INVESTIGATION OF SOME SELECTED LANDSLIDES IN 2000 (VOLUME 3)

GEO REPORT No. 131

Fugro Maunsell Scott Wilson Joint Venture

First published, December 2002

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PREFACE

In keeping with our policy of releasing information which may be of general interest to the geotechnical profession and the public, we make available selected internal reports in a series of publications termed the GEO Report series. 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
December 2002

EXPLANATORY NOTE

This GEO Report consists of three Landslide Study Reports on the investigation of selected slope failure occurred in 2000. The investigations were carried out by Fugro Maunsell Scott Wilson Joint Venture (FMSW) for the Geotechnical Engineering Office as part of the 2000 and 2001 Landslide Investigation Consultancy.

The LI Consultancies aim to achieve the following objective through the review and study of landslides:

(a) establishment of an improved slope assessment methodology,

(b) identification of slopes requiring follow-up action, and

(c) recommendation of improvement to the Government's slope safety system and current geotechnical engineering practice in Hong Kong.

The Landslide Study Reports prepared by FMSW are presented in two sections in this Report. Their titles are as follows:

The Landslip Investigation Division of the Geotechnical Engineering Office worked closely with the LI Consultants and provided technical input and assistance to the landslide studies.

SECTION 1: DETAILED STUDY OF THE 24 AUGUST 2000 LANDSLIDE NEAR 2B BOWEN ROAD

Fugro Maunsell Scott Wilson Joint Venture

This report was originally produced in August 2001 as GEO Landslide Study Report No. LSR 8/2001

FOREWORD

This report presents the findings of a detailed study of a landslide (GEO Incident No. HK2000/08/006) which occurred on 24 August 2000 involving unregistered fill on the hillside adjacent to No. 2B Bowen Road on Hong Kong Island. Debris from the landslide, with an estimated volume of 120 m^3, entered the adjacent nullah and was transported downstream for a long distance beyond the landslide site (up to about 250 m on plan) to reach Hong Kong Park below Kennedy Road.

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

The report was prepared as part of the 2000/2001 Landslide Investigation Consultancy (LIC) for Hong Kong Island and Outlying Islands, for the Geotechnical Engineering Office (GEO), under Agreement No. CE 1/2000. This is one of a series of reports produced during the consultancy by Fugro Maunsell Scott Wilson Joint Venture (FMSW).

Y.C. Koo
Project Director
Fugro Maunsell Scott Wilson Joint Venture

Agreement No. CE 1/2000
2000 and 2001 Landslide Investigation Consultancy for Hong Kong Island and Outlying Islands

CONTENTS

1. INTRODUCTION

At around 5:30 a.m. on the morning of 24 August 2000, a landslide (GEO Incident No. HK2000/08/006) occurred on the terrain adjacent to No. 2B Bowen Road during the period of a Black Rainstorm Warning (Figure 1 and Plate 1). Debris from the landslide entered an adjacent nullah and was transported downstream for a long distance beyond the landslide site (up to about 250 m on plan) to reach Hong Kong Park below Kennedy Road. No fatalities or injuries were reported as a result of the landslide. One of the two westbound lanes of Kennedy Road was blocked temporarily by the landslide debris.

Following the landslide, Fugro Maunsell Scott Wilson Joint Venture (FMSW, the 2000/2001 Landslide Investigation Consultants for Hong Kong Island and Outlying Islands) carried out a detailed study of the failure for the Geotechnical Engineering Office (GEO), Civil Engineering Department (CED), under Agreement No. CE 1/2000.

The key objectives of the study were to document the facts about the landslide, present relevant background information and establish the probable causes of the failure. The scope of the study comprised desk study, site reconnaissance, ground investigation and laboratory testing. 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) aerial photograph interpretation,

(c) topographical survey, geological mapping, and detailed observations and measurements at the landslide site,

(d) ground investigation and laboratory testing,

(e) analysis of rainfall records, and

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

2. THE SITE

2.1 Site Description

The landslide site is located on the terrain above Bowen Road, adjacent to the high-rise residential development at No. 2B, “Fairlane Tower” (Figure 1 and Plate 1). The general landform in this area consists of a broad, northerly-trending spur feature comprising mostly undeveloped hillside between Magazine Gap Road (at 200 mPD) and Bowen Road (at 119 mPD). The terrain typically slopes at angles of about 25° to 50°, and at about 35° at the landslide site. The terrain is vegetated with small to medium size trees and a dense undergrowth of grass and shrubs. The area below Bowen Road has been extensively developed as residential estates.

A natural drainage line is located to the west of the landslide site, initially trending in a NNW direction below Magazine Gap Road, before turning NNE at an elevation of 140 mPD and back to NNW at Bowen Road. A masonry-lined nullah measuring 1.5 m wide and 1.5 m deep occupies the drainage line below 140 mPD and extends below Bowen Road, passing beneath MacDonnell Road (at 80.5 mPD) and Kennedy Road (at 55.5 mPD) before entering Hong Kong Park about 250 m on plan to the north.

The site formation for No. 2B Bowen Road, located about 20 m east of the landslide site, comprises a building platform measuring roughly 1500 m^2 in area excavated into the spur at an elevation of about 120 mPD. Slope No. 11SW-B/C180 (Figure 1) is a soil/rock cut which extends above the southern edge of the platform. The slope is approximately 30 m high, with slope angles in the range of 35° to 65° and is protected with a shotcrete surface cover. Slope No. 11SW-B/C179 extends along the western edge of the platform and to the west along Bowen Road as far as the nullah. This slope is up to 8 m in height, with slope angles in the range of 20° to 45° and a hydroseeded surface cover. Slope No. 11SW-B/CR613 in the vicinity of the 24 August 2000 landslide site was registered a short time after the landslide. It is noted that the boundary of the recently registered feature does not correspond entirely to the repaired landslide scar (Figure 1).

The boundary of Lot No. IL8845 (i.e. No. 2B Bowen Road) is shown on Figure 1 and broadly encloses the building platform and a substantial portion of slope No. 11SW-B/C180. The "Green Hatched Black" (GHB) areas associated with the lease conditions of No. 2B Bowen Road, which extend to the east, south and west of the lot boundary and partially contain the landslide site, are also shown in Figure 1. GHB areas comprise Government land, the maintenance responsibility of which has been assigned to an adjacent private lot under the lease agreement (Section 2.3).

2.2 Water-carrying Services and Utilities

According to the available information, there are no recorded water-carrying services in the vicinity of the landslide site. Desk study indicates that a water tank was previously located on the hillside about 10 m to the east of the 2000 landslide scar but this was removed during the re-development of No. 2B Bowen Road in the 1990's (Section 3.2). A survey plan from this time also shows a well adjacent to the water tank; however, this could not be identified on site by FMSW and no further records relating to the well could be located.

The layout of the surface drainage channels, gas utilities and reported locations of the water tank and well are shown on Figure 2. Surface drainage channels associated with slope No. 11SW-B/C180 converge at a catchpit approximately 12 m southeast of the 2000 landslide scar, from which a 450 mm stepped channel extends in a westerly direction, passing within a short distance of the landslide scar, and discharges into the adjacent nullah. A gas supply utility box (Plate 2) and gas pipeline are located along the eastern side of the nullah at the toe of the 2000 landslide.

2.3 Maintenance Responsibility

According to the Slope Maintenance Responsibility Information System of the Lands

Department, slopes within the GHB areas are under the maintenance responsibility of the owners of Lot No. IL8845 (i.e. No. 2B Bowen Road).

3. SITE HISTORY AND PREVIOUS STUDIES

3.1 General

The development history of the landslide site and details of previous studies carried out on the western GHB area have been compiled from a review of the available aerial photographs and relevant documentation. Details of observations from aerial photographs are given in Appendix A and the salient points are presented in the following sections.

3.2 Site History and Past Landslides

The main observations in relation to the history of the landslide site are shown on Figure 3. The 1945 aerial photographs show a track extending across the hillside on a similar alignment to Bowen Road. Vegetated hillside, comprising a broad northerly-trending spur feature defined by two natural drainage lines to the east and west extends above the path to Magazine Gap Road.

The 1949 aerial photographs show that Bowen Road had been formed to its present alignment and a lined nullah constructed in the western drainage line. A building platform had been excavated into the hillside above road level at the present location of No. 2B Bowen Road and a building was under construction on the platform. The site formation resulted in the formation of a large cut slope (registered as slope No. 11SW-B/C180 on the 1977/78 Catalogue of Slopes, see Section 3.3). This cut slope extended along the eastern, southern and western edges of the platform and a drainage channel extending from the slope to the nullah is visible above the August 2000 landslide site. The hillside to the west of the cut slope and below the channel was disturbed about mid-way to the nullah and was occupied by four huts, which appear to be associated with the adjacent construction works. Minor filling/spoiling is visible around the huts, and notably at and above the August 2000 landslide site. The remaining portion of the hillside extending to the nullah was heavily vegetated.

In the 1963 aerial photographs, the building on the platform at the present location of No. 2B Bowen Road had been demolished and the platform was unoccupied. The entire portion of hillside extending west from the platform was heavily vegetated, completely obscuring the ground surface.

The 1967 aerial photographs show the building site at the present location of No. 2B Bowen Road to have been re-developed and a multi-storey building was constructed. Additional site formation works had been carried out to lower the platform to the level of Bowen Road. The cut slope surrounding the platform had been modified, notably at the western edge, where it had been cut back and covered with chunam. A portion of the hillside immediately to the west of the cut slope and below the August 2000 landslide site was cleared of vegetation and the lower area terraced to form two narrow platforms, with retaining walls along the lower edge. The remainder of the hillside to the west of the cleared area was heavily vegetated.

No significant changes in the area were observed between 1967 and 1993. Vegetation became heavier on the cleared portion of slope, obscuring the ground surface, while the platforms remained visible. Repair/replacement of the chunam surfacing on slope No. 11SW-B/C180 was visible in the 1978 photographs and around the platforms in 1980. A water tank was visible on the hillside about 30 m above Bowen Road and 10 to 15 m west of slope No. 11SW-B/C180 from 1979 onwards.

The building present during this time was also named Fairlane Tower and the building lot was referenced as Lot No. IL6363 and No. 7B Bowen Road. The lease arrangements for Lot No. IL6363 contained GHB area clauses (Section 2.1), which covered two small areas extending east and west of the lot boundary respectively (Figure 3). In early 1993, the lot owners applied for modification to the lease agreement to re-develop the site as the present Fairlane Tower. The extent of the modification resulted in a new lease agreement being drawn up and the lot was given the new reference of IL8845 and No. 2B Bowen Road. The revised lot boundary is shown on Figure 3. The extent of the western GHB area was also increased at this time.

The 1991 and 1994 aerial photographs show possible breaks, or changes, in the vegetation at the August 2000 landslide site, which may be indicative of previous instability. However, neither the GEO landslide database nor the Natural Terrain Landslide Inventory (NTLI) records any past instability in the general vicinity.

A “mud-flow” in the western GHB area was observed by a local resident in May 1992, who reported the incident to the District Lands Office (DLO) in February 1993. The GEO inspected the area in March 1993 in relation to the proposed re-development of No. 2B Bowen Road and identified illegally formed concrete platforms, which were cracked and undermined, as well as bare soil cut faces, a water tank, burnt rubbish and debris. GEO suggested that the “mud-flow” incident “may be resulted from the excavated materials or rubbish/debris left over the hillside being washed down by rainwater during the rainstorm”. The GEO recommended to the DLO that the boundary of the western GHB area should be extended under the new lease agreement to its present alignment in order to cover the areas of illegal construction. The GEO also made recommendations on repair works for the affected area, which included removal of the water tank, provision/repair of chunam and removal of rubbish and debris.

No. 2B Bowen Road was re-developed as the present Fairlane Tower by Fairlane Holding Corporation (FHC - the lot owners) between 1994 and 1999. The DLO wrote to the lot owners in January 1994 with respect to the illegal construction within the western GHB area and requested removal and reinstatement as a “matter of urgency”. Desk study records indicate that the water tank was removed prior to April 1994. Slope trimming works were carried out in the vicinity of slope No. 11SW-B/C179 resulting in the present geometry. Clearance and slope re-profiling works were completed for the remainder of the western GHB area (with the mature trees left in place), following which the entire western GHB area was hydroseeded (Plates 3, 4 and 5). The boundary of slope No. 11SW-B/C180 was extended to the south and west during the re-development of the site, which required the GHB areas to be further extended (Figure 3), increasing the extent of the eastern GHB area and creating a southern GHB area. The extension of the slope included the construction of a new crest channel, which was connected into the existing surface drainage system at the catchpit located above the August 2000 landslide site.

3.3 Previous Studies

In April 1978, slopes Nos. 11SW-B/C179 and 11SW-B/C180 were inspected by Binnie and Partners as part of the "Phase I Re-appraisal of Cut and Natural Slopes and Retaining Walls Study" and were subsequently included in the 1977/78 Catalogue of Slopes (Binnie and Partners, 1978).

In August 1993, CYS Associates (Hong Kong) Ltd (CA - Architects for FHC) submitted a set of "General Building Plans" to the Buildings Department (BD) for the proposed re-development of No. 2B Bowen Road as the present Fairlane Tower, noting that a "geotechnical assessment report" would be submitted. The GEO noted in October 1993 that all adjacent slopes would be affected by the development and "…substantial geotechnical input…" would be necessary in future submissions.

In July 1994, a "Report on Stability Study of Existing Slopes and Walls in I.L. 8845 at 7B Bowen Road Hong Kong" was submitted by the geotechnical consultants for the Fairlane Tower project, MAA Engineering Consultants Ltd (MAA, 1994). The report focused on existing features within the lot boundary and did not consider the GHB areas. BD approved the submission in September 1994, on the condition that an assessment report be submitted on the "effect of the existing water tank and the concrete platform on the stability of slopes/walls to the west of the site".

The GEO initiated the consultancy agreement entitled "Systematic Inspection of Features in the Territory" (SIFT) in 1992 which, inter alia, aimed to identify features not registered in the 1977/78 Catalogue of Slopes and to update information on registered slopes based on studies of aerial photographs and limited site inspection. Slopes Nos. 11SW-B/C179 and 11SW-B/C180 were both designated as Class 'C1', i.e. a slope "…formed or substantially modified before 30.6.78 or to have been illegally formed after 30.6.78" by the SIFT study in August 1994. However, SIFT did not identify the zones of fill material on the terrain within the present western GHB area.

In October 1994, CA made a submission to BD entitled "Formation Green Area Submission" which included details of the proposed site formation works in the western GHB area. A tree survey report and geotechnical report for the site formation works prepared by the structural consultants, HK Cheng and Partners Ltd (HKC), were also included in the submission. The proposed works comprised the removal of the existing water tank, concrete platforms, a staircase linking the platforms and broken chunam, the trimming of all steep terraces to 45° and the protection of bare surfaces with hydroseeding or turf. It was also proposed that the GHB area would be "inspected by the engineer and improvement and protective works to be carried out as directed".

MAA informed the GEO in December 1994 that a note was to be added to the site formation drawing to the effect that remedial and stabilisation works to the western GHB area should be submitted to BD for approval before completion of the site formation works as per PNAP 168. BD approved the site formation plans in December 1994.

In January 1995, CM Wong and Associates Ltd (CMW) replaced MAA and HKC as the structural and geotechnical consultants. CMW submitted a report entitled "Slope Stability Analysis for the Western Slopes" and amended site formation plans for the "Green

Area" to BD in February 1995. The GEO advised that they had no adverse geotechnical comment on the plans and the report on the western GHB area, but requested verification of the slope geometry, as the illegal platforms and the water tank had not been shown on the topographical survey plans included with the submission.

In March 1995, CMW submitted a report to the BD entitled "The Effect of Existing Water Tank and Concrete Platform on the Stability of Slopes/Wall on the West, 7B Bowen Road Hong Kong" (CMW, 1995a). The report presented the results of stability analyses, which included Section X-X and Section Y-Y (locations shown on Figure 3), the latter of which cut along the northeastern edge of the August 2000 landslide scar. The ground models assumed for the analyses were based on data from the adjacent drillholes BH3 to BH5 (Figure 6), which was completed as part of the site-specific ground investigation for the Fairlane Tower project and indicated Grade V tuff throughout. Shear strength parameters adopted for the Grade V tuff (i.e. $c'=7$ kPa and $\phi'=36°$) were based on laboratory test results. Groundwater levels assumed for Section X-X and Section Y-Y were taken as 15 m and 3 m above the "actual" levels (no information was given to elaborate what "actual" levels referred to); however, no groundwater monitoring data was presented to support this assumption. The minimum calculated factors of safety based on the above assumptions were 1.376 (Section X-X) and 1.448 (Section Y-Y). The report concluded that the "slope/wall" to the west of the site would not be adversely affected by the water tank and concrete platform and that the slope was "safe with respect to current design standards".

In April 1995, the GEO noted that the concrete platform still existed and had been undermined, "imposing a threat to the public using Bowen Road". The GEO stated that the topographic survey and profiles used in the report required verification and that the above assessment report should be re-submitted.

In October 1995, CMW submitted the "Supplementary Geotechnical Assessment Report on the Effect of the Existing Water Tank and Concrete Platform on the Stability of the Slopes/Walls to the West" (CMW, 1995b) to BD, which presented revised stability analyses based on updated survey information. Three sections were cut through the western GHB area (Sections 1-1, 2-2 and 3-3 on Figure 3). Only Sections 1-1 and 2-2 were analysed in the report.

The ground models and shear strength parameters were the same as that previously adopted in the former report by CMW (1995a) and the design geological model did not include any fill. The design groundwater levels were similar to those given in the earlier submission for Section Y-Y. Surcharge loads of 7.2 kPa and 24 kPa were applied at the concrete platforms, with 5 kPa assumed elsewhere for human access. The minimum calculated factors of safety were 1.255 and 1.342 for Sections 1-1 and 2-2 respectively. The report concluded that the required minimum factor of safety of 1.2 was achieved without the need for any upgrading works within the western GHB area. The GEO advised that they had no adverse geotechnical comment on the submission in October 1995.

In May 1998, CMW submitted a Maintenance Manual for "Slope No. 11SW-B/C179 Western Green Hatched Black Area" (CMW, 1998a) to the GEO. The manual described the "existing slope" at the western GHB area as comprising slope No. 11SW-B/C179 and a "natural slope with some man-made features", and outlined the works to be carried out within the area, which were the same as those proposed in the October 1994 submission by CA

(see above). The manual also indicated that following completion of the works, the extent of slope No. 11SW-B/C179 should be revised to include the entire western GHB area. Record photographs show the western GHB area to have been recently hydroseeded (Section 3.2).

Also in May 1998, CMW submitted a "Slope Inspection Report" for the western GHB area (CMW, 1998b) to BD. The report stated that CMW had inspected the western GHB area and that the works indicated on drawings relevant to the "Site Formation (Green Formation Area)" had been carried out.

In July 1998, the GEO's Island Division requested the Slope Safety Division to update the boundary of slope No. 11SW-B/C179 to include the entire western GHB area.

The consultancy agreement entitled "Systematic Identification and Registration of Slopes in the Territory" (SIRST) was initiated by the GEO in 1994 to update the 1977/78 Catalogue of Slopes and to prepare a New Catalogue of Slopes. SIRST inspections were carried out for slope No. 11SW-B/C179 on 15 December 1994 and 3 August 1998. Documentation from the August 1998 inspection includes photographs showing the slope works in the western GHB area to have been completed. However, details of the slope geometry and surface cover recorded at the time appear to be inconsistent (e.g. a 26 m high slope with 75% of the surface cover being shotcrete shown in the SIS record as opposed to an 8 m high slope with a vegetated cover in reality).

4. THE LANDSLIDE

4.1 Description of the Landslide

Based on the results of the post-failure topographic survey of the landslide site, the general topography and profile of the landslide are presented on Figures 4 and 5.

The landslide was reported by a security guard from the adjacent construction site as having occurred at about 5:30 a.m. on 24 August 2000. The landslide exposed fill on the northwesterly sloping ground along the southern extent of the western GHB area (Plate 1). The landslide occurred in an area which is not registered in the New Catalogue of Slopes. The landslide scar measured approximately 4 m to 12 m in width and was about 12 m long on plan. The main scarp was located about 22 m (on plan) upslope from the masonry-lined nullah and a short distance from the surface drainage channels associated with slope No. 11SW-B/C180. Landslide debris comprising soil, cobbles and vegetation with an estimated volume of about 120 m^3 entered the nullah and was transported approximately 250 m (on plan) to Hong Kong Park below Kennedy Road. A small proportion of the debris was deposited on the western side of the nullah opposite the scar (Figure 4 and Plate 2). The travel angle of the landslide debris (Wong & Ho, 1996) is estimated to be about 34° to the base of the nullah opposite the scar.

The maximum depth of the landslide scar, measured normal to the surface of rupture, was about 1 to 1.5 m. The scar was planar in appearance, with the main scarp dipping at 50° and with relatively well defined flanks. The surface of rupture dipped sub-parallel to the inferred pre-failure ground surface (inclined at about 35°). The toe of the surface of rupture was poorly defined and was estimated to lie about 10 m on plan above the nullah. General views of the landslide scar are presented in Plates 6 and 7. Material exposed in the scar

comprised fill of sandy, clayey silt with distinct layering and voiding within selected layers. A topsoil horizon was exposed beneath the fill in two erosion channels, about 0.5 m wide and 0.1 m to 0.2 m deep, on the surface of rupture.

The debris that entered the nullah caused blockage of the channel at MacDonnell Road and Kennedy Road, resulting in overflow of water and debris onto the respective carriageways, and into Hong Kong Park via access steps off Kennedy Road (Figure 1).

4.2 Observations Made Following the Landslide

The landslide site was inspected by the GEO and HyD at about 2:30 p.m. on 24 August 2000. The GEO Incident Report described the failure as a landslide which had occurred in "possibly disturbed terrain" and recorded no signs of seepage at the failure location. The FMSW inspection team visited the site at about 4:00 p.m. on 24 August 2000.

The surface drainage channels and catchpit associated with slope No. 11SW-B/C180 located above the landslide scar were observed to have been blocked with vegetation (Figure 4 and Plate 8). There was also evidence of overland flow in the form of aligned vegetation and surface erosion between the channel and the main scarp (Figure 4 and Plate 9). No groundwater seepage was noted from the scar area at the time of inspection.

The detailing of the surface drainage provisions associated with slope No. 11SW-B/C180 at this location tends to concentrate surface runoff at the catchpit above the landslide site (Figure 4). The topography of the shotcreted terrain above slope No. 11SW-B/C180 is such that runoff from this local catchment (about 300 m^2) would be directed towards the area immediately upstream of the catchpit. The westerly flowing drainage channel entering the catchpit does not have an upstand to cope with the high entry velocities of flows from the shotcreted area, hence giving rise to the potential to overshoot onto the western GHB area. The northerly flowing drainage channel upstream of the catchpit (Figure 4) has been formed above the surrounding ground surface (by about 400 mm). This has the effect of runoff being directed from upslope (with a local catchment of about 700 m^2) along the outer face of the channel to the downstream side of the catchpit. The detailing of the surface drainage provisions in this area is liable to lead to surface water being directed towards the landslide site.

Bowen Road was observed to be free of debris on 24 August 2000, while much of the debris remained on MacDonnell Road and Kennedy Road (Plate 10), with paths having been cleared to permit the passage of vehicles. From the landslide scar to MacDonnell Road, the nullah is an open stepped-channel. It is culverted beneath Bowen Road and MacDonnell Road, with a trash screen located upstream of the MacDonnell Road culvert. Much vegetation and debris was observed blocking the culvert beneath Bowen Road. The debris deposited on MacDonnell Road comprised a very wet, sandy, clayey silt with gravel, some cobbles and vegetation.

Between MacDonnell Road and Kennedy Road, the nullah is covered with stepped concrete slabs, which form a pedestrian access between the two roads. At the Kennedy Road level, the concrete slabs had lifted (Plate 11), allowing water and debris to inundate the carriageway. The debris on Kennedy Road comprised predominantly orangish-brown sandy,

clayey silt and was noted to be coarser than that on MacDonnell Road, with more gravels and cobbles observed. The debris was very wet, with much excess water resulting from the blockage and subsequent overflow of the nullah.

4.3 Urgent Repair Works

Recommendations on urgent repair works were made by the GEO following a joint site inspection with the BD on 31 August 2000. Urgent repair works were arranged by the owners of No. 2B Bowen Road and comprised the removal of loose material form the landslide scar and the application of a 75 mm thick layer of reinforced shotcrete with weepholes. The works were completed on 21 September 2000.

5. SUBSURFACE CONDITIONS

5.1 General

The subsurface conditions within the landslide site have been assessed on the basis of information obtained from the desk study, field mapping and post-failure ground investigation.

5.2 Previous Ground Investigation

Previous ground investigation carried out in the vicinity of the landslide site was associated with the Fairlane Tower re-development in the mid-1990's and included eight drillholes, five trial pits and three surface strips. The locations of previous investigation stations are shown in Figure 6. No previous investigation has been carried out within and adjacent to the August 2000 landslide site.

5.3 Post-2000 Landslide Ground Investigation

The exposed landslide scar was mapped by FMSW on 24 August 2000 and 5 September 2000. The relevant observations are presented on Figure 4.

The post-landslide ground investigation was carried out between February and March 2001 and comprised six trial pits to a maximum depth of 3 m, one vegetation strip and the retrieval of disturbed and undisturbed samples. The locations of ground investigation stations are indicated on Figure 6. GCO probing was carried out at each trial pit location and at other locations on the local hillside. Insitu density tests were carried out within the pits. The results of this work are reported in Gammon Construction Ltd (2001). Insitu density test results are summarised in Table 1.

Laboratory testing on samples included classification, moisture content determination and compaction tests. A summary of the laboratory test results is presented in Table 1.

5.4 Information from Geological Maps

Sheet 11 of the Hong Kong Geological Survey 1:20 000 scale map series HGM20 (GCO 1986) indicates that the solid geology of the landslide site and its surroundings is fine ash vitric tuff from the Ap Lei Chau Formation of the Repulse Bay Volcanics Group (Figure 7). Two NNW-trending photogeological lineaments are indicated on the map which coincide with the natural drainage lines defining the spur feature containing the landslide site.

5.5 Geology at the Landslide Site

The landslide scar exposed about 1 m to 1.5 m of fill consisting of brown and orangish-brown, gravelly sandy silt in the main scarp (Plates 6, 7 and 12) and flanks. Similar material was exposed along the surface of rupture. Two well-defined channels eroded into the surface of rupture exposed topsoil consisting of a brown and greyish-brown sandy silt beneath the fill. A similar thickness of fill was indicated by trial pits TP1, TP2 and TP5 excavated around the scar periphery, as well trial pit TP6, located at the crest of the trimmed face of slope No. 11SW-B/C179 above Bowen Road, which exposed approximately 2 m of fill.

Particular observations made in relation to the fill material were the presence of layering parallel to the slope face (Plate 13) in trial pits TP1 to TP6, voiding (Plates 13 and 14) in trial pits TP1 to TP6, which provides some indication of the manner of placement (i.e. probably loosely tipped). The presence of thin (20 to 50 mm) topsoil horizons separating the fill layers (Plate 15) in trial pit TP1 indicates that the fill was deposited in distinct layers over a period of time.

The landslide debris consisted mostly of fill material. There was little evidence that the surface of rupture had penetrated the insitu profile to a significant depth, and the exposures of the insitu profile appeared to have resulted from erosion of the fill by subsequent flow of water (Plate 6).

The results of insitu density testing and laboratory compaction tests indicate that the fill material on the local hillside is in a loose state, with relative compaction generally in the range of 64% to 84%, with an average of 76% from 16 results. GCO probe results within the fill material in trial pits and located along the flanks of the landslide scar were typically in the range of 1 to 10 blows/100 mm with an average of 5 blows/100 mm.

The natural ground profile beneath the fill comprised a thin topsoil layer overlying a brown and dark brown gravelly sandy silt matrix containing cobbles and boulders of moderately to slightly decomposed tuff. The interpretation of this material as a colluvium, or an essentially insitu weathering profile that has undergone some downslope movement, is uncertain. However, it does not appear to have been derived from previous landsliding.

A geological section through the landslide site is presented in Figure 5.

GCO probe results at trial pit locations indicated similar blow counts for the fill and the underlying colluvium/disturbed insitu material and therefore the subsequent probing carried out on the local hillside were not capable of defining the extent of fill present.

5.6 Groundwater

Information on the groundwater regime at the landslide site is limited. The main source of information based on the desk study was the "Geotechnical Report for Foundation Re-submission at No. 7B Bowen Road Hong Kong", prepared by CMW (CMW, 1994), presenting data obtained from the 1994 ground investigation associated with the re-development of Fairlane Tower.

The report presents monitoring data from piezometers installed at drillholes BH1 to BH3, BH5, BH7 and BH8 (Figure 6). Piezometer tips were located within Grade V to Grade III tuff, about 0.8 m above to 2.7 m below rockhead and at depths of 7 m to 15 m below ground surface. Monitoring was carried out from 24 March 1994 to 30 April 1994 during which time water levels generally remained about 1 m to 3 m above rockhead, with BH7 recording the highest water level of 6 m below ground surface.

No groundwater table or seepages were observed in trial pits excavated as part of the post-landslide ground investigation carried out in February and March 2001, during which time little rainfall was recorded.

6. ANALYSIS OF RAINFALL RECORDS

The nearest GEO automatic raingauge (No. H17) to the landslide is located at No. 25 Borrett Road, about 425 m to the east from the site.

For the purposes of rainfall analysis, it is assumed that the landslide occurred at 5:30 a.m. on 24 August 2000 based on eye-witness accounts.

The daily rainfall for the period of one month preceding and seven days following the landslide, together with hourly rainfall for 48 hours before and 6 hours following the landslide, are given in Figure 8. The daily rainfall record shows that the storm was concentrated on 24 August 2000, with the hourly data indicating peak rainfall intensities from 2:00 a.m. to 6:00 a.m., generally in the range of 60 mm/hr to 80 mm/hr. About 260 mm of rainfall was recorded in the four hours prior to the failure.

Table 2 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 maximum rolling rainfall (257.5 mm) was the most severe, with a return period of about 50 years. A comparison of the severity of the August 2000 rainstorm and other historical major rainstorms recorded by raingauge No. H17 is presented in Figure 9. This shows that the August 2000 rainstorm was the most severe for durations up to 4 hours since installation of the raingauge in the mid-1980's.

7. DIAGNOSIS OF PROBABLE CAUSES OF THE LANDSLIDE

7.1 Mode and Sequence of Failure

In the absence of detailed eyewitness accounts, the reconstruction of the failure scenario is based primarily on observations made at the landslide source area and debris trail

mapped shortly following the failure.

The surface drainage system associated with slope No. 11SW-B/C180 concentrates runoff from a potentially large catchment (about 1000 m^2) immediately above the landslide scar. The drainage channels and a catchpit were observed to have been blocked by vegetation on the day of failure and there was evidence of overland flow between the channel and the landslide scar (Section 4.2), indicating that water had overspilled from the drainage system.

The geometry of the source area of the landslide, together with the location of the surface of rupture near the interface between fill and natural ground, suggest that the landslide involved primarily a sliding type failure mainly within fill material. The deposition of debris on the western side of the nullah indicates that the failure probably occurred rapidly. The debris either completely filled the nullah, spilling onto the far side before being transported downstream, or the velocity of the debris was sufficiently high to cross the nullah. The presence of eroded channels in the landslide scar indicates that there was concentrated flow across the scar following the main failure.

Debris from the landslide was transported northwards along the nullah by surface water flow. At MacDonnell Road, the debris would have accumulated at the trash screen south of the road crossing, causing partial blockage of the nullah and resulting in water and debris overflowing onto the carriageway. The concrete slabs covering the nullah between MacDonnell Road and Kennedy Road were seen to have lifted above Kennedy Road (Plate 11), suggesting blockage of the nullah below this point, possibly by the landslide debris, and build-up of water pressures sufficient to lift the slabs. Water and debris then overflowed from the nullah and was deposited on Kennedy Road and the entry area to Hong Kong Park. The runout of the landslide debris was a result of surface water flow in the nullah in the form of a major washout.

7.2 Probable Causes of Failure

The landslide involved old loose fill deposited on terrain at angles of up to about 35°. The close correlation between the rainstorm of 24 August 2000 and the timing of the landslide suggests that the failure was triggered by rainfall. Direct surface infiltration into the fill would have resulted from the rainfall recorded in the early hours of 24 August 2000. The rainfall preceding the failure was heavy, with a return period of about 50 years.

The location of the surface of rupture near the interface between fill and insitu material below suggests that the landslide was probably caused by wetting up of the fill and the build-up of transient perched water pressures along the interface. Subsurface seepage through the fill would also have been promoted by the loose and voided state of the fill.

Concentrated surface runoff originating from the poorly detailed surface drainage provisions of the adjacent slope No. 11SW-B/C180, which was exacerbated by blockages of the drainage channels (with vegetation), is likely to have been an important source of water ingress at the landslide site. Thus, poor detailing and inadequate maintenance of surface drainage provisions were contributory factors to the failure.

7.3 Discussion

The landslide occurred in old, loose fill, which was deposited on steeply-sloping ground over a number of years, probably in association with the construction works undertaken at No. 2B Bowen Road in 1949 and 1967. API has revealed that the subject local hillside was disturbed in the past.

The western GHB area, which included slope No. 11SW-B/C179, was assessed by geotechnical consultants and checked by the GEO as conforming to the required geotechnical standards during the re-development of No. 2B Bowen Road in the late 1990's. However, the assessment did not include the consideration of fill in the western GHB area where the 2000 landslide site is located. The area received superficial trimming/profiling and was hydroseeded as part of the re-development works, but the presence of fill was not recorded during this operation. The past instability in 1992 (Section 3.2) in the vicinity of the 2000 landslide site does not appear to have been considered in the geotechnical assessment in 1995.

8. CONCLUSIONS

It is concluded that the 24 August 2000 landslide, which involved unregistered loose fill on a hillside previously disturbed by human activities, was triggered by heavy rainfall.

The failure was probably caused by the build-up of transient perched water pressures in the fill following severe rainfall. Blockage of surface drainage provisions above the landslide site caused overflow and provided an additional source of water ingress into the slope-forming materials at the landslide site. Poor detailing and inadequate maintenance of the surface drainage system were likely to have contributed to the failure.

The stability of the area affected was previously assessed and checked as conforming to the required geotechnical standards in 1995. The presence of fill was not identified by the SIFT project and was not considered by the geotechnical consultants during the re-development of Fairlane Tower in the 1990's.

9. REFERENCES

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

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Table 1 - Summary of Classification, Index and Compaction Test Results for Soil Samples (Sheet 1 of 2)

Material Type	Sample Location	Depth (m)	Sample Type	Particle Size Distribution				LL (%)	PL (%)	PI (%)	Moisture Content (%)	Maximum Dry Density (t/m^3)	Insitu Dry Density (t/m^3)	Relative Compaction (%)
				Gravel (%)	Sand (%)	Silt (%)	Clay (%)							
Fill	TP1	0.0-0.5	Bulk	31	21	40	8	33	22	11	17	1.82	1.22	67
Fill		0.5-1.0	Bulk	27	26	37	10	33	22	11	15	1.88	1.21	64
Fill		1.0-1.5	Bulk	31	15	42	12	34	22	12	19	1.8	1.47	82
Coll/CDT		1.5-2.0	Bulk	3	15	58	24	38	22	16	24	-	-	-
Coll/CDT		2.0-2.5	Bulk	15	10	50	25	41	21	20	21	-	-	-
Coll/CDT		2.5-3.0	Bulk	38	9	35	18	46	22	24	20	-	-	-
Fill	TP2	0.0-0.5	Bulk	15	14	52	19	37	22	15	22	-	-	-
Fill		0.5-1.0	Bulk	8	17	55	20	36	23	13	24	1.75	1.41	81
Coll/CDT		1.0-1.5	Bulk	5	12	56	27	43	24	19	24	-	-	-
Coll/CDT		1.5-2.0	Bulk	23	10	45	22	46	23	23	21	-	-	-
Fill	TP3	0.0-0.5	Bulk	16	48	25	11	44	30	14	18	1.72	1.34	78
Fill		0.5-1.0	Bulk	28	35	23	14	44	31	13	17	1.71	1.31	77
Fill		1.0-1.5	Bulk	21	36	31	12	44	30	14	17	1.69	1.29	76
Fill?		1.5-2.0	Bulk	37	23	35	5	37	26	11	17	1.78	1.44	81
Fill	TP4	0.0-0.5	Bulk	18	24	46	12	34	23	11	15	1.85	1.43	77
Fill		0.5-1.0	Bulk	10	25	50	15	38	24	14	15	1.79	1.42	79
Coll/CDT		1.0-1.5	Bulk	1	12	60	27	43	23	20	21	-	-	-
Coll/CDT		1.5-2.0	Bulk	25	10	44	21	46	23	23	20	-	-	-

Table 1 - Summary of Classification, Index and Compaction Test Results for Soil Samples (Sheet 2 of 2)

Material Type	Sample Location	Depth (m)	Sample Type	Particle Size Distribution				LL (%)	PL (%)	PI (%)	Moisture Content (%)	Maximum Dry Density (t/m^3)	Insitu Dry Density (t/m^3)	Relative Compaction (%)
				Gravel (%)	Sand (%)	Silt (%)	Clay (%)							
Fill	TP5	0.0-0.5	Bulk	23	24	45	8	34	23	11	19	1.76	1.22	69
Fill		0.5-1.0	Bulk	13	22	50	15	37	23	14	19	1.77	1.24	70
Coll/CDT		1.0-1.5	Bulk	63	22	12	3	31	21	10	27	-	-	-
Coll/CDT		1.5-2.0	Bulk	27	14	45	14	36	23	13	20	-	-	-
Fill	TP6	0.0-0.5	Bulk	19	25	46	10	35	25	10	19	1.75	1.46	83
Fill		0.5-1.0	Bulk	15	23	54	8	33	23	10	16	1.77	1.48	84
Fill		1.0-1.5	Bulk	6	27	57	10	34	24	10	17	1.79	1.26	70
Fill		1.5-2.0	Bulk	12	20	56	12	34	23	11	17	1.79	1.58	88

Legend:

LL	Liquid Limit	PL	Plastic Limit	PI	Plasticity Index
Coll	Colluvium	CDT	Completely Decomposed Tuff		

Notes: (1) See Figure 6 for location of trial pits.
(2) Insitu density testing was carried out by Gammon Construction Ltd.

Table 2 - Maximum Rolling Rainfall at GEO Raingauge No. H17 and Estimated Return Periods of Different Durations Preceding the Landslide

Duration	Maximum Rolling Rainfall (mm)	End of Period	Estimated Return Period (Years)
5 Minutes	16.5	04:15 on 24 August 2000	7
15 Minutes	41	04:20 on 24 August 2000	18
1 Hour	110.5	04:25 on 24 August 2000	16
2 Hours	159.5	04:20 on 24 August 2000	17
4 Hours	257.5	04:35 on 24 August 2000	49
12 Hours	262.5	04:35 on 24 August 2000	7
24 Hours	263	04:35 on 24 August 2000	4
48 Hours	263	04:35 on 24 August 2000	2
4 Days	263	04:35 on 24 August 2000	< 2
7 Days	263	04:35 on 24 August 2000	< 2
15 Days	290	04:35 on 24 August 2000	< 2
31 Days	640	04:35 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 period using Lam & Leung (1994)'s data, which are based on hourly rainfall for these durations.
(4) Assumed time of failure at 05:30 on 24 August 2000.

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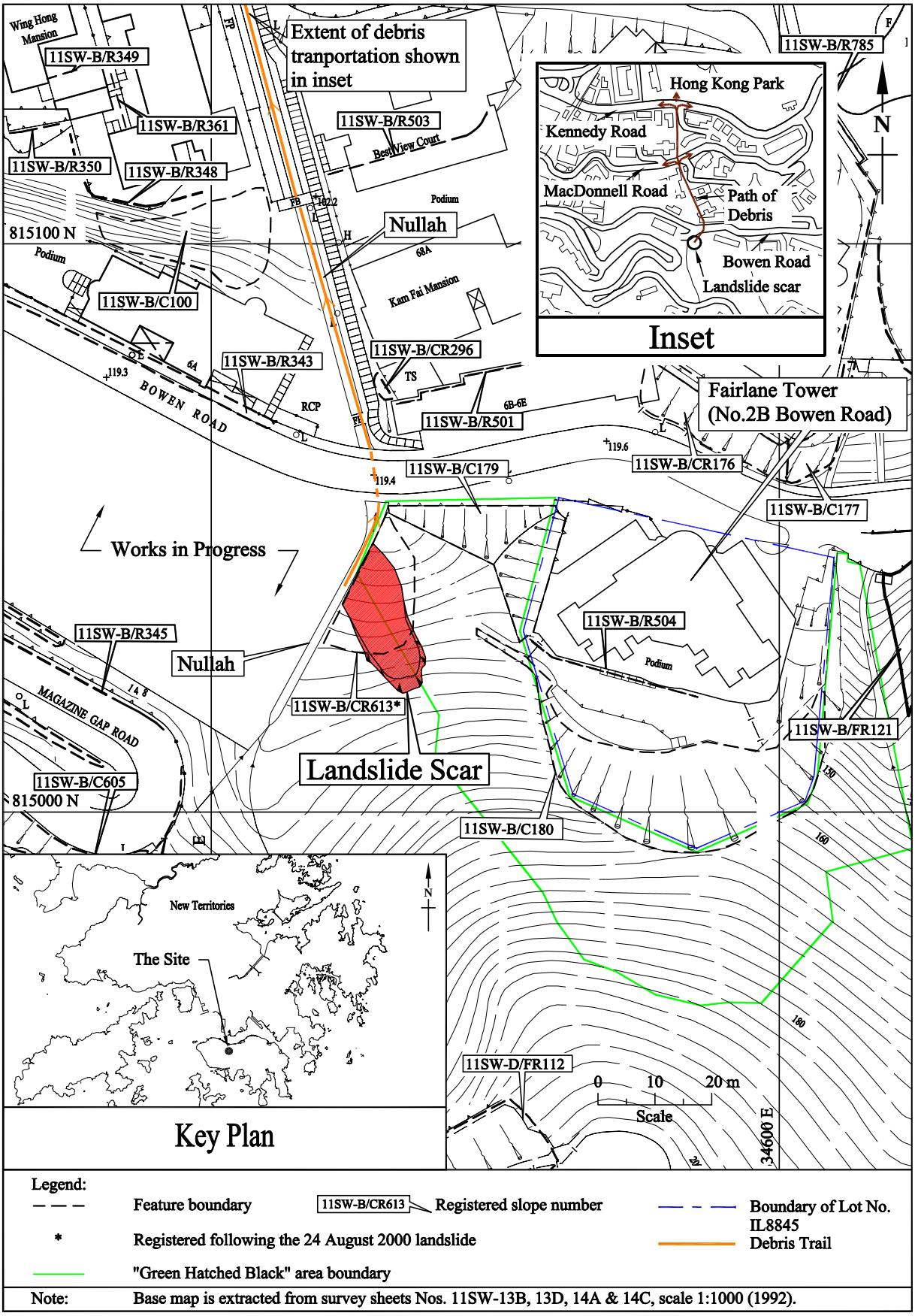
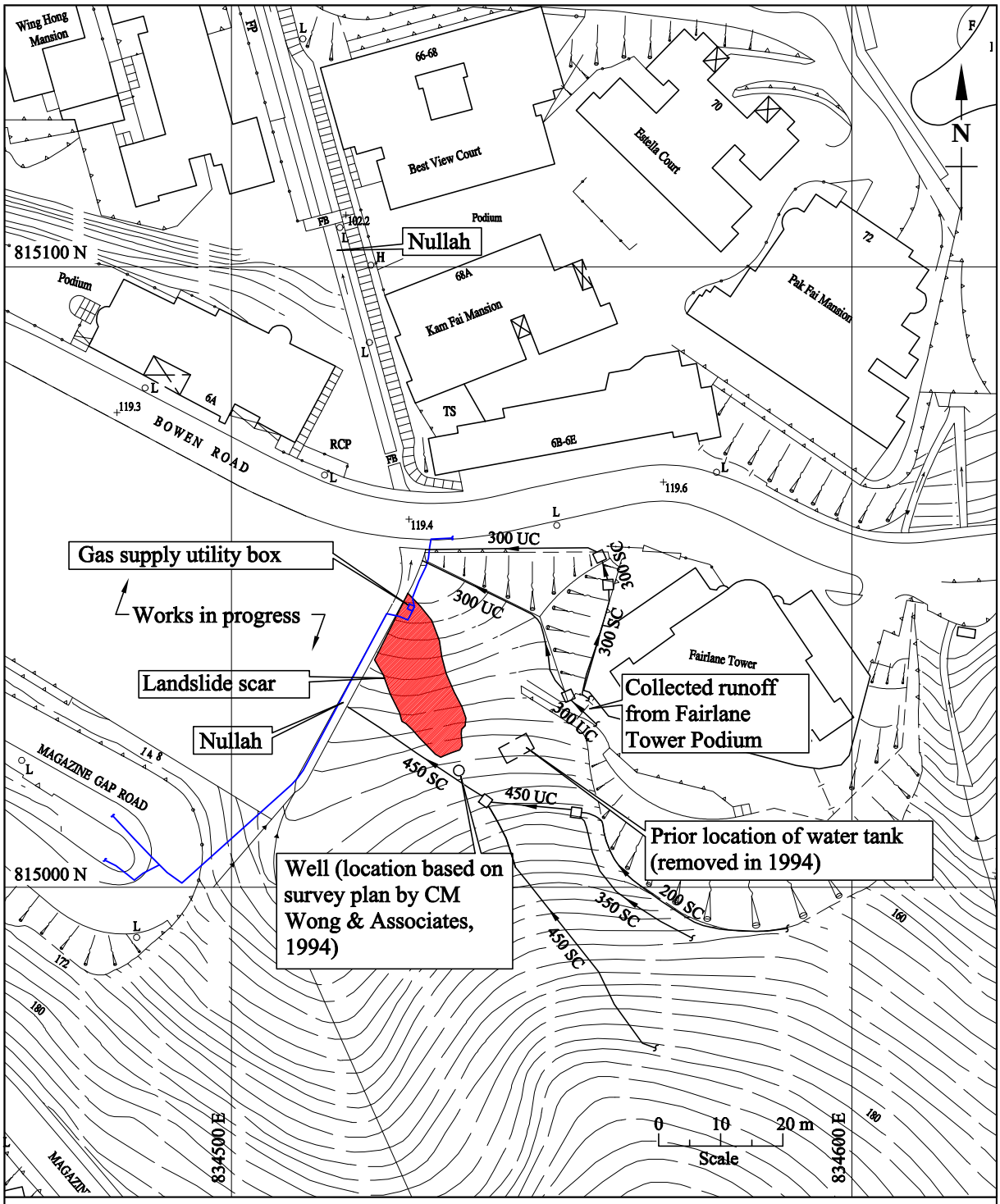


Figure 1 - Site Location Plan



Legend:

□	Catchpit	300 UC	U-Channel and size
———	Gas Main (LPA)	450 SC	Stepped channel and size

Notes:

(1) Channel widths are in millimetres.
(2) The locations of the various existing services are based on visual inspection.
(3) Bowen Road also contains fresh water and saltwater supply mains, foulwater and stormwater drains, high and low voltage power cables and telecom pilot cables, not shown for clarity.

Figure 2 - Existing Water-carrying Services and Utilities

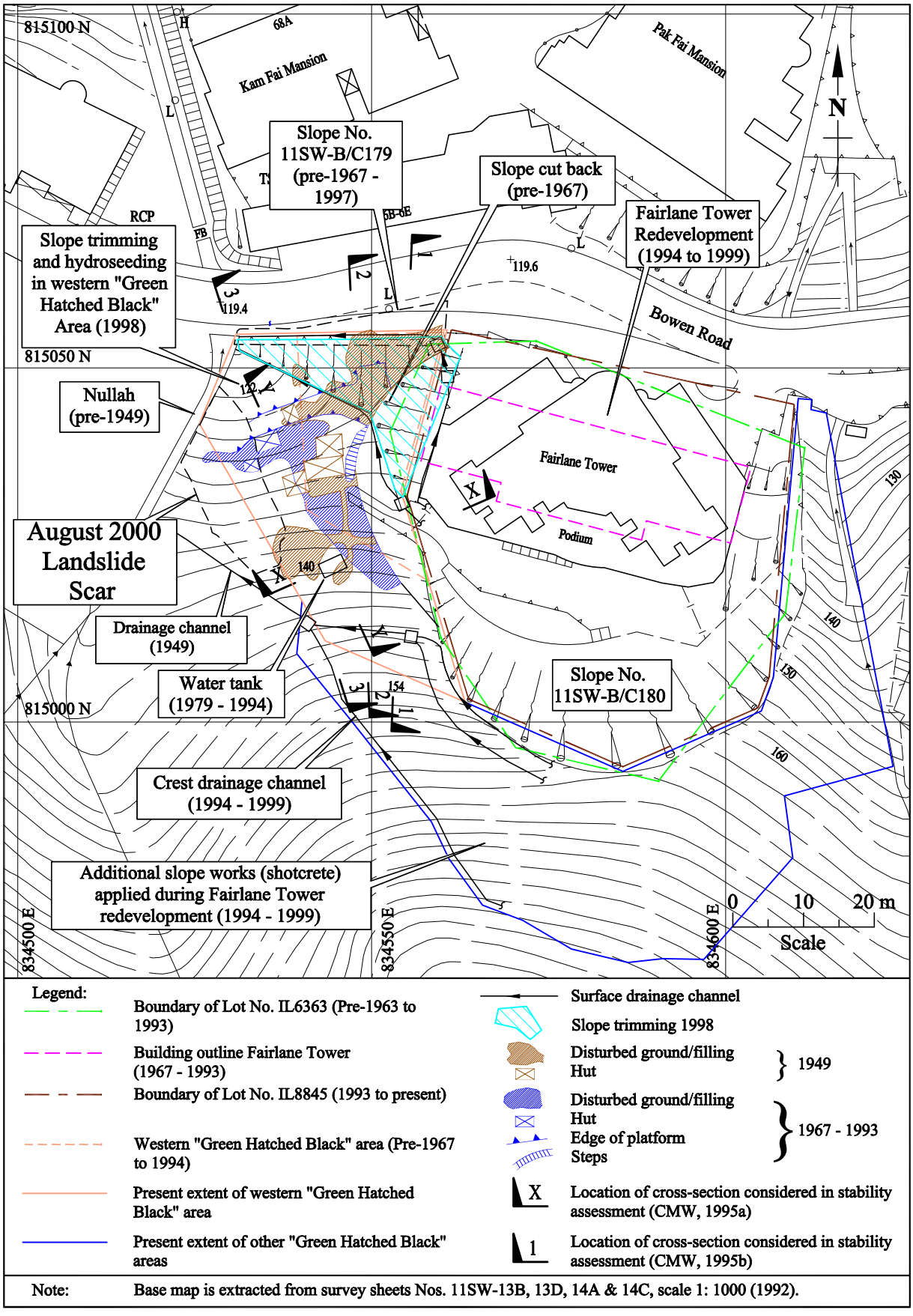


Figure 3 - Site History

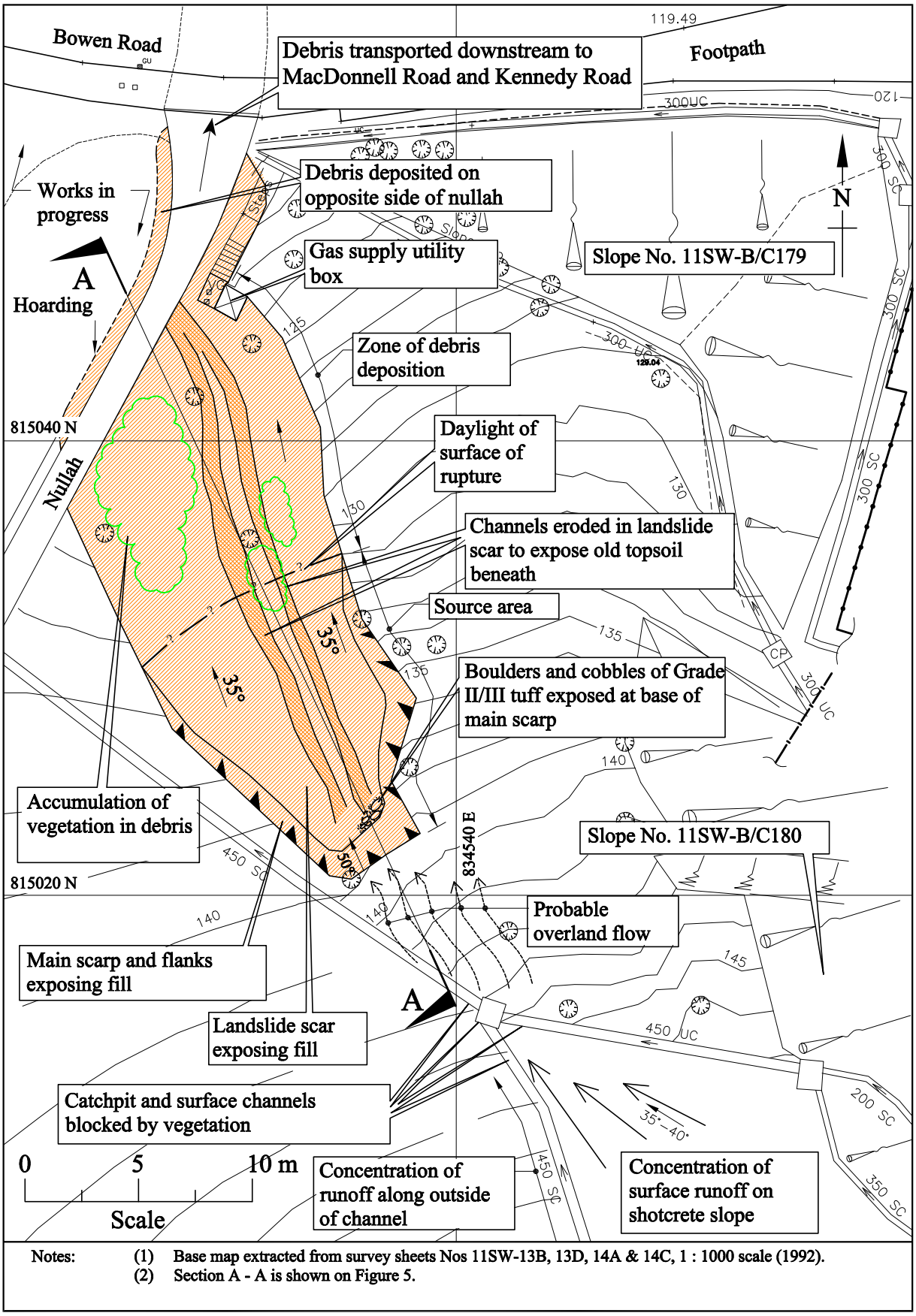
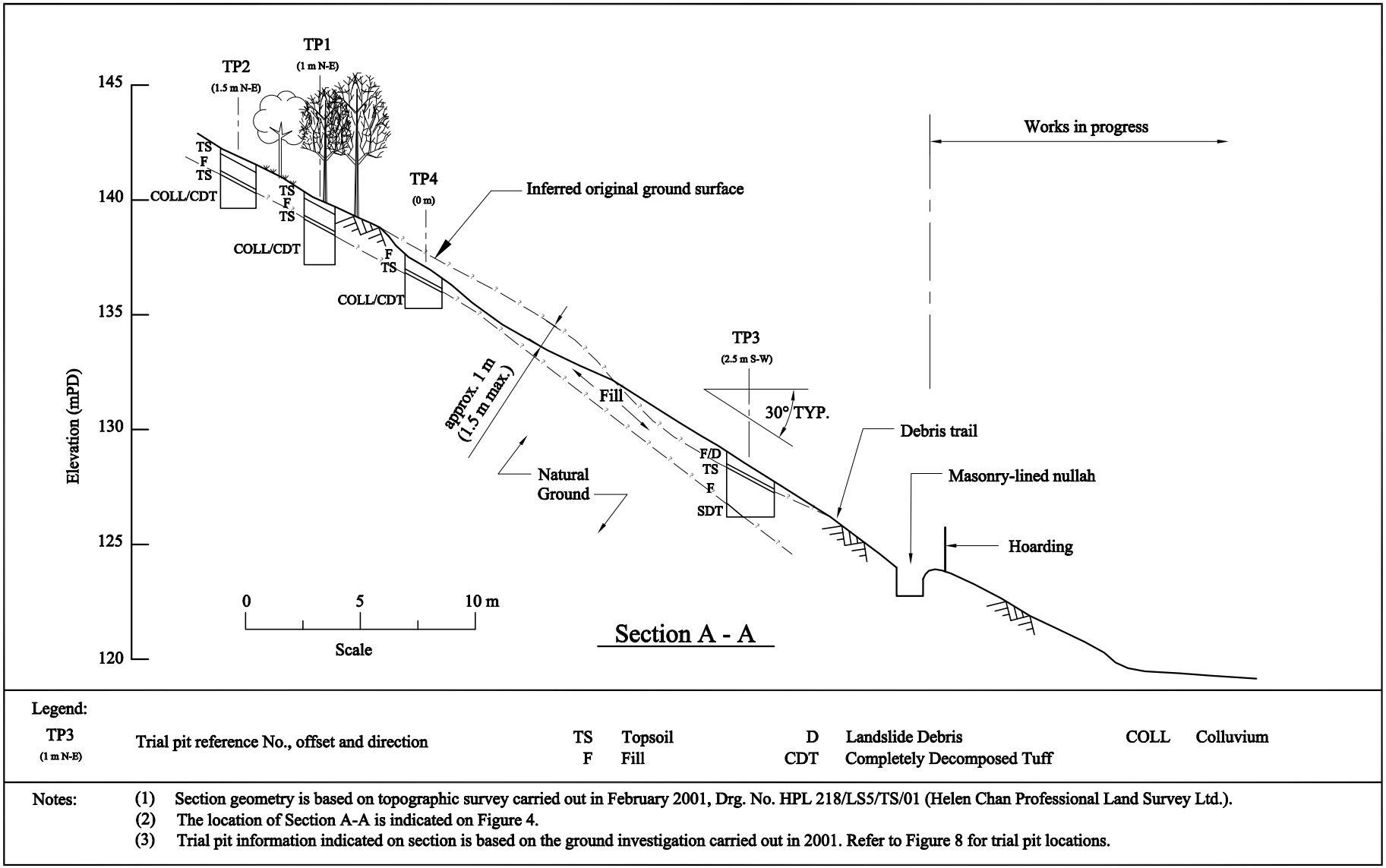


Figure 4 - Plan View of the Landslide



Legend:

TP3 (1 m N-E)	Trial pit reference No., offset and direction	TS	Topsoil	D	Landslide Debris	COLL	Colluvium
		F	Fill	CDT	Completely Decomposed Tuff		

Notes:

(1) Section geometry is based on topographic survey carried out in February 2001, Drg. No. HPL 218/LS5/TS/01 (Helen Chan Professional Land Survey Ltd.).
(2) The location of Section A-A is indicated on Figure 4.
(3) Trial pit information indicated on section is based on the ground investigation carried out in 2001. Refer to Figure 8 for trial pit locations.

Figure 5 - Section A - A through the Landslide

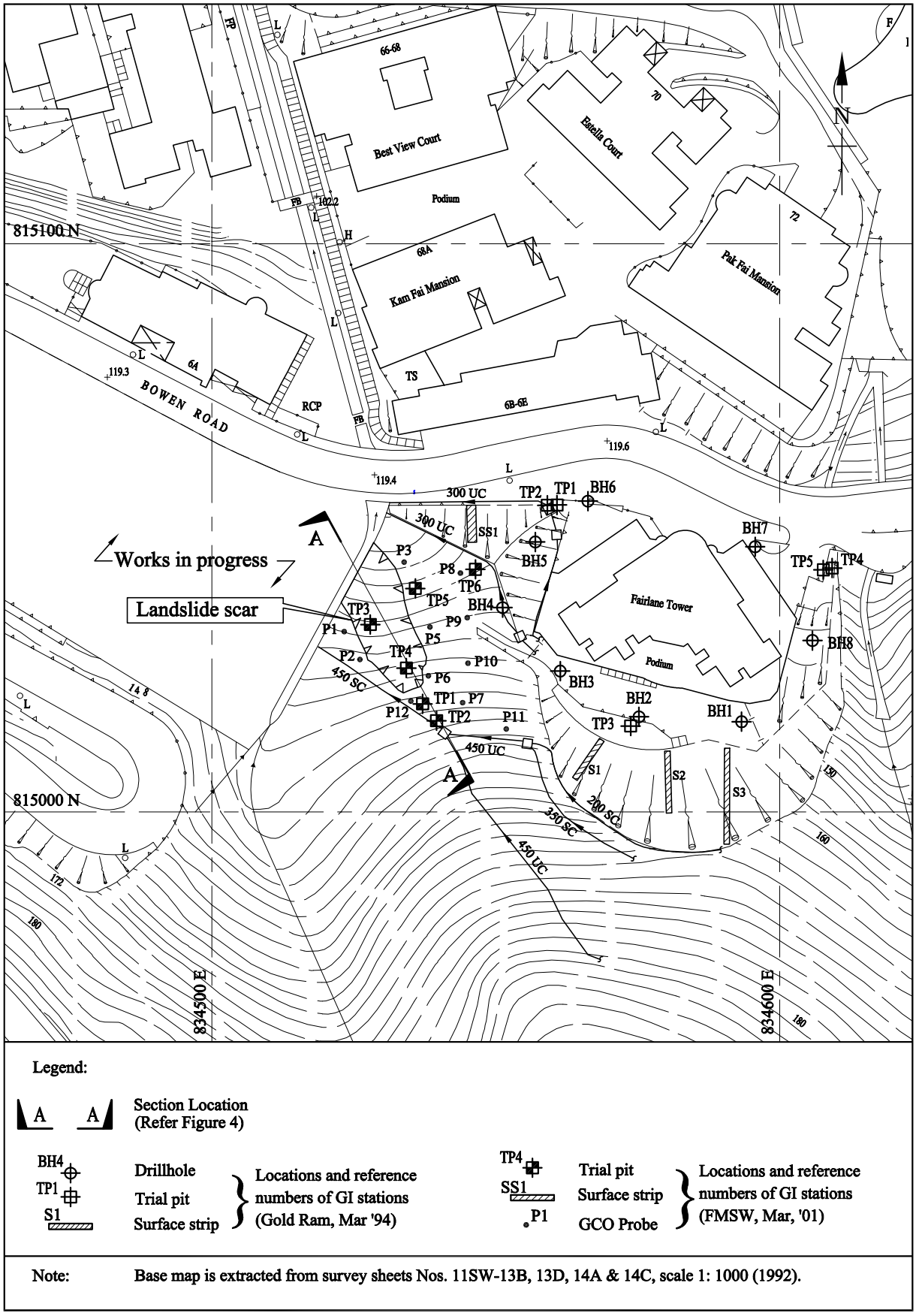
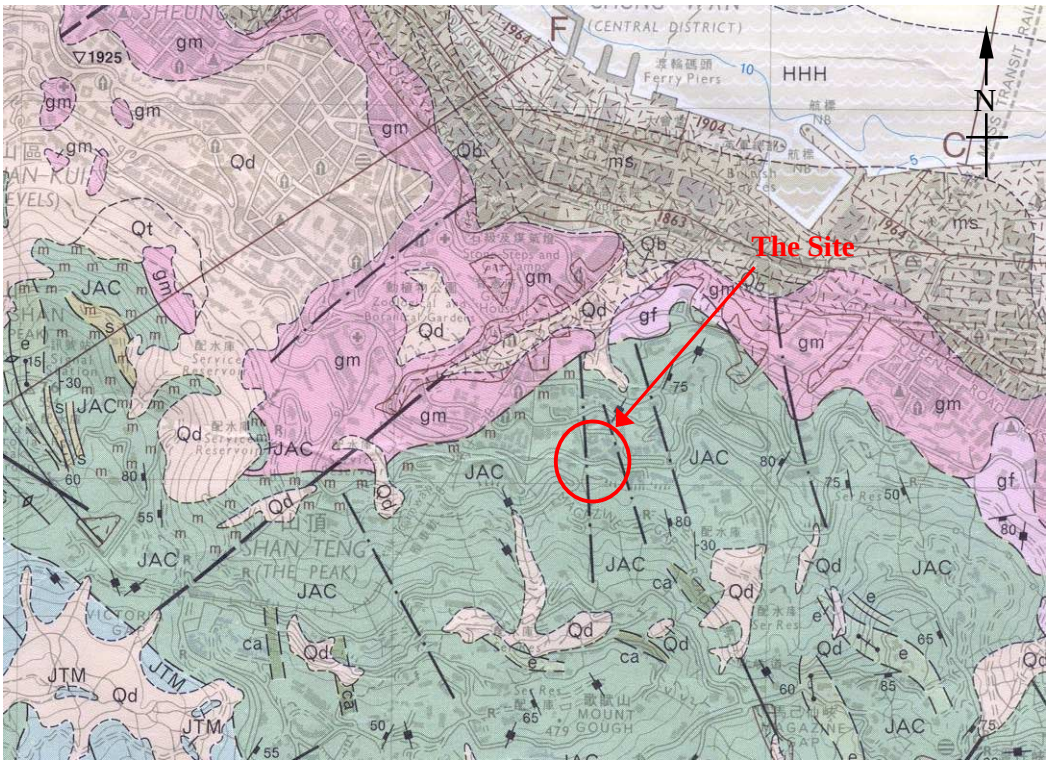


Figure 6 - Ground Investigation Stations



LEGEND:

SUPERFICIAL DEPOSITS

	Natural earth and waste (Fill)
ms	Marine sand, Part silty
Qt	Gravel, cobbles and boulders
Qb	Sand
Qd	Unsorted sand, gravel, cobbles and boulders; clay/silt matrix

SOLID GEOLOGY

gf	Fine-grained granite, <2 mm
gm	Medium-grained granite, 2-6 mm
s	Sandstone
e	Eutaxite
JAC	Fine ash vitric tuff
JTM	Coarse ash crystal tuff
ca	Coarse ash tuff (without Ap Lei Chau Formation)

GEOLOGICAL LINES

- Geological boundary, superficial deposits
- Fill boundary, with limit of reclamation at date shown
- Geological boundary, solid rock (* Broken lines denote uncertainty)
- Fault (crossmark indicates downthrow side)
- Mineral vein
- Photogeological lineament

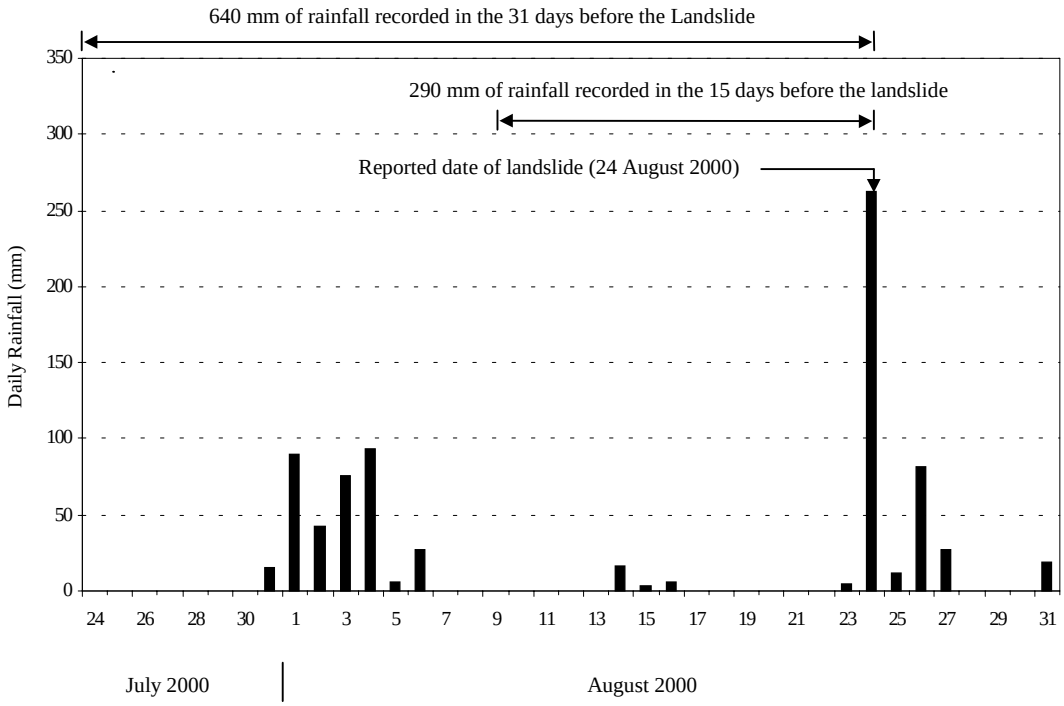
STRUCTURAL SYMBOLS

Inclined

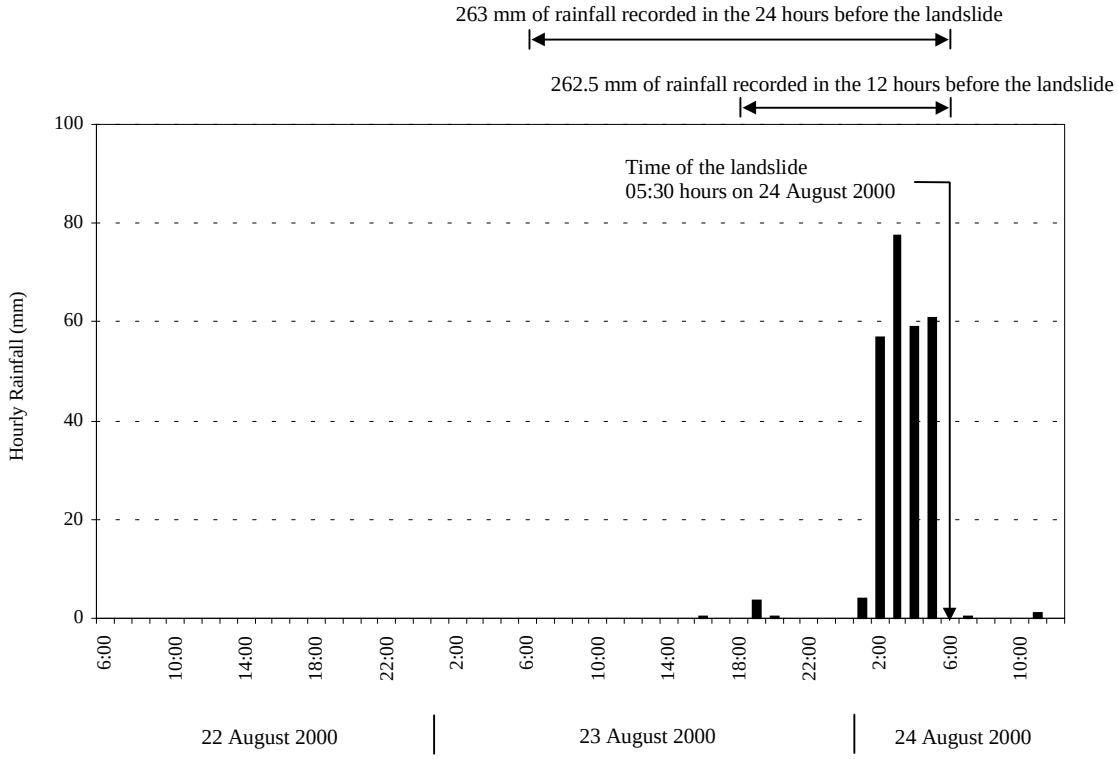
- Bedding
- Flow fabric
- Intrusive contact
- Jointing

Note: Extracted from Hong Kong Geological Survey, Map Series HGM20, Sheet No. 11, 1:20 000 scale (GCO, 1986).

Figure 7 - Solid and Superficial Geology of the Landslide Site

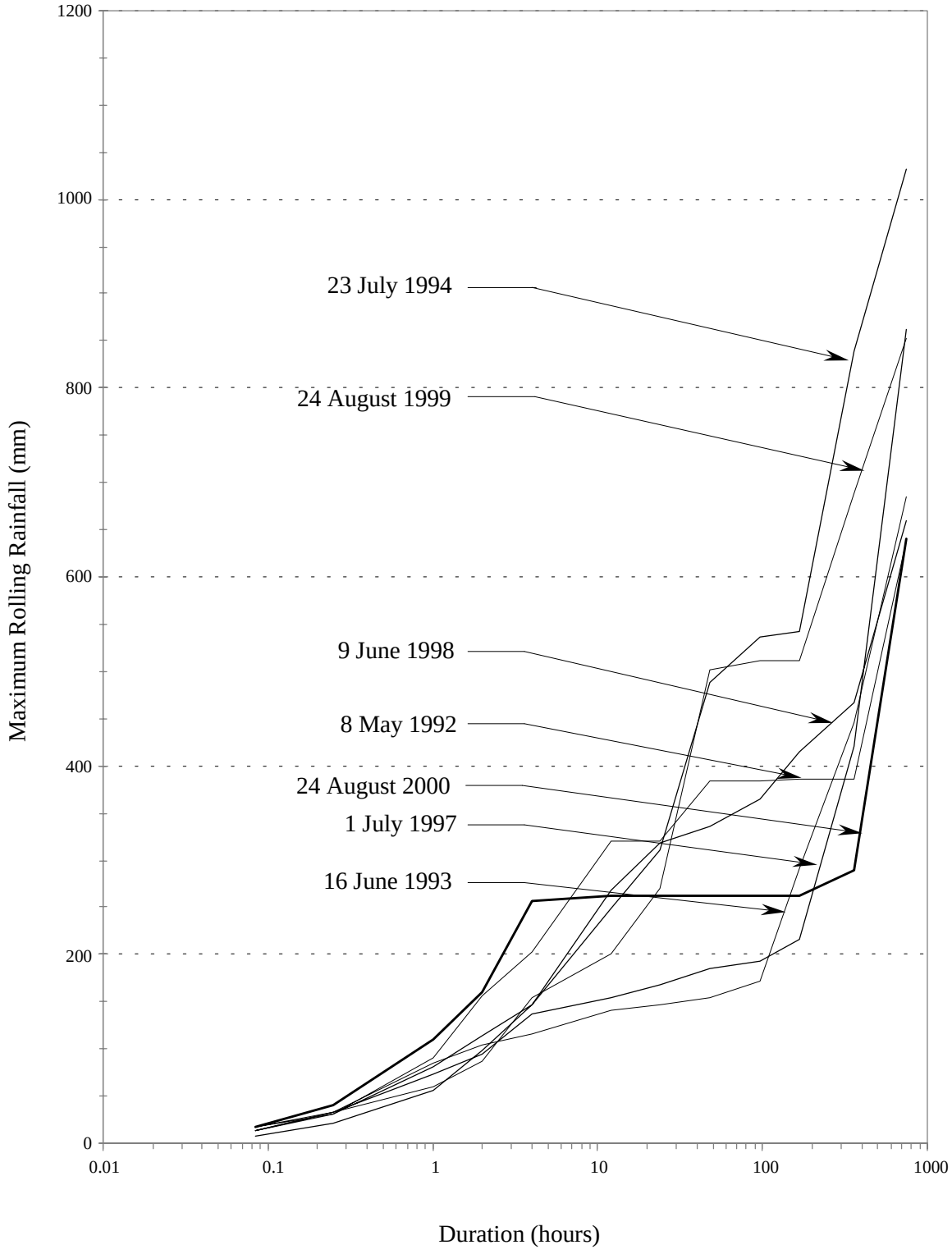


(a) Daily Rainfall Recorded between 24 July and 31 August 2000



(b) Hourly Rainfall Recorded between 06:00 hours on 22 August and 12:00 hours on 24 August 2000

Figure 8 - Rainfall Recorded at GEO Raingauge No. H17



Note: Rainfall data are 5-minute statistics from GEO raingauge No. H17.

Figure 9 - Maximum Rolling Rainfall Preceding the Landslide and Selected Previous Major Rainstorms Recorded at GEO Raingauge No. H17

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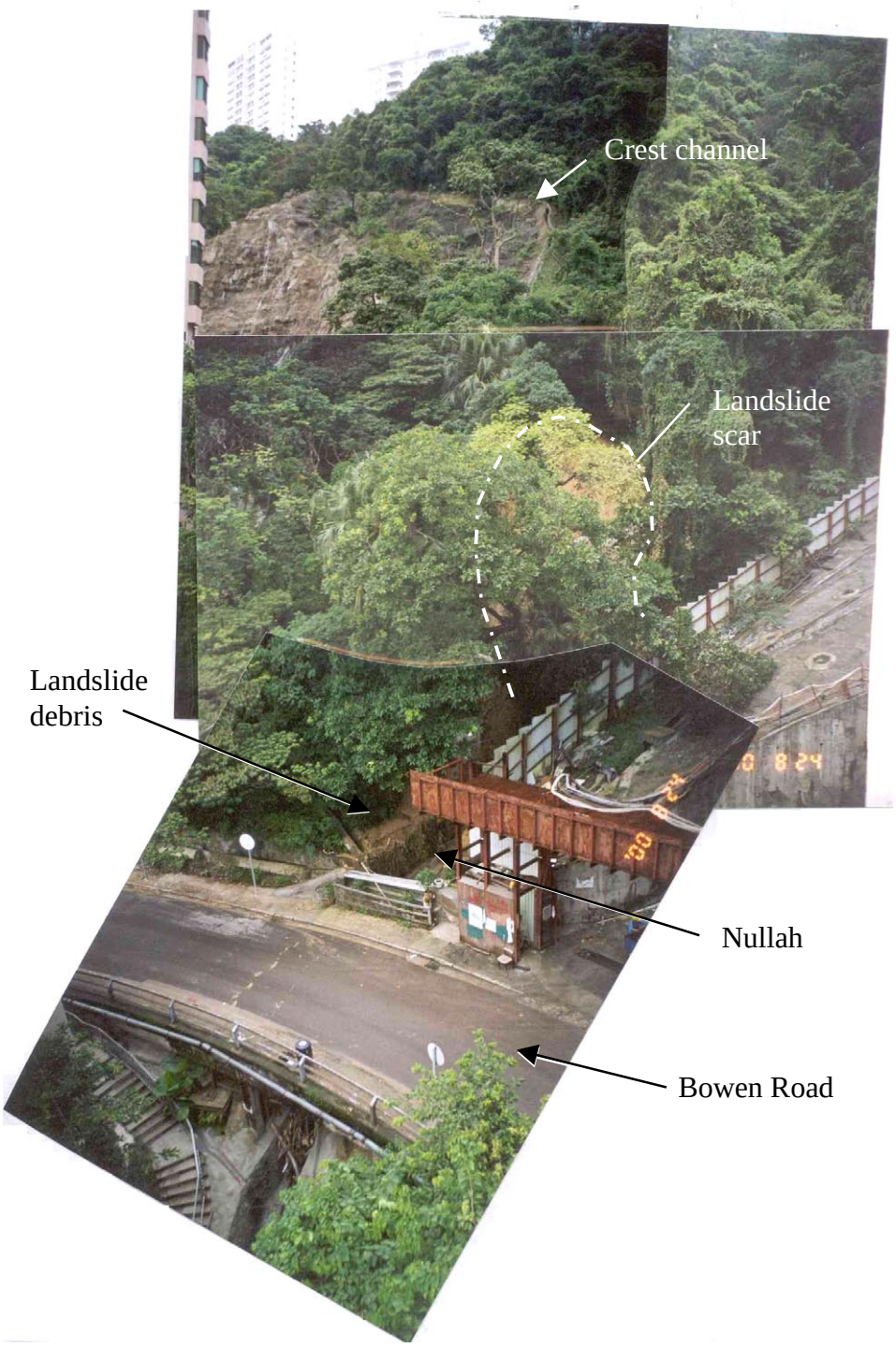

Plate 1 - View Southeast across Bowen Road towards Landslide Site (Photograph Taken on 24 August 2000. Extent of Landslide Scar Indicated. Slope No. 11SW-B/C180 Visible in Upper Left of Frame. Crest U-channel Indicated. Note Debris on Ground Surface Adjacent to Nullah and Absence of Debris on Bowen Road)

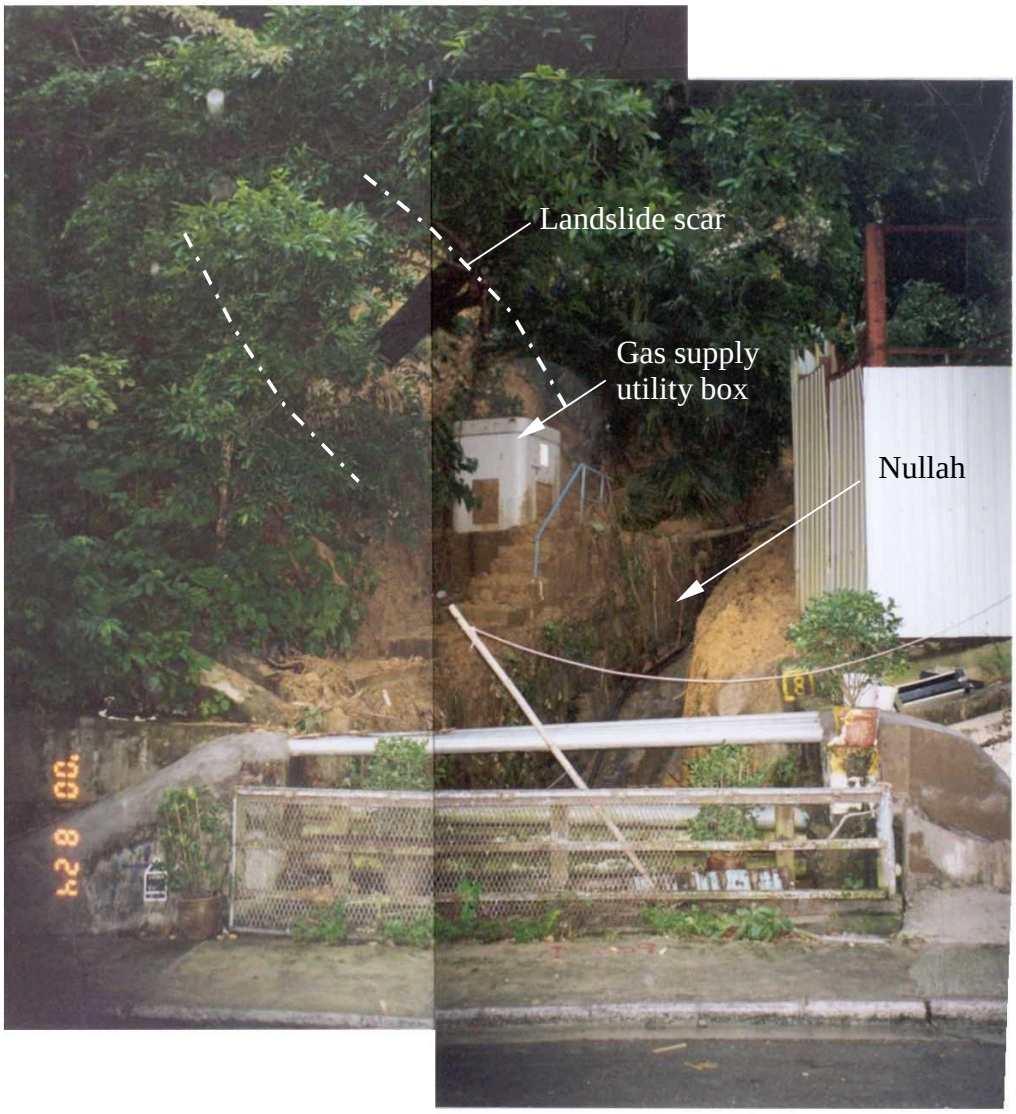

Plate 2 - View South along Nullah from Bowen Road (Photograph Taken on 24 August 2000. Landslide Scar Visible through Trees. Gas Supply Utility Box Adjacent to Nullah in Centre of Frame. Note Debris Deposited on Western side of Nullah)

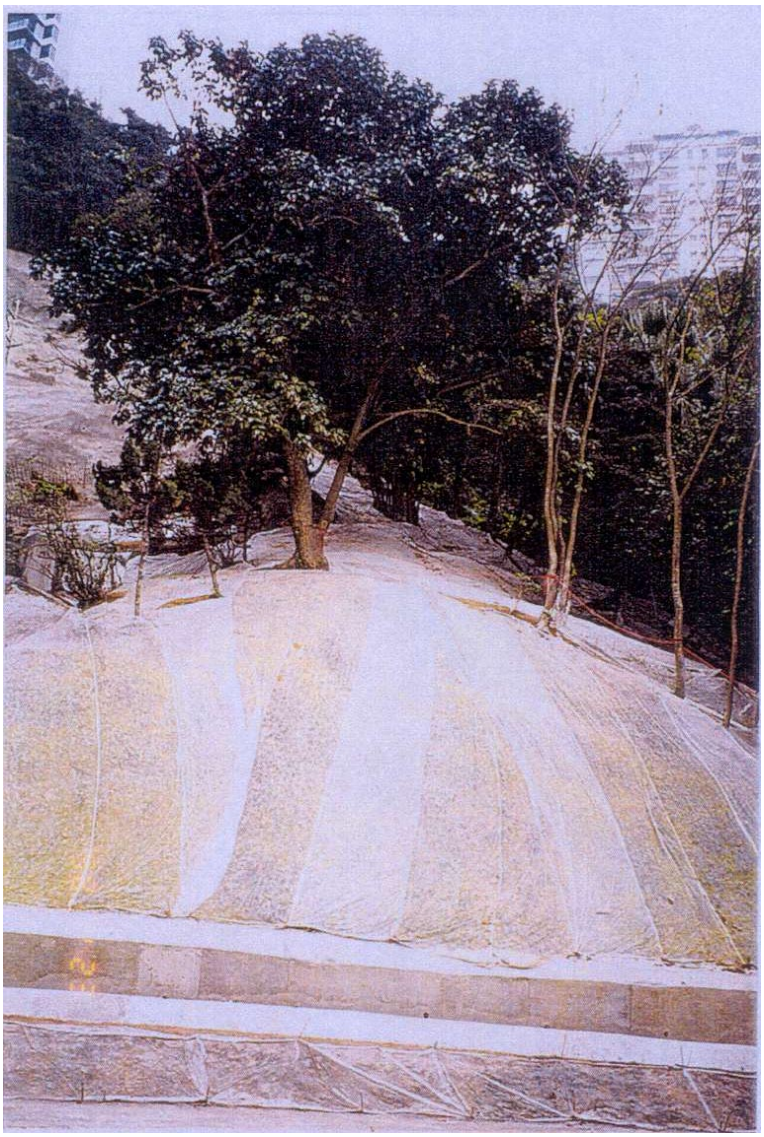

Plate 3 - View South from Bowen Road towards Newly Hydroseeded Slope No. 11SW-B/C179 and Western “Green Hatched Black” Area (Extract from CMW (1998b))

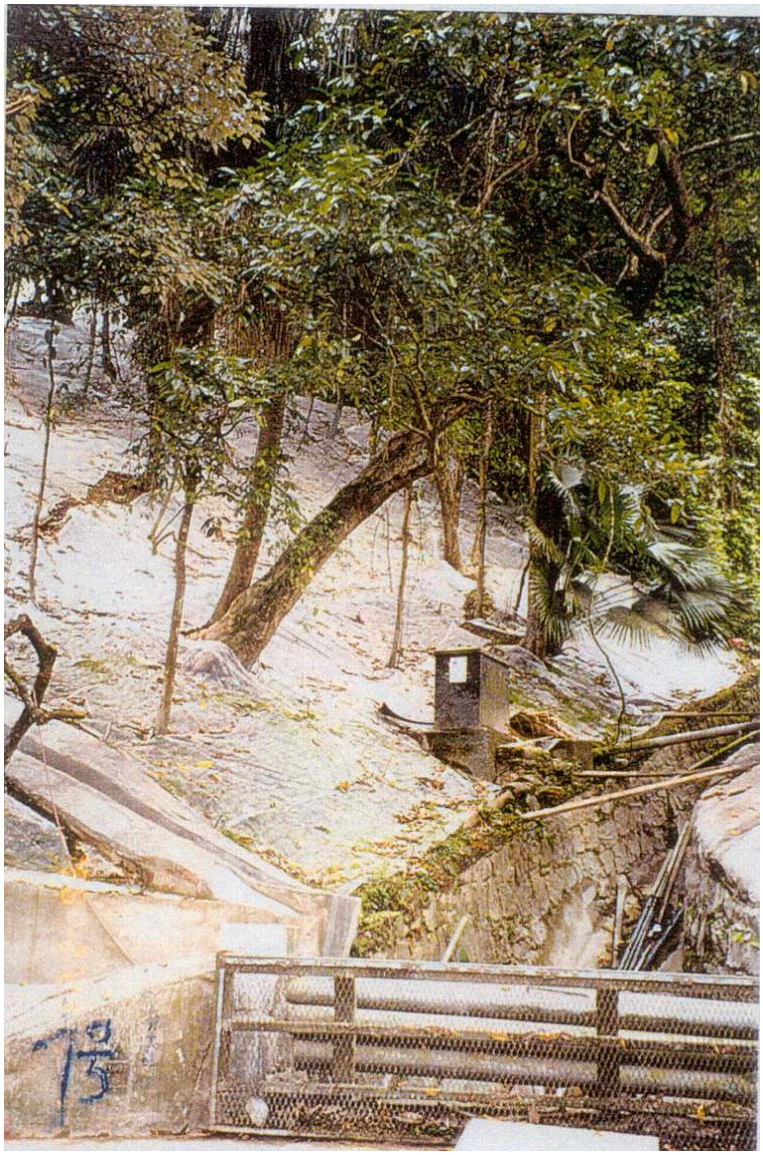

Plate 4 - View South from Bowen Road towards Newly Hydroseeded Western "Green Hatched Black" Area above Nullah (Extract from CMW (1998b). Note Gas Supply Utility Box Adjacent to Nullah, as Shown in Plate 2)

Plate 5 - View Northwest towards Nullah across Location of August 2000 Landslide Scar Showing Newly Hydroseeded Western “Green Hatched Black” Area (Extract from CMW (1998b))

Plate 6 - View Northwest down Landslide Scar from Main Scarp (Photograph Taken on 24 August 2000. Note Old Topsoil Horizon Exposed in Channels Scoured in Fill)

Plate 7 - View Southeast up Landslide Scar Showing Fill Material Exposed in Scar and Old Topsoil Horizon Exposed in Scoured Channel (Photograph Taken on 9 September 2000)

Plate 8 - View South from Catchpit above August 2000 Landslide Scar Showing Steeply Inclined 450 mm Crest U-channel of Slope No. 11SW-B/C180 (Photograph Taken on 9 March 2001)

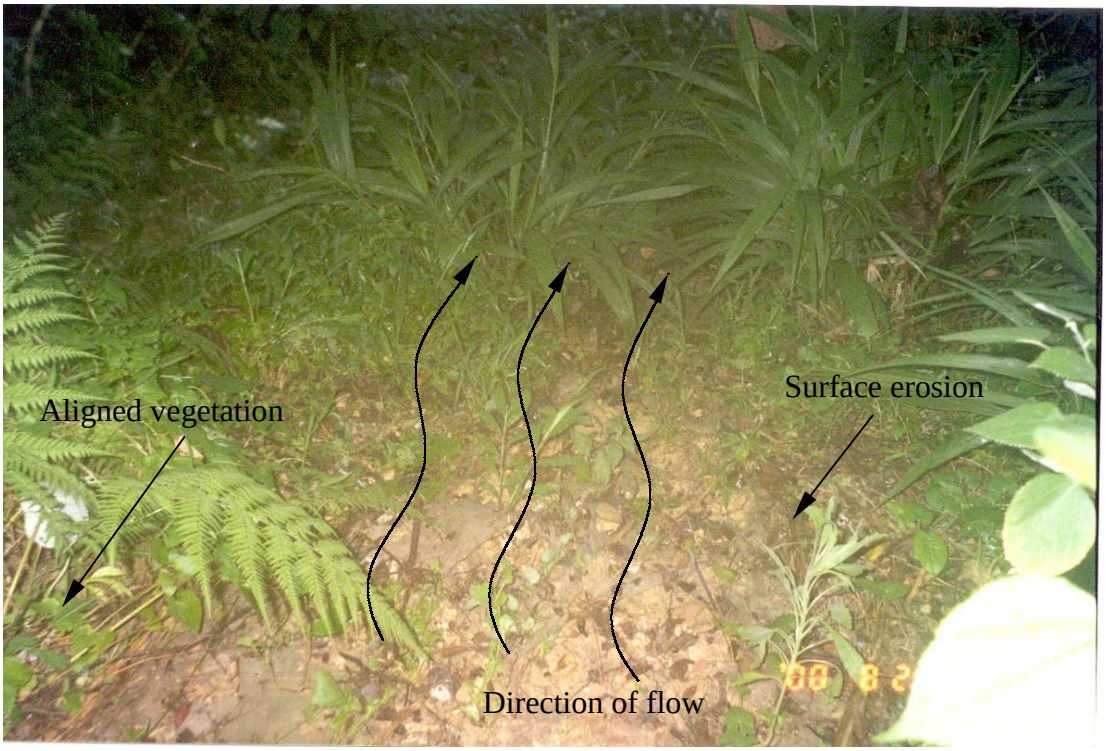

Plate 9 - Close View of Ground Surface below Catchpit and Crest Drainage Channel of Slope No. 11SW-B/C180 Showing Evidence of Overland Flow (Photograph Taken on 24 August 2000)

Plate 10 - View West along MacDonnell Road Showing Deposited Landslide Debris (Photograph Taken on 24 August 2000)

Plate 11 - View North along Covered Nullah at Kennedy Road Showing Cover Slabs Having Been Lifted and Broken by Force of Water and Debris (Photograph Taken on 24 August 2000)

Plate 12 - Close View of Main Scarp Showing Exposed Fill Material (Photograph Taken on 9 September 2000. Note Old Topsoil Horizon Exposed in Base of Scarp at Location of Geological Hammer)

Plate 13 - Southwestern Face of Trial Pit TP5 Showing Fill Material Overlying Topsoil and Colluvium/CDT (Photograph Taken on 5 March 2001. Note Layering Parallel to Slope Face, and Voiding of Fill Indicated. Shotcreted Landslide Scar Visible at Top of Frame)

Plate 14 - Southwestern Face of Trial Pit TP5 Showing Voids in Fill
(Photograph Taken on 5 March 2001)

Plate 15 - Southwestern Face of Trial Pit TP1 Showing Thin Topsoil Layer Separating Fill Layers (Photograph Taken on 28 February 2001)

APPENDIX A

AERIAL PHOTOGRAPH INTERPRETATION

A.1 DETAILED OBSERVATIONS

The following comprise the detailed observations made from the aerial photographs studied. A list of aerial photographs used in this study is given in Section A.2.

YEAR	OBSERVATIONS
November 1945	Photographs show vegetated hillside extending above path/track on similar alignment to Bowen Road. The general landform in the subject area comprises a broad, northerly-trending spur feature bordered to the east and west by natural drainage lines. The resolution of the photographs is poor and the subject portion of hillside is uniform in appearance. A NNW-trending lineament, possibly indicating a shallow gully within the overall spur geometry, is visible above the path within the area presently occupied by the Fairlane Tower development. The presence of the feature is reflected in the alignment of the path where the two meet.
May 1949	Bowen Road has been formed to its present alignment. A lined channel/nullah is visible in the western drainage line. A building platform with a ramp driveway access has been cut into the hillside above Bowen Road at the present location of No. 2B, and a building has recently been completed on the platform. Works appear still to be underway on the cut slope bordering the southern extent of the platform and extending along the eastern and western sides (now slope No. 11SW-B/C180). A surface channel is visible extending from the crest of the cut slope west to the nullah on a similar alignment to the present channel. A strip of the hillside bordering the western portion of the cut slope and extending about half way to the nullah west of the site has been disturbed and is occupied by four huts, which appear to be associated with the adjacent construction works (workers accommodation). Some minor filling/spoiling is visible around and above the huts, most noticeably at and above the upper portion of the 2000 landslide scar. The hillside between the western extent of the disturbed strip and the nullah is heavily vegetated.
February 1963	The building under construction in the 1949 photographs has been removed and the building platform remains empty. The entire portion of hillside west of the cut slope is heavily vegetated with trees, which obscure the ground surface. No obvious features visible at the 2000 landslide site.

May 1967	The building site has been re-developed and is occupied by the old Fairlane Towers building which appears to be complete and occupied. Additional earthworks have been carried out to lower the platform level to Bowen Road and the cut slope bordering the platform has been modified, notably along the western edge of the platform where the slope face has been cut back and grassed/chunammed. Clearance works have been carried out on the hillside to the west of the cut slope and below the 2000 landslide site. The lower portion of the cleared area has been terraced and two narrow platforms about 15 m long, with walls along the downslope edges, are visible. A hut has been constructed at the western end of the upper platform. The formation of the platforms in cut, fill, or a combination of both is not clear. The remainder of the subject portion of hillside is heavily vegetated.
November 1972	No obvious changes. There has been some encroachment/new growth of vegetation on the upper portion of the cleared area (1967). Both platforms are clearly visible and well defined in these photographs and there are possibly squatter huts on the upper platform. The surrounding area of hillside remains heavily vegetated.
December 1973	No obvious changes. The subject portion of hillside is partially obscured by shadow. Platforms are more overgrown with vegetation. The huts (1972) are not clearly visible and may have been removed. Hillside above remains obscured by tree canopy.
January 1976	The two platforms remain visible through the vegetation. The huts have been removed. Otherwise no obvious changes. The hillside above remains obscured by tree canopy.
June 1977	No obvious changes.
December 1977	Site obscured by shadow. No obvious changes.
December 1978	No obvious changes. There have been some recent slope works (chunam) completed on slope No. 11SW-B/C180. Lighter toned patches are visible in the vicinity of the platforms to the west of the cut slope, indicating that chunam surfacing may have been applied here also.

September 1979	Vegetation is heavier. A rectangular structure is visible on the hillside about 30 m on plan upslope of Bowen Road and 10 m to 15 m west of slope No. 11SW-B/C180, which is consistent with the location of a water tank on record survey drawings. The platforms are clearly visible and are overgrown with vegetation.
January 1980	No obvious changes. The two platforms and steps joining them are clearly visible. Recent chunam surfacing is visible around the platforms in the April photographs.
April 1980	No obvious changes.
November 1980	No obvious changes.
May 1981	No obvious changes.
July 1982	No obvious changes. The water tank is clearly visible.
March 1984	No obvious changes.
July 1985	No obvious changes. The water tank is clearly visible.
September 1986	No obvious changes.
July 1987	No obvious changes.
September 1987	No obvious changes.
January 1988	No obvious changes.
September 1988	No obvious changes.
November 1989	No obvious changes.
November 1990	No obvious changes.
October 1991	No obvious changes. There is a possible break in the vegetation at the 2000 landslide site.
July 1993	No obvious changes. There are possible breaks in the vegetation at and below the 2000 landslide site.
October 1993	No obvious changes.
December 1993	No obvious changes.

November 1994	No obvious changes in subject area. The old Fairlane Tower building on the adjacent building platform to the east appears to be unoccupied and prepared for demolition. A hoarding has been erected along the road frontage on Bowen Road. Recent chunam strips have been carried out on slope No. 11SW-B/C180. The water tank is visible.
December 1995	Vegetation has become heavier on local hillside. No obvious changes in subject area. The old Fairlane Tower building on the adjacent building platform to the east has been demolished.
May 1997	The present Fairlane Tower building is under construction. Additional site formation works have been carried out to extend the crest line of slope No. 11SW-B/C180 to the west. No obvious changes are observed in the subject area.
November 1999	The present Fairlane Tower building appears to be complete. Recent slope works have been completed on slope No. 11SW-B/C180 (shotcrete). And slope No. 11SW -B/C179 has been modified to the present geometry. The subject portion of hillside remains heavily vegetated.
December 1999	No obvious changes.

A.2 LIST OF AERIAL PHOTOGRAPHS

A list of aerial photographs used in this API study is presented below.

Date	Flight Height (Feet)	Photograph
11.11.1945	20000	Y00469, Y00470
08.05.1949	8600	Y01414, Y01415, Y01416, Y01466, Y01467
01.02.1963	2700	Y07454, Y07455, Y07456
06.02.1963	3700	Y07511, Y07512, Y07513
16.05.1967	6250	Y13277, Y13278, Y13279, Y13301, Y13302
Nov. 1972	Unknown	97, 99
12.12.1973	4000	7077, 7078, 7079
28.01.1976	4000	12647, 12648
14.06.1977	4000	18429, 18430, 18431
05.12.1977	9000	19693, 19694
05.12.1978	4000	23872, 23873, 23874, 23898, 23899, 23900

14.09.1979	4000	26916, 26917, 26918
28.09.1979	5500	27154, 27155, 27156
24.01.1980	2000	28986, 28987, 28988
16.04.1980	4000	29833, 29815, 29816
04.11.1980	3100	31967, 31968, 31969
18.05.1981	4000	37406, 37407
28.07.1982	3500	43063, 43064, 43065
02.03.1984	4000	53672, 53673, 53688, 53689, 53690
07.07.1985	10000	A01704, A01705, A01706
20.09.1986	4000	A05956
13.07.1987	9000	A09899
09.09.1987	4000	A10311, A10312
19.01.1988	6000	CN2101, CN2102
27.09.1988	4000	A14424, A14425
20.11.1989	10000	A19300, A19301, A19302
14.11.1990	4000	A23758, A23759, A23804, A23805
02.10.1991	4000	A27727, A27728, A27729
04.10.1991	4000	A28055, A28056
09.07.1993	4000	A35383, A35384, A35385
08.10.1993	4000	CN4716
05.12.1993	4000	A36995, A36996
17.11.1994	4000	CN7914, CN7915, CN7916, CN8106, CN8107, CN8108
07.12.1995	3500	CN12632, CN12633
26.05.1997	4000	CN25703
05.11.1999	5000	CN24038, CN24039
09.12.1999	8000	CN17060, CN17061

SECTION 2: DETAILED STUDY OF THE SEEPAGE INCIDENT AT FEATURE NO. 11SW-A/R625 AND GROUND SUBSIDENCE BEHIND SLOPE NO. 11SW-A/FR12 NEAR OAKLANDS AVENUE ON 18 JUNE 2000

Fugro Maunsell Scott Wilson Joint Venture

This report was originally produced in January 2002 as GEO Landslide Study Report No. LSR 2/2002