SECTION 2: DETAILED STUDY OF THE LANDSLIDE AT CHUNG SHAN TERRACE, LAI KING HILL ROAD ON 4 JUNE 1997

Halcrow Asia Partnership Ltd

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FOREWORD

This report presents the findings of a detailed study of a landslide (GEO Incident No. MW97/6/15) which occurred on 4 June 1997 at Chung Shan Terrace, Kwai Chung. The landslide involved the failure of an unregistered fill body and resulted in the collapse of a buried retaining wall. Approximately 450 m^3 of debris from the landslide completely blocked Lai King Hill Road and an access road to Chung Shan Terrace. A car travelling along the access road was carried by landslide debris to the far side of Lai King Hill 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. Limited ground investigation works were carried out to obtain information on subsurface ground conditions and the data were also used by the GEO in the design of permanent slope stabilisation works on behalf of the Highways Department (HyD). Recommendations for follow-up actions are reported separately.

This 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. It is one of a series of reports produced during the consultancy by Halcrow Asia Partnership Limited (HAP).

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CONTENTS

1. INTRODUCTION

This report presents the findings of a detailed study of a landslide which occurred on 4 June 1997 at Chung Shan Terrace, Kwai Chung (Figure 1). The landslide involved the failure of an unregistered fill body and resulted in the collapse of a buried retaining wall (Plate 1). Approximately 450 m^3 of debris from the landslide completely blocked Lai King Hill Road and an access road to Chung Shan Terrace. A car (with 3 passengers) travelling up the access road was carried by the landslide debris to the far side of Lai King Hill Road. No fatalities or injuries were reported.

Following the landslide, Halcrow Asia Partnership Limited (the 1997 Landslip Investigation Consultants) carried out a detailed study of the landslide for the Geotechnical Engineering Office (GEO), Civil Engineering Department (CED), under Agreement No. CE 68/96. It is one of a series of reports produced during the consultancy by Halcrow Asia Partnership Limited (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 study was generally limited to site reconnaissance, desk study and analysis. Limited ground investigation works were carried out to obtain information on subsurface ground conditions and the data were also used by the GEO in the design of permanent slope stabilisation works on behalf of the Highways Department (HyD). Recommendations for follow-up actions are reported separately.

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

(a) a review of all known 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) detailed site observations and measurements at the landslide,

(e) ground investigation, and

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

2. THE SITE

2.1 Site Description

The landslide is located above Chung Shan Terrace Access Road which connects Lai King Hill Road with Castle Peak Road (Figure 1). The fill slope on which the failure occurred is about 22 m high and has a horizontal extent of about 35 m (Plate 1). Average slope angles adjacent to the area of the failure ranged from about 32° to 34° to the horizontal. Prior to the failure, much of the slope was densely vegetated.

Nos. 14A and 14B Crawford Court are located at the crest of the landslide and the recently built Greenwood Regency is situated to the west (Figure 2). Between Crawford Court and Greenwood Regency, there is a 500 mm U-channel which drains southeast, past the crest of the landslide (Plate 2) to a natural stream course. The stream conveys water to a culvert at the toe of the slope, south of the landslide. After the landslide, it was noted that the U-channel was blocked with vegetation about 6 m southeast of the landslide.

The landslide occurred within an unregistered fill slope, exposing two concrete retaining walls that were previously buried in the fill (Plate 3). The upper concrete retaining wall, about 1 m high, was located just downslope of the crest of the landslide and failed during the incident. The lower wall, about 1.7 m high, was at about mid-slope and remained intact. Both walls were about 0.5 m thick.

The landslide mostly affected unallocated Government land, but the adjacent SIFT Feature No. 11NW-7B/S12 was also involved (Figure 3).

2.2 Site History

The history of the site has been established from a sequential series of aerial photographs and documentary records. Locations relevant to the site history are shown in Figure 3.

Aerial photographs taken in 1949 show a natural hillside at the location of the 1997 landslide which had been cleared of vegetation and terraced for cultivation. A road existed beyond the toe of the slope, but this followed a different alignment to the present Chung Shan Terrace access road.

By 1963, Nos. 14A and 14B Crawford Court and Nos. 21 and 22 Chung Shan Terrace had been built. The site of the landslide is shown to have been covered by fill of indeterminable thickness, possibly deposited during the construction of Crawford Court and Chung Shan Terrace. The concrete retaining walls exposed by the 1997 landslide are not visible on the 1963 aerial photographs but, presumably, had been formed before placement of the fill at some time between 1949 and 1963. In 1969 an open area adjacent to the toe of the slope was cleared for use as a car park. This area was subsequently extended between 1977 and 1984.

At some time between 1977 and 1984, the drainage U-channel along the southwest edge of Crawford Court was constructed to convey surface water to the stream southeast of the 1997 landslide site.

In 1982, work commenced on the design of the proposed realignment of the Chung Shan Terrace access road. The consultant appointed by the Tsuen Wan New Town Development Office identified the slope to the west of the recent landslide (the site now occupied by the Greenwood Regency, see Figure 3) as being in a "potentially unstable state" (P & T Geotechnics, 1982). The GCO confirmed these observations (GCO, 1983) and photographs presented in the GCO report indicate that this slope also contains retaining walls of a similar construction to those exposed by the 1997 landslide.

Construction work on the Chung Shan Terrace access road commenced in 1986 and was completed by 1989. The realignment of the access road over the former car park area required the emplacement of a fill platform of up to 2 m in depth. Further modifications included the removal of a U-channel at the toe of the slope with the construction of a subsurface drainage system below the fill platform.

A new 150 mm PVC disposal pipe was installed at Crawford Court in 1995 to accept both stormwater and foulwater from the buildings. The water was discharged to a drain in the basement. Plans for the new drainage were not submitted to the Buildings Department for approval (Buildings Department, 1998).

The area was evaluated by the GEO's SIFT (Systematic Inspection of Features in the Territory) programme in March 1995 and it was found that a 'Works in Progress' (WIP) feature was located within the area of interest. It is noted in the SIFT records that "works in progress, registerable features may be present". The boundary of the area is shown in Figure 3.

The feature was subsequently submitted to the GEO's SIRST (Systematic Identification and Registration of Slopes in the Territory) programme as part of map sheet report 11NW-7B together with the SIFT Transmittal Plan. As the feature was identified as a 'Work in Progress' SIFT feature, no inspection was carried out at the time by the SIRST consultants. The WIP site was to be reviewed under the subsequent SIRST Consultancy Agreement No. CE 50/97.

The WIP site identified by the SIFT consultants referred to the construction of Greenwood Regency. This development was constructed between 1995 and 1997. A temporary emergency vehicular access road was constructed across SIFT Feature No. 11NW-7B/S12 directly to the west of the landslide area. This development removed the previously observed potentially unstable slope and on demobilisation from the site, the temporary access road was removed and part of the SIFT feature reinstated and hydroseeded (Figure 2).

The landslide affected part of the 'WIP' SIFT feature No. 11NW-7B/S12 as well as the adjacent unregistered fill slope. None of the slopes that failed was registered in the 1977/78 Catalogue of Slopes and the registrable fill slope adjacent to the WIP site had no SIRST follow-up inspections or assessments.

2.3 Subsurface Conditions

Sheet 11 of the Hong Kong Geological Survey 1:20 000 scale map series (GCO, 1986) and the Engineering Geology Map for the Central New Territories (GCO, 1987), indicate that the site is underlain by coarse-grained granite.

Information on subsurface conditions has been obtained from two boreholes (BH6 and BH7) and one trial pit (TP8) sunk during the investigations for the development of Greenwood Regency (Enpack Geotechnical Engineering, 1993), and from the ground investigation carried out for the present study. The latter comprised three trial pits (TP1, TP2 and TP3), two chunam strips (S1 and S2) and one trial trench (S3). The trial pits were excavated and logged by the GEO's term contractor (GEO, 1997) whilst the chunam strips and trial trench were excavated by HyD. The locations of all the exploratory holes are shown on Figure 3.

A geological section through the landslide is presented in Figure 4, which is based on the results of the recent investigation and site observations. The site is mantled by fill whose thickness varies across the site from about 2 m in the southeast to about 4 m in the northwest flank of the landslide. The fill consists mainly of sandy silt to sandy clayey silt with gravel and brick fragments. Three in situ density tests carried out in the fill within the failed slope gave an average degree of compaction of 75% (GEO, 1997) indicating that the fill was in a loose state. The fill beneath the upper concrete wall comprised cobbles and gravel of granite.

The trial pits showed that the fill rested on highly to moderately decomposed fine- to medium-grained granite containing closely spaced, sub-vertical undulating rough joints which were slightly infilled with clay. Two joint trends were recorded, having dip angles and directions of 41°/224° and 50°/310°, respectively. No colluvium or residual soil was found beneath the fill.

3. THE LANDSLIDE

3.1 Time of the Landslide

The occupants of the car which was struck by the landslide debris confirmed the time of failure as being at 07:15 hours on 4 June 1997.

3.2 Description of the Landslide

The landslide was 18 m wide, 15 m long and had an average depth of about 3 m, with an estimated volume of about 450 m^3. The height of the main scarp varied from about 2 m in its eastern part adjacent to the U-channel (Plate 2), to about 4 m in the northern corner where a podium of Greenwood Regency was slightly undermined (Plate 1).

A relatively smooth surface, slightly eroded along its northwestern side and dipping at 32° downslope, was observed after the failure between the main scarp and the lower concrete retaining wall. A 6 m-long section of the failed upper concrete wall came to rest on this

surface (Plate 3). The ends of the upper concrete retaining wall left within the slope protruded from the fill on either side of the main scarp (Plate 4). The eastern end was relatively straight indicative of a construction joint whilst the western end was uneven and had been fractured. There were no weepholes within the wall. It was noted that the wall was founded on coarse fill. The lower concrete retaining wall was founded on moderately decomposed granite. It, too, had no weepholes. About 8 m of the wall became exposed and, the full height of the wall was made visible by erosion of fill on its downslope side. An erosion gully originating in the northern corner of the main scarp extended through the upper part of the landslide. Downhill of the lower concrete retaining wall and beyond the limits of the gully, slope angles of 32° to the horizontal were measured. Comparison with the pre-landslide topography suggests that these slopes formed part of the original ground, over which the landslide debris travelled.

During inspections after the landslide, seepages were noted from the base of the northern corner of the main scarp and from the base of a masonry wall just outside the basement of No. 14B Crawford Court. At a later date, seepages were also seen from the toe of the slope, northwest of the landslide.

After the landslide, leakage from the recently installed disposal pipe at Crawford Court (see Section 2.2 above) was established by a tracer test. On 29 October 1997, red dye was poured into the 150 mm PVC pipe in the basement at Crawford Court. The dye reappeared 10 minutes later within seepages from the main scarp of the landslide (Figure 2 and Plate 6). The average velocity of the tracer was about 1 m/min. No dye appeared from the other seepages in the main scarp of the landslide.

A cross-section through the slope, based on the observations described above is shown in Figure 4. It is concluded that a sliding failure occurred within the fill along a failure surface which extended from the upper concrete retaining wall to a 'strong point' in the slope formed by the lower concrete retaining wall. The displaced material passed over the lower concrete retaining wall and crossed Chung Shan Terrace Access Road where it hit the car, which was pushed about 30 m over gently-sloping ground to the north-bound lane of Lai King Hill Road. The occupants of the car escaped without injury. The water which subsequently flowed down the landslide eroded an estimated 50 m^3 of material and resulted in wash out of fine material for a considerable distance beyond the toe of the landslide, southwards down Lai King Hill Road.

The travel angle of the landslide, measured from its crest to the distal end of the debris, was 18° (Figure 4). The landslide ran out about 45 m from the toe of the slope, mostly over the gently inclined, lower part of Chung Shan Terrace access road.

Emergency repair works, comprising removal of landslide debris, shotcreting of the failure scar and clearance of the roadside U-channel, were completed by the Highways Department in June 1997 (Plate 5).

4. RAINFALL

The nearest GEO automatic raingauge, No. N04, is located about 880 m northwest of the landslide on the roof of Kai Kwong Lau, Cho Yiu Estate, Lai King (Figure 1). The daily

rainfall between 4 May and 4 June 1997 and hourly rainfall between 2 June and 4 June 1997 are presented in Figure 5.

On 4 June 1997, intermittent rainfall occurred between 01:30 hours and 05:10 hours before intensifying up to the time of the landslide at 07:15 hours. Isohyets of rainfall for the period prior to the landslide are shown in Figure 6. The 12-hour and 24-hour maximum rolling rainfalls before the landslide were 252.5 mm and 263 mm respectively (Table 1). The maximum rolling hourly rainfall of 128.5 mm occurred between 06:15 hours and 07:15 hours on 4 June, i.e. immediately before the landslide.

Table 1 presents the maximum rolling rainfall before the landslide for selected durations based on historical rainfall data published by the Hong Kong Observatory (Lam & Leung, 1994). The table also shows the corresponding estimated return periods for the rainfall. The maximum 1-hour rainfall immediately before the landslide was the most severe, with an estimated return period of about 41 years.

Figure 7 presents a comparison of the pattern of the rainfall prior to the landslide with those of previous major rainstorms recorded at GEO raingauge No. N04 since its installation in 1978. It can be seen that the rainfall preceding the landslide was the highest recorded at the raingauge for durations of less than 12 hours but was comparatively less intense than some of the previous rainstorms for rainfall durations of 12 hours or more.

5. PROBABLE CAUSES OF FAILURE

The close correlation between the peak rainfall intensity and the reported time of the landslide on 4 June 1997 indicates that intense rainfall probably triggered the landslide. The maximum 1-hour rainfall prior to the landslide was very severe, having a return period of about 41 years.

The landslide was sudden and fast moving, and involved run out of debris for a considerable distance over gently sloping ground with a low travel angle of 18°. These characteristics, together with the almost complete detachment of the failed material from the main scarp, indicate that the failure was very mobile and that liquefaction of the loose fill probably occurred. The travel angle of the debris is within the range of other liquefaction failures of fill slopes in Hong Kong reported by Wong & Ho (1996).

The initial failure probably occurred as a result of the collapse of the fill upslope of the lower concrete retaining wall. Collapse of the fill was most likely to have been promoted by infiltration and consequent saturation and possible elevation of porewater pressure within it and, probably, by water pressures acting on the upper concrete retaining wall which would have impounded water behind it in the absence of weep holes. The foundation of the wall may have also been undermined by water passing beneath it. Failure occurred along a surface which extended from behind the upper concrete retaining wall and daylighted above the lower wall. An alternative, but less likely, scenario could be that the initial failure took place between the two retaining walls, thereby allowing the upper wall to topple forward.

After rapid detachment of debris from the main scarp, the debris would have passed over the lower retaining wall and fill downslope which may have been locally scoured, before impacting on Chung Shan Terrace access road. The wet surface of the road and run off may have imparted some additional buoyancy to the debris, thereby contributing to its low travel angle. Possible release of water impounded behind the upper retaining wall as it collapsed and surface run off due to heavy rain after the landslide, eroded a gully within the main scarp and the remaining fill material.

Four possible sources of water at the landslide site have been identified:

(a) overflow or leakage from the U-channel and drainage apron at the crest of the failed slope,

(b) subsurface groundwater flow,

(c) leakage from the buried utility drainage system, and

(d) direct rainfall infiltration into the unprotected fill slope.

During the severe rainstorm, overflow from the U-channel that passes along the crest of the landslide would probably have occurred where the channel was blocked. However, the blockage does not correspond with the landslide location and any water overtopping the channel would probably have flowed towards the stream and not the landslide area. Elsewhere, the U-channel was found to be in a good maintenance condition. Overflow or leakage from the U-channel is therefore not considered to be a likely source of water entering the failed slope.

Water stains were observed in the vicinity of weepholes on the retaining wall located on the northern boundary of Greenwood Regency. Seepage from the weepholes and rainfall falling directly on to the apron between Greenwood Regency and Crawford Court drains into the north corner of the landslide (Figure 2). However, the quantity of water flow into the crest of the landslide was likely to be limited because of its very small catchment and therefore it is considered that surface water derived from the drainage apron was not a significant contributory factor to the landslide.

A void or soil pipe 20 mm in diameter at a depth of about 300 mm was found within the fill below the surface drainage U-channel in the main scarp indicating possible subsurface water flow from the surrounding area. This void may have acted as a subsurface water flow path during the rainstorm, although this cannot be confirmed as seepage from the void was not observed.

Leakage from the combined storm and foulwater drainage system from Crawford Court was confirmed by the tracer test after the incident (Section 3.2). If the leakage were present on 4 June 1997, the combined foul and (mainly) stormwater discharges from Crawford Court would soon have entered the upper part of the slope where its downslope flow would have been impeded by the upper concrete retaining wall. Alternatively, the drainage system may have fractured suddenly, for some unidentified reason, before the landslide.

Given the absence of an impermeable cover and the very severe rainstorm, direct infiltration of rain into the slope was also likely to be an important source of water at the landslide site.

6. CONCLUSIONS

It is concluded that the failure at Chung Shan Terrace, Lai King Hill Road probably involved liquefaction of an unregistered old loose fill slope.

The landslide was triggered by the intense rainfall immediately before the failure. The probable contributory factors of the landslide include the following:

(a) the loose nature of the fill which was susceptible to collapse and liquefaction,

(b) leakage of the combined stormwater and foulwater drainage system at Crawford Court,

(c) the absence of surface protection to the fill, which allowed infiltration, and

(d) the existence of buried retaining walls, the upper one of which dammed the water flow.

Given the relative severity of the rainstorm and the nature of the fill slope, it is possible that the landslide could have occurred irrespective of the leakage from Crawford Court. The relative contributions of direct rainfall infiltration and leakage from Crawford Court to the failure cannot be established from the information available to this study.

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Table 1 – Maximum Rolling Rainfall at GEO Raingauge No. N04 for Selected Durations Preceding the 4 June 1997 Landslide and The Corresponding Estimated Return Periods

Duration	Maximum Rolling Rainfall (mm)	End of Period	Estimated Return Period (Years)
5 minutes	16	10:35 on 8 May 1997	6
15 minutes	43	10:40 on 8 May 1997	26
1 hour	128.5	07:15 on 2 June 1997	41
2 hours	162.5	07:00 on 2 June 1997	18
4 hours	205	07:00 on 2 June 1997	14
12 hours	252.5	07:00 on 3 June 1997	6
24 hours	263	07:00 on 3 June 1997	3
2 days	294	07:00 on 3 June 1997	3
4 days	294	07:00 on 3 June 1997	2

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 of up to 1 hour and from hourly data for longer durations.

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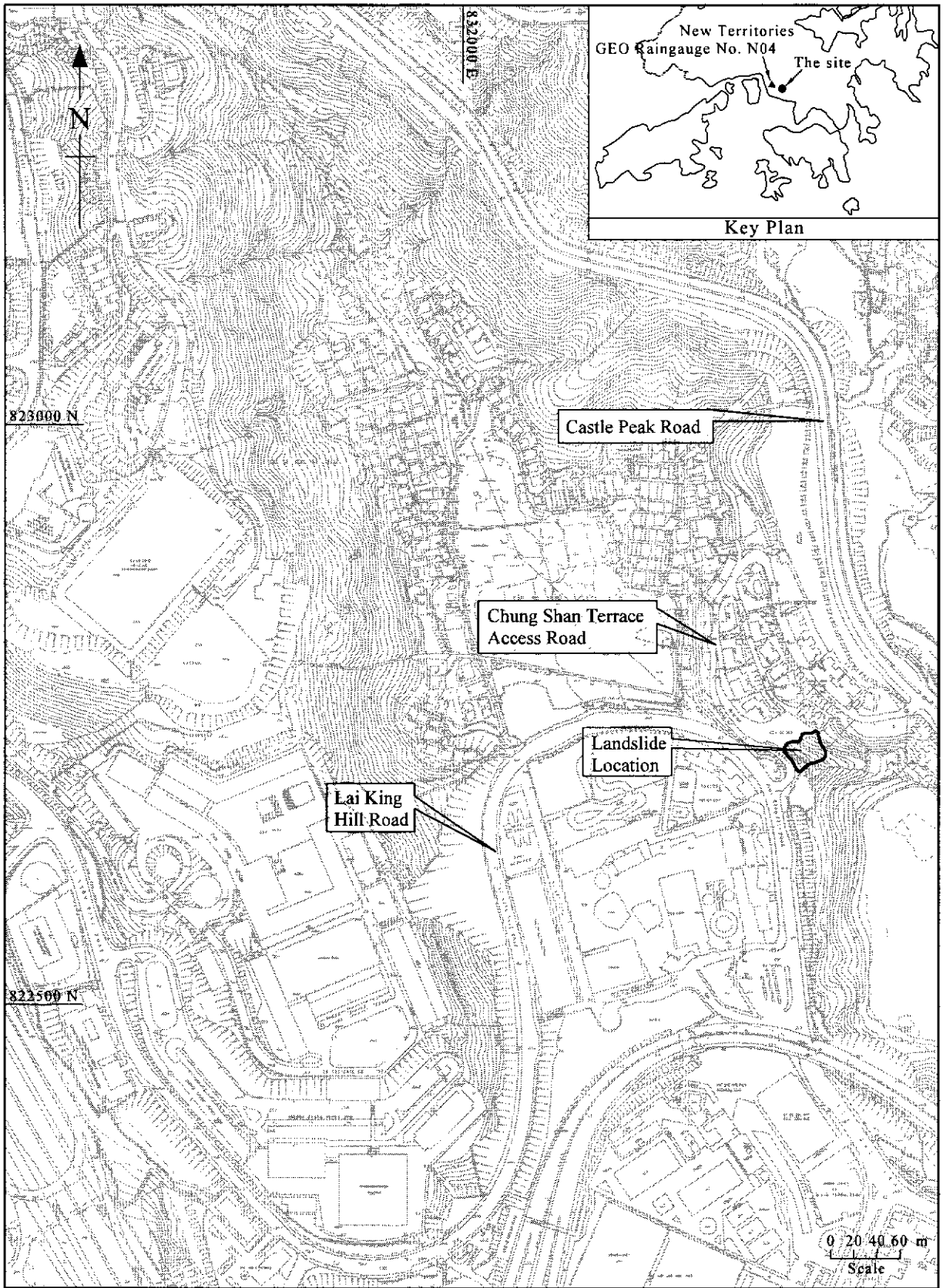


Note : Base map is extracted from Survey Sheet No. 11NW-2C, 11NW-2D, 11NW-7A and 11NW-7B dated October 1992 (Scale 1:1 000).

Figure 1 - Location Plan

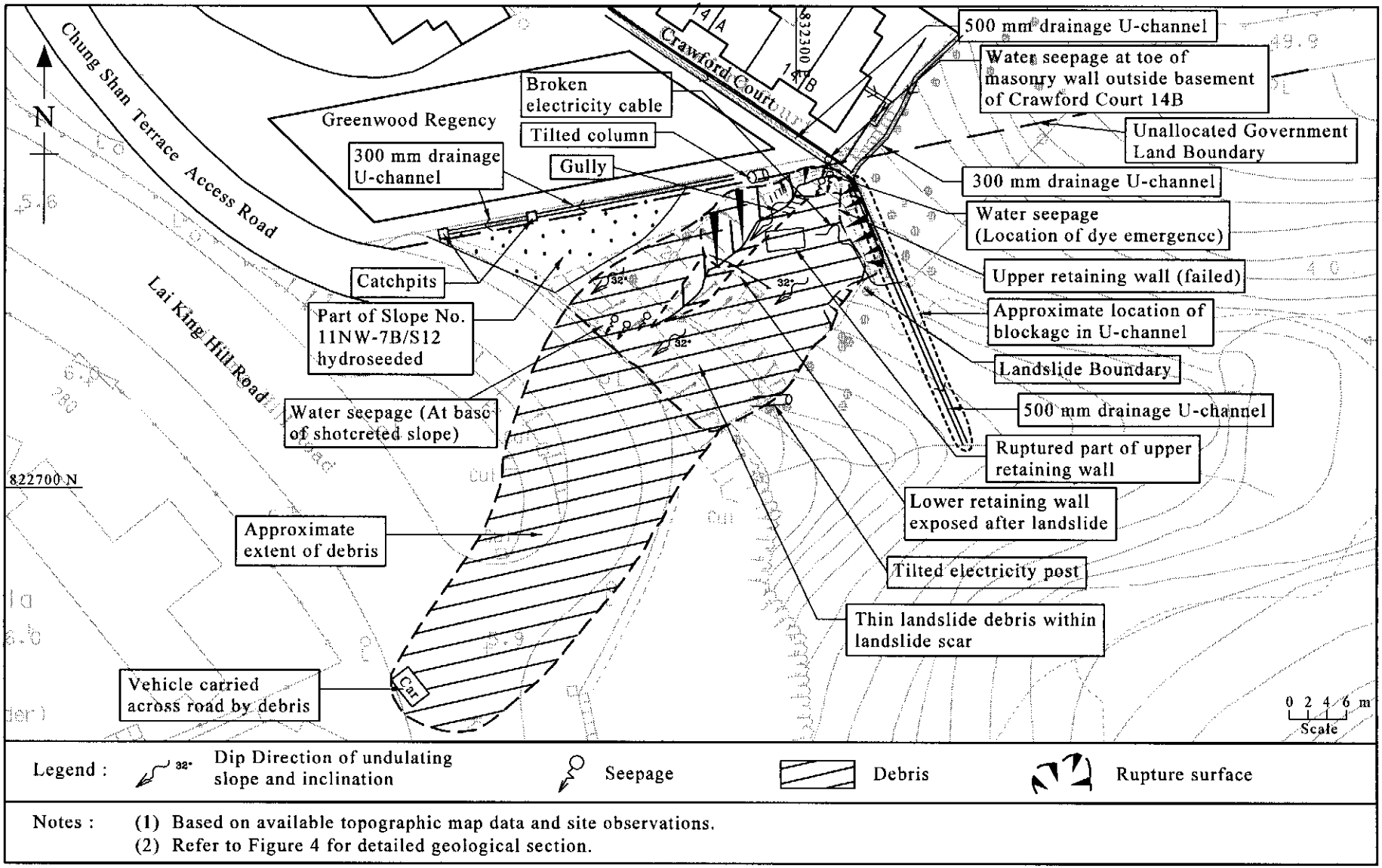


Figure 2 - Plan of Landslide Site

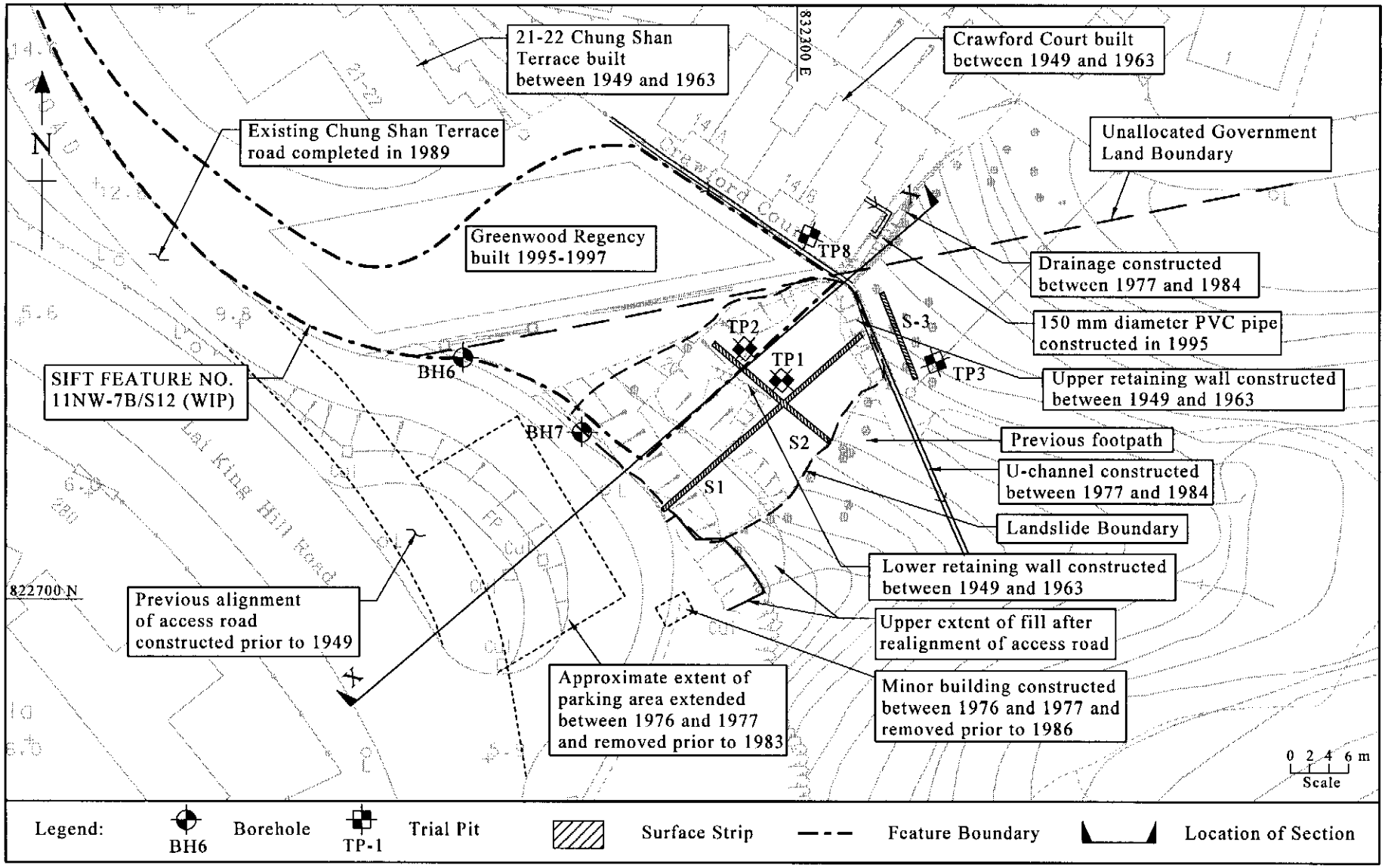
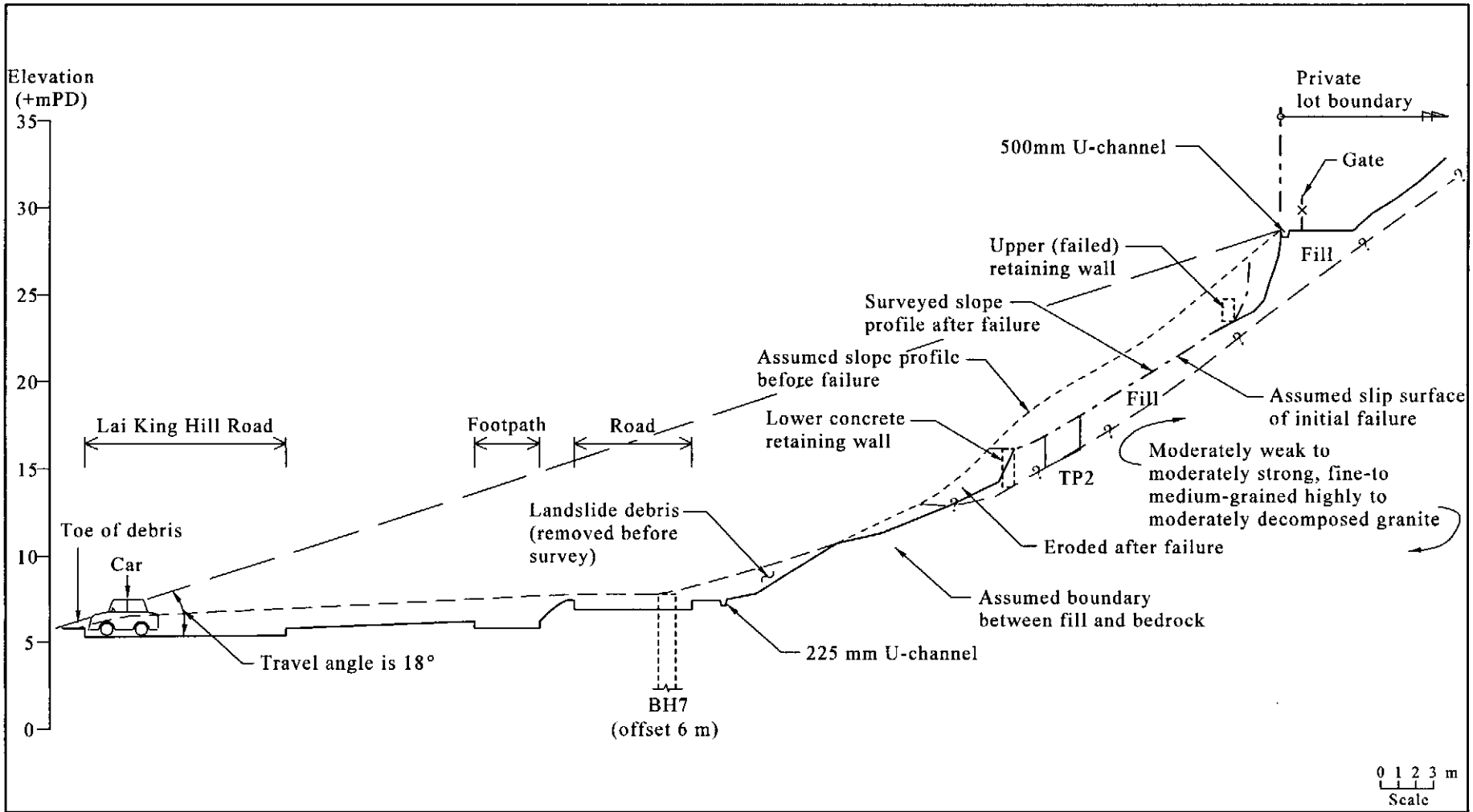


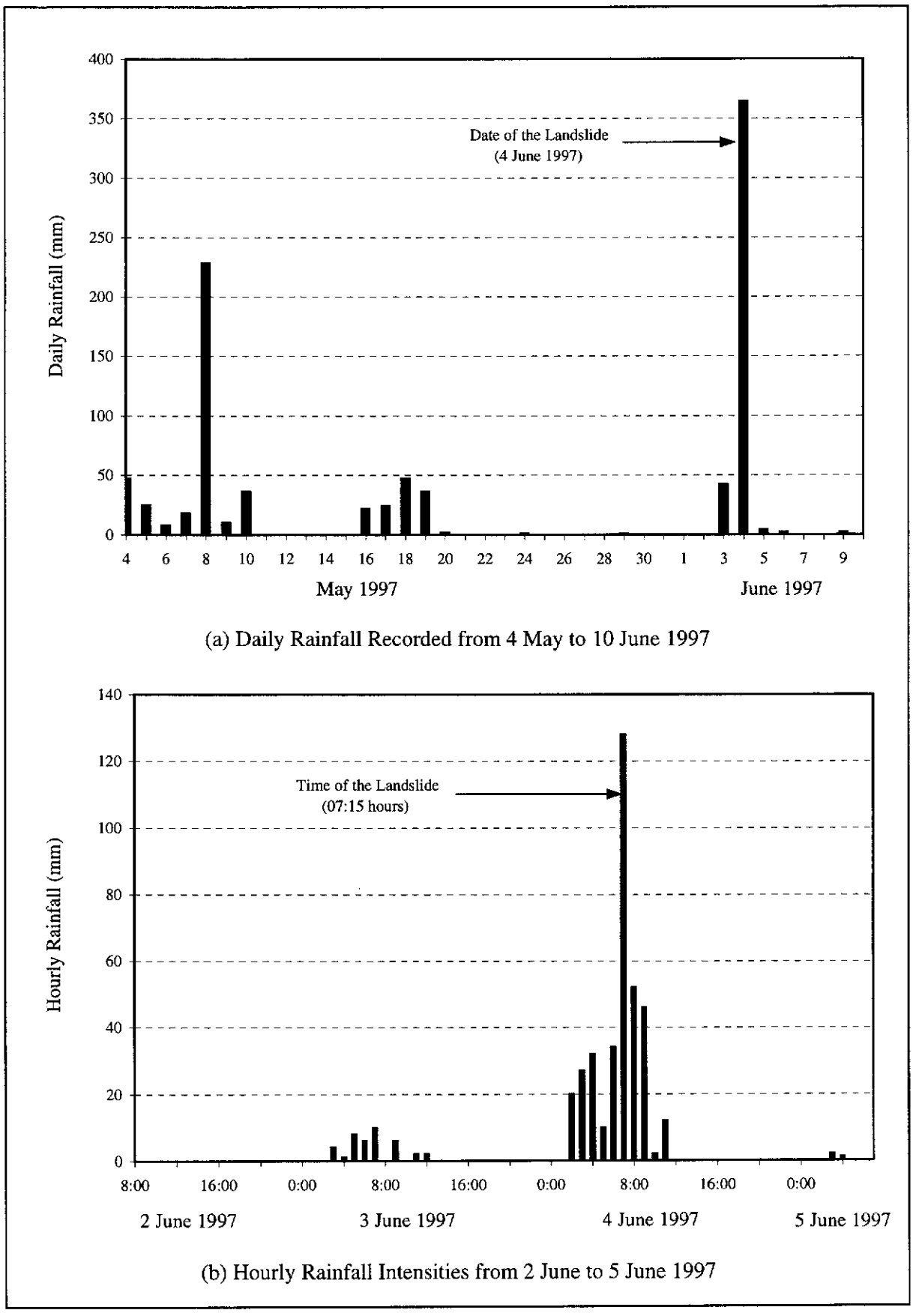
Figure 3 - Land Status and Site History



Notes: (1) Refer to Figure 3 for location of section.

(2) Section prepared using borehole BH6, BH7 and trial pit TP8 from site investigation work in 1993 (Enpack Geotechnical Engineering Co. Ltd. W.O. 15.1/2/1572); trial pit TP2 and chunam strip S2 G.I. work in 1997 (Advisory Report ADR 7/97, 1997).

Figure 4 - Geological Section Through the Landslide



(a) Daily Rainfall Recorded from 4 May to 10 June 1997

(b) Hourly Rainfall Intensities from 2 June to 5 June 1997

Figure 5 - Rainfall Records of GEO Raingauge No. N04

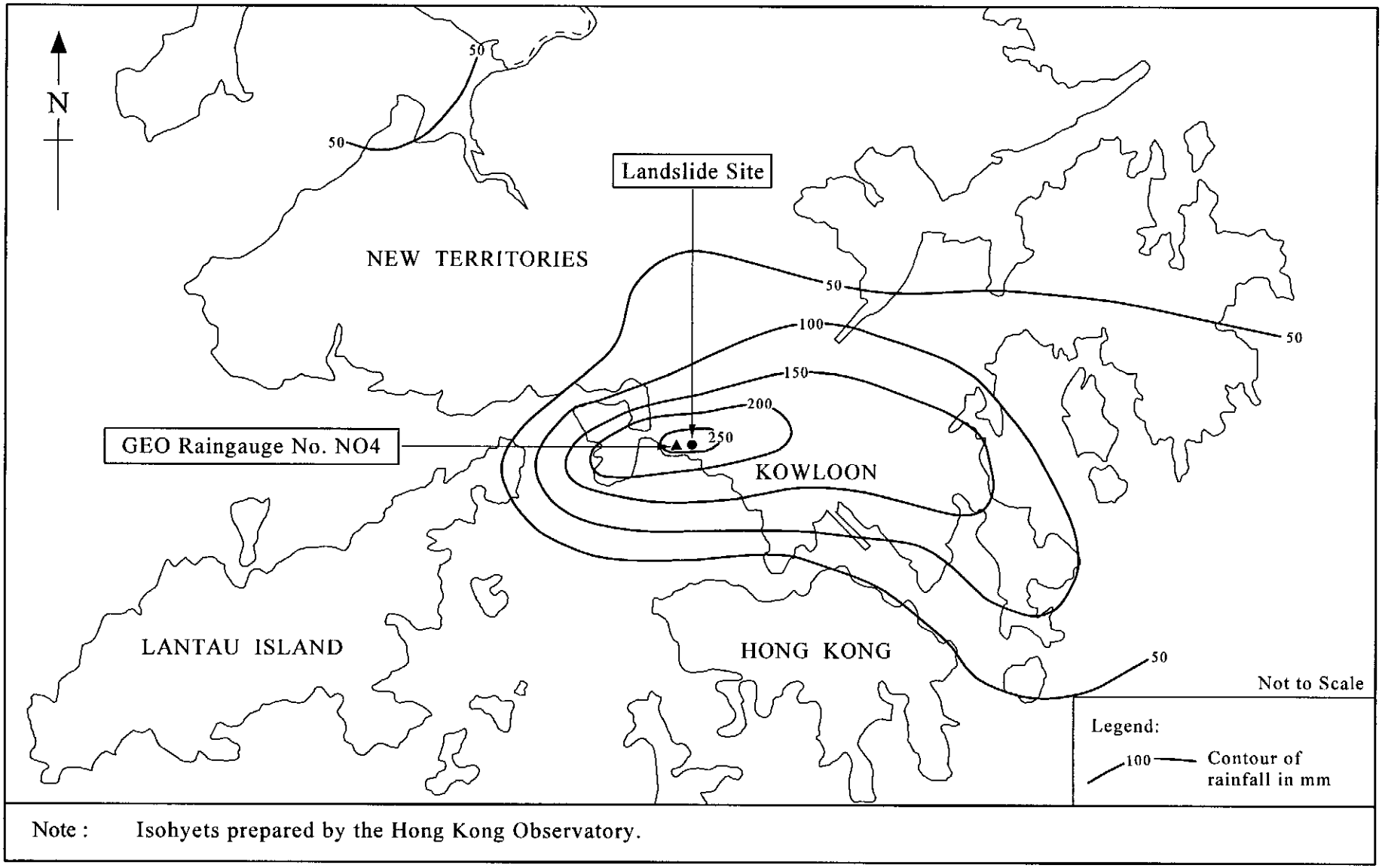


Figure 6 - Isohyets of Rainfall from 01:30 Hours to 07:15 Hours on 4 July 1997

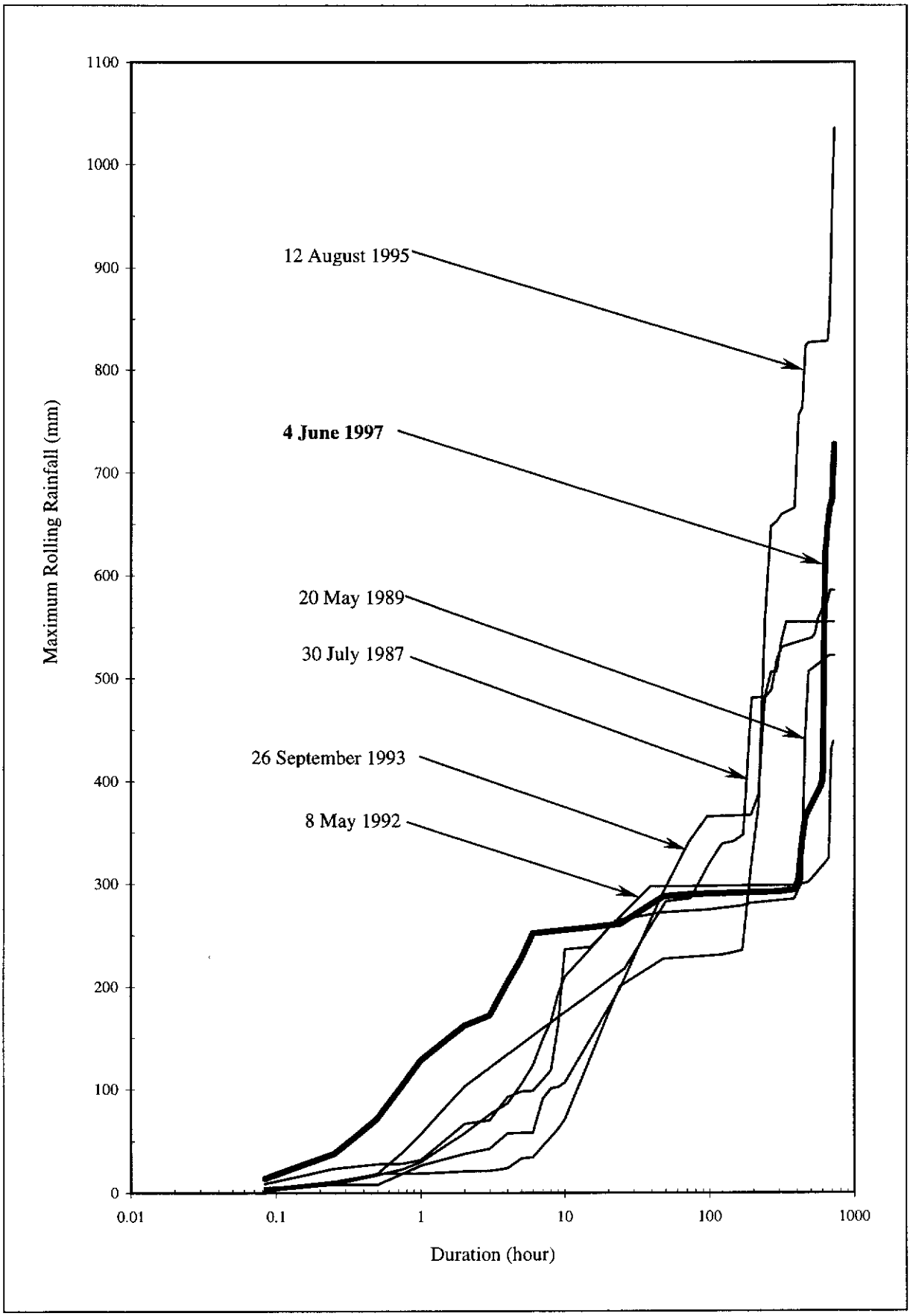


Figure 7 - Maximum Rolling Rainfall at GEO Raingauge No. N04 for Major Rainstorms

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