SECTION 5: DETAILED STUDY OF THE LANDSLIDE AT LAI CHO ROAD KWAI CHUNG ON 4 JUNE 1997

Halcrow Asia Partnership Ltd

This report was originally produced in October 1998 as GEO Landslide Study Report No. LSR 16/98

FOREWORD

This report presents the findings of a detailed study of a landslide (GEO Incident No. MW97/6/41) which occurred on 4 June 1997 on a cut slope above Lai Cho Road, Kwai Chung. Debris from the landslide remained on the slope and did not travel as far as Lai Cho Road. No fatalities or injuries were reported.

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 was generally limited to site reconnaissance, desk study and analysis. Recommendations for follow-up actions are reported separately.

The report was prepared as part of the 1997 Landslip Investigation Consultancy (LIC), for the Geotechnical Engineering Office (GEO), Civil Engineering Department (CED), under Agreement No. CE 68/96. This is one of a series of reports produced during the consultancy by Halcrow Asia Partnership Ltd (HAP). The report was written by Mr M Riley and reviewed by Dr R Moore and Mr H Siddle. The assistance of the GEO in the preparation of the report is gratefully acknowledged.

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CONTENTS

1. INTRODUCTION

On the morning of 4 June 1997, a landslide (GEO Incident No. MW97/6/41) occurred on the upper part of Slope No. 11NW-A/C7 above Lai Cho Road, Kwai Chung (Figure 1). Debris from the landslide remained on the slope and did not travel as far as Lai Cho Road. No fatalities or injuries were reported.

Following the landslide, Halcrow Asia Partnership Ltd (the 1997 Landslip Investigation Consultants) carried out a detailed study of the failure for the Geotechnical Engineering Office (GEO), Civil Engineering Department (CED), under Agreement No. CE 68/96. This is one of a series of reports produced during the consultancy by Halcrow Asia Partnership Ltd (HAP).

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 was generally limited to site reconnaissance, desk study 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) analysis of rainfall records,

(c) interviews with witnesses and persons affected by the landslide,

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

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

2. THE SITE

2.1 Site Description

The landslide occurred immediately below the crest of the cut slope which is situated on the eastern side of Lai Cho Road, southwest of the Lai Yiu Estate in Kwai Chung (Figure 1). At the location of the landslide, the cut slope is about 55 m high and consists of a lower rock slope and an upper soil slope. The rock slope is about 22 m high and is inclined generally between about 50° and 60° to the horizontal. Much of its surface is protected with shotcrete. The soil slope above is about 33 m high and is inclined at 35° to the horizontal. Before the landslide, much of the soil slope, including the part affected by the landslide, was covered with small trees and shrubs but an area near the crest of the cut slope was covered with shotcrete (Figure 2). An access stairway extends between the crest of the central part of

the soil slope and the top of the rock slope. A system of J- and U-channels, installed on the soil slope, directs surface water to catchpits on Lai Cho Road (Figure 2).

Ko Ho Ning Memorial Primary School is located on a level platform above the crest of the slope. The area of the platform immediately upslope of the landslide location is used as a playground by the school. A 400 mm-deep U-channel follows the edge of the playground close to the crest of the slope which collects and discharges surface water away from the slope.

Lai Cho Road is located about 10 m from the toe of the cut slope. A planting berm separates the road from the toe of the slope.

The landslide occurred within the boundary of Slope No. 11NW-A/C7 for which Highways Department (HyD) are responsible for slope maintenance.

2.2 Site History

The history of the site was determined from a review of aerial photographs, available documentary information and records maintained by the GEO of past landslides in the area. Information sources consulted during the study are summarised in Table 1.

Aerial photographs taken in 1969 indicate the site was natural terrain on the western side of a north-south trending ridge. The hillside was incised by a number of gullies and was vegetated with trees and shrubs.

By 1976, construction of the Lai Yiu Estate was underway on the northern part of the ridge and Lai Yiu Street, Wah Yiu Road and Ko Ho Ning Memorial Primary School had been substantially formed at this time (Figure 3). Lai Cho Road had also been constructed, requiring the formation of a number of cut slopes, including Slope No. 11NW-A/C7, in the lower part of the hillside. The slope extended about half-way up the hillside towards Wah Yiu Road (Figure 3). Localised placement of fill and minor cutting of the upper part of the slope adjacent to Ko Ho Ning School was also evident at this time (Figure 3).

The site remained substantially unchanged until 1988, when the natural hillside was cut back as far as the boundary of Ko Ho Ning Memorial Primary School and a network of surface drains was installed (see Section 2.3). No significant changes were apparent at the site since 1988.

There are no reports of past landslides in the vicinity of the 1997 incident in the GEO's landslide database. The GEO's Natural Terrain Landslide Inventory (NTLI) shows four "relict" landslides in the area (Figure 3) which were identified on aerial photographs taken in 1964. The landslides were classified in the NTLI as being less than 20 m wide (GEO, 1996). The lengths of the landslides shown on the NTLI map sheets, measured from the source area to the distal end of the observable run-out track, were generally about 20 m.

Aerial photographs taken in 1976 show a landslide scar about 40 m southwest of the location of the 1997 incident (Figure 3). The landslide was about 20 m wide and appeared to

have occurred during the construction of Slope No. 11NW-A/C7, which was newly formed at that time.

2.3 Previous Studies and Assessments

Slope No. 11NW-A/C7 was registered in the 1977/78 Catalogue of Slopes.

The slope was inspected in May 1977 by the consultants engaged by the Government to prepare the 1977/78 Catalogue of Slopes (Binnie & Partners, 1977). The inspection noted seepage from "rock joints 10 m above (the) toe", a "previous failure" and signs of distress including "loose blocks" on the slope. Recommendations to "remove loose blocks on (the) slope" and "provide fencing at the toe" were made and it was noted that the slope was "included in Scott Wilson Kirkpatrick & Partners study area in Lai Yiu Estate" (see below).

Scott Wilson Kirkpatrick and Partners Limited (SWK) were engaged by the Housing Authority in 1977 to undertake a geotechnical investigation of existing slopes at Lai Yiu Estate, including Slope No. 11NW-A/C7. Ground investigations were carried out in 1978, 1980 and 1985. Slope stability analysis was carried out at a section about 10 m south of the part of the slope affected by the 1997 landslide (Figure 3). The analysis was based on a geological model comprising a thin layer of completely decomposed granite (CDG, with assumed shear strength parameters of $c' = 15$ kPa and $\phi' = 39^{\circ}$) overlying moderately decomposed granite. A "water table 1 m above rock level" was adopted for the analysis, as "being representative of the 1-in-10 year phreatic surface".

Upgrading works for the upper soil portion of the slope were proposed to the Housing Authority in 1983 (SWK, 1983). These included "trimming back of the soil face to a flatter angle" and installation of surface J-channels. The design was based on "a calculated factor of safety 1.3 against overall failure for a 1-in-10 year occurrence of the critical phreatic surface". The calculated factors of safety for shallow failures in the CDG for the proposed design ranged between 1.35 and 1.39. The upgrading works were completed in 1988 under New Territories Development Department (NTDD) Contract No. 8/TW/82 (GEO, 1997a).

In March 1987, a Stage 1 Studies Summary Report was prepared by the Planning Division of the Geotechnical Control Office (GCO, 1987a). The report indicated that a detailed Stage 1 Study of the slope was not required because "slope remedial works (had been) carried out under NTDD contract 8/TW/82" using a "slope design checked by GCO".

In 1992, the GEO initiated a consultancy agreement entitled "Systematic Inspection of Features in the Territory" (SIFT), which, inter alia, aims to identify features not registered in the 1977/78 Catalogue of Slopes and update information on registered slopes based on studies of aerial photographs and limited site inspections. The SIFT report, prepared in February 1995, indicated that the slope was formed between 1973 and 1974 and reprofiled in 1986, presumably in association with the slope works described above. The slope was assigned to SIFT Class C2, which is for slopes "assumed (to be) formed post 1977."

In 1994, the GEO initiated a consultancy agreement 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. A SIRST report was not prepared for Slope No. 11NW-A/C7, as the information required for the New Catalogue of Slopes had been obtained during an Engineer Inspection carried out in 1995 by consultants to HyD (Section 2.4 below).

The GEO's records indicate that no further actions under the LPM Programme have been carried out.

2.4 Maintenance Inspections by Highways Department

HyD appointed consultants to carry out Engineer Inspections of the slope in 1995 and 1998.

An Engineer Inspection was carried out by Fugro-Mouchel-Rendel Consultants (FMR, 1995) in August 1995 under Agreement No. CE 29/94. The inspection report recorded that the overall state of slope maintenance was "good". Routine maintenance works were recommended that included:

(a) clearance of drainage channels,

(b) repair of cracked/damaged drainage channels and damaged slope surfacing,

(c) removal of surface vegetation, and

(d) unblocking of weepholes.

The report also recommended detailed stability assessment of the slope because "geotechnical conditions (are) not known" and because the "slope (is) considered very steep". HyD subsequently recommended the slope for inclusion in the 1995 LPM Programme. It was not selected because of the upgrading works already carried out on the slope.

An Engineer Inspection was carried out by Halcrow Asia Partnership Limited in April 1998. The overall state of maintenance was considered "fair" and recommendations were made for routine maintenance works of a similar nature to that by FMR in 1995 (HAP, 1998). The 1997 landslide was not recorded on the Engineer Inspection Report.

2.5 Subsurface Conditions

Sheet 11 of the Hong Kong Geological Survey 1:20 000-scale map series (GCO, 1986) and the Geotechnical Area Studies Programme (GASP) engineering geology map for the area (GCO, 1987b) show the site to be underlain by coarse-grained granite.

The locations of relevant exploratory holes sunk for the geotechnical assessment of the slope (Section 2.3) are shown on Figure 3. Two boreholes, D114 and D135P, were sunk in 1980 (Gammon, 1980) and 1985 (Enpack, 1985) respectively, near the location of the main

scarp. Borehole D114, about 17 m north of the landslide, reached a depth of 7 m and identified 0.5 m of sandy colluvium, overlying 1 m of "completely weathered" granite, above coarse-grained "strong" granite. Borehole D135P, about 3 m north of the landslide, reached a depth of 16.1 m and identified about 6 m of highly and moderately decomposed granite, overlying predominantly slightly decomposed granite. SWK also identified "fill material that overlies the weathered granite at some locations at the top of the slope" and noted that this material "appears to be poorly compacted" (SWK, 1983). No fill or colluvium was included in the geological model in SWK's assessment of the section nearest the landslide site (Section 2.3).

Monitoring of piezometers and standpipes in the area, including a standpipe installed at a depth of 7 m in borehole D114, was undertaken during the geotechnical assessment of the slope by SWK. The monitoring indicated "that the water table generally lies within the rock mass but is subject to considerable variation as a result of rainfall" (SWK, 1983). For the design of the upgrading works to the slope, "a water table 1 m above rock level was used as being representative of the 1-in-10 year phreatic surface" (SWK, 1983).

3. THE LANDSLIDE

3.1 Time of the Landslide

There were no witnesses to the landslide and the earliest observation of the landslide was made at about 12:00 hours on 4 June 1997 by the Principal of Kwai Chung Methodist College, which is situated 100 m southeast of the landslide site (Figure 1).

3.2 Description of the Landslide

Observations made by HAP in a walkover survey at the site on 18 June 1997 are presented in Figure 4 and a representative cross-section through the landslide is given in Figure 5. Photographs of the landslide are shown in Plates 1 to 8.

The landslide occurred about 5 m below the crest of the slope and formed a main scarp 11 m long, 6 m wide and about 1 m deep. The volume of the main scarp was estimated at 33 m^3. A drainage channel and the access stairway located immediately behind the main scarp were partially covered with fallen leaves and branches and showed no evidence of surface water flow.

Moderately decomposed coarse-grained granite was exposed in the base of the main scarp. The weathered granite was overlain by about 1 m of loose fine- to coarse-grained sand with some angular cobble- and boulder-sized fragments of highly and moderately decomposed granite, which was interpreted by HAP as colluvium (Plates 3 and 4).

There was no significant erosion of the main scarp or seepages in the area at the time of inspection at about 13:30 hours on 18 June 1997. There was no record of seepage on the GEO Incident Report prepared following an inspection of the landslide on 6 June 1997 (GEO, 1997b).

Debris from the landslide travelled down the slope and accumulated at the toe of the soil portion of the slope (Figures 4 and 5, Plate 5). The run-out track was about 40 m long and 6 m to 7 m wide. Inspection of the landslide track showed that the debris travelled over the prevailing ground surface, flattening vegetation along its path and locally eroding the slope surface. Low levées were present predominantly on the northern side of the run-out track (Figure 4 and Plate 6). The levées were generally between 0.1 m and 0.5 m deep and a maximum of about 2 m wide. The size of the levées generally decreased towards the toe of the slope.

The mode of detachment appeared to be a shallow sliding failure of the superficial colluvium, controlled in part by the interface with the underlying moderately decomposed granite.

The travel angle of the landslide debris, as measured from the crest of the landslide scar to the distal end of the debris, was 34°. This travel angle is consistent with the typical range observed for rain-induced landslides in cut slopes in Hong Kong (Wong & Ho, 1996).

Following the landslide, urgent repair works were carried out by HyD based on GEO's recommendations. These included immediate temporary covering of the landslide with tarpaulin and subsequent trimming back of the failure surface and application of shotcrete with weepholes. Surface channels damaged by the landslide were also repaired.

4. RAINFALL

The nearest GEO automatic raingauge No. N04 is located at Kai Kwong Lau of Cho Yiu Estate, about 900 m south of the landslide site (Figures 1 and 6). The time of failure is not precisely known but for the purpose of analysis, all rainfall recorded up to 12:00 hours on 4 June 1997, by which time the landslide is known to have occurred, has been included.

An isohyet map of rainfall recorded between 01:25 hours on 4 June 1997 and 12:00 hours on 4 June 1997 is shown in Figure 6. The daily rainfall recorded between 1 May and 10 June 1997 and clock hourly rainfall between 2 and 4 June 1997 are shown in Figures 7a and 7b respectively .

Rainfall on 4 June 1997 started at about 01:00 hours and continued until around 11:00 hours. The maximum 12-hour rainfall was 364 mm recorded between 00:00 hours and 12:00 hours and the maximum hourly rainfall was 128.5 mm recorded between 06:00 hours and 07:00 hours (Table 2).

Table 2 presents the estimated return periods for the maximum rolling rainfall for selected durations based on historical rainfall data recorded at the Hong Kong Observatory (Lam & Leung, 1994). The 4-hour rainfall ending at 09:00 hours on 4 June was the most extreme with a corresponding estimated return period of about 50 years.

The maximum rolling rainfall for the rainstorm has been compared with selected past severe rainstorms recorded at raingauge No. N04 since 1982 when the raingauge began operation (Figure 8). The maximum rolling rainfall for the rainstorm of 4 June 1997 for

durations between about 15 minutes and 80 hours exceeds that of previous rainstorms recorded at the raingauge.

5. PROBABLE CAUSES OF FAILURE

The landslide occurred during or shortly after a period of intense rain, for which the 4-hour rainfall had an estimated return period of about 50 years. Short-duration intense rainfall most probably triggered the landslide.

Three possible sources of water which may have contributed to the failure were considered, namely:

(a) stormwater run-off from the playground above the crest of the slope possibly concentrated by the stairway upslope of the landslide site,

(b) overflow of stormwater onto the slope from the U-channel behind the main scarp of the landslide, and

(c) direct infiltration of rainfall into the unprotected slope.

Inspection of the area upslope of the landslide scar indicates that rainfall accumulating on the playground would flow into a 400 mm deep U-channel and be diverted away from the landslide site. Interviews with staff members of the Ko Ho Ning Memorial Primary School indicated that water up to about 40 mm deep was observed on the playground during the rainstorm on the day of the failure but that run-off did not overtop the channel and flow onto the slope. There was no evidence of surface water flow between the playground and the landslide site. Stormwater run-off from the playground seems, therefore, an unlikely source of water at the landslide site.

The landslide was inspected by the GEO on 6 June 1997. According to the Incident Report prepared by the GEO, there was no evidence that blockage of the U-channel above the landslide scar obstructed passage of stormwater along the channel and caused overtopping onto the crest of the slope. In addition, the channel falls away from the landslide and the shotcreted catchment between the playground area and the landslide scar is small and unlikely to generate a significant amount of stormwater run-off.

It is probable therefore that direct infiltration of intense rainfall through the thin colluvium on the slope, which was not covered by an impermeable slope surface, was the principal source of water.

The morphology of the landslide scar suggests that the mechanism of failure probably involved shallow sliding in colluvium, controlled in part by its interface with the underlying moderately decomposed granite. The lack of evidence of water flow into the failed area from the surface channel and stairway behind the main scarp and absence of significant signs of erosion indicate that washout due to concentrated surface water flow did not occur.

It is probable that rain water infiltrated the vegetated slope and formed a transient perched water table within the thin colluvium, above its interface with the underlying moderately decomposed granite. This would have resulted in an increase in the degree of saturation of the colluvium and possible development of positive porewater pressures, with corresponding reduction in the available shear strength and leading to failure.

The failed material travelled down the slope and water from each of the U-channels was probably directed towards the debris. Levées were only present on the north side of the landslide track, indicating that some of the landslide debris was probably subsequently washed from the slope by water overtopping U-channels which had become blocked by the landslide debris.

6. DISCUSSION

The 4 June 1997 landslide occurred at Slope No. 11NW-A/C7 which had previously been subjected to a detailed stability assessment and upgraded in 1988 comprising cutting back of the slope.

The relatively small-scale landslide (about 30 m^3), which occurred during heavy rainfall, involved a shallow failure affected by locally adverse geological and hydrogeological conditions. The colluvium involved in the failure was previously identified as completely decomposed granite with shear strength parameters $c' = 15$ kPa and $\phi' = 39°$.

7. CONCLUSIONS

It is concluded that the landslide at Slope No. 11NW-A/C7 on 4 June 1997 was triggered by heavy rainfall.

The mechanism of failure involved shallow sliding in a thin layer of colluvium. It is probable that rain water infiltrated the vegetated slope and formed a transient perched water table within the colluvium above its interface with the underlying moderately decomposed granite. This led to a reduction in the available shear strength and resulted in the failure.

The slope where the landslide occurred was previously upgraded in 1988 through cutting back. The relatively small-scale landslide (about 30 m^3) was affected by locally adverse geological and hydrogeological conditions.

8. REFERENCES

Binnie & Partners (1977). Landslide Studies Phase 1 Re-Appraisal Cut Slopes and Natural Slopes and Retaining Walls. Slope No. 11NW-A/C7. Technical Report, Binnie & Partners (HK) Limited, Consulting Engineers for Government of Hong Kong, 1 p.

Enpack (Hong Kong) Limited (1985). Lai Yiu Estate and Other Areas. Ground Investigation Factual Report (GIU Reference 7759).

Fugro-Mouchel Rendel Consultants (1995). Record of Engineers Inspection of Slope No. 11NW-A/C7. Technical Report, Fugro-Mouchel-Rendel-Consultants, Consulting Engineers to Highways Department, 14 p.

Gammon (Hong Kong) Limited (1980). Works order Q7/2/5.71, Lai Yiu Estate and Lai Cho Road. Ground Investigation Factual Report (GIU Reference 2718).

Geotechnical Control Office (1986). Hong Kong and Kowloon: Solid and superficial Geology. Hong Kong Geological Survey, Map Series HGM 20, Sheet 11, 1:20 000 scale, Geotechnical Control Office, Hong Kong.

Geotechnical Control Office (1987a). Feature Reference No. 11NW-A/C7, Hill Road to Lai Yiu Estate. Stage 1 Studies Summary Report, Geotechnical Control Office, Hong Kong, 1 p.

Geotechnical Control Office (1987b). Geotechnical Area Studies Programme – Central New Territories. Geotechnical Control Office, Hong Kong, GASP Report no. II, 165 p. plus 4 maps.

Geotechnical Engineering Office (1996). Map Sheet Reference Number 11NW-A. Catalogue of Natural Landslides Map Sheet Report, Geotechnical Engineering Office, Hong Kong, 5 p.

Geotechnical Engineering Office (1997a). Nomination of Slope No. 11NW-A/C7 Location: Lai Cho Road, Kwai Chung (below TWGH Ko Ho Ning Memorial Primary School) GEO Incident No. MW97/6/41. Government Memorandum Reference GCD2/A1/620-8, dated 20 August 1997, Hong Kong, 1 p.

Geotechnical Engineering Office (1997b). Incident No. MW97/6/41 Lai Cho Road, below Tung Wah Group of Hospitals Ko Ho Ning Memorial Primary School, Kwai Chung. Geotechnical Engineering Office Landslide Incident Report, Hong Kong, 6 p.

Halcrow Asia Partnership (1998). Record of Engineers Inspection of Slope No. 11NW-A/C7. Technical Report, Halcrow Asia Partnership Ltd, Consulting Engineers to Highways Department, 20 p.

Lam, C.C. and 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.

Scott Wilson Kirkpatrick & Partners (1983). Lai Yiu Estate & Lai Cho Road Remedial Works to Slopes. Geotechnical Submission, Vol. 12, Slope No. 11NW-A/C7 (Soil Slope), 19 p. plus 7 drawings.

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 Information Sources (Sheet 1 of 3)

Information Source	Reference	Principal Relevant Content / Comment
Mainland West Division, GEO	GCMW 2/E1/11NW-A/C7	Background information relating to history of the slope.
	GCMW 2/B4/1 (Pt. 4)	1985 Ground Investigation Information for Slope Remedial Works at Lai Yiu Estate by Enpack (1985) Limited.
	GCMW 2/E2/97	Photographs of Incident No. MW97/6/41 taken 6 June 1997, and relevant correspondence.
	GCMW 2/B4/1 (Pt. 1-5)	Engineering Projects / TW (NT) Projects, Lai Yiu Estate Study of Slope Stability.
	GCMd 3/2/45	Lai Yiu Estate, Study of Slope Stability. Final Report (April 1979).
	GCMd5/6/2 Pt. 6 Case (14)	Land Allocation for Engineering Projects, Kowloon.
	GCMd4/1c/2-8 Pt. 2 f(26)	Technical Administration Policy and Procedures Committee / Conference / Meeting.
Design Division, GEO	GCD 2/A1/11NW-A/C7	Planning Division Stage 1 Summary Report, March 1987.
	Cut Slope Master List Date 17 February 1998	Briefly summarises work carried out on the slope under the Landslip Preventive Measures (LPM) Programme.
	LPM Selection Exercise from 1988-89 to 1994-1995	Not selected for LPM works in view of upgrading works under NTDD 8/TW/82.
Planning Division, GEO	SIFT Report for Slope No. 11NW-A/C7	Construction date, geometry and general condition.
	Natural Terrain Landslide Inventory	Details of natural terrain failures in the area based on high level aerial photographs.

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

Information Source	Reference	Principal Relevant Content / Comment
Geotechnical Information Unit (GIU)	GIU Ref: 19357	1994 Ground Investigation Information for Stage 2 Study of Feature No. 11NW-A/CR176 (not relevant to study).
	GIU Ref: 7759	1985 Ground Investigation Information for Slope Remedial Works at Lai Yiu Estate (Enpack, 1985).
	GIU Ref: 2718	1980 Ground Investigation Information at Lai Yiu Estate and Lai Cho Road Works Order 07/2/5.71 (Gammon, 1980).
	GIU Ref: 13571	Lai Yiu Estate and Lai Cho Road Remedial Works to Slopes. Geotechnical Submission: Volume 1: Introduction and Background Document Volume 9: Slope No. 11NW-A/C7 (Rock Slope) Volume 12: Slope No. 11NW-A/C7 (Soil Slope)
	GIU Ref: 13564	Lai Yiu Estate Study of Slope Stability Final Report (Volume V) April 1979.
	1977/78 Catalogue of Slopes	Field sheet for Slope No. 11NW-A/C7.
Highways Department (HyD)	Slope Maintenance Records for Slope No. 11NW-A/C7 (HyD Slope No. 38382C00130)	Details of 1995 Engineer Inspection by FMR Consultants. Details of 1998 Engineer Inspection by HAP Consultants.

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

Information Source	Reference	Principal Relevant Content / Comment
Published Reports and Documents	Geotechnical Area Studies Programme Report II: Central New Territories Hong Kong Geological Survey Memoir No. 2 Hong Kong Geological Survey Sheet No. 11 (1:20 000 Scale)	Background geological and geomorphological information of area.
Water Supplies Department (WSD)	Letter Reference (6) in WSD 674/16/2/4/90 Part 8 TJ(8) dated 9 March 1998	Details of existing utilities in the vicinity of Incident No. MW97/6/41.
Drainage Services Department (DSD), Mainland South Division	Letter Reference (18) in MS 8/6896 dated 10 March 1988	Details of existing drainage in the vicinity of Incident No. MW 97/6/41.

Table 2 – Maximum Rolling Rainfall at GEO Raingauge No. N04 for Selected Durations Preceding Incident No. MW97/6/41 and The Corresponding Estimated Return Periods

Duration	Maximum Rolling Rainfall (mm)	End of Period	Estimated Return Period (Years)
5 minutes	14	07:00 hours on 4 June 1997	3
15 minutes	38	07:00 hours on 4 June 1997	10
1 hour	128.5	07:00 hours on 4 June 1997	41
2 hours	180	08:00 hours on 4 June 1997	33
4 hours	259.5	09:00 hours on 4 June 1997	51
12 hours	364	12:00 hours on 4 June 1997	32
24 hours	366.5	12:00 hours on 4 June 1997	10
2 days	405.5	12:00 hours on 4 June 1997	8
4 days	405.5	12:00 hours on 4 June 1997	4
7 days	406.5	12:00 hours on 4 June 1997	3
15 days	408	12:00 hours on 4 June 1997	2
31 days	874.5	12:00 hours on 4 June 1997	6

Notes: (1) Return periods were derived from the Gumbel equation and data published in Table 3 of Lam & Leung (1994).

(2) Maximum rolling rainfall was calculated from 5-minute data for durations up to one hour and from hourly data for longer rainfall durations.

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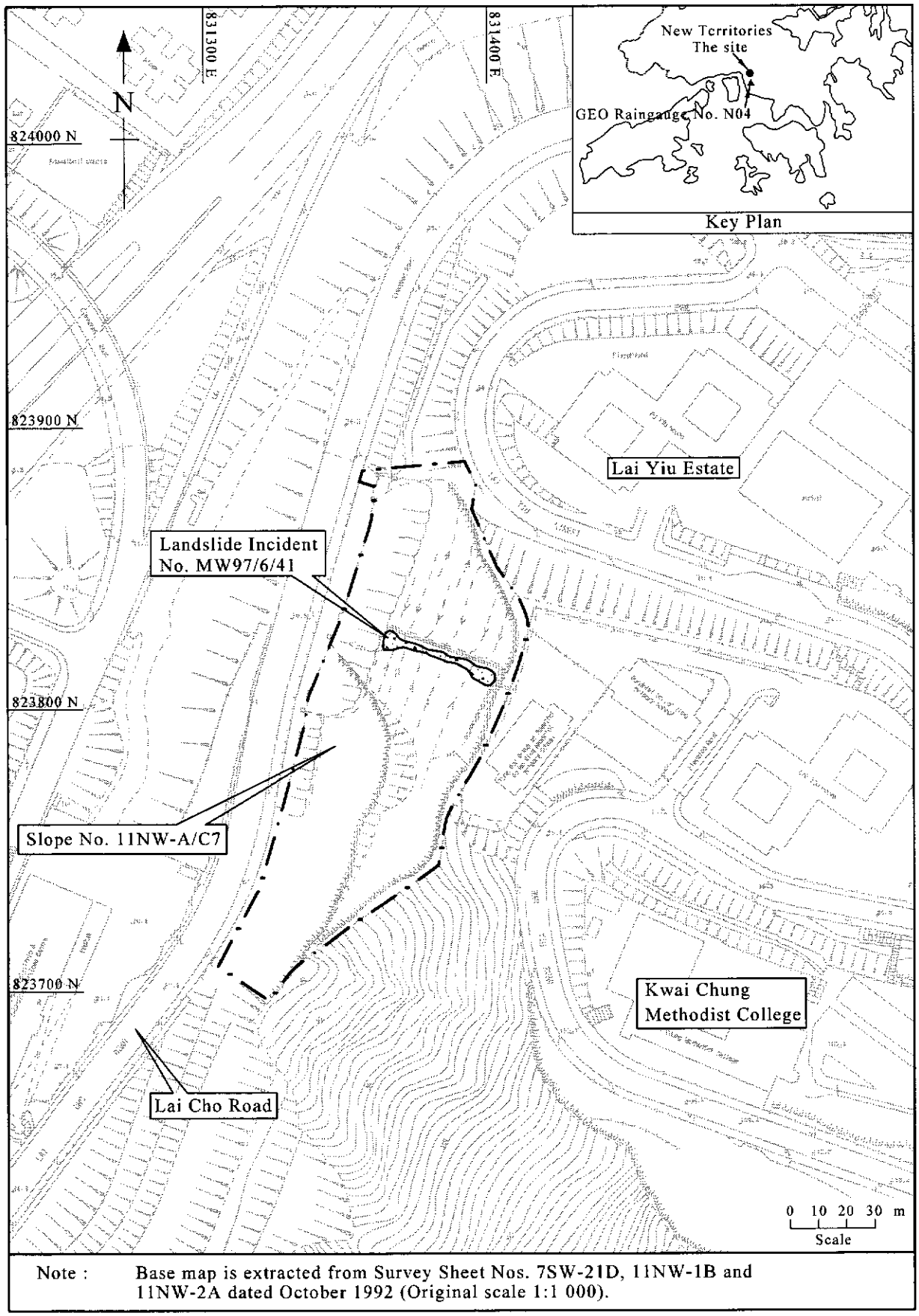


Note : Base map is extracted from Survey Sheet Nos. 7SW-21D, 11NW-1B and 11NW-2A dated October 1992 (Original scale 1:1 000).

Figure 1 - Site Location Plan

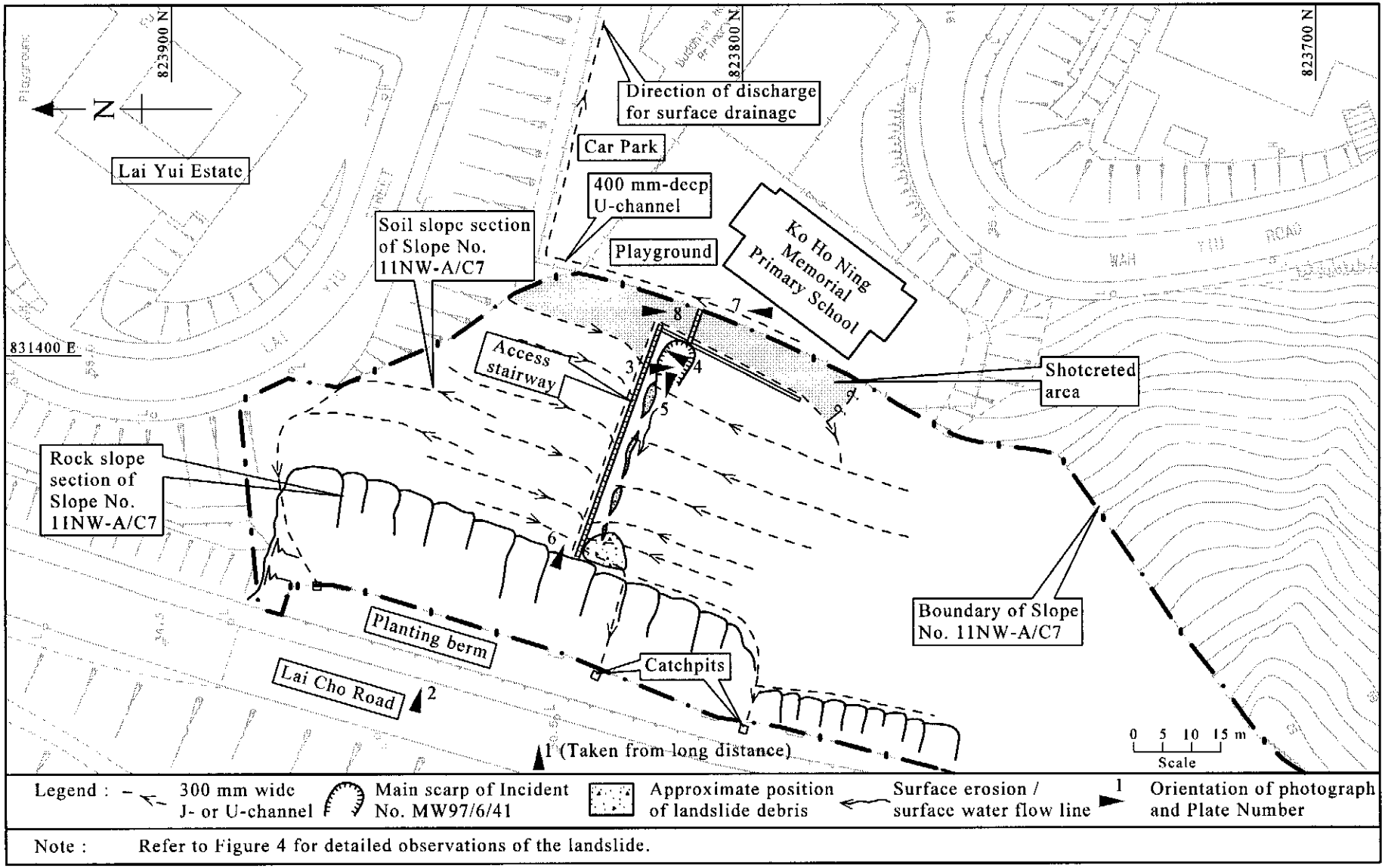


Figure 2 - Plan of the Landslide Site

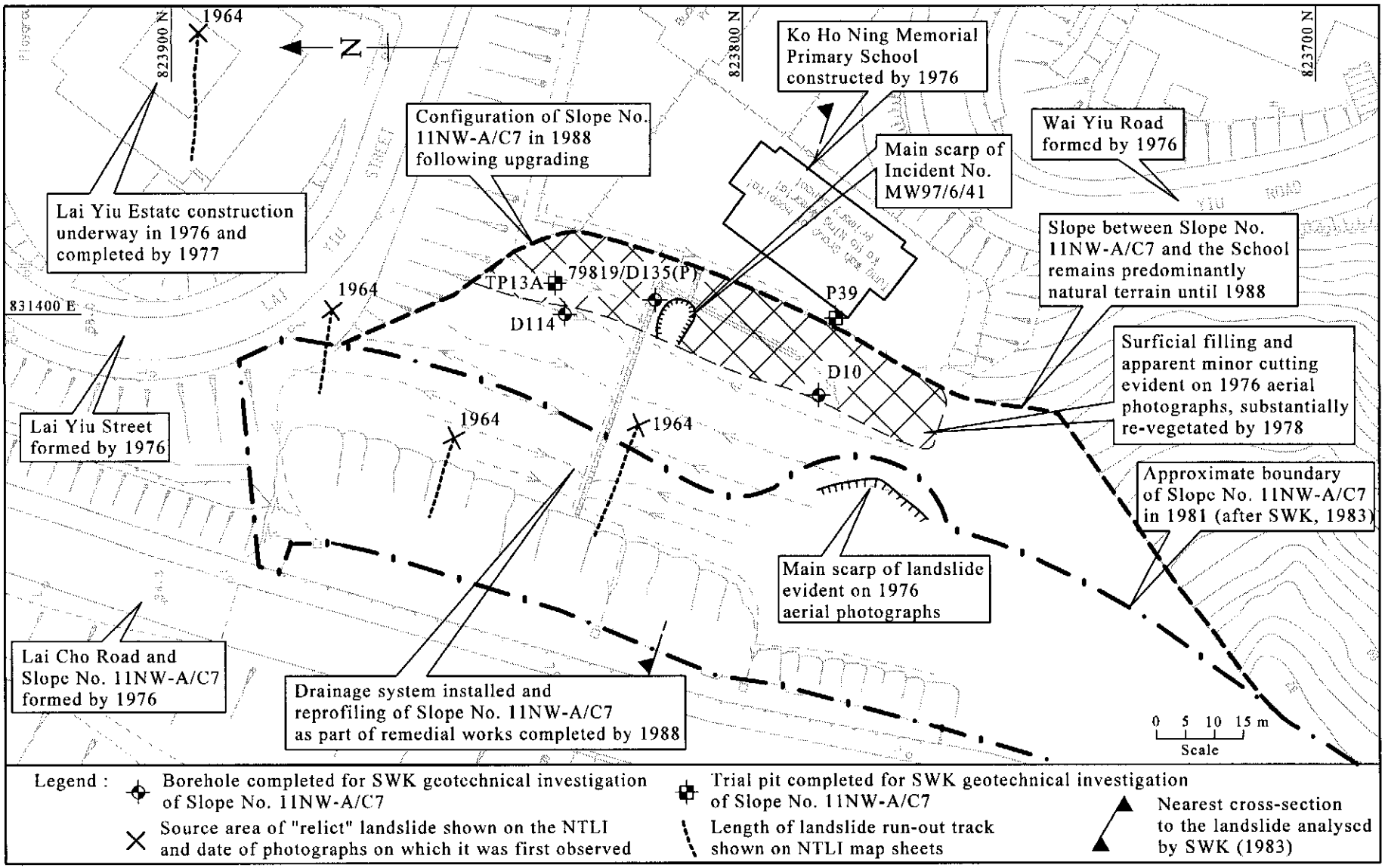


Figure 3 - Site History

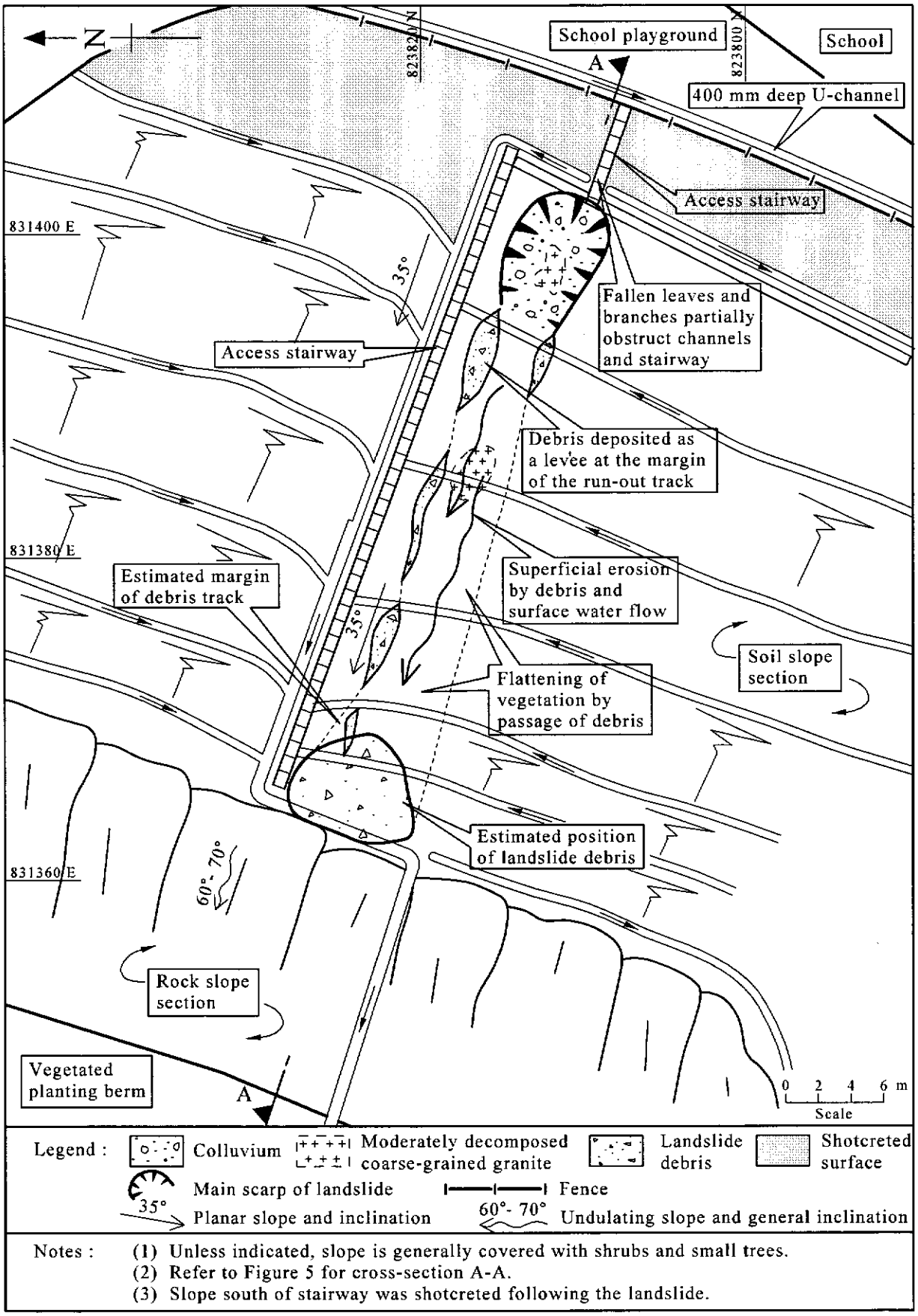


Figure 4 - Observations of the Landslide

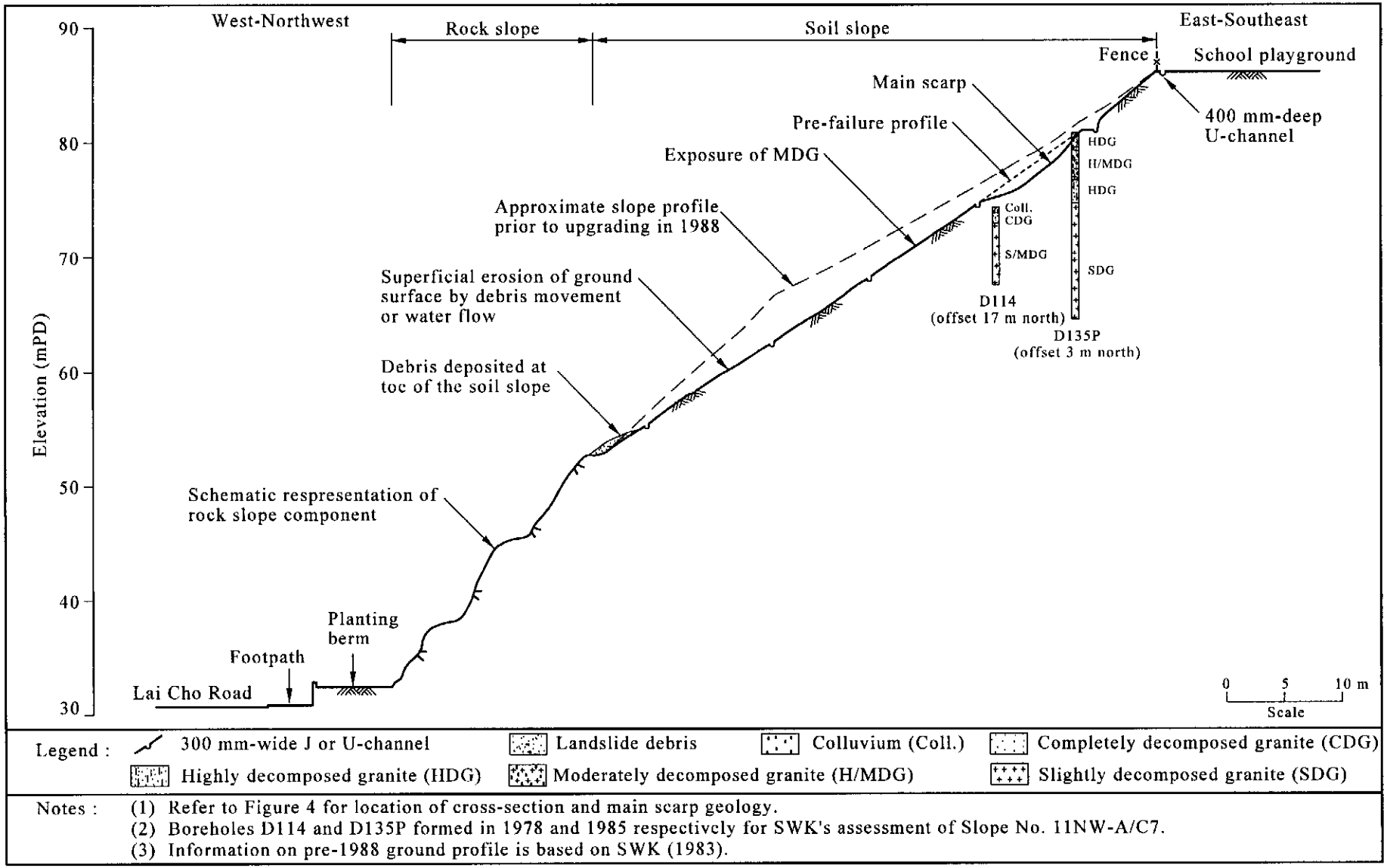
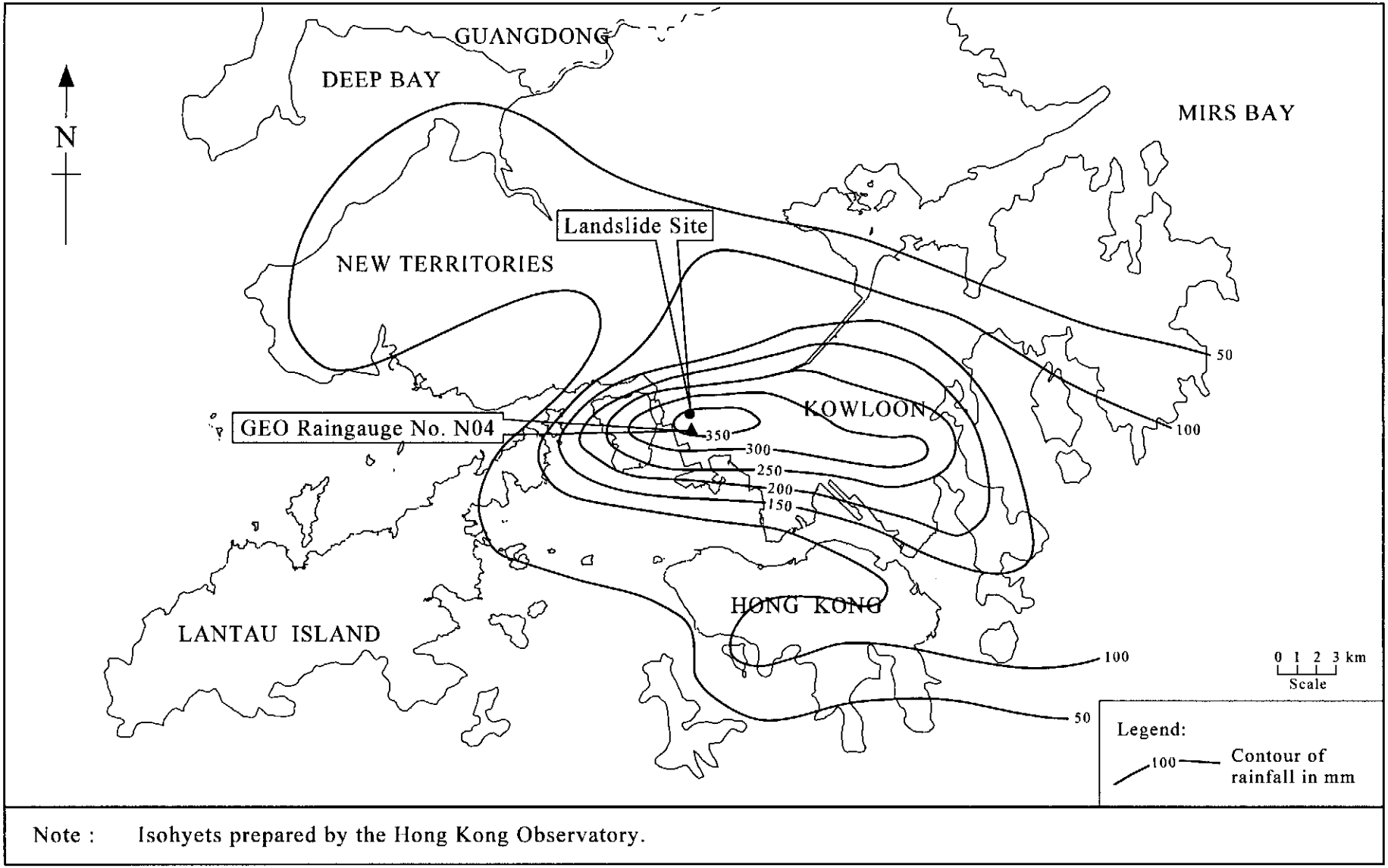
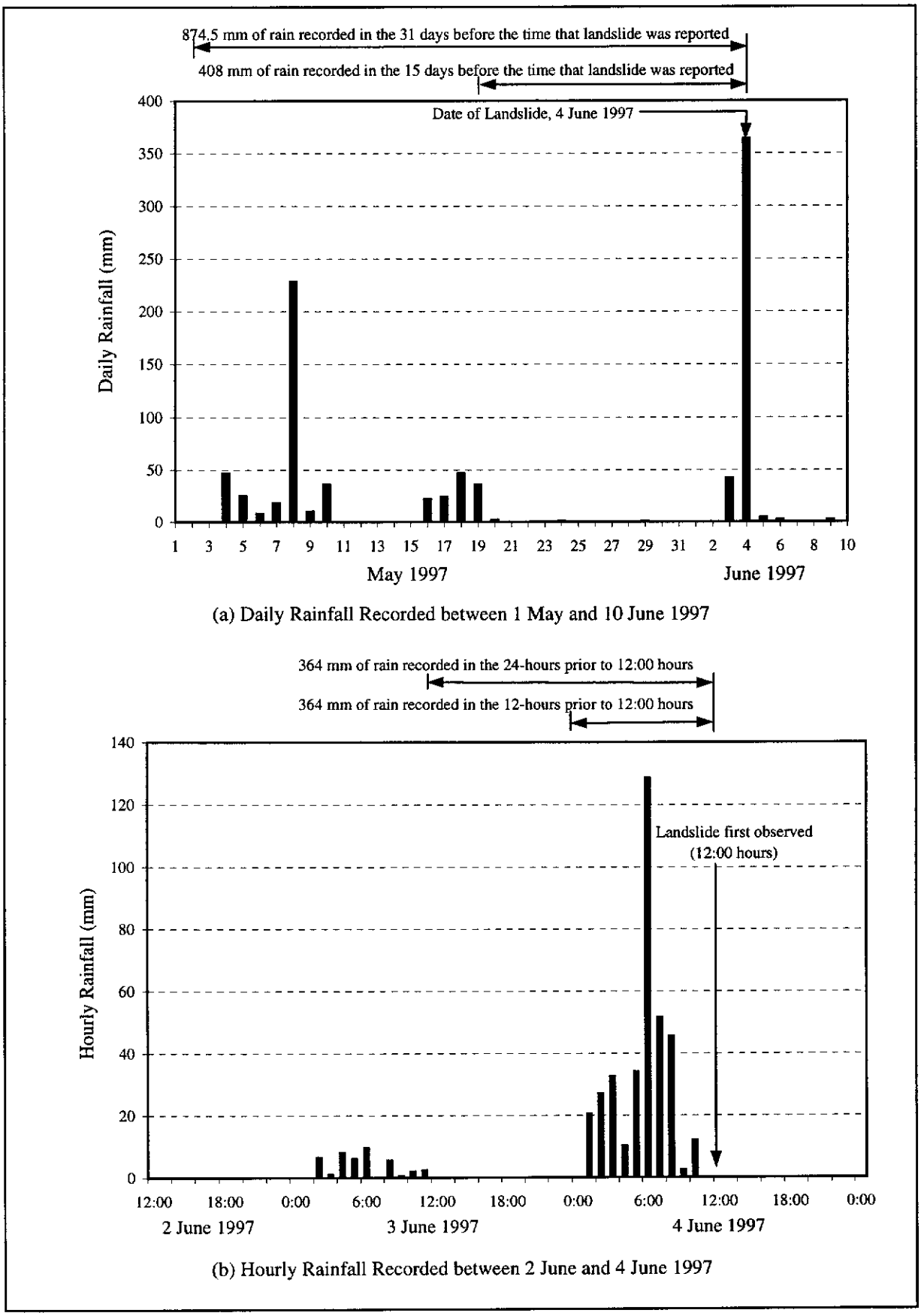


Figure 5 - Cross-section A-A through the Landslide



Note : Isohyets prepared by the Hong Kong Observatory.

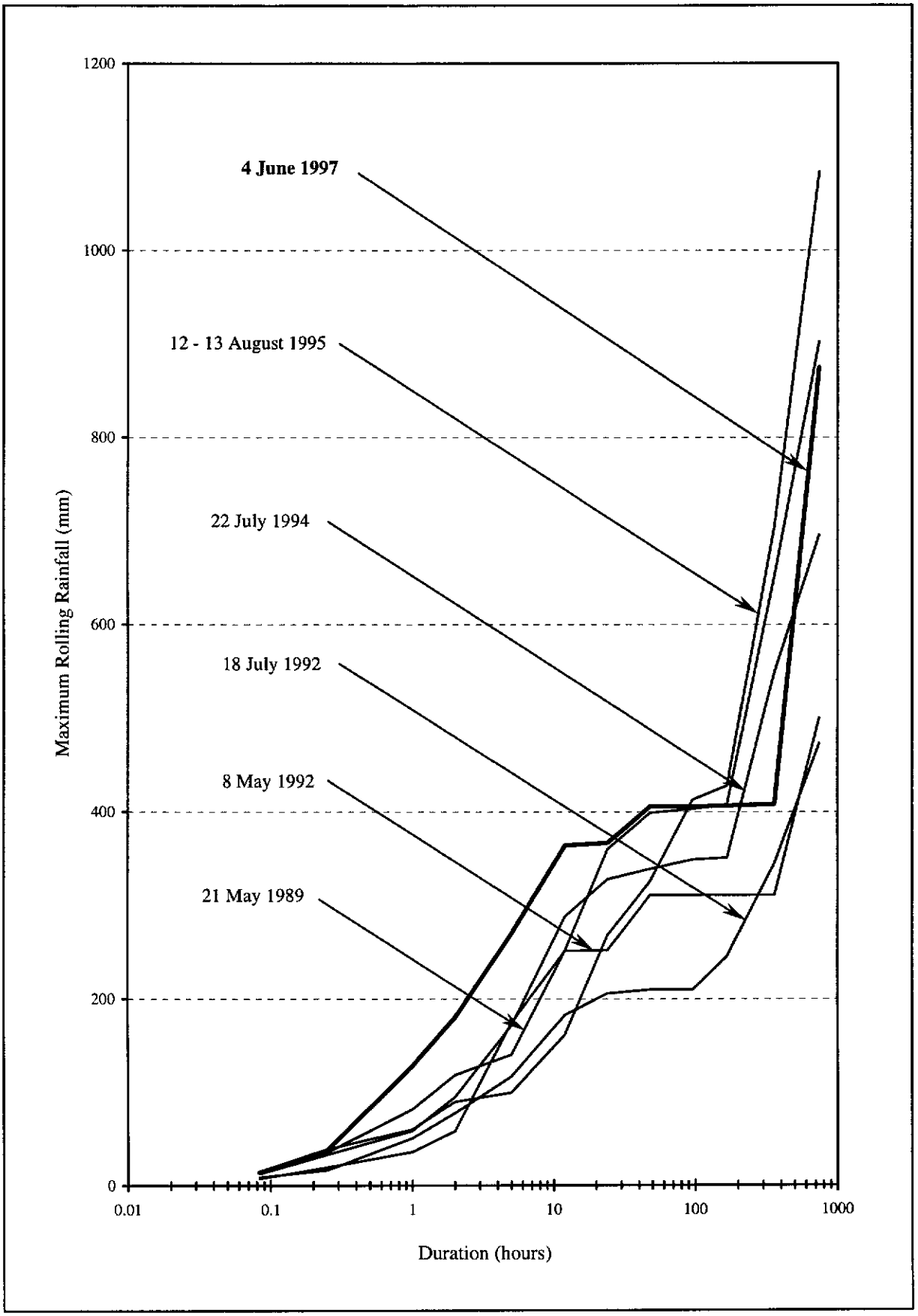
Figure 6 - Isohyets of Rainfall between 01:25 Hours and 12:00 Hours on 4 June 1997



(a) Daily Rainfall Recorded between 1 May and 10 June 1997

(b) Hourly Rainfall Recorded between 2 June and 4 June 1997

Figure 7 - Rainfall Records at GEO Raingauge No. N04



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