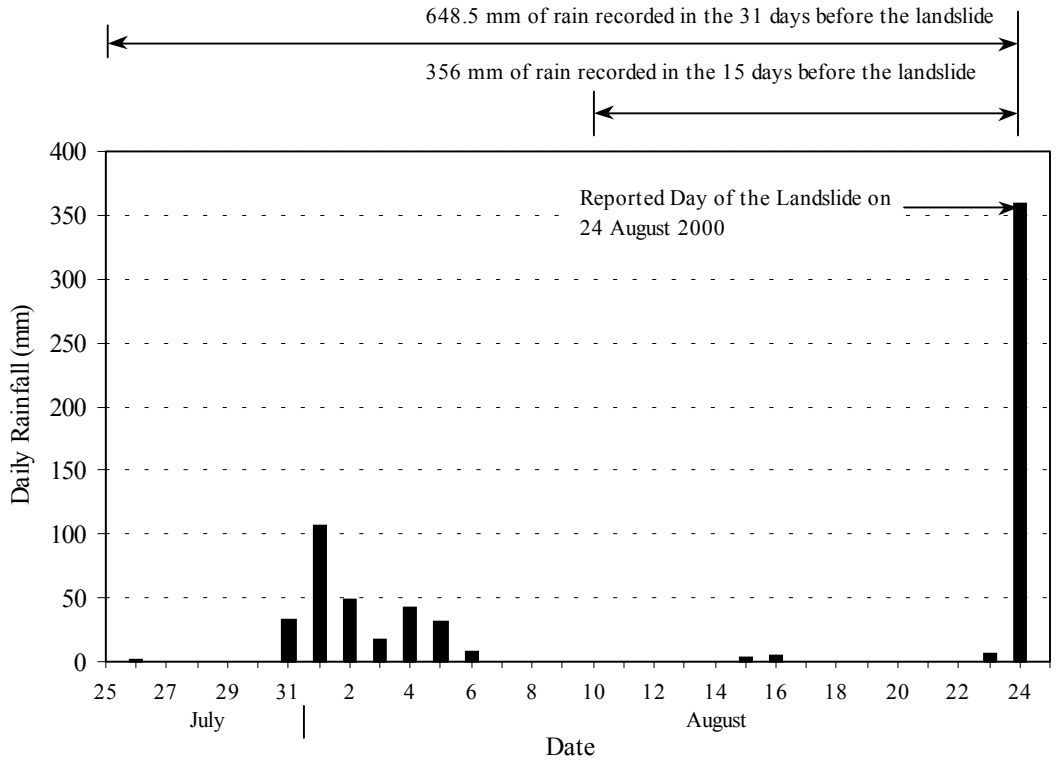
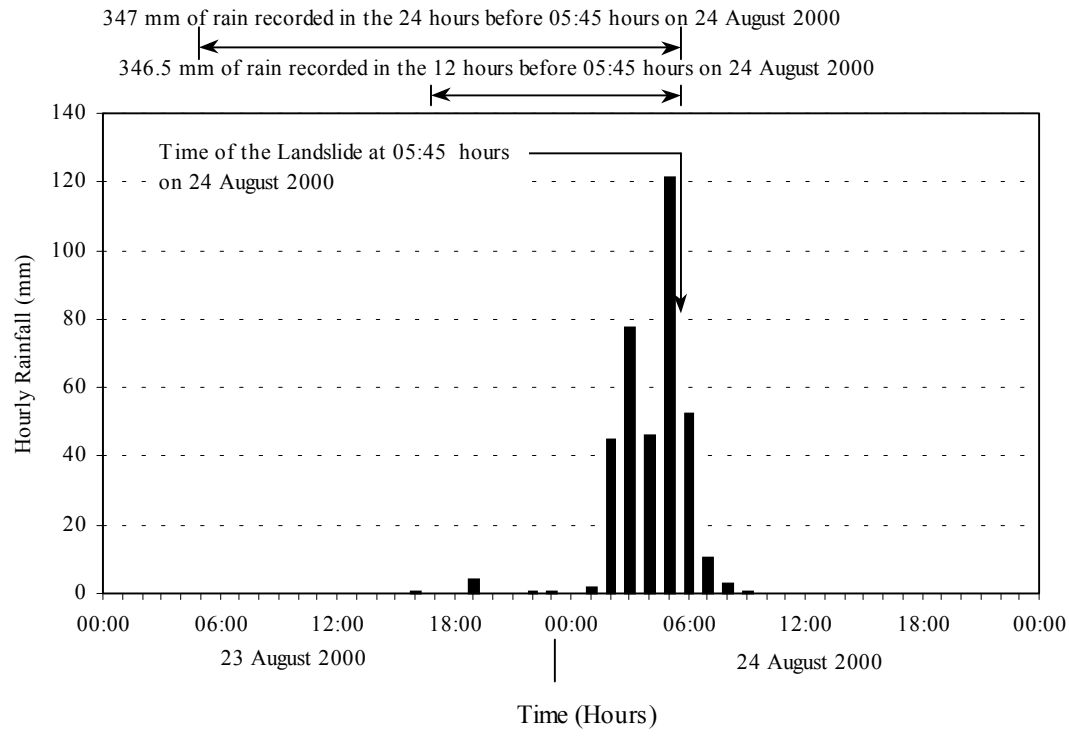


Figure 7 - Ground Investigation and Site History



(a) Daily Rainfall Recorded between 25 July and 24 August 2000



(b) Hourly Rainfall Recorded between 23 and 24 August 2000

Figure 8 - Rainfall Recorded at GEO Raingauge No. H28

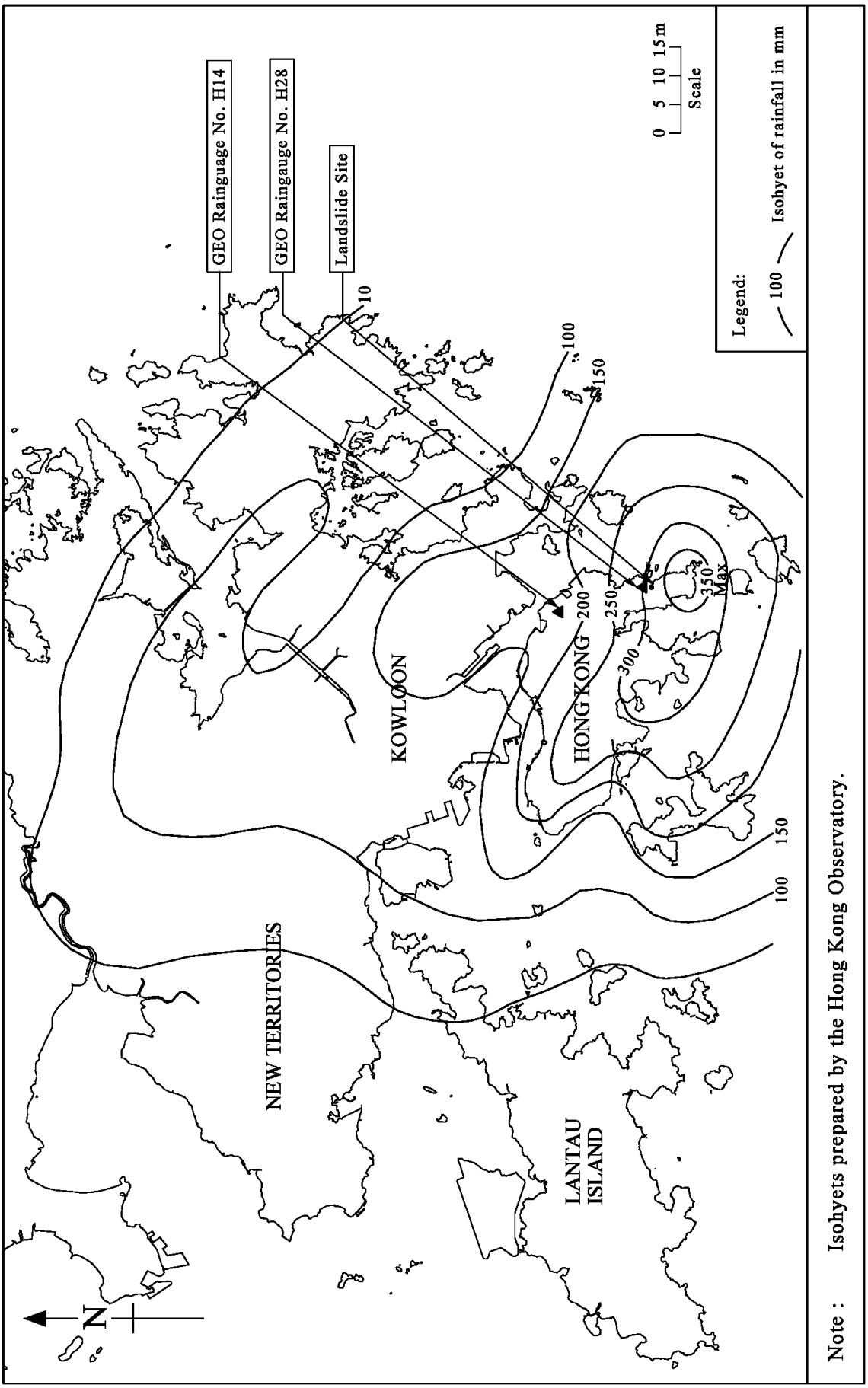
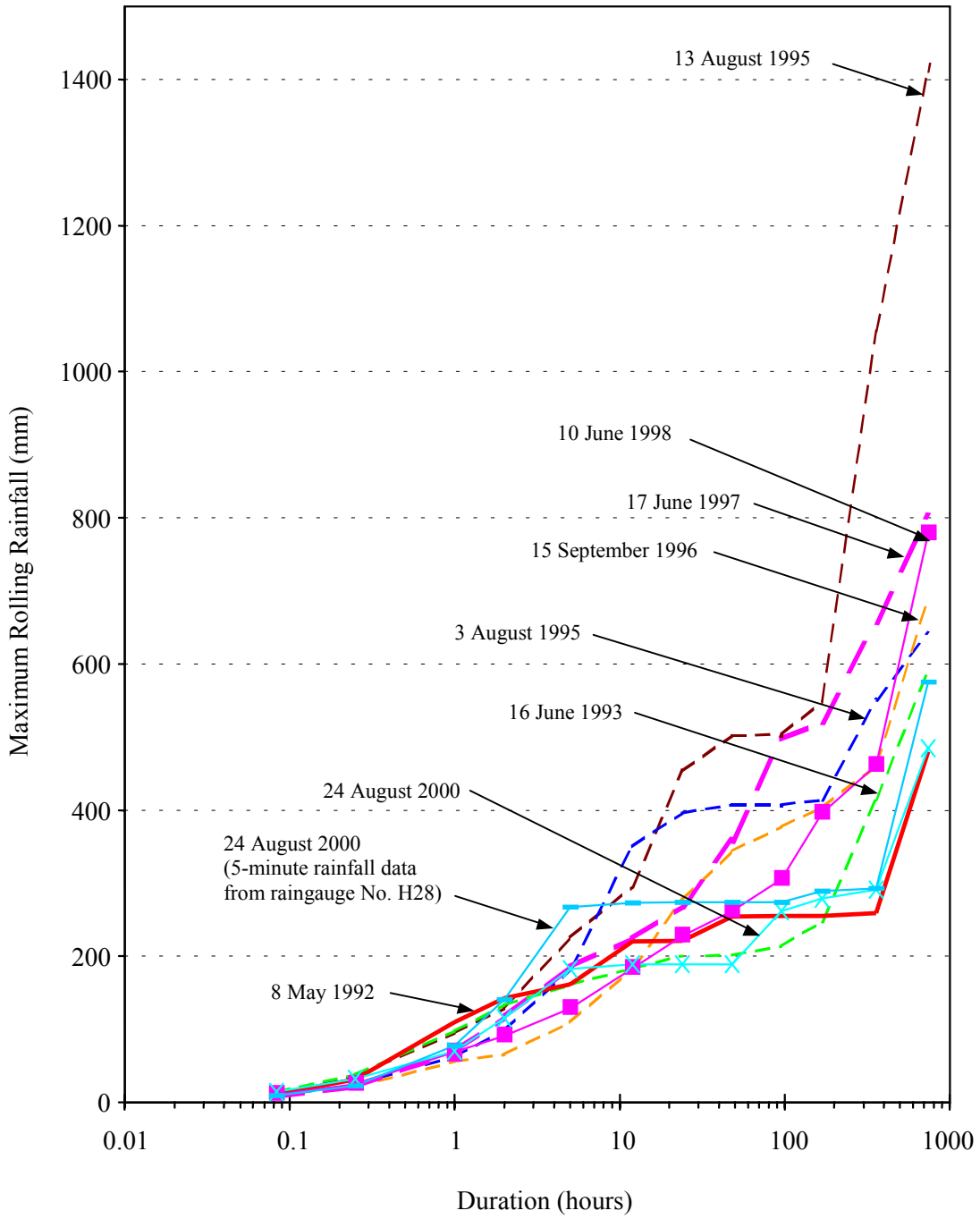


Figure 9 - Isohyets of Rainfall from 00:00 Hours to 05:45 Hours on 24 August 2000



Notes: (1) Rainfall data are 5-minute statistics from GEO raingauges Nos. H14 and H28.
(2) Since GEO raingauge No. H28 was installed after 1 November 1999, therefore, 5-minute rainfall data from raingauge No. H14 are used instead for comparison.

Figure 10 - Maximum Rolling Rainfall for Selected Major Rainstorms at GEO Raingauge Nos. H14 and H28

LIST OF PLATES

Plate 1 - Aerial View of the Landslide (Photograph Taken on 5 September 2000)

Plate 2 - Aerial View of the Landslide (Photograph Taken on 5 September 2000)

Plate 3 - General View of the Landslide (Photograph Taken on 24 August 2000)

Plate 4 - General View of the Main Scarp of the Landslide (Photograph Taken on 24 August 2000)

Plate 5 - Water Flowing from Access Road to No. 18 Shek O Road towards Slope No. 15NE-B/FR123 (Photograph Taken on 20 October 2000)

Plate 6 - Debris Washout onto the Golf Course (Photograph Taken on 24 August 2000)

Plate 7 - General View of the Collapsed Retaining Wall
(Photograph Taken on 29 August 2000)

Plate 8 - General View of the Masonry Toe Wall
(Photograph Taken on 24 August 2000)

Plate 9 - View Showing Northern End of the Masonry Toe Wall and Location from Where Masonry Blocks have been Dislodged (Photograph Taken on 24 August 2000)

Plate 10 - Ponding Water Adjacent to HEC Transformer Pillar (Photograph Taken on 20 October 2000)

Plate 11 - View Showing the Crack on Kerb on the Northbound Lane of Shek O Road (Photograph Taken on 11 September 2000)

Plate 12 - The Cracks with Maximum Width of 10 mm on the Concrete Foundation Pad of HEC Transformer Pillar (Photograph Taken on 10 October 2000)

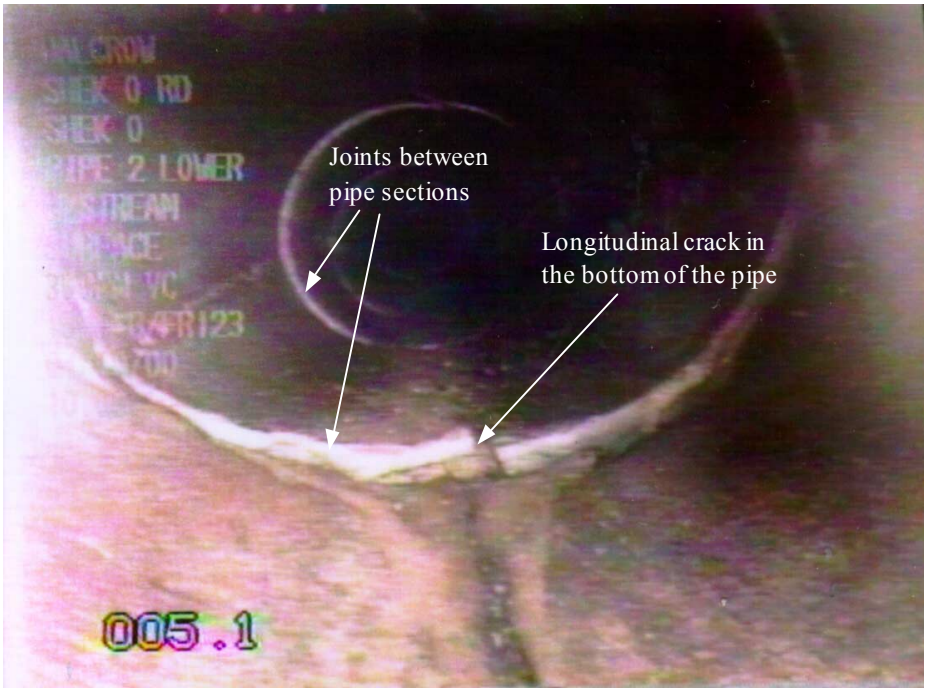


Plate 13 - Internal Condition of Lower 350 mm Diameter Vitrified Clay Drainage Pipe from CCTV Survey (Photograph Taken on 4 October 2000)

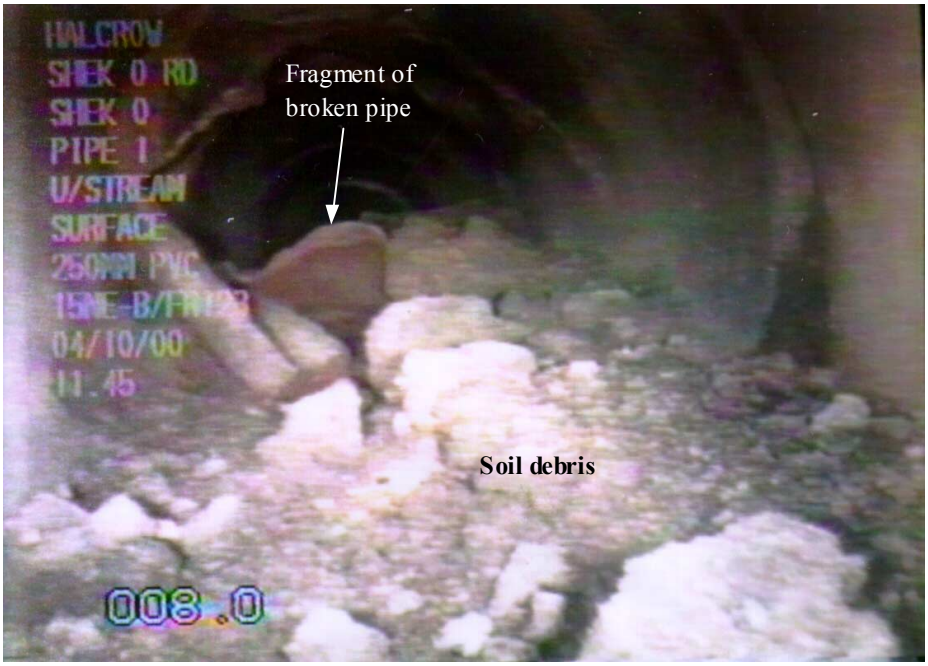


Plate 14 - Internal Condition of Upper 350 mm Diameter Vitrified Clay Drainage Pipe Showing Soil Debris from CCTV Survey (Photograph Taken on 4 October 2000)

APPENDIX A

REPORT OF AERIAL PHOTOGRAPH INTERPRETATION

CONTENTS

REPORT OF AERIAL PHOTOGRAPH INTERPRETATION

Feature No. 15NE-B/FR123
Location: Shek O Road, Opposite Access Road to No. 18

A1. INTRODUCTION

An aerial photograph interpretation (API) has been carried out as part of the desk study, for the purposes of formulating a site history and assessing the site conditions. A series of aerial photographs (listed in Section 5) have been studied. Photographs have typically been taken at an altitude of 4000 ft but some are from the higher altitude of 8000 ft. This report represents an interpretation of site history based largely an API together with ground truthing and analysis of all other available data. A sketch showing aspects identified from the aerial photographs and diagrams representating four significant periods in the history of the site are presented as Figures A1 and A2 respectively.

The landslide occurred at the northern end of a fill slope where it traverses an old drainage line.

In summary, the photographs show that the fill body was placed as part of the construction of Shek O Road some time before 1945. The slope at the location of the recent landslide, appears to have been subject to remedial works as the result of a discrete landslide in 1979, which included the provision of a hard surface cover over part of the slope and included the construction of the crest retaining wall affected by the 2000 landslide.

A2. SITE HISTORY

Year	Observations
1924	Photographs show the terrain along Big Wave Bay Road to the north of Shek O Road and the site of the 2000 landslide. Big Wave Bay Road is clearly visible and appears to have been recently completed – the road and adjacent development sites appear as solid white tone indicating bare soil or new concrete, set against dark, vegetated undisturbed natural terrain.
11.11.45	Moderate to poor resolution, high altitude aerial photographs; the eastern image has high contrast, the two images further west have low contrast.

Year	Observations
	The section of Shek O Road immediately to the east of No. 18 is formed on embankment where the road traversed a smaller valley within the larger catchment area. This smaller catchment was bounded by the large ridge through the future site of No. 18 that extends across Shek O Road immediately to the north of the slope later registered as slope No. 15NE-B/FR123, and by the smaller ridge that meets Shek O Road at the location of the future access road to No. 18. The slopes of the embankment are covered with dense vegetation which indicates that it was formed many years earlier. It is probable that the drainage for this depression, and the catchment upslope, passed under Shek O Road near the future location of the crest concrete retaining wall in slope No. 15NE-B/FR123. The original catchment formed an approximate triangle, with an apex some 200 m upslope from Shek O Road, and about 80 m wide at the road. An older, unoccupied cut platform and rear cut slope can be seen cut into the ridge on the southern side of the catchment. A small rectangular building is present on the platform. No. 18 Shek O Road is not present, although the cut slope to the north of the later landslide is clearly visible and unvegetated. An area of pale tone is visible crossing Shek O Road about 5 m to the south of the 2000 landslide.
8.5.49	Very grainy, slightly blurred, moderate resolution aerial photographs. The view is vertical, but the long focal length of the lens has flattened the relative relief. The natural vegetation is moderately dense, with many mature trees and bushes.

Year	Observations
	The access road to No. 18 appears to be recently formed, unpaved road, as it is very pale toned, and excavation works for the development platform for No. 18 are in progress. The lower part of the access road is built on fill, and some fill is seen spilling over the naturally vegetated slopes on the northern edges of the fill. A small valley is present between the access road and the ridge where the site formation for No. 18 is underway. Fill can be seen to be end-tipped on the southern and eastern sides of the cut and fill platform; the fill appears to have reached the northern end of the small drainage depression formed between the ridge that runs through the location of No. 18 and the Shek O Road embankment. The access road to No. 18 cut through the central part of this catchment, reducing the catchment to the area between the access road and Shek O Road. The downslope side of Shek O Road is mostly obscured by mature vegetation. The edge of the road appears to be less curved than the road alignment; at the apex of the curve, the road appears to be 10 m wide as compared to 8 m wide 20 m on either side. The downslope side of the road appears to be a very steep embankment. At the approximate location of the 2000 landslide, a mid-toned feature extends from approximately 3 m to the west of the eastern side of the road, eastwards for a distance of about 6 m, i.e. onto the embankment on the downslope side of the road. The western edge of this feature is parallel to the edge of the road and about 5 m long. The relative relief of this feature is not strong, but it appears to be a pile of earth or debris. A smaller wall appears to be present some 18 m to 20 m downslope, crossing the valley parallel to the road; downslope of the wall, the vegetation appears lower than the surrounding trees and bushes, and may be ground vegetation colonising an area of erosion. The Shek O Road carriageway shows signs of recent resurfacing at the junction with the access road to No. 18, as there is a dark toned rectangular section of road. Other dark-toned road sections are present to the south along Shek O Road.

Year	Observations
1.2.63	Shek O Road appears to be in its present configuration at the site of the 2000 landslide. The road appears to have a small, pale-toned parapet wall at the crest of the eastern embankment. Below the road crest, a small very steeply sloping, mid to dark toned apparently smooth surface may be the upper part of the embankment; the lower section is obscured by vegetation. Downslope of the lower (masonry toe) wall, the gullied drainage channels are clearly visible.
16.5.67	Medium altitude photography. No changes to the embankment terrain are apparent, except that the base of the slope on the western side of the embankment opposite the location of the 2000 landslide has become obscured by vegetation. Some locally taller trees are present on the side of the embankment in the area of the 2000 landslide. The downslope extension of the small convex slope between the two drainage lines on the upslope side of the road is marked by darker vegetation.
30.11.78	No changes to the embankment downslope of the road are apparent. The vegetation downslope of Shek O Road is becoming more dense and the crest of the embankment is not visible.
25.1.79	High altitude aerial photographs, but No. 24624 provides an oblique view of the terrain downslope of the road. A small, steep, mid to dark-toned area with low vegetation is visible through a narrow gap in the taller vegetation on the downslope side of the road, and this may be the upper section of the embankment prior to the 1979 landslide. The drainage line downslope is heavily vegetated, but lower vegetation can be seen along the gully downslope of the lower masonry toe wall.
14.9.79	Low altitude stereo pair. A white-toned, elongate area is prominent extending from the eastern edge of Shek O Road and the adjacent surface of Shek O Road has been resurfaced, indicating that remedial works to a landslide are complete.

Year	Observations
	The remedial works consist of a concrete retaining wall supporting the eastern side of Shek O Road; a dark-toned rectangle of new black-top is visible on the eastern half of the road surface, indicating that the failure had extended into part of the road surface. A small, dark sloping surface is visible on the southern side of the upper section of new hard surface, indicating that the hard surface has been placed within a concave depression into the embankment formed by the failure scar. The hard surfacing extends further downslope than the limit of the concave depression, indicating that the hard surface has been placed over the upper part of landslide debris across the embankment surface. A second pale-toned area is visible along the crest of the lower masonry toe wall; this second area appears rough textured and may be a pile of boulders from the landslide debris. The intervening section of the landslide trail is darker toned, and appears to be the landslide debris revegetating. Downslope of the lower masonry toe wall, the curving gully remains visible.
25.10.79	Single photograph, no stereo overlap. No significant changes are apparent.
24.11.80	High altitude photography. No significant changes are apparent.
26.10.81	High altitude photography. The pale-toned, hard-surfaced area downslope of the retaining wall is visible; the retaining wall is not clearly visible due to the view direction.
10.10.82	High altitude photography. The parapet wall, a dark mottled berm at the base of the crest concrete retaining wall and the hard surfaced area downslope are just visible. The crest concrete retaining wall is not visible due to the view direction.
15.10.82	Low level, high-resolution aerial photographs. Frame 45312 was taken to the east and just to the south of the crest concrete retaining wall, which is clearly visible as a white-toned, smooth feature. The berm at the base of the crest concrete retaining wall is clearly visible as a pale-toned structure with a large, dark-toned area in the centre. The dark-tone may be due to either seepage or low vegetation.

Year	Observations
	Within the resurfaced 1979 landslide scar downslope of the berm is a small patch of slightly darker tone that may be indicative of seepage.
	The masonry toe wall downslope of Shek O Road is not directly visible, but a line of paler-toned tree canopies marks its location.
	The edge of the eastern side of Shek O Road shows a white coloured, approx. 0.4 m wide strip; along the crest of the concrete retaining wall, this increases to approx. 0.8 m wide.
3.2.83	Low level, high-resolution aerial photographs. Both stereo pairs show similar features to those observed on the 15.10.82 photography.
27.9.83	Frame 49753 contains a high-oblique view of the crest concrete retaining wall, near the north west corner of the photograph. The wall appears darker than previously, but this is probably due to the photographic exposure conditions rather than any changes to the wall. The photograph was taken at about 12:55 pm and the wall is in partial shadow.
	Two bushes appear to be growing on the berm at the base of the crest concrete retaining wall that cast dark shadows on the basal platform; these shadows may account for some of the dark mottled appearance in earlier aerial photographs.
1.12.83	High altitude aerial photographs. No significant changes are apparent.
2.3.84	The crest concrete retaining wall is partially visible. The base of the concrete retaining wall appears as a mottled dark tone, indicative of irregular, damp soil, or a rough low vegetation cover. Two eastward extensions of the dark area are seen, extending onto the top of the pale-toned slope to the east and downslope.
22.10.84	The crest concrete retaining wall is in shadow, but the berm at the base of the wall is visible. A dark trace crosses the berm that appears to be due to water seepage from the wall. The shadow direction is towards the north-northeast.

Year	Observations
	The upper section of the slope immediately downslope of the berm appears to be rough, with a dark area in the centre. A thin bush appears to be present in the centre of this section of slope, and the dark area may be its shadow, although water staining cannot be discounted. The area downslope is also pale-toned, but appears to have a shallow channel curving from north to south as it moves from top to bottom. It is not clear when this depression was formed and it may even pre-date the 1979 landslide.
20.9.86	The crest concrete retaining wall is clearly visible and mostly pale-toned. The berm at the base of the retaining wall appears dark across its full width, and a line of three bushes can be seen growing along the length of the berm. The hard surface downslope of the berm is mostly pale toned, except for a dark downslope-oriented line running down the upper southern edge. The side edges of the structures downslope of the road are obscured by vegetation. The stream valley adjacent to and upslope of Shek O Road is obscured by trees.
9.9.87	The face of the crest concrete retaining wall appears dark, but this may be due to the exposure conditions. No changes are apparent. In frame A10426, slope No. 15NE-B/FR123 is located in the extreme northwest corner, so the view direction is from the south east; the side slope on the northern side of the retaining wall is visible and appears to be covered by ground vegetation.
27.9.88	The crest concrete retaining wall is clearly visible and is a uniform pale tone. The base of the wall is obscured by vegetation.
14.11.90	Frames A23878 – 23879 were taken to the north of slope No. 15NE-B/FR123, and A23907 – 23908 are from the south. The face of the crest concrete retaining wall is visible. A faint, thin, dark vertical line of unknown origin is visible on the face of the retaining wall. The base of the wall is obscured by vegetation. The electricity transformer pillar structure appears to be present on the western side of Shek O Road.

Year	Observations
4.10.91	The flight line passes almost directly over slope No. 15NE-B/FR123. The crest concrete retaining wall is visible, but a large bush and its shadow are obscuring the base of the wall (time of photography – 11:28 am). The face of the wall appears uniformly pale toned.
13.5.92	The photographs were taken at 14:55 pm, and the crest concrete retaining wall is in shadow and no details are visible. The valley downslope appears fully vegetated.
9.7.93	The photographs were taken at 14:40 pm, and the retaining wall is in shadow and no details are visible. The valley downslope appears fully vegetated.
5.12.93	The crest concrete retaining wall is visible. The base of the wall appears to be obscured by vegetation. No dark colouration is visible; the photographs were taken in the dry season, and long shadows obscure part of the base (taken at 11:15, shadows are from the south-southeast across the drainage line).
17.11.94	The berm is obscured by oblique deep shadows from the vegetation on the southern side of the retaining wall, as this photography was taken at 12:17 pm on a very sunny day. The flight line passes almost directly overhead above slope No. 15NE-B/FR123. Good view of the northern end of the crest concrete retaining wall downslope of the road, and the adjacent return slope 40 m north of the access to No. 18, marking the end of the embankment section of the road. The return makes a sharp approx. 65 degree angle with the retaining wall, and appears hard surfaced (same tone as the retaining wall, no visible junction or change in tone) for a distance of about 3 m. The eastern end of the concrete wall is obscured by vegetation but appears to turn northwards as the terrain reaches the hillside spur through which Shek O Road has been cut. The terrain downslope of the road is thickly vegetated and few ground details are visible. A gap in the toe vegetation appears to mark the flow area at the crest of the masonry wall in the northern minor valley.

Year	Observations
31.10.95	CN11752 – 53 shows the view from south of slope No. 15NE-B/FR123, CN11729 – 11730 show the view from the north. The crest concrete retaining wall is visible on all 4 frames, but the berm is visible only on the eastern, more-vertical frames, 11730 and 11752. Using the two more-vertical frames, 11729 and 11752 as a north-south oriented stereo pair, the concrete retaining wall is visible together with the berm. The berm appears dark, being partly in shadow, and a mixed grey-green and brown-grey colour, indicating low vegetation cover, possibly indicative of seepage. The 1979 landslide scar downslope is indicated by a linear depression in the vegetation crown (indicating younger vegetation) upslope of the masonry toe wall, leading to the crest concrete retaining wall supporting the road.
23.10.96	The crest concrete retaining wall is mostly obscured by shadow of the trees on the western side of the road as the photographs were taken at 14:21 pm. Slope No. 15NE-B/FR123 appears uniformly dark and no changes are apparent.
23.6.97	Slope No. 15NE-B/FR123 is mostly obscured by vegetation except for the crest. No changes are apparent.
23.10.98	The crest concrete retaining wall is visible, but the berm is obscured by vegetation and shadow. No changes are apparent.
8.9.99	Using CN23914 and CN23944 as a north-south oriented stereo pair, the crest concrete retaining wall and berm are visible. The berm appears uniformly pale toned, except for shadows on the southern part. The concrete retaining wall also appears uniformly pale-toned. Using CN 23113 and CN23114 as an east-west oriented stereo pair, the retaining wall and northern return are visible. A vertically extensive dark green-brown-grey toned area, narrowing downslope marks the angle between the concrete retaining wall and the adjoining slope, indicating a tapering of the wall towards the base.

A3. PAST INSTABILITY

There is no record of past instability, however there is inferential evidence from the above review of aerial photographs that a landslide occurred at the same location as the

landslide of 24 August 2000, sometime between January and September 1979. This inferred landslide lead to the provision of a hard (shotcrete) slope surface cover over part of the fill slope and the crest concrete retaining wall which subsequently failed in 2000.

A4. SURFACE HYDROLOGY

A drainage line is identified crossing from the natural terrain west of Shek O Road down through and below the northern end of the fill body (the east side of which is registered as slope No. 15NE-B/FR123). South of the fill slope is another drainage line which drains a larger catchment to the west and south.

A5. AERIAL PHOTOGRAPHS REVIEWED

Date	Reference No.	Altitude
1924	Y00038-00040	
11.11.1945	Y0343-00345	20,000’
8.5.1949	Y1120-1121 (81A/127: 6213-14)	8600’
1.2.1963	Y6820-6821 (11:6773-6772)	2700’
	Y6762-6764 (11:6630-6628)	
16.5.1967	Y13365-13366 (9:5670-5669)	6250’
30.11.1978	23682-23683, 23720-23721	4000’
25.1.1979	24624-24625	12,500’
14.9.1979	26764-26765	4000’
25.10.1979	27738	10,000’
24.11.1980	33226-33227	10,000’
26.10.1981	38951-38952	10,000’
10.10.1982	44407-44408	10,000’
15.10.1982	45311-45312	4000’
3.2.1983	47795-47796	4000’
1.12.1983	51731-51733	20,000’
2.3.1984	53801-53802	4000’
22.10.1984	56763-56764	4000’
20.9.1986	A06130-6131	4000’
9.9.1987	A10422-10423, A10426-10427	4000’
27.9.1988	A14567-14568	4000’

Date	Reference No.	Altitude
14.11.1990	A23879-23879, A23907-23908	4000’
4.10.1991	A28023-28025	4000’
13.5.1992	A31102-31103	4000’
9.7.1993	A35147-35149	4000’
5.12.1993	A37086-37088	4000’
17.11.1994	CN7980-7982	4000’
31.10.1995	CN11729-11730; CN11752-11753	4000’
23.10.1996	CN145421-145422	4000’
23.6.1997	CN17519-17520	4000’
23.10.1998	CN20996-20997, CN21040-21041	4000’
8.9.1999	CN23913-23914, CN23944	8000’

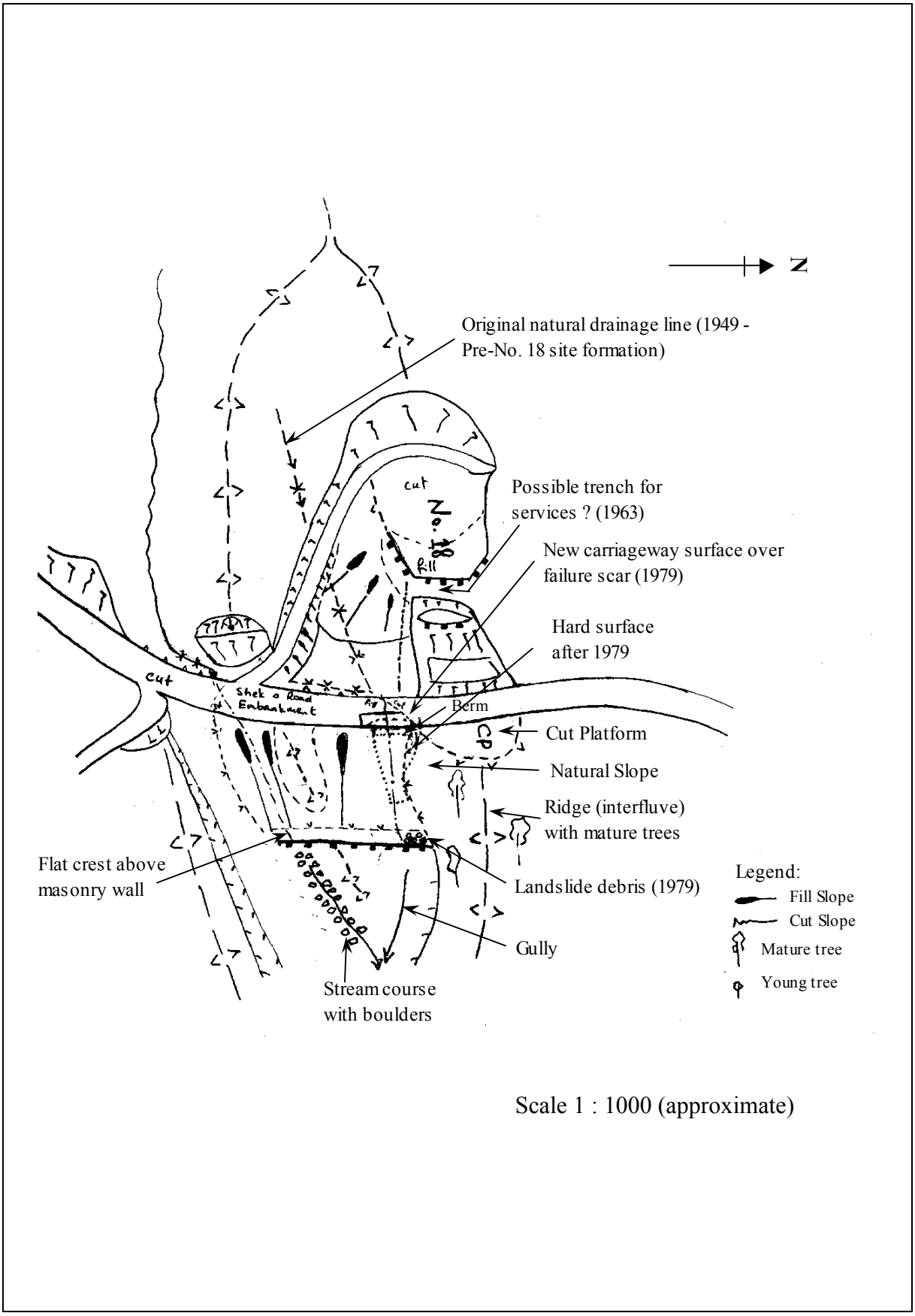
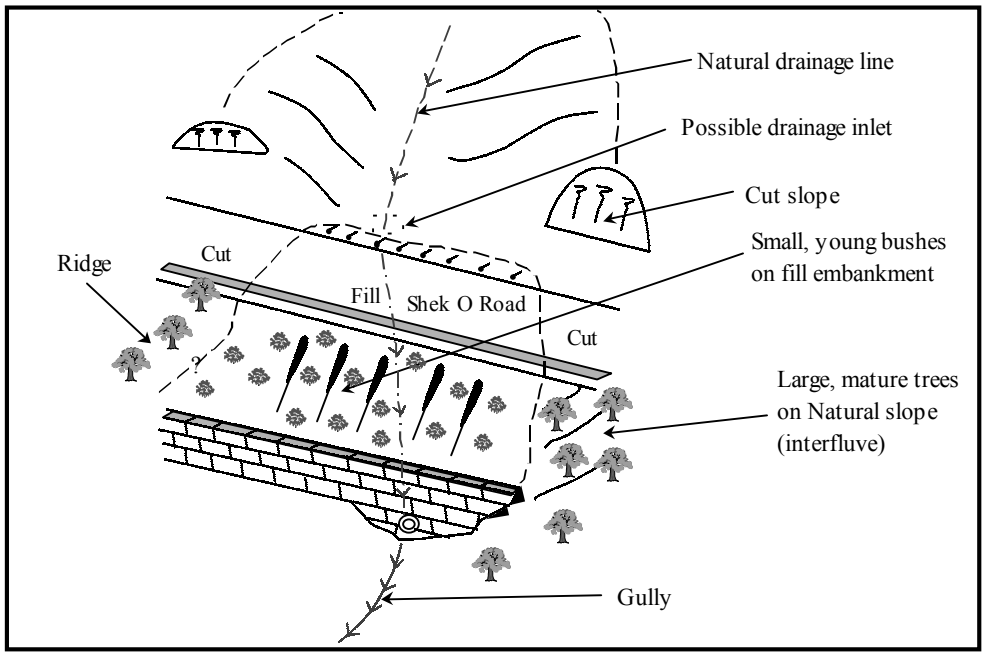


Figure A1 - Sketch Showing Aspects Identified from Aerial Photograph Interpretation

1945



1949

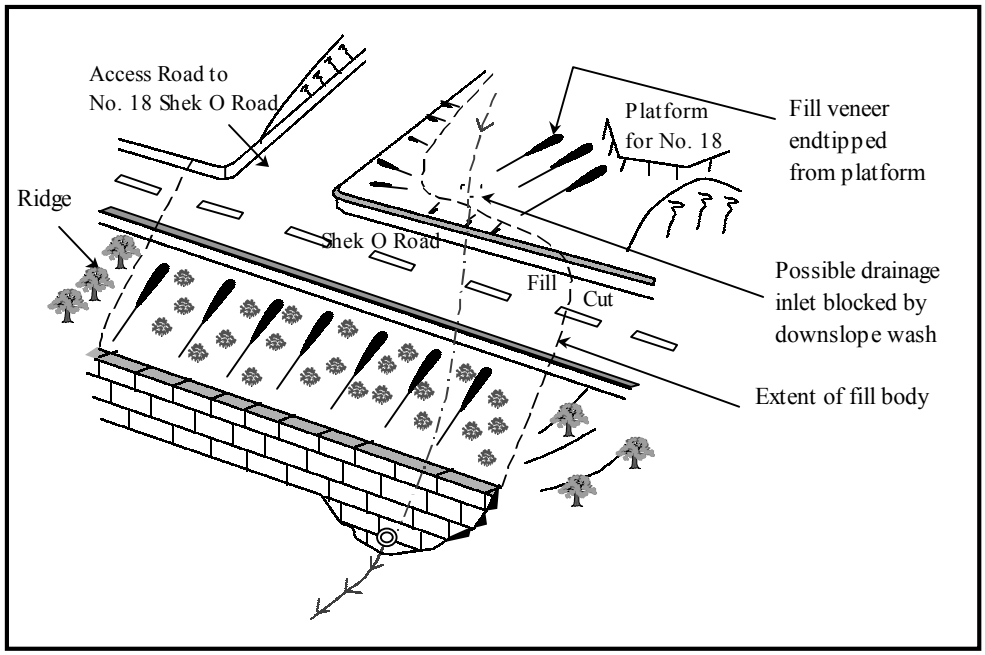
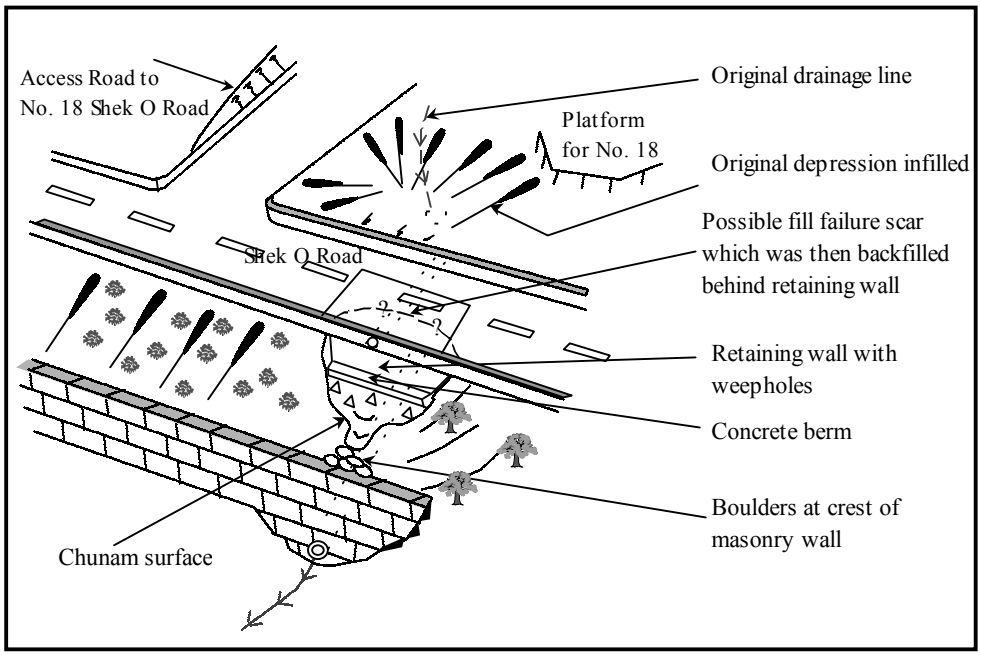


Figure A2 - Interpreted Site History (Sheet 1 of 2)

10.1979



2000

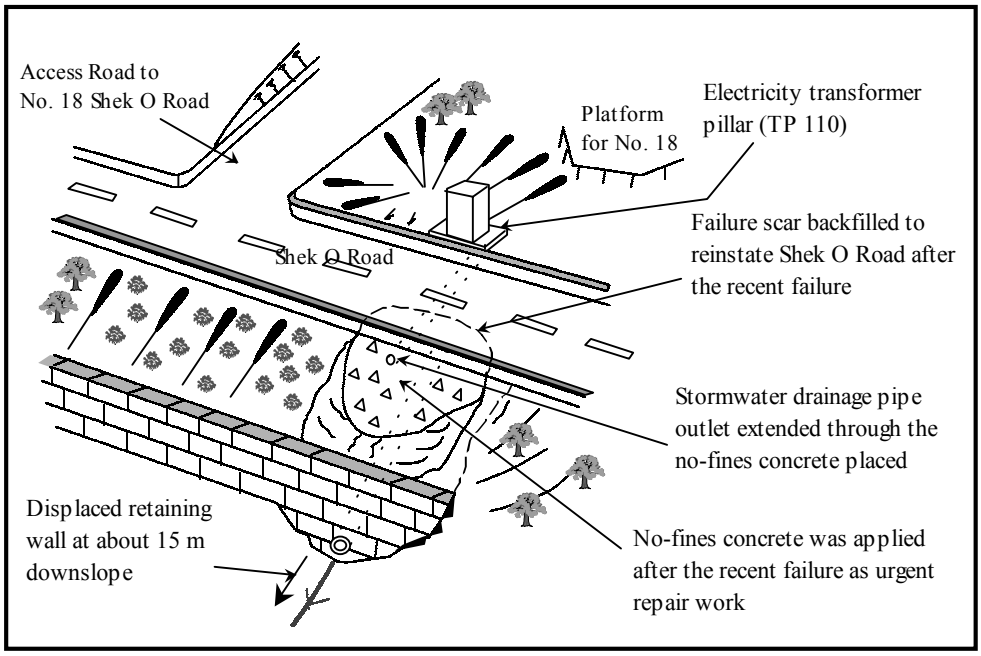


Figure A2 - Interpreted Site History (Sheet 2 of 2)

APPENDIX B

TRIAL PIT AND INSPECTION PIT LOGS

Halcrow China Limited - Agreement No. CE 2/2000
Landslide Investigation Consultancy for Kowloon and the New Territories in 2000 and the First Quarter of 2001
Landslide on Fill Slope Below Shek O Road on 24 August 2000

TRIAL PIT RECORD

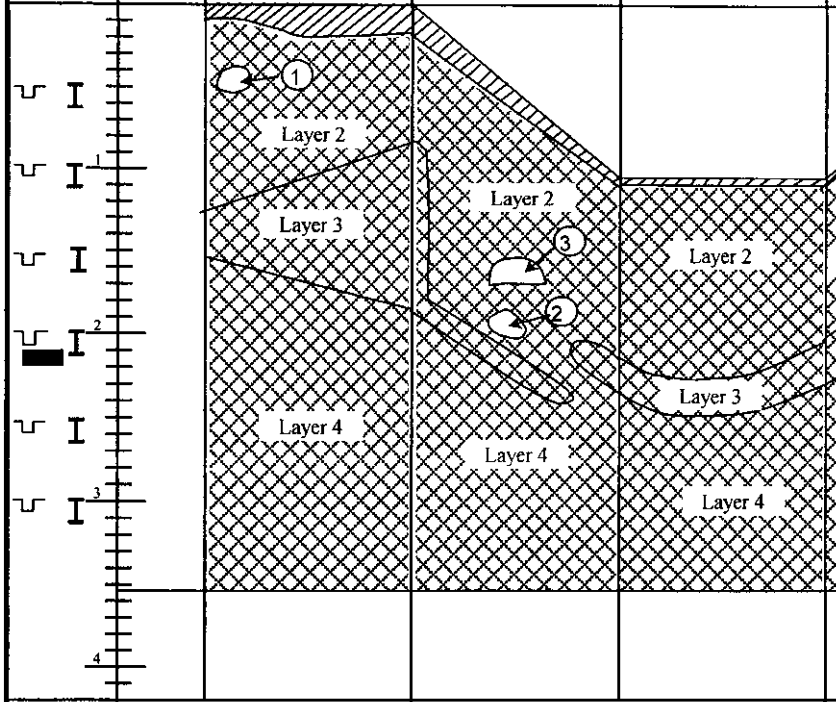
Sheet 1 of 1

TRIAL PIT NO. TP1

Co-ordinates: 843542.14 E
810423.76 N
Ground Level: 36.88mPD

Excavation Date: 3-10-00 Backfilling Date:11-10-00

Logged By: Priscilla Huong Date: 9-10-00
Checked By: Martin Devonald Date: 11-10-00



Description

Loose, dry, greyish brown, slightly clayey, silty fine to coarse SAND with much fine to coarse sub-angular to angular gravel, some angular cobbles and many tree roots. (TOPSOIL)

Loose, moist, yellowish brown, slightly clayey, silty fine to coarse SAND, with some angular fine gravel and occasional tree roots. (FILL)

Loose, moist, reddish brown, silty fine to coarse SAND, with some fine to coarse gravel and cobbles. (FILL)

Loose to medium dense, moist, yellowish brown, slightly clayey, silty SAND,with some fine to medium gravel and occasional angular cobbles and tree roots. (FILL)

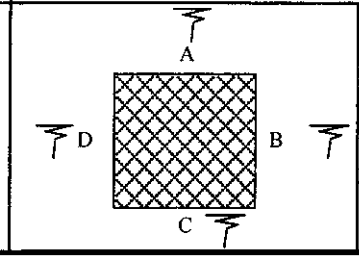
Trial Pit completed at 3.55m.

SYMBOL

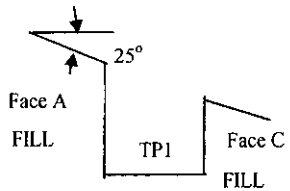
SAMPLES / TEST / WATER

- Small Disturbed Sample
- Large Disturbed Sample
- U100/U76
- Undisturbed Sample
- Block Sample
- Insitu Density Test
- Water Sample
- Seepage

PLAN (not to scale)



SECTION (A - C)



REMARK

Maximum Depth: 3.55m Average Depth: 3.0m
Shoring: Yes Stability: STABLE
Water Seepage: No

① Cobble of Completely Decomposed Granite
② Cobble of Moderately Decomposed Granite
③ Termite nest

Halcrow China Limited - Agreement No. CE 2/2000
Landslide Investigation Consultancy for Kowloon and the New Territories in 2000 and the First Quarter of 2001
Landslide on Fill Slope Below Shek O Road on 24 August 2000

TRIAL PIT RECORD

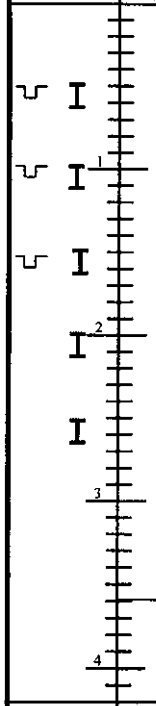
Sheet 1 of 1

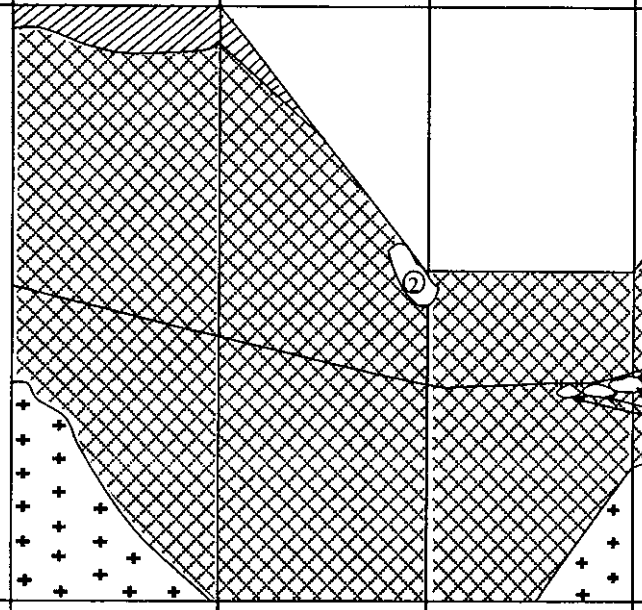
TRIAL PIT NO. TP2

Excavation Date: 3-10-00 Backfilling Date:11-10-00

Co-ordinates: 843548.46 E
840424.92 N
Ground Level: 32.69mPD

Logged By: Priscilla Huong Date: 8-10-00
Checked By: Martin Devonald Date: 11-10-00

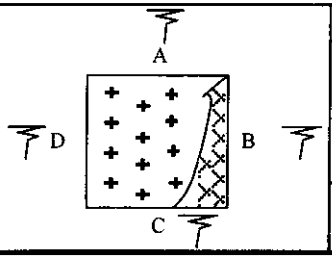




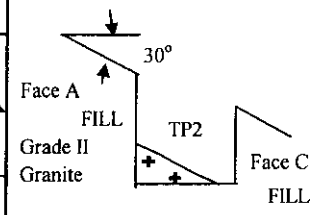
Legend	Grade	Description
		Loose, dry, greyish brown, slightly clayey, silty fine to coarse SAND with much fine to coarse sub-angular to angular gravel, some angular cobbles and many tree roots. (TOPSOIL)
		Loose, moist, yellowish brown, slightly clayey, silty fine to coarse SAND, with some fine to medium sub-angular to angular gravel and occasional angular cobbles. (FILL)
		Loose, moist, yellowish brown, clayey, silty fine to coarse SAND, with much fine to medium sub-angular to angular gravel and occasional tree roots. (FILL)
	II	Strong, grey, coarse-grained slightly decomposed GRANITE.
		Trial Pit completed at 3.6m.

SYMBOL	SAMPLES / TEST / WATER
H	Small Disturbed Sample
I	Large Disturbed Sample
□	U100/U76
▯	Undisturbed Sample
■	Block Sample
⊔	Insitu Density Test
▲	Water Sample
⇲	Seepage

PLAN (not to scale)



REMARKS



Maximum Depth: 3.6m Average Depth: 2.7m
Shoring: Yes Stability: STABLE
Water Seepage: No

① Cobbles of Highly Decomposed Granite
② 70 mm dia. cobble of Slightly Decomposed Granite

Halcrow China Limited - Agreement No. CE 2/2000
Landslide Investigation Consultancy for Kowloon and the New Territories in 2000 and the First Quarter of 2001
Landslide on Fill Slope Below Shek O Road on 24 August 2000

TRIAL PIT RECORD

Sheet 1 of 1

TRIAL PIT NO. TP3

Co-ordinates: 843541.51 E
810413.86 N
Ground Level: 38.13mPD

Excavation Date: 3-10-00 Backfilling Date:11-10-00

Logged By: Priscilla Huong Date: 8-10-00
Checked By: Martin Devonald Date: 11-10-00

Samples and Tests	Depth (m)	FACE A: 1.5m	FACE B: 1.5m	FACE C: 1.5m	FACE D: 1.5m	Legend	Grade	Description
	0							Loose, dry, greyish brown, slightly clayey, silty fine to coarse SAND with much fine to coarse sub-angular to angular gravel, some angular cobbles and many tree roots. (TOPSOIL)
	1							Dense, dry, brown, slightly clayey, silty fine to coarse SAND with much fine to medium sub-angular to angular gravel and some tree roots. (FILL)
	2							Loose, moist, reddish brown, slightly clayey, silty fine to coarse SAND with much sub-angular to angular fine to medium gravel and occasional tree roots. (FILL)
	3							Dense, moist, yellowish brown, very clayey medium to coarse sandy SILT with occasional tree roots. (FILL)
	4							Trial Pit completed at 3.5m.

SYMBOL	SAMPLES / TEST / WATER	PLAN (not to scale)	SECTION (A - C)	REMARK
	Small Disturbed Sample Large Disturbed Sample U100/U76 Undisturbed Sample Block Sample Insitu Density Test Water Sample Seepage	A, B, C, D; KEY: 103°, North Arrow	35°; Face A FILL; TP3; Face C FILL	Maximum Depth: 3.5m Average Depth: 3.0m Shoring: Yes Stability: STABLE Water Seepage: No ① Cobble of Highly Decomposed Granite ② Cobble of Moderately Decomposed Granite ③ Cobbles of Slightly Decomposed Granite

Halcrow China Limited - Agreement No. CE 2/2000
Landslide Investigation Consultancy for Kowloon and the New Territories in 2000 and the First Quarter of 2001
Landslide on Fill Slope Below Shek O Road on 24 August 2000

TRIAL PIT RECORD

Sheet 1 of 1

TRIAL PIT NO. IP1

Co-ordinates: 843542.14 E
810423.76 N
Ground Level: 36.88mPD

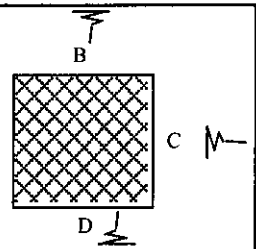
Excavation Date: 9-10-00 Backfilling Date:9-10-00

Logged By: Priscilla Huong Date: 9-10-00
Checked By: Martin Devonald Date: 11-10-00

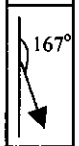
Samples and Tests	Depth (m)	FACE A: 0.75m	FACE B: 0.75m	FACE C: 0.75m	FACE D: 0.75m	Legend	Grade	Description
	1							Loose, dry, greyish brown, slightly clayey, silty fine to coarse SAND with much fine to coarse sub-angular to angular gravel, some angular cobbles and many tree roots. (TOPSOIL)
	2							Loose, dry, light brown, slightly clayey, silty fine to coarse SAND, with fine to coarse angular gravel and occasional cobbles and some tree roots. (FILL)
	3							Loose, dry, grey, slightly clayey, silty fine to coarse SAND, with much medium to coarse gravel and occasional cobbles and many tree roots. (FILL)
	4							Loose, moist, reddish brown, slightly clayey, silty fine to coarse SAND, with much fine to medium gravel and occasional cobbles and tree roots. (FILL)
								Loose, moist, yellowish brown, slightly clayey, silty fine to coarse SAND, with some fine to medium gravel and occasional cobbles and tree roots. (FILL)
								Inspection Pit completed at 2.1m.

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

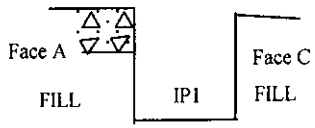
PLAN (not to scale)



KEY



North Arrow



REMARK

Maximum Depth: 2.1m Average Depth: 2.0m
Shoring: No Stability: STABLE
Water Seepage: No

① Cobble of Slightly Decomposed Granite
② Cobble of Highly Decomposed Granite

Concrete from TP foundation pad

APPENDIX C

GCO PROBE TEST RESULTS

Table C1 - Summary of GCO Probe Test Results from 5 October 2000

Depth (mbGL)	GCO Probe Test Number									
	G1	G2	G3	G4	G5	G6	G7	G8	G9	G10
	Blows /100mm	Blows /100mm	Blows /100mm	Blows /100mm	Blows /100mm	Blows /100mm	Blows /100mm	Blows /100mm	Blows /100mm	Blows /100mm
0.1	8	6	5	1	2	3	3	4	7	3
0.2	7	6	3	1	1	3	2	5	6	3
0.3	15	6	3	1	1	5	2	5	5	2
0.4	10	6	3	3	1	4	2	3	1	2
0.5	5	4	3	3	2	3	2	2	3	3
0.6	3	5	3	2	1	2	2	1	2	5
0.7	3	6	4	2	6	2	2	1	2	5
0.8	3	6	4	2	5	2	2	2	2	5
0.9	4	7	4	3	3	2	2	1	2	4
1.0	3	4	2	4	3	5	2	4	2	5
1.1	3	4	3	5	3		3	2	1	4
1.2	3	1	3	3	3	2	3	2	2	6
1.3	3	2	3	4	3	3	4	4	3	6
1.4	4	3	2	4	4	2	4	6	4	6
1.5	3	7	3	4	3	2	4	5	5	6
1.6	2	2	4	5	4	2	3	5	3	5
1.7	2	2	3	5	4	3	4	5	4	4
1.8	2	3	3	4	4	3	5	4	4	6
1.9	1	3	4	4	5	4	4	4	4	5
2.0	1	3	3	5	5	4	3	3	4	3
2.1	3	4	4	5	6	4	5	7	3	4
2.2	2	4	4	5	5	3	6	17	4	4
2.3	3	5	4	4	6	3	24	12	4	6
2.4	2	5	4	5	9	4	15	15	5	6
2.5	3	4	6	10	6	6	22	42	5	6
2.6	5	4	4	7	11	5	29	26	6	7
2.7	4	4	4	7	7	6	100	51	14	6
2.8	3	5	5	8	7	100		100	6	5
2.9	4	5	7	9	3				5	5
3.0	3	4	5	8	5				6	3
3.1	4	6	6	10	7				6	4
3.2	5	11	6	6	6				6	4
3.3	4	4	6	100	17				6	5
3.4	4	4	5		19				5	5
3.5	5	5	5		22				5	6
3.6	4	5	6		22				6	7
3.7	5	6	5		80				6	6
3.8	5	7	5		100				6	8
3.9	4	7	6						4	8
4.0	6	6	5						5	10
4.1	6	7	5						5	12
4.2	3	8	5						5	9
4.3	7	6	5						6	8
4.4	6	7	150						6	6
4.5	4	6							6	11
4.6	6	6							6	16
4.7	6	9							8	17
4.8	5	9							8	15
4.9	5	9							9	11
5.0	7	5							9	43
5.1	7	10							11	82
5.2	5	14							16	100
5.3	5	9							10	
5.4	6	7							9	
5.5	7	7							10	
5.6	6	12							10	
5.7	6	17							12	
5.8	7	100							9	
5.9	8								9	
6.0	7								10	
6.1	6								10	
6.2	7								13	
6.3	7								46	
6.4	6								78	
6.5	15								100	
6.6	13									
6.7	15									
6.8	19									
6.9	12									
7.0	7									
7.1	4									
7.2	7									
7.3	33									
7.4	49									
7.5	70									
7.6	100									

Table C1 - Summary of GCO Probe Test Results from 5 October 2000

Depth (mbGL)	GCO Probe Test Number									
	G11	G12	G13	G14	G15	G16	G17			
	Blows /100mm	Blows /100mm	Blows /100mm	Blows /100mm	Blows /100mm	Blows /100mm	Blows /100mm			
0.1	4	3	6	6	2	3	2			
0.2	2	2	5	4	4	3	3			
0.3	3	3	4	4	4	3	3			
0.4	4	5	2	4	3	2	3			
0.5	4	4	2	9	3	2	3			
0.6	4	3	3	5	3	3	4			
0.7	5	3	3	4	5	2	3			
0.8	5	3	3	5	4	3	5			
0.9	4	2	3	5	4	4	4			
1.0	5	2	61	4	3	5	4			
1.1	5	4	3	5	2	4	3			
1.2	6	8	6	11	3	5	3			
1.3	4	9	3	14	2	4	3			
1.4	5	11	6	10	2	6	4			
1.5	4	8	4	12	2	3	7			
1.6	4	31	4	11	4	4	4			
1.7	4	28	4	6	4	3	4			
1.8	4	28	3	14	6	4	5			
1.9	5	28	13	8	6	11	6			
2.0	4	30	6	8	5	100	4			
2.1	5	55	8	8	5		5			
2.2	7	76	8	11	5		5			
2.3	7	100	8	11	4		5			
2.4	7		8	12	5		4			
2.5	7		6	13	6		4			
2.6	8		3	15	5		4			
2.7	8		3	16	6		4			
2.8	5		8	14	5		4			
2.9	7		1	18	4		4			
3.0	7		2	19	4		4			
3.1	5		9	52						
3.2	52		100	30						
3.3	100			31						
3.4				100						
3.5										
3.6										
3.7										
3.8										
3.9										
4.0										
4.1										
4.2										
4.3										
4.4										
4.5										
4.6										
4.7										
4.8										
4.9										
5.0										
5.1										
5.2										
5.3										
5.4										
5.5										
5.6										
5.7										
5.8										
5.9										
6.0										
6.1										
6.2										
6.3										
6.4										
6.5										
6.6										
6.7										
6.8										
6.9										
7.0										
7.1										
7.2										
7.3										
7.4										
7.5										
7.6										

Table C2 - Summary of GCO Probe Test Results from 23 October 2000

Depth (mbGL)	GCO Probe Test Number									
	GC1	GC2	GC3	GC4						
	Blows /100mm	Blows /100mm	Blows /100mm	Blows /100mm						
0.1	6	3	1	2						
0.2	2	4	1	4						
0.3	1	3	6	2						
0.4	1	4	10	2						
0.5	1	4	6	1						
0.6	-	4	2	3						
0.7	-	6	2	3						
0.8	-	4	5	2						
0.9	-	5	3	2						
1.0	-	4	2	2						
1.1	2	2	100	14						
1.2	2	4		30						
1.3	3	3		7						
1.4	1	3		3						
1.5	1	3		4						
1.6	1	3		3						
1.7	3	4		5						
1.8	2	3		4						
1.9	3	5		7						
2.0	2	8		100						
2.1	3	27								
2.2	3	100								
2.3	3									
2.4	3									
2.5	3									
2.6	4									
2.7	4									
2.8	3									
2.9	2									
3.0	3									
3.1	6									
3.2	10									
3.3	3									
3.4	2									
3.5	3									
3.6	3									
3.7	3									
3.8	1									
3.9	12									
4.0	10									
4.1	100									
4.2										
4.3										
4.4										
4.5										
4.6										
4.7										
4.8										
4.9										
5.0										
5.1										
5.2										
5.3										
5.4										
5.5										
5.6										
5.7										
5.8										
5.9										
6.0										
6.1										
6.2										
6.3										
6.4										
6.5										
6.6										
6.7										
6.8										
6.9										
7.0										
7.1										
7.2										
7.3										
7.4										
7.5										
7.6										