REVIEW OF THE 20 AUGUST 2005 LANDSLIDE ON SLOPE NO. 11NW-D/C144 BEHIND NOS. 12 AND 14 WYLIE ROAD KING'S PARK

GEO REPORT No. 283

Halcrow China Limited

GEOTECHNICAL ENGINEERING OFFICE
CIVIL ENGINEERING AND DEVELOPMENT DEPARTMENT
THE GOVERNMENT OF THE HONG KONG
SPECIAL ADMINISTRATIVE REGION

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This report is largely based on GEO Landslide Study Report No. LSR 9/2009 produced in September 2009

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PREFACE

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

The Geotechnical Engineering Office also produces documents specifically for publication in print. These include guidance documents and results of comprehensive reviews. They can also be downloaded from the above website.

The publications and the printed GEO Reports may be obtained from the Government's Information Services Department. Information on how to purchase these documents is given on the second last page of this report.

H.N. Wong
Head, Geotechnical Engineering Office
July 2013

FOREWORD

This report presents the findings of a review of a major landslide (Incident No. 2005/08/0327) which occurred on slope No. 11NW-D/C144 behind Nos. 12 and 14 Wylie Road, King's Park on 20 August 2005. The landslide involved a failure volume of about 200 m^3. The landslide debris was deposited on an access road at the slope toe, near the entrance to a carpark for a residential building. Some debris travelled along the access road and came to rest at Wylie Road. As a result of the incident, the access road was temporarily closed and no casualties were reported.

The key objectives of this review were to document the facts about the incident and to present relevant background information and pertinent site observations made under this review. The scope of the review does not include any ground investigation or detailed diagnosis of the causes of the incident. Recommendations for follow-up actions are reported separately.

The report was prepared as part of the Landslide Investigation Consultancy for landslides occurring in Kowloon and the New Territories, for the Geotechnical Engineering Office, Civil Engineering and Development Department, under Agreement No. CE 53/2006 (GE). This is one of a series of reports produced during the consultancy by Halcrow China Limited.

Gerry Daughton
Project Director
Halcrow China Limited

Agreement No. CE 53/2006 (GE)
Study of Landslides Occurring in Kowloon and the New Territories in 2007 – Feasibility Study

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1. INTRODUCTION

At about 11:30 a.m. on 20 August 2005, a major landslide (Incident No. 2005/08/0327) occurred on slope No. 11NW-D/C144 behind Nos. 12 and 14 Wylie Road, King's Park, Kowloon (Figure 1 & Plates 1 to 6) when an Amber Rainstorm Warning and a Landslip Warning were in force. The landslide involved a failure volume of about 200 m^3. The landslide scar extended into a grassed football field of King's Park Sports Ground, at the crest of the slope. The landslide debris was deposited on an access road at the slope toe, near the entrance to a carpark for the residential building, Canterbury Court. Some debris travelled down the access road and came to rest at Wylie Road. The access road was temporarily closed and no casualties were reported as a result of the incident.

Halcrow China Limited (HCL), the Landslide Investigation Consultants for Kowloon and the New Territories, carried out a review of the failure for the Geotechnical Engineering Office (GEO) of the Civil Engineering and Development Department (CEDD) under Agreement No. CE 53/2006 (GE).

This review report documents the facts about the incident, and presents background information and relevant observations made by HCL. The scope of the review does not include any ground investigation or detailed diagnosis of the causes of the incident.

2. THE SITE

2.1 Site Description

The landslide occurred on the southern portion of a west-facing soil cut slope No. 11NW-D/C144 which is located behind a podium of two vacant residential buildings, viz. Canterbury Court and Worcester Heights at Nos. 12 and 14 Wylie Road respectively. Above slope No. 11NW-D/C144 is a grassed football field, part of King's Park Sports Ground, which is separated from the subject slope by a steel fence. A private development, Parc Palais, is situated to the north of slope No. 11NW-D/C144 while the Filipino Club is located to the south of the subject slope.

Slope No. 11NW-D/C144 is approximately 96 m long and has a maximum height of about 13.5 m. The slope comprises one batter inclined at an angle ranging from 35^o to 50^o. The slope has a chunam surface cover, with 50 mm diameter weepholes spaced at about 1.5 m centres vertically and horizontally, except for the southern end where the slope surface is covered with vegetation. Some boulders protruding from the slope surface are present at the mid-height of the slope. A site layout plan showing the location of the 20 August 2005 landslide is presented in Figure 2. A cross section through the August 2005 landslide is shown in Figure 3.

The surface drainage provisions on slope No. 11NW-D/C144 comprise a 225 mm U-channel at the slope toe and a 300 mm U-channel about 1.0 m behind the crest, along the edge of the grassed football field.

2.2 Geological Setting

According to Sheet 11 of the Hong Kong Geological Survey (HKGS) 1:20 000 scale map series HGM20 (GCO, 1986), the solid geology at the subject slope comprises Megacrystic fine- to medium-grained GRANITE. It is also noted that a northwest-trending photolineament runs close to the slope toe (Figure 4).

2.3 Maintenance Responsibility

According to the Slope Maintenance Responsibility Information System (SMRIS) of the Lands Department (Lands D), the subject slope is under the maintenance responsibility of the Government Property Agency (GPA) and Architectural Services Department (Arch SD) is the maintenance agent.

The King's Park Sports Ground above slope No. 11NW-D/C144 is maintained by Hong Kong Rugby Football Union under a Short Term Tenancy (STT) No. KX2153, based on the information provided by Lands D.

2.4 Water-carrying Services

According to the information provided by various utility companies and services departments, no water mains are located on the subject slope.

The 1963 aerial photographs and a drainage plan located in Arch SD reveal the layout of herringbone sub-soil drains underneath the King's Park Sports Ground (Figure 5). However, no other surface or underground drainage plans for the subject slope or the sports ground could be located in Arch SD or the Hong Kong Rugby Football Union (HKRFU), the tenant of King's Park Sports Ground under Lands D's STT No. KX2153.

The layout plan of water-carrying services at and in the vicinity of slope No. 11NW-D/C144, which were identified during the course of this study, is presented in Figure 6.

3. SITE HISTORY AND PAST SLOPE INSTABILITIES

3.1 Site History

The development history of the site (Figure 7) has been established from a review of aerial photographs and inspection of available relevant documentary records. A detailed account of the aerial photograph interpretation (API) is presented in Appendix A. Salient aspects of the key observations are summarised below.

The earliest available aerial photographs, taken in 1945, show that the August 2005 landslide site is located on a southwest-facing natural hillside, which is generally covered with a thin veneer of vegetation comprising grass and sporadic shrub. Sheet and gully erosion can be identified in the vicinity of the ridgeline extending across the upper catchment area towards the lower terrain near the foothill. A spurline is observed running from the ridgeline in a

south-westerly direction to the southern portion of the present-day layout of slope No. 11NW-D/C144. Wylie Road, which trends northwest to southeast, had been formed along the lower reaches of the subject foothill. A bowling green and tennis courts are present to the south of the 2005 landslide location.

The 1949 aerial photographs indicate that the subject hillside suffered severe sheet and gully erosion, giving a general appearance of a barren and hummocky terrain. Several ephemeral drainage lines, draining from northeast to southwest, are visible along the incised erosion gullies. Tor stones are present along a northwest-trending ridgeline to the northeast of the landslide site, indicating a shallow rockhead at that location. Subangular colluvial boulders are deposited at the low-lying sloping ground, near the toe of the subject hillside. A deeply excavated borrow area can be identified at about 50 m to the east of the subject slope near the ridgeline.

In the 1963 aerial photographs, it is apparent that the slope No. 11NW-D/C144 was formed by cutting and filling at the slope portions to the north and south of the spurline identified in the 1945 aerial photographs, respectively and the sports ground above the crest was under construction. The layout of the subsoil herringbone drainage system on the sports ground is observed. A bare slope surface with occasional subangular boulders, probably corestones, is visible at the northern portion of slope No. 11NW-D/C144, while a thin veneer of short grass appears on the slope surface near its southern boundary. An access road, connecting Wylie Road and the elevated platform in front of the subject slope had been built. The British Military Hospital adjacent to the northern end of the subject slope was under construction. By 1964, Wylie Path which connected Wylie Road to the eastern locality of the subject slope had been constructed.

By 1967, a highly reflective soil surface, which was possibly a shallow failure, is apparent in the aerial photographs at the lower southern portion of slope No. 11NW-D/C144, while the northern portion of the subject slope appears to be a bare soil surface. A cluster of temporary structures is present on the elevated platform in front of the subject slope. Construction of the British Military Hospital adjacent to the northern end of the subject slope had been completed.

Based on the 1969 aerial photographs, a strip of hard surface had been applied at the lower southern portion of the subject slope, which may have been the result of remedial measures for the slope failure identified in 1967. Thin vegetation is observed on the rest of the slope surface. The temporary structures on the elevated platform in front of the subject slope identified in 1967 had been cleared.

Between 1975 and 1977, Worcester Heights and Canterbury Court had been constructed on the elevated platform in front of the subject slope.

In the 1988 aerial photographs, an area of high reflectivity, possibly a new hard surface cover, is apparent at the lower southern portion of slope No. 11NW-D/C144. In 1991, linear grey tone features are observed on the new hard surface cover identified in 1988, which might be indicative of water seepage in that area.

Based on the 2001 aerial photographs, it is evident that the British Military Hospital to the north of slope No. 11NW-D/C144 had been demolished and extensive site clearance for the

construction of Parc Palais had been carried out. By 2004, construction of Parc Palais had been completed.

The 2005 aerial photographs, taken on 24 October 2005, reveal an area lighter in tone at the southern portion of slope No. 11NW-D/C144, which might be indicative of hard surface having been applied on the August 2005 landslide scar (Incident No. 2005/08/0327). The failure scar appears to extend into the area of the sports ground above. The landslide source and debris trail cannot be identified. The remaining parts of the subject slope are densely covered with grass and shrubs.

3.2 Past Slope Instabilities

According to the GEO's landslide database, there are no previous records of any reported landslides on the subject slope.

According to the API, a shallow failure is evident at the lower southern portion of the subject slope in 1967.

4. PREVIOUS ASSESSMENTS AND SLOPE WORKS

4.1 Phase 1 Landslide Studies by Binnie & Partners

The subject slope was registered as slope No. 11NW-D/C144 in the 1977/78 Catalogue of Slopes and was investigated under the Landslide Studies entitled "Phase 1 Re-appraisal Cut and Natural Slopes and Retaining Walls", carried out by Binnie & Partners (B&P) for the Geotechnical Control Office (GCO, renamed GEO in 1991) in 1977. According to the report prepared by B&P in August 1977, the condition of the slope was assessed as "Satisfactory". It was also noted in the report that no signs of seepage were observed but signs of distress, i.e. cracks on the chunam surface, were identified at the slope. Repairing of the damaged chunam surface was recommended. There are, however, no records available to confirm whether the repair works were carried out.

4.2 Stage 1 Study by GEO

In October 1994, a Stage 1 Study of the subject slope was carried out by the Planning Division of the GEO. According to the study report, no suspected leakage of water-carrying services and no signs of distress were identified on the slope. In addition, "Further Study" and "Engineer Inspection" were recommended in the report.

4.3 SIFT and SIRST Studies

In August 1995, under the study entitled "Systematic Inspection of Features in the Territory" (SIFT) initiated by the GEO, the subject slope was designated as SIFT Class 'C1' (i.e. a slope that had been formed or substantially modified before 30 June 1978 or had been illegally formed after 30 June 1978).

In October 1994, the subject slope was inspected as part of the study entitled "Systematic Identification and Registration of Slopes in the Territory" (SIRST) initiated by the GEO. According to the inspection record of the SIRST consultant, Binnie Consultants Limited, the U-channels at the slope crest and toe were in good condition and no signs of seepage and no "potential leaky services" were noted. The overall maintenance condition of the slope was assessed as "Good" and its consequence category was classified as "High".

4.4 LPM Stage 3 Study

In 1996, slope No. 11NW-D/C144 was included in the LPM Programme and a Stage 3 Study was undertaken by Scott Wilson Kirkpatrick (Hong Kong) Limited under Supplementary Agreement to Agreement No. CE 53/94. However, the results of desk study revealed that the area at the British Military Hospital adjacent to the northern end of the slope, had been scheduled for land sale in April 1998 for private development and the subject slope would be handed over to the Education and Manpower Bureau (EMB) of Hong Kong SAR Government for a primary school development in the period from 1998 to 2002. As a result, the LPM Stage 3 Study for the subject slope was deferred.

In March 2004, the subject slope was selected for inclusion in the LPM Programme by the GEO. A Stage 3 Study was carried out by Maunsell Geotechnical Services Limited (MGSL) under Agreement No. CE 24/2003 (GE) and the draft Stage 3 Study Report was submitted on 29 July 2005 before the occurrence of the 20 August 2005 landslide. The desk study carried out by MGSL revealed that EMB and Arch SD had no plan for school development in front of the subject slope. MGSL completed the Stage 3 Study (S3R 149/2005) in January 2006.

As part of the Stage 3 Study, site-specific ground investigation (GI) works, including the sinking of four drillholes and excavation of three trial pits and three surface strippings, were carried out on the slope before the 20 August 2005 landslide under Contract No. GE/2004/34. The locations of the GI works are shown in Figure 8. The GI results showed that completely decomposed granite (CDG) was encountered from the ground level to the termination depth in all four drillholes (i.e. ranging from 4 m to 9 m below the slope toe) and also in the trial pits and surface strippings, except for the surface stripping (S3) at the southern portion of the slope, where fill material was encountered. The CDG is described in the Stage 3 Study Report as "extremely weak, reddish yellow, occasionally brownish yellow and red spotted grey, slightly clayey silty fine to coarse sand with some angular to sub-angular fine to medium gravel of granite and quartz".

Groundwater monitoring devices were installed in the drillholes with details as follows.

(a) One standpipe in drillhole No. DH 1 to a depth of 9 m.

(b) Two piezometers in drillhole No. DH 2 to depths of 4 m and 8 m.

(c) Two piezometers in drillhole No. DH 3 to depths of 2 m and 6 m.

(d) Two piezometers in drillhole No. DH 4 to depths of 2.5 m and 5 m.

The groundwater monitoring records taken between 22 January 2005 and 16 February 2005 by the GI contractor manually before completion of the GI report indicated that the standpipe and piezometers were dry during the monitoring period.

As part of the Stage 3 Study, groundwater monitoring using automatic sensors in the standpipe and in the lower level piezometers of the drillholes was carried out during the period from 4 May 2005 to 8 September 2005. The groundwater monitoring results and the daily rainfall records are presented in Figures 9 to 12. The monitoring records revealed that the highest recorded groundwater level at drillhole No. DH 1 was about 1.5 m below the crest of the subject slope. The highest recorded groundwater levels at drillhole Nos. DH 2 and DH 3 (the nearest drillholes to the landslide) were at about 5.8 m and 5 m below the slope crest respectively. The highest recorded groundwater level at drillhole No. DH 4 was at about 600 mm below the slope toe. All the highest groundwater levels were recorded during the 20 August 2005 rainstorm.

The Stage 3 Study Report indicated that the highest groundwater level recorded in drillhole No. DH 1 was about 3.5 m higher than that measured in drillhole Nos. DH 2 and DH 3, even though the three drillholes were located along the crest of the slope at similar ground levels and with similar ground conditions. The report suggested that probable leakage of buried drainage pipes at concentrated locations near drillhole No. DH 1 could be the explanation for the difference in the recorded groundwater levels.

According to the Stage 3 Study Report, the high groundwater levels recorded in the wet season of 2005 were attributed to the infiltration of rainfall into the large area of the grassed sports ground behind the crest of the subject slope. Leakage of buried drainage pipes at certain locations behind the crest of the slope could also be a contributory factor to the high groundwater level.

During site inspections for the Stage 3 Study between May and August 2005, seepage from weepholes and from the slope surface above mid-height of the subject slope was evident at several locations. Some newly formed cracks on the chunam surface were also observed at the locations of high seepage after the August 2005 failure. In the Stage 3 Study Report, it was suggested that the buried drainage pipes were leaking at a number of locations, in addition to the location of the August 2005 failure.

The Stage 3 Study Report concluded that excess water pressure resulted from heavy rainfall and leakage of buried drainage pipes was the probable cause of the August 2005 landslide.

4.5 LPM Works

Subsequent to the August 2005 landslide, LPM works were undertaken by China GEO-Engineering Corporation, between 15 November 2005 and 4 November 2006, under Contract No. GE/2005/39.

According to the information provided by MGSL, two unrecorded underground drainage pipes were identified at the southern portion of the slope after commencement of the LPM works in November 2005. Closed circuit television (CCTV) surveys were then carried out to check the alignment and internal condition of those buried drainage pipes. It was noted that a 375 mm diameter concrete drainage pipe discharging from the King's Park Sports Ground at the slope crest and a 225 mm diameter concrete drainage pipe discharging from the bowling green of the Filipino Club were located in the survey (Figure 6). The drainage pipes were found to be broken and their internal condition was poor. As a result, the 375 mm diameter and the 225 mm diameter concrete drainage pipes were replaced by 600 mm and 300 mm stepped channels respectively, as part of the LPM works. The buried drainage pipes running along the slope crest within the area of the King's Park Sports Ground (i.e. a 150 mm diameter cast iron (CI) drainage pipe and a 225 mm diameter vitrified clay (VC) drainage pipe, see Section 5.3) were not included in the 2005 CCTV survey and no works to these drainage pipes were carried out as part of the LPM works. As the HKRFU, the tenant of the Sports Ground under STT No. KX2153, was responsible for the maintenance of these buried drains, the HKRFU was requested to repair these drains and to upgrade the surface and sub-surface drainage system of the Sports Ground. The broken sections of the 150 mm diameter CI drainage pipe and the 225 mm diameter VC drainage pipe within the landslide scar were subsequently repaired by the HKRFU. The repair works involved the construction of manholes and the replacement of the broken sections of the 150 mm diameter and 225 mm diameter drainage pipes with 225 mm diameter and 400 mm diameter drainage pipes respectively. The 150 mm diameter PVC drainage pipe passing across the sports ground, which was exposed within the landslide scar, was also repaired and connected to a manhole of the new drainage system. The proposed drainage system for the LPM works is presented in Figure 13.

5. MAINTENANCE AND REPAIR RECORDS

5.1 Engineer Inspections

In May 1996, Fugro (Hong Kong) Limited (FHK) carried out an Engineer Inspection (EI) of the subject slope under Agreement No. CE 76/94 with Arch SD. The classification of the overall state of slope maintenance was assessed as "Fair". The defects identified by the inspection of the slope included blockages in U-channels, catchpits and weepholes. According to the EI report, no recent seepage was noted and no signs of water leakage from utility services were evident at the time of inspection. FHK recommended that stability assessment be carried out as the stability of the slope had not been assessed previously. Some routine maintenance works (RMW), including reinstatement of cracked hard surface cover and U-channels, replacement of undermined hard surface cover, together with clearance of blocked weepholes and U-channels, were recommended. However, the completion of those RMW could not be identified in the corresponding files.

In September 2000, Arch SD carried out another EI by in-house staff. According to the EI report, weepholes and catchpits were partly blocked. The classification of the overall state of maintenance was assessed as "Fair". No recent seepage, no erosion and no signs of distress were noted at the time of inspection. Moreover, no signs of leakage from underground water-carrying services were observed. As noted in the EI report, "no water-carrying services was identified in the record plans provided by WSD and DSD" but three manholes "were identified at [the] slope crest" which appeared "to be serving the football ground on [the slope] crest". Leakage checks on the three manholes and their associated buried drains were

recommended to be carried out at a minimum frequency of every 10 years in the EI report. The consequence-to-life (CTL) category of the slope was recommended to be revised from Category "2" to Category "1" in the EI report, due to the proximity of the high-rise residential building (Worcester Heights) from the slope toe. Some RMW, including repair of damaged chunam, clearance of blocked weepholes, sand traps and surface channels, clearance of unplanned vegetation on the slope and leakage checks on water-carrying utilities were recommended. Other recommendations including stability assessment and upgrading works by prescriptive measures were made in the EI report. However, no details of the prescriptive measures are given in the EI report.

In June 2005, Maunsell Geotechnical Services Limited (MGSL) carried out a further EI for Arch SD. According to the EI report, the CTL category of the slope was recommended to be downgraded from Category "1" to Category "2" according to GEO TGN No. 15.

It was noted from the 2005 EI report that inspection of buried water-carrying services was carried out in 2001 and the re-lining works were completed in 2002. It also recorded that "Most of the weepholes of [*sic*] the southern portion were blocked by undesirable vegetation" and "Water stains from some of the partly blocked weepholes were also observed". The EI concluded that "In view of the re-lining works completed in 2002, leakage from the drains routed along the slope crest was unlikely" and "The water was probably resulted from the irrigation water to the sport ground at the slope crest". No evidence or photograph showing moist soil was included in the EI report.

MGSL reported that no recent erosion, no seepage and no signs of distress were observed on the slope. In addition, no signs of leakage from buried water-carrying services were noted. The EI report recommended leakage checks for two buried storm water drains along the slope crest (150 mm & 225 mm diameter) and one buried storm water drain on the slope (375 mm diameter) at a minimum frequency of every 10 years and visual inspections for an exposed 150 mm diameter water pipe at the southern end of the slope during annual routine maintenance inspections. However, apart from a plan indicating the alignment of the exposed 150 mm diameter water pipe at the southern end of the slope, no other plans or photographs showing the buried water pipes and their alignments could be found in the EI report.

The 2005 EI report recommended that stability assessment and/or upgrading works should be considered. The report further stated that the feature was not suitable for upgrading by prescriptive measures due to the slope height and facilities to be affected. RMW, including repairing of hard surface cover and cracked channels, as well as clearance of blocked weepholes, were recommended. However, it was not certain whether the recommended RMW had been completed before the August 2005 landslide. The overall state of slope maintenance was assessed as "Class 1" (i.e. considered to be satisfactory in general).

5.2 Routine Maintenance Inspections

Routine maintenance inspections (RMI) of the subject slope have been carried out since 1979. A review of all the available inspection records was carried out by HCL as part of this landslide study and the key findings are summarised below.

Annual maintenance inspections of the subject slope were carried out by FHK in the period from August 1979 to April 1985. From the inspection records, cracks on the slope surface and drainage channels, as well as blockage of weepholes and drainage channels were observed. No seepage was noted in the inspection records. The recommended maintenance works included clearance of weepholes and drainage channels and repairing of chunam surface and cracked channels.

Arch SD carried out further routine maintenance inspections in September 1988, August 1994, and December 1995 and annually in the period from June 1998 to November 2005. However, records of the 2002 and 2003 RMI could not be located in Arch SD. The recommended maintenance works arising from the RMI mainly included repair of cracked slope surface cover and drainage channels, removal of surface debris and unplanned vegetation on the surface cover and drainage channels and also unblocking of weepholes. No signs of leakage, seepage, movement or tension cracks were noted in the RMI records. The maintenance works were generally completed within six months after the recommendation.

5.3 Maintenance and Repair of Water-carrying Services

The 2000 EI Report prepared by Arch SD revealed that three manholes were identified at the crest of slope No. 11NW-D/C144 and leakage checks on the three manholes and their associated buried drains were recommended.

In October 2001, a report entitled "Inspection and Testing of Buried Water-Carrying Services Affecting Slopes at Slope No. 11NW-D/C144 at Ex-British Military Hospital, Yaumatei" was prepared by Freyssinet Hong Kong Limited (FreyHKL) for Arch SD. According to the report, visual inspection of the internal conditions of drainage pipes by CCTV survey, visual inspection of the drainage manholes, together with water main utility location survey and leakage tests were carried out.

The report recorded that two buried water pipes (i.e. a 225 mm diameter VC drainage pipe and a 150 mm diameter CI drainage pipe) were found running along the crest of slope No. 11NW-D/C144 in a south-easterly direction to a manhole near the southern end of the subject slope. Another buried 225 mm diameter VC drainage pipe was connecting to the manhole from the southeast of the slope. Water was then discharged from the manhole to a buried 375 mm diameter concrete pipe running down the slope in a south-westerly direction to another manhole (Figure 14). However, the depths of the buried drainage pipes were not indicated in the report.

The survey results showed that some displaced/open joints were present along the two 225 mm diameter VC drainage pipes at several locations and "infiltration (seeper)" (signs of water seepage) were found at the northern section of the 150 mm diameter CI drainage pipe. No defect was found inside the drainage pipes along the section immediately above the August 2005 landslide area after clearance of debris/obstructions using high pressure water jetting. Broken sections were found inside the 375 mm diameter concrete pipe near the mid-height of the slope and at the middle portion of the 225 mm diameter VC drainage pipe at the slope crest. However, the sizes of the broken sections were not given in the survey report. The locations of defects recorded in the report are shown in Figure 14.

The report also recorded that a 150 mm diameter water main running along the southern boundary of the subject slope was tested by Leak Noise Correlator (LNC) methods and no leakage was detected (Figure 14). The three manholes located at the crest of the slope were also inspected and found to be in fairly good condition.

The report recommended that the 375 mm diameter concrete drainage pipe near the mid-height of the slope, the 225 mm diameter VC drainage pipe running from the southeast of the slope to a manhole near the southern end of the slope and the northern section of the 225 mm diameter VC drainage pipe at the slope crest be replaced or re-lined in order to prevent any leakage from the pipes into the slope. However, no remedial works to the northern section of the 150 mm CI pipe were recommended in the report.

The video of the 2001 CCTV survey was viewed as part of this study. It was noted that no branches of drains were found in connecting the 150 mm diameter CI drainage pipe and the 225 mm diameter VC drainage pipe at the crest of the subject slope. A number of small holes were evenly distributed on the upper half of the 225 mm diameter VC drainage pipe. Roots of vegetation were found growing through some of the small holes. Such small holes were not visible inside the 150 mm diameter CI drainage pipe and the 375 mm diameter concrete drainage pipe running down the slope in a south-westerly direction.

Following the recommendations made by FreyHKL, Biwater Man Lee Limited (BMLL) carried out the re-lining works and post-lining CCTV survey to the buried water pipes concerned at slope No. 11NW-D/C144 in February and March 2002. As noted in the report prepared by BMLL, the re-lined pipes comprised the 375 mm diameter concrete drainage pipe (17.44 m long), a section of the 225 mm diameter VC drainage pipe at the crest of the northern portion of the slope (4 m long) and the 225 mm diameter VC drainage pipe running from the southeast to the southern end of the slope (20.87 m long). The re-lining works did not include the displaced joints at the northern section of the 225 mm diameter VC drainage pipe as identified by FreyHKL in 2001. The video of the 2002 CCTV survey was also viewed and roots of vegetation were also found at some of the small holes on the upper half of the 225 mm diameter VC drainage pipe as noted in the video of the 2001 CCTV survey. No other findings could be located in the video of the 2002 CCTV survey.

After the completion of LPM works in November 2006, Arch SD took over the maintenance responsibility of the subject slope with effect from 30 October 2007. INFO Site Investigation Engineering and Consulting Company Limited (INFO) prepared a CCTV survey report entitled “Inspection and Testing of Buried Water-Carrying Services Affecting Slope” in November 2007 for Arch SD after examining the internal conditions of the buried water pipes in the vicinity of the subject slope. CCTV Survey, Manhole Survey, Leak Noise Correlation (LNC) Survey and High Pressure Water Jetting were carried out. The 2007 survey report shows a 150 mm diameter PVC drainage pipe passing across the sports ground discharging to a 250 mm diameter PVC drainage pipe running along the crest of slope No. 11NW-D/C144. This 150 mm diameter PVC drainage pipe was not identified in the 2001, 2002 and 2005 CCTV surveys. The 150 mm diameter PVC drainage pipe was found to contain cracks, displaced joints, open joints, multiple fractures and circumferential cracks and it was recommended for replacement. The video of the 2007 CCTV survey showed branches of buried drains present alternatively along both sides of the 150 mm diameter PVC drainage pipe. Obstructions were found in the 250 mm diameter drainage pipe running along the slope crest and in the 400 mm diameter PVC drainage pipe at the crest of the slope within the landslide scar. Displaced joints,

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longitudinal cracks and obstructions were also found in the 225 mm diameter PVC pipe running along the crest of the slope. The defects recorded and recommendations made in the report are summarised and presented in Figure 15.

6. THE 20 AUGUST 2005 INCIDENT AND POST-FAILURE OBSERVATIONS

6.1 Description of the Incident

According to the incident report prepared by the GEO, a major landslide occurred on slope No. 11NW-D/C144 behind Canterbury Court and Worcester Heights at Nos. 12 and 14 Wylie Road, and below King's Park Sports Ground on 20 August 2005 at about 11:30 a.m. At the time of failure, an Amber Rainstorm Warning and a Landslip Warning were in force. The landslide, with a failure volume of about 200 m^3, occurred on the southern portion of the slope with an average slope angle of 55^o. The landslide debris was deposited on the access road in front of the slope toe near the entrance of Canterbury Court. Some debris travelled further downward along the access road to Wylie Road. The access road connecting the residential buildings and Wylie Road was temporarily closed and no casualties were reported as a result of the landslide.

6.2 Post-failure Observations of the Incident Site

The first site inspection was carried out by Maunsell Geotechnical Services Limited (MGSL), the 2005 Landslide Investigation Consultants for Kowloon and the New Territories, for the Geotechnical Engineering Office (GEO) of the Civil Engineering and Development Department (CEDD) under Agreement No. CE 15/2004 (GE) in the late afternoon of 20 August 2005.

According to the information provided by MGSL, the dimensions of the failure scar was about 12 m high by 15 m long by 3 m deep, with an estimated failure volume of about 200 m^3. At the time of inspection, three buried water-carrying pipes were found broken and exposed at the crest of the scar and were still discharging water onto the failed area, resulting in significant erosion and subsequent washout. Several footings of a steel fence, which separated the grassed sports ground and the subject slope, were found overhanging at the crest of the landslide scar. MGSL stated that close inspection was not carried out for safety reasons and the observations on the crest of the failed slope were made from a distance.

The landslide site was originally covered with chunam with 50 mm diameter weepholes. The failed material mainly comprised completely decomposed granite in the form of reddish brown silty sand. A 300 mm wide U-channel was found running along the crest of the subject slope. Another 375 mm diameter buried water pipe was exposed near the southern flank of the landslide scar. MGSL also recorded that, according to their in-house information and site interview with the Electrical and Mechanical Services Department (EMSD) staff (i.e. the maintenance agent to Arch SD), no record of all the buried water-carrying pipes exposed in the landslide was available.

HCL first inspected the landslide site on 12 November 2007, by which time the LPM works to the slope were already completed. The landslide area was covered with a series of planter walls. The slope portions adjoining the northern and southern ends of the August 2005

landslide area were covered with vegetation and reinforced concrete grillage respectively. Some boulders were observed at the northern portion of the slope protruding from mid-height of the slope surface. No seepage was observed on the slope surface during the inspection. Four manhole covers were present along the perimeter of the grassed sports ground at about 2 m to 2.5 m away from the crest of slope No. 11NW-D/C144.

A 300 mm U-channel, located about 1.0 m behind the crest of the subject slope, was found connecting to a 600 mm stepped channel which discharges water downslope to a sand trap at the slope toe.

7. ANALYSIS OF RAINFALL RECORDS

Rainfall data were obtained from the nearest GEO automatic raingauge No. K01, which is located at the Civil Engineering and Development Building, Homantin, about 670 m to the northeast of the subject slope. This raingauge records and transmits rainfall data at 5-minute intervals via a telephone line to the Hong Kong Observatory and the GEO. According to the landslide incident report prepared by the GEO, the landslide incident occurred at about 11:30 a.m. on 20 August 2005.

The daily rainfall recorded by raingauge No. K01 over one month preceding the landslide, together with the hourly rainfall readings for the period of 19 to 20 August 2005, are presented in Figure 16. The records show that rainfall began from 9 August 2005 and intense rainfall was recorded until the evening of 20 August 2005. The maximum 24-hour and 48-hour rolling rainfall before the incident were 316.5 mm and 471.5 mm respectively. The maximum 1-hour rolling rainfall was recorded as 44.5 mm between 7:25 p.m. and 8:25 p.m. on 19 August 2005 (Table 1).

The return period for the rainfall recorded at raingauge No. K01 preceding the landslide was estimated based on historical rainfall data at the Hong Kong Observatory (Lam & Leung, 1994). The maximum rolling rainfall for various durations was derived and is given in Table 1. The results show that the 31-day rolling rainfall of 1124 mm before the incident was the most severe, with a corresponding return period of about 30 years.

The return periods were also assessed based on the statistical parameters derived by Evans & Yu (2001) for rainfall data recorded by raingauge No. K01. The return periods estimated using data of Lam & Leung (1994) and Evans & Yu are very similar for durations less than or equal to two days. The 7-day rainfall at raingauge No. K01 was the most critical with a return period of 14 years, which is less than that estimated by the historical rainfall data at the Hong Kong Observatory.

A comparison of the maximum rolling rainfall of the 20 August 2005 rainstorm with that of past major rainstorms recorded by raingauge No. K01 is presented in Figure 17. The rainstorm of 20 August 2005 is the most severe for rainfall durations between 24 hours and 15 days.

8. DISCUSSION

The August 2005 landslide occurred on a substandard soil cut slope which had been included in the LPM Programme for a Stage 3 Study. The close correlation between the landslide and the preceding prolonged and heavy rainfall suggests that the landslide was probably rain-induced. As a result of the initial failure, three buried water-carrying pipes were broken at the crest of the landslide scar, discharging a large volume of water onto the failure scar and resulting in significant erosion and subsequent washout.

The build-up of groundwater pressure during heavy rainfall in the groundmass behind the slope might have been a key contributory factor to the initial failure. Transient groundwater pressure might have been developed as a result of the 150 mm diameter PVC subsurface pipe discharging water direct to the soil mass at the slope crest. This PVC pipe forms part of the subsurface drainage system collecting infiltration of rainfall from the grassed football field behind the slope crest. However, the PVC pipe did not have a proper outlet and discharged water direct to the soil mass close to a perforated 225 mm diameter VC pipe. In addition, many of the holes in the VC pipe were blocked by roots of vegetation and hence the pipe might not have been effective in relieving the build-up of groundwater pressure in the area during heavy rainfall.

The subsurface drainage system was laid in 1963 during the formation of the King's Park Sports Ground. The buried drainage system had been in service for about 40 years and was likely not in a good condition prior to the 2005 landslide. It was possible that water leakage had been occurring for some time at different locations, including from the 150 mm PVC pipe, in which cracks and fractures were observed during the 2007 CCTV survey. Leakage from the subsurface drainage system behind the slope crest would have further reduced the margin of stability of the substandard slope.

It is important to maintain comprehensive drainage records to enable prompt detection of potential problems and to facilitate regular maintenance of the drains. Special care should also be taken to the maintenance of subsurface drainage systems behind slope to minimise the risk of leakage, as water leakage from such drains would cause build-up of transient groundwater pressure in the groundmass and jeopardize the stability of the slopes.

9. CONCLUSION

The failure on 20 August 2005 on slope No. 11NW-D/C144 was triggered by prolonged and heavy rainfall. The landslide was probably caused by the build-up of groundwater pressure in the groundmass due to infiltration from the football field behind the slope and water discharged direct to the soil mass at the slope crest from a 40-year old subsurface pipe which did not have a proper outlet. Possible leakage of the old buried drainage system might also be a contributory factor to the failure.

10. REFERENCES

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Evans, N.C. & Yu, Y.F. (2001). Regional Variation in Extreme Rainfall Values. Geotechnical Engineering Office, Hong Kong, 81 p. (GEO Report No. 115).

Maunsell Geotechnical Services Limited (2005). Stage 3 Report No. S3R 149/2005 for Feature No. 11NW-D/C144 at Canterbury Court, Wylie Road. Geotechnical Engineering Office, Hong Kong, 14 p. and 7 appendices.

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.

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

LIST OF TABLES

Table 1 – Maximum Rolling Rainfall at GEO Raingauge No. K01 for Selected Durations preceding the landslide on 20 August 2005 and Estimated Return Periods

Duration	Maximum Rolling Rainfall (mm)	End of Period (Hours) (see Note 4)	Estimated Return Period (Years) (see Note 3)	
			A	B
5 minutes	5.5	20:05 hours on 19 August 2005	1	< 2
15 minutes	14.5	20:05 hours on 19 August 2005	1	< 2
1 hour	44.5	20:25 hours on 19 August 2005	< 2	< 2
2 hours	75.0	20:25 hours on 19 August 2005	< 2	< 2
4 hours	136.5	22:15 hours on 19 August 2005	3	3
12 hours	229.0	06:00 hours on 20 August 2005	4	4
24 hours	316.5	11:30 hours on 20 August 2005	5	7
2 days	471.5	11:30 hours on 20 August 2005	14	11
4 days	564.5	11:30 hours on 20 August 2005	14	7
7 days	696.5	11:30 hours on 20 August 2005	26	14
15 days	836.0	11:30 hours on 20 August 2005	20	7
31 days	1124.0	11:30 hours on 20 August 2005	30	6

Notes:

(1) Maximum rolling rainfall was calculated from 5-minute rainfall data.

(2) The nearest GEO raingauge to the landslide site is Raingauge No. K01 located at Civil Engineering Building, 101 Princess Margaret Road at about 670 m to the northeast of the landslide site.

(3) Return periods were derived from Table 3 of Lam & Leung (1994) (Column A refers) and using data of Raingauge No. K01 from Evans & Yu (2001) (Column B refers). The return periods of the rainstorms with durations over 48 hours preceding the landslide based on the statistical parameters derived by Evans & Yu (2001) are generally less than those estimated by the historical rainfall data at the HKO.

(4) The landslide occurred at about 11:30 hours on 20 August 2005.

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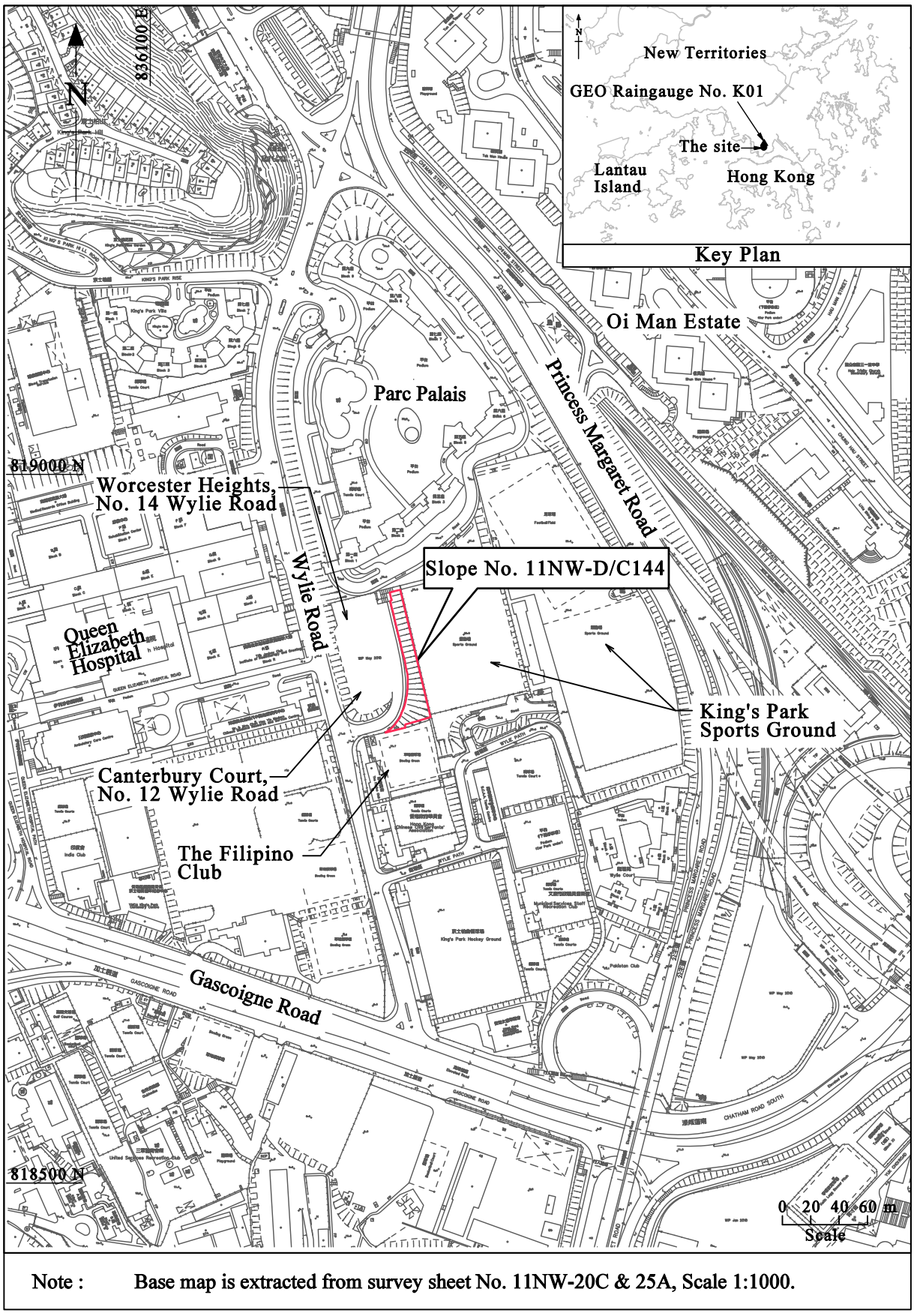


Note : Base map is extracted from survey sheet No. 11NW-20C & 25A, Scale 1:1000.

Figure 1 - Location Plan

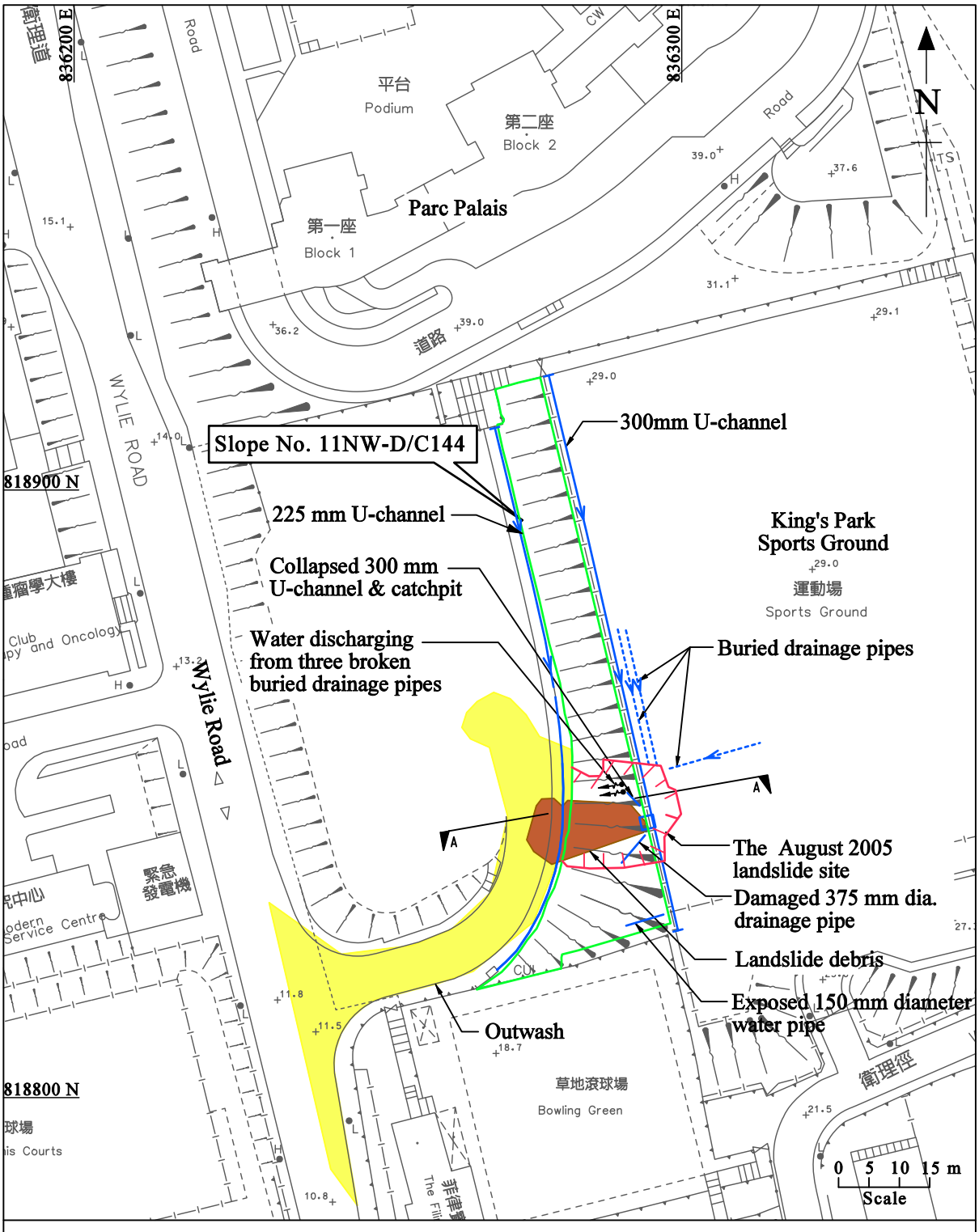


Figure 2 - Site Layout Plan

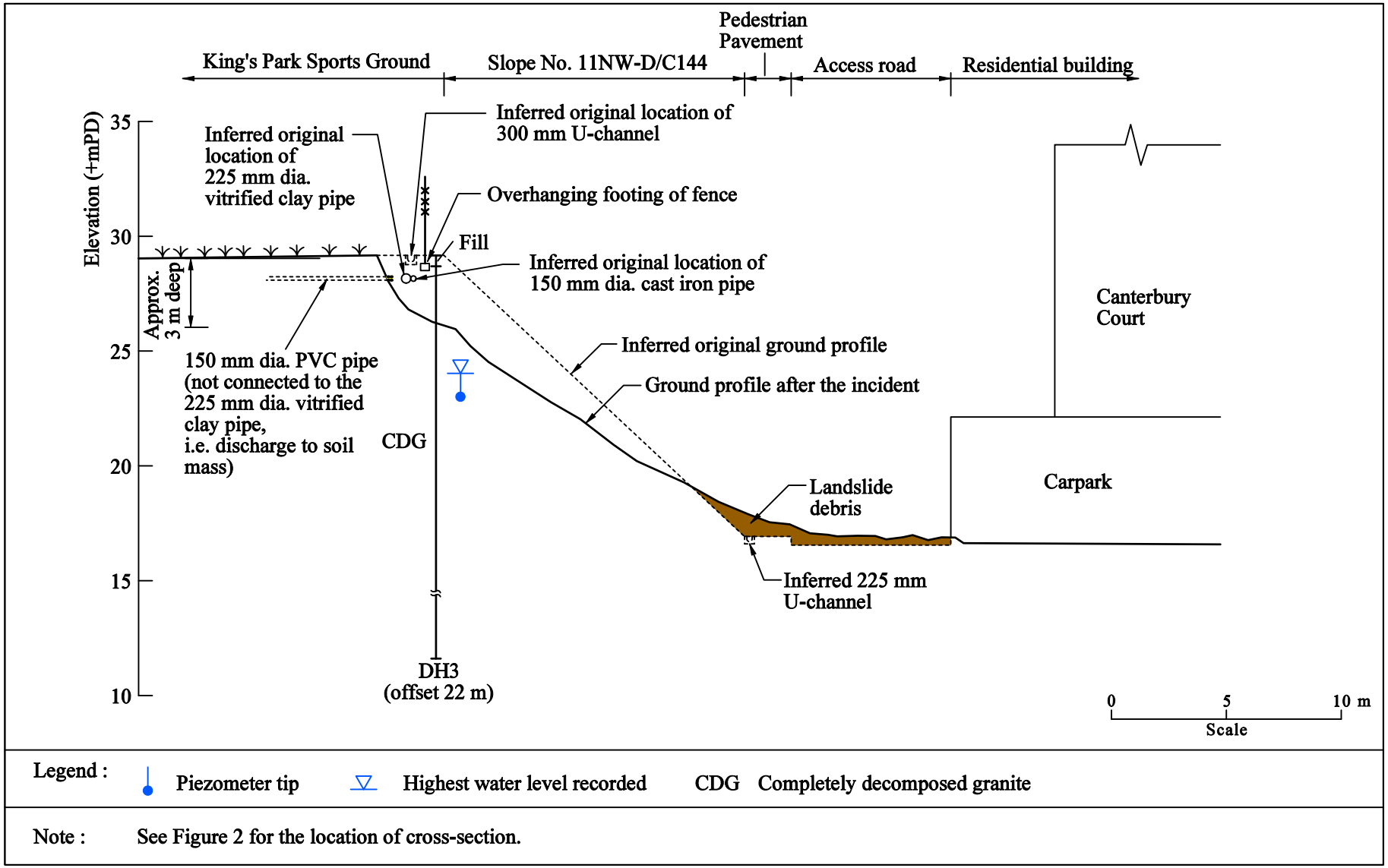


Figure 3 - Section A-A through the 20 August 2005 Landslide

0 m 1000m

Scale

LEGEND:

SUPERFICIAL DEPOSITS

Qa	Alluvium		Megacrystic
Qd	Debris flow deposits	ms	Marine sand
	Fill		

SOLID GEOLOGY

gf	Fine grained granite	ap	Aplite
gm	Medium grained granite	gfm	Fine- to medium-grained granite

GEOLOGICAL LINES

Geological boundary, superficial deposit

1982 Fill boundary, with limit of reclamation at date shown

Geological boundary, solid rock (* Broken lines denote uncertainty)

Fault (* Broken lines denote uncertainty)

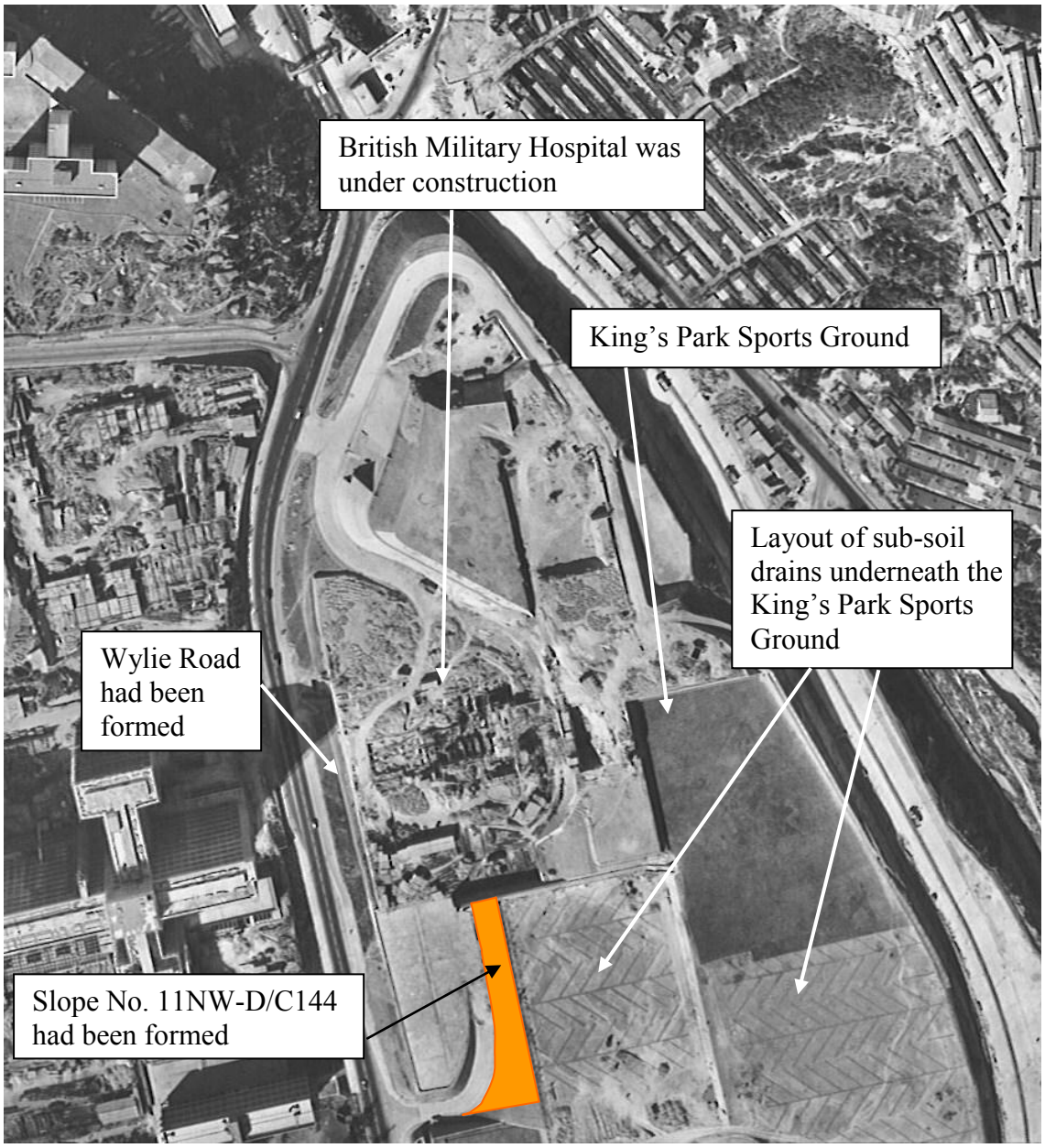
Photogeological lineament

STRUCTURAL SYMBOLS

Inclined 20 Vertical Jointing

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

Figure 4 – Regional Geology



Interpretation of 1963 Aerial Photograph

Note : Reproduced from Aerial Photograph No. Y07751 taken on 25 January 1963.

Figure 5 – The 1963 Aerial Photograph Showing Sub-soil Drains Underneath the King's Park Sports Ground

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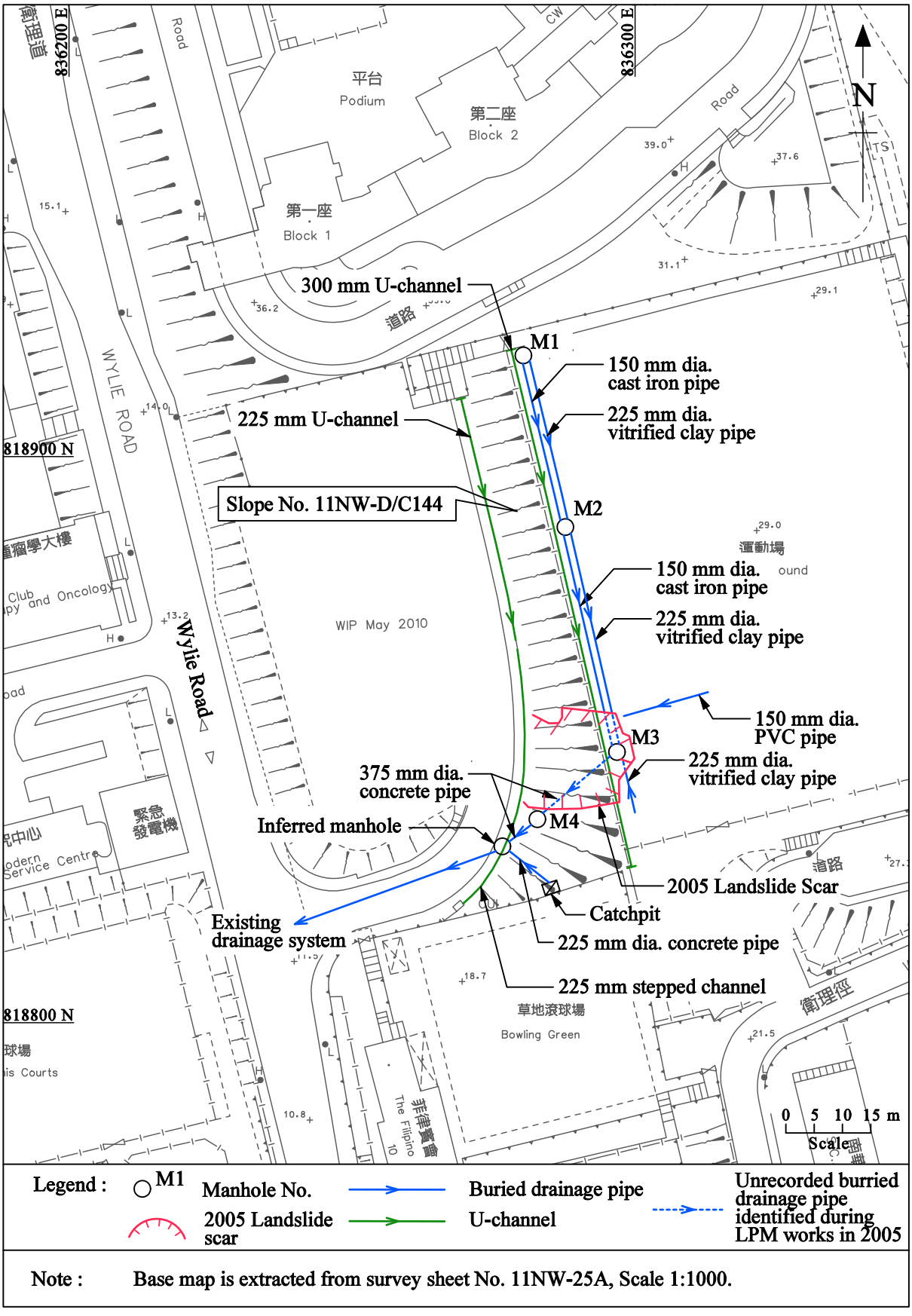

Figure 6 - Layout Plan of Water-carrying Services at and in the Vicinity of Slope No. 11NW-D/C144 before the August 2005 Landslide

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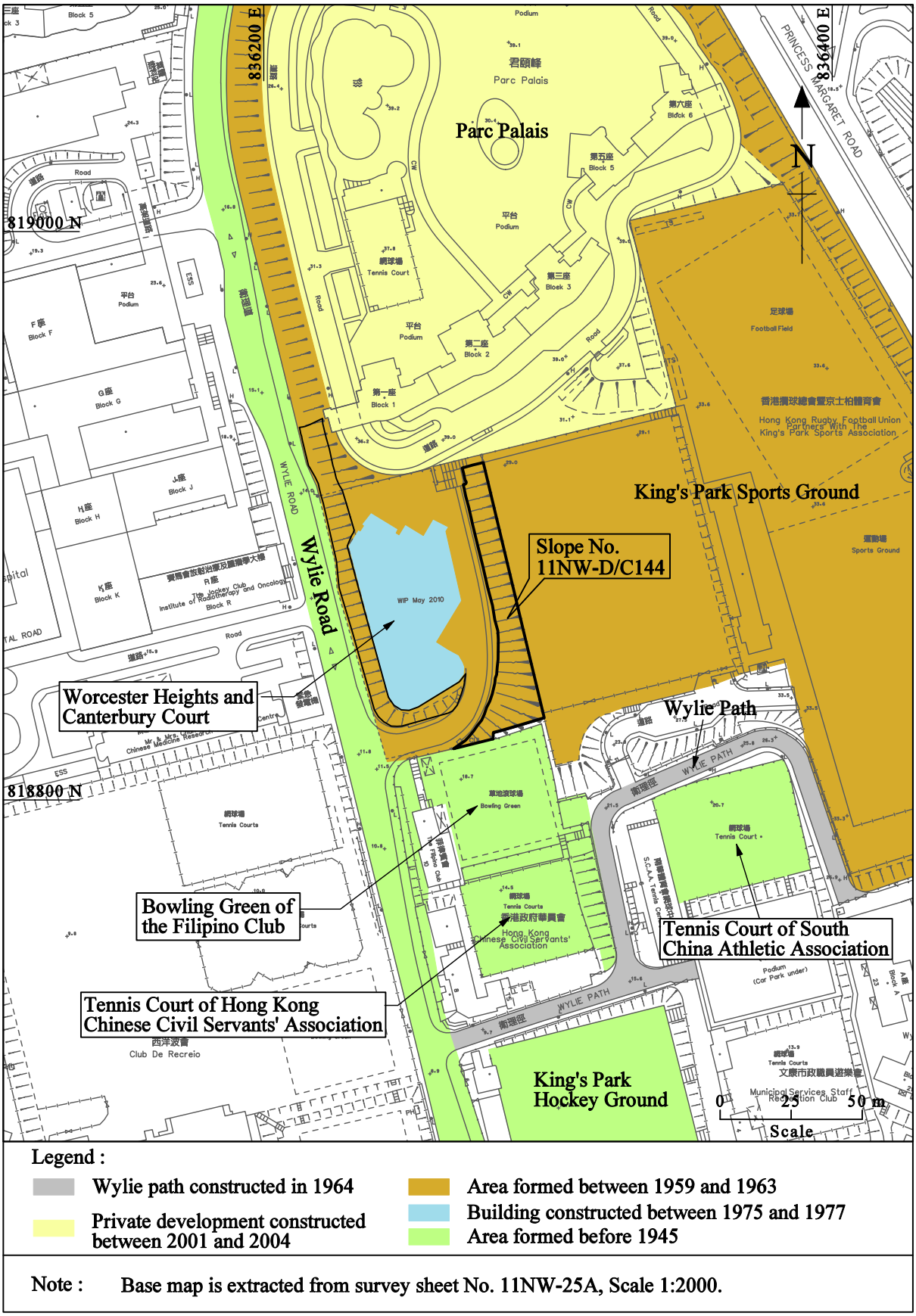
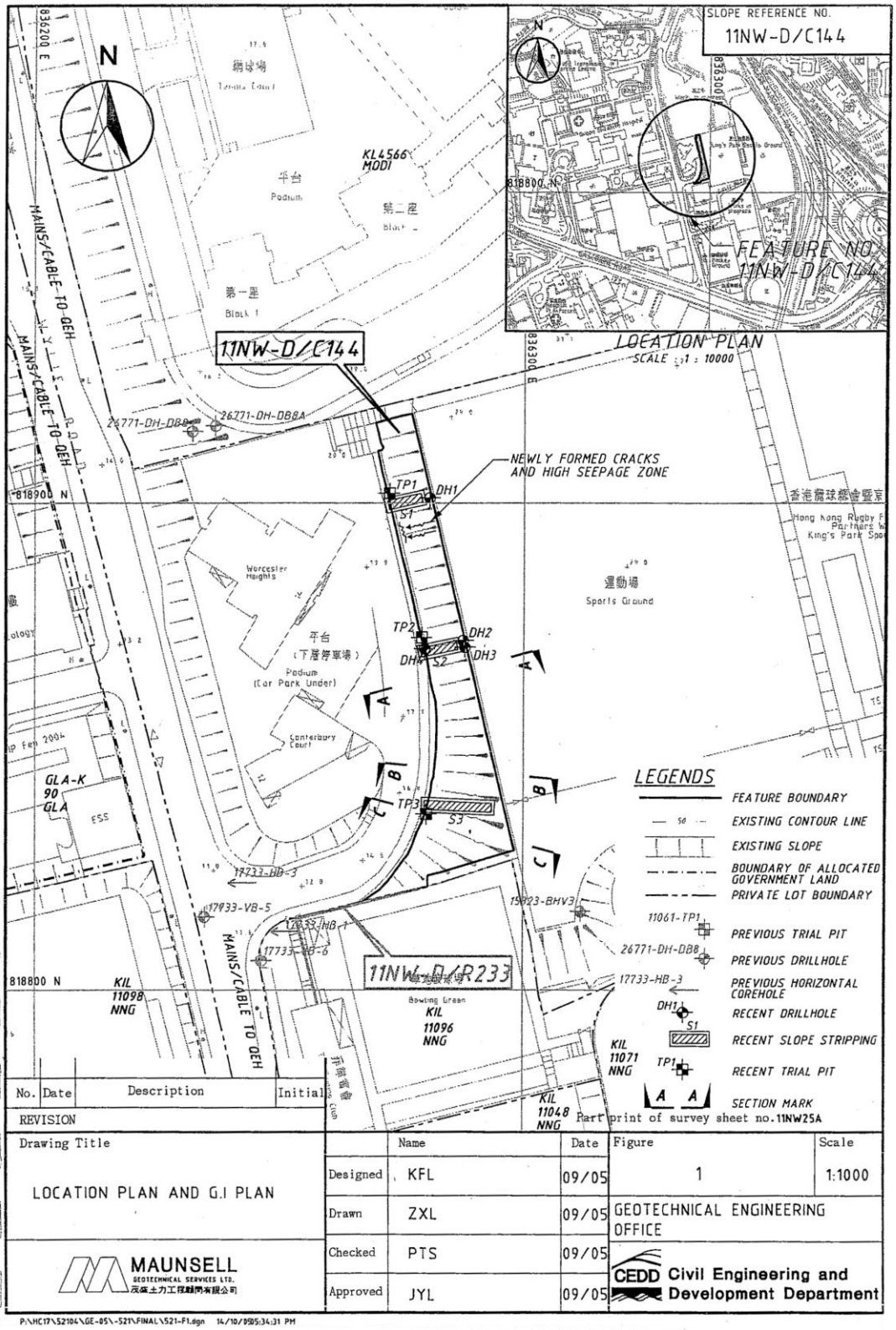


Figure 7 - Site History



Note : Reproduced from Stage 3 Report (S3R 149/2005) dated October 2005.

Figure 8 – Location Plan of Ground Investigation Works Extracted from Stage 3 Report (S3R 149/2005) dated October 2005

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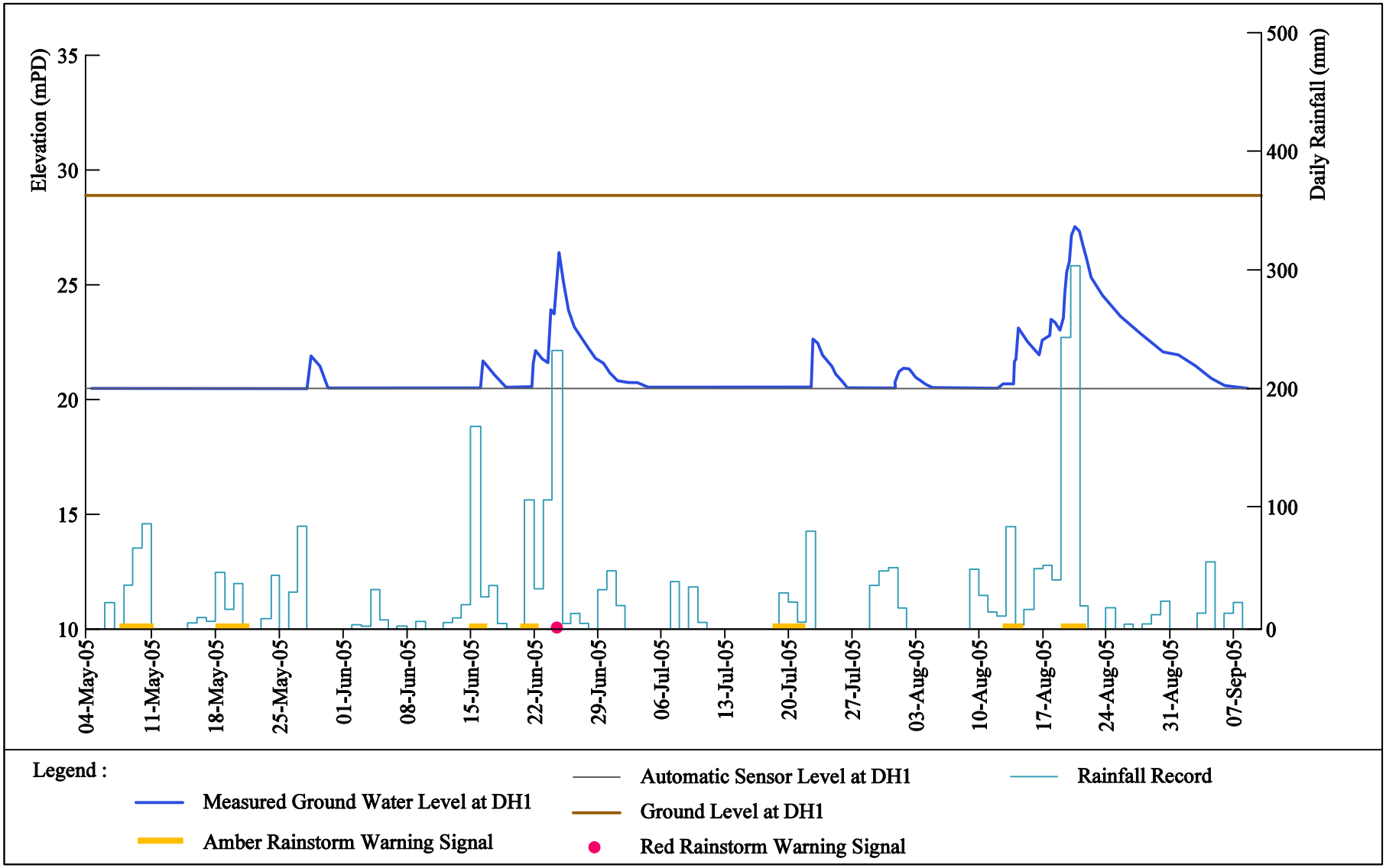


Figure 9 - Ground Water Monitoring Results and Daily Rainfall Records (DH1)

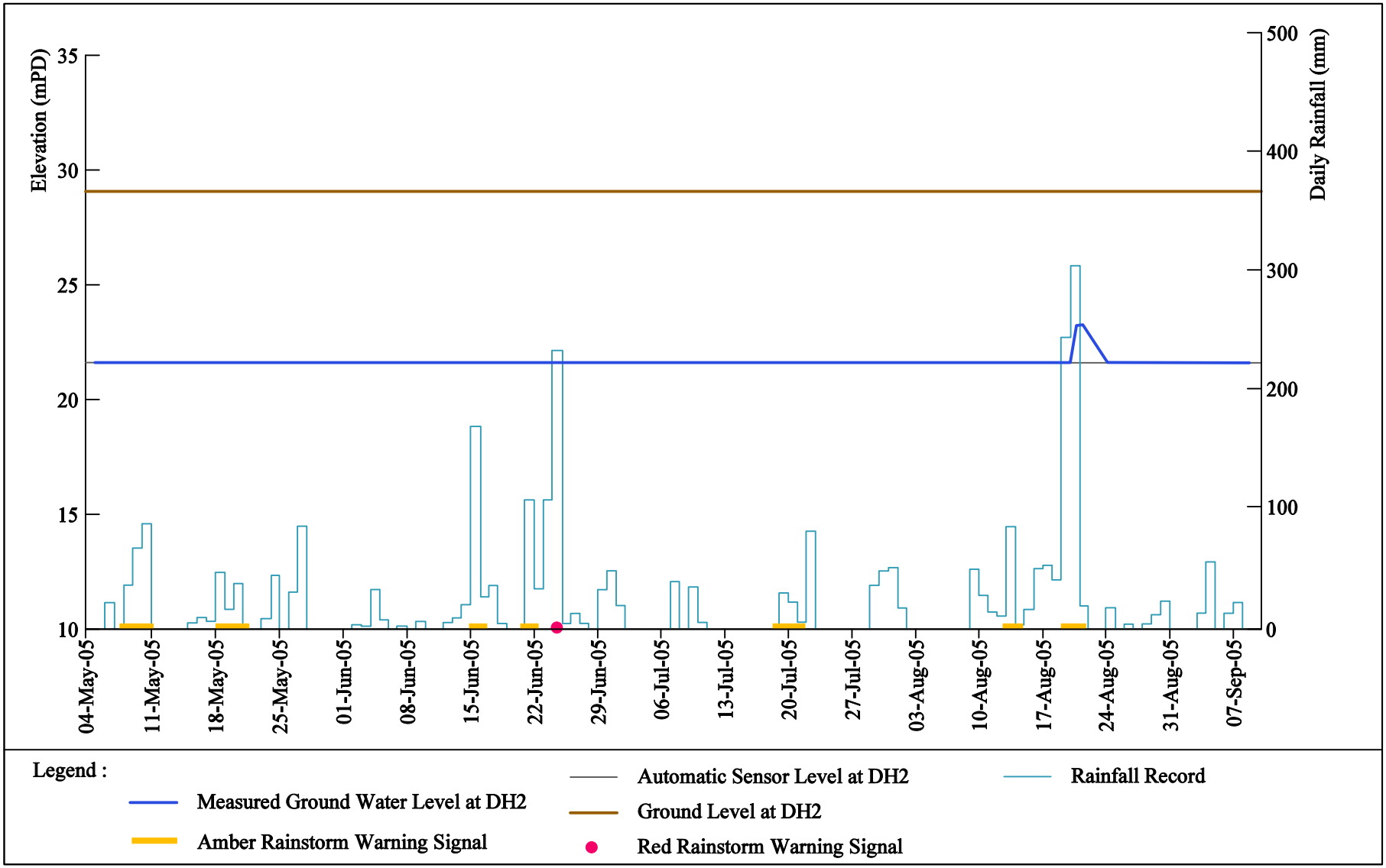


Figure 10 - Ground Water Monitoring Results and Daily Rainfall Records (DH2)

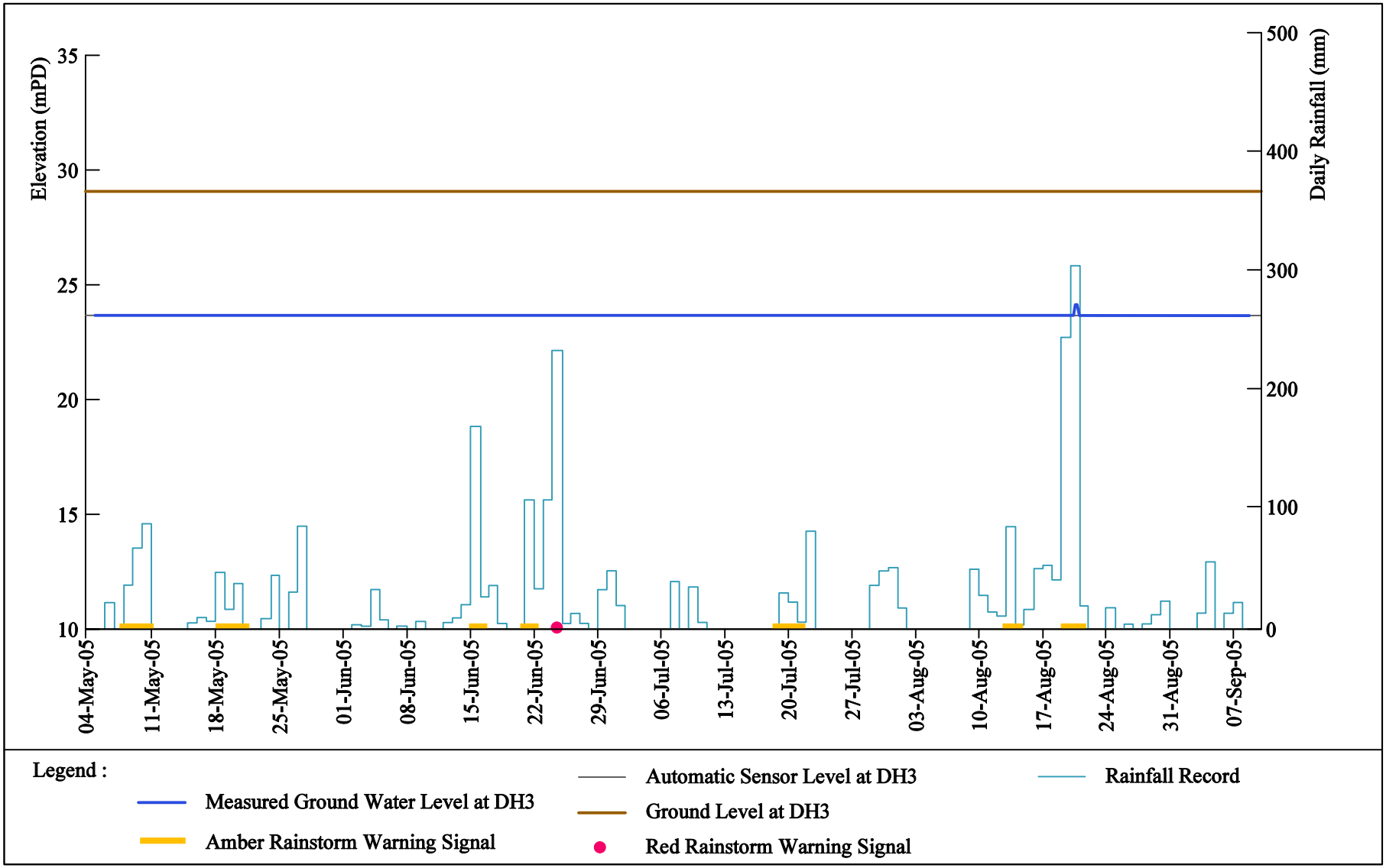


Figure 11 - Ground Water Monitoring Results and Daily Rainfall Records (DH3)

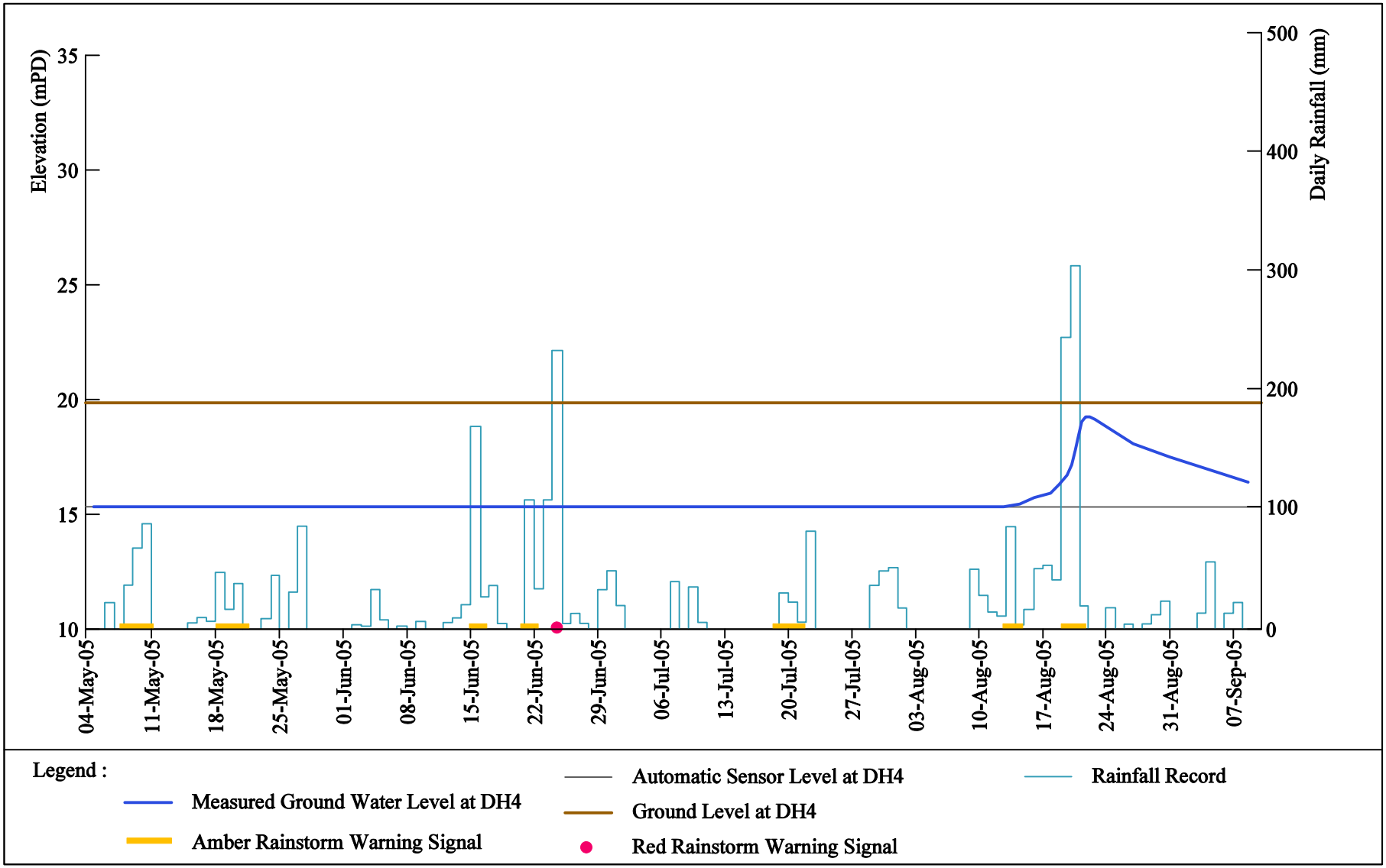
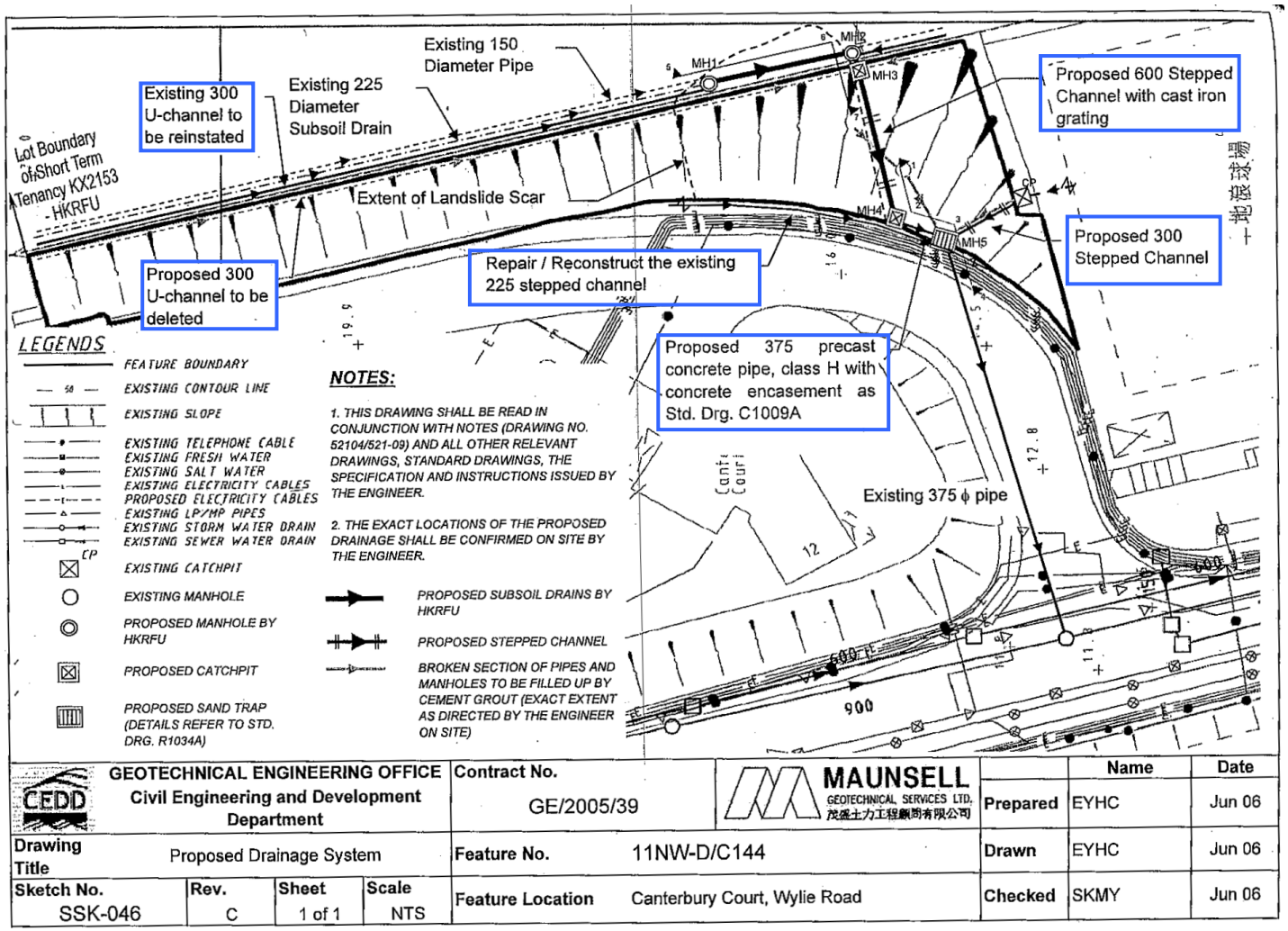
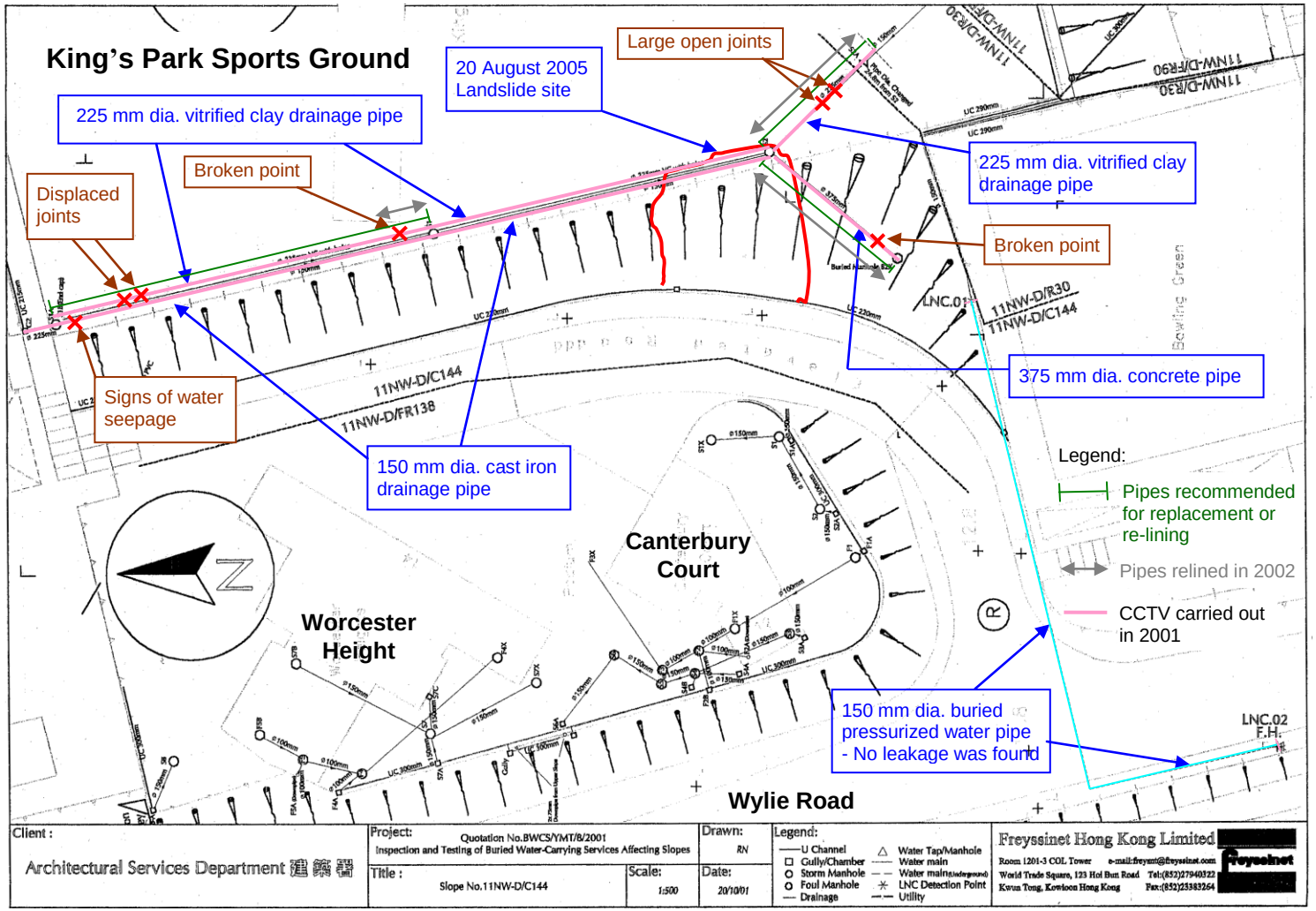


Figure 12 - Ground Water Monitoring Results and Daily Rainfall Records (DH4)



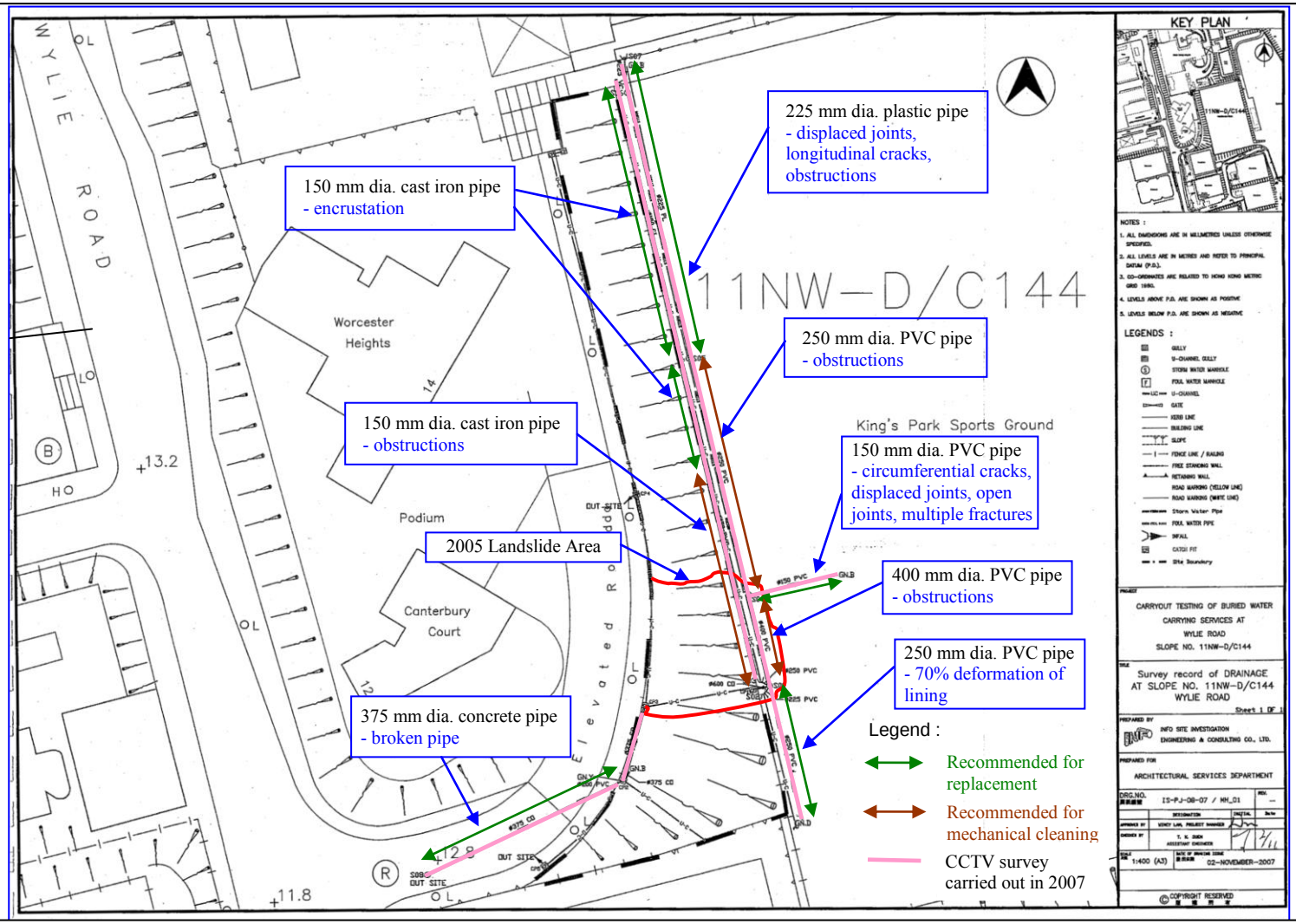
Legend : Plan extracted from Arch SD File No. ASD. PB PA-023-08019-007 II.

Figure 13 – Proposed Drainage System for LPM Works at Slope No. 11NW-D/C144



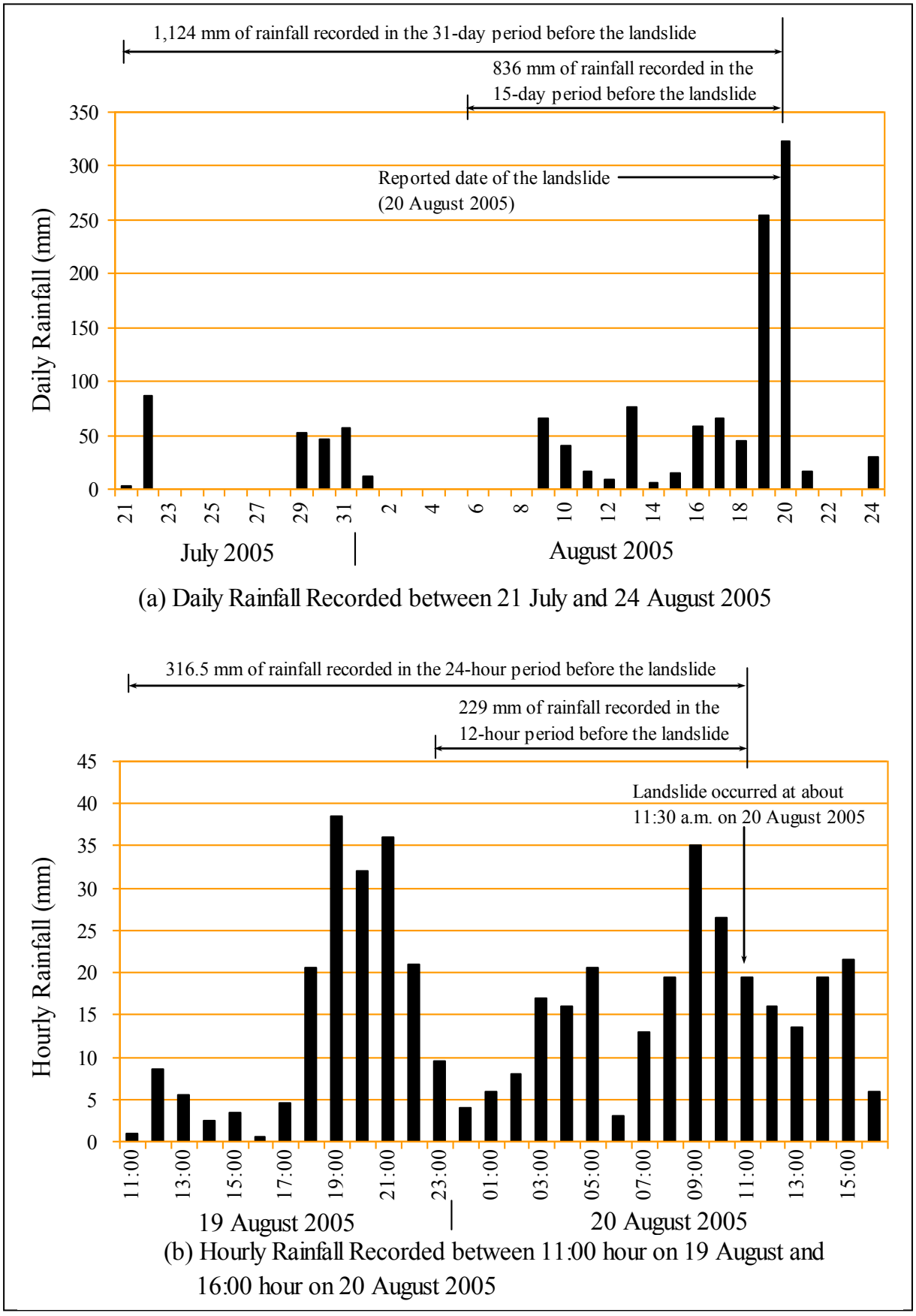
Note : Base plan extracted from Report for Inspection and Testing of Buried Water-Carrying Services prepared by Freyssinet Hong Kong Ltd. in 2001.

Figure 14 – Inspection Records of Buried Water-carrying Services at Slope No. 11NW-D/C144 in 2001



Legend : Base plan extracted from Water Leakage Detection Report prepared by INFO Site Investigation Engineering & Consulting Co. Ltd. in 2007.

Figure 15 – Survey Records of Drainage at Slope No. 11NW-D/C144 in 2007



(a) Daily Rainfall Recorded between 21 July and 24 August 2005

(b) Hourly Rainfall Recorded between 11:00 hour on 19 August and 16:00 hour on 20 August 2005

Figure 16 – Daily and Hourly Rainfall Recorded at GEO Raingauge No. K01

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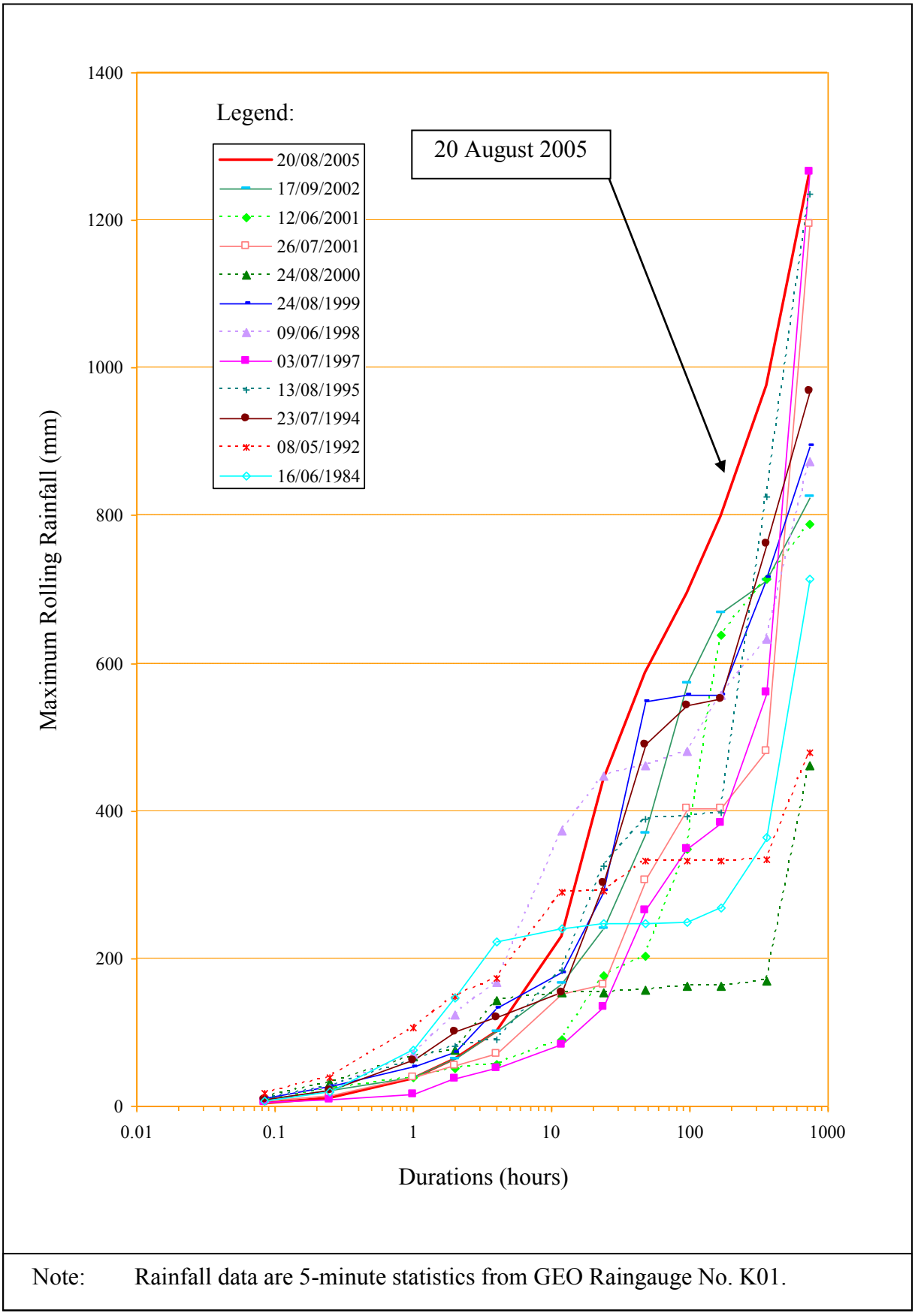

Note: Rainfall data are 5-minute statistics from GEO Raingauge No. K01.

Figure 17 – Maximum Rolling Rainfall for Previous Major Rainstorms at GEO Raingauge No. K01 between 1984 and 2005

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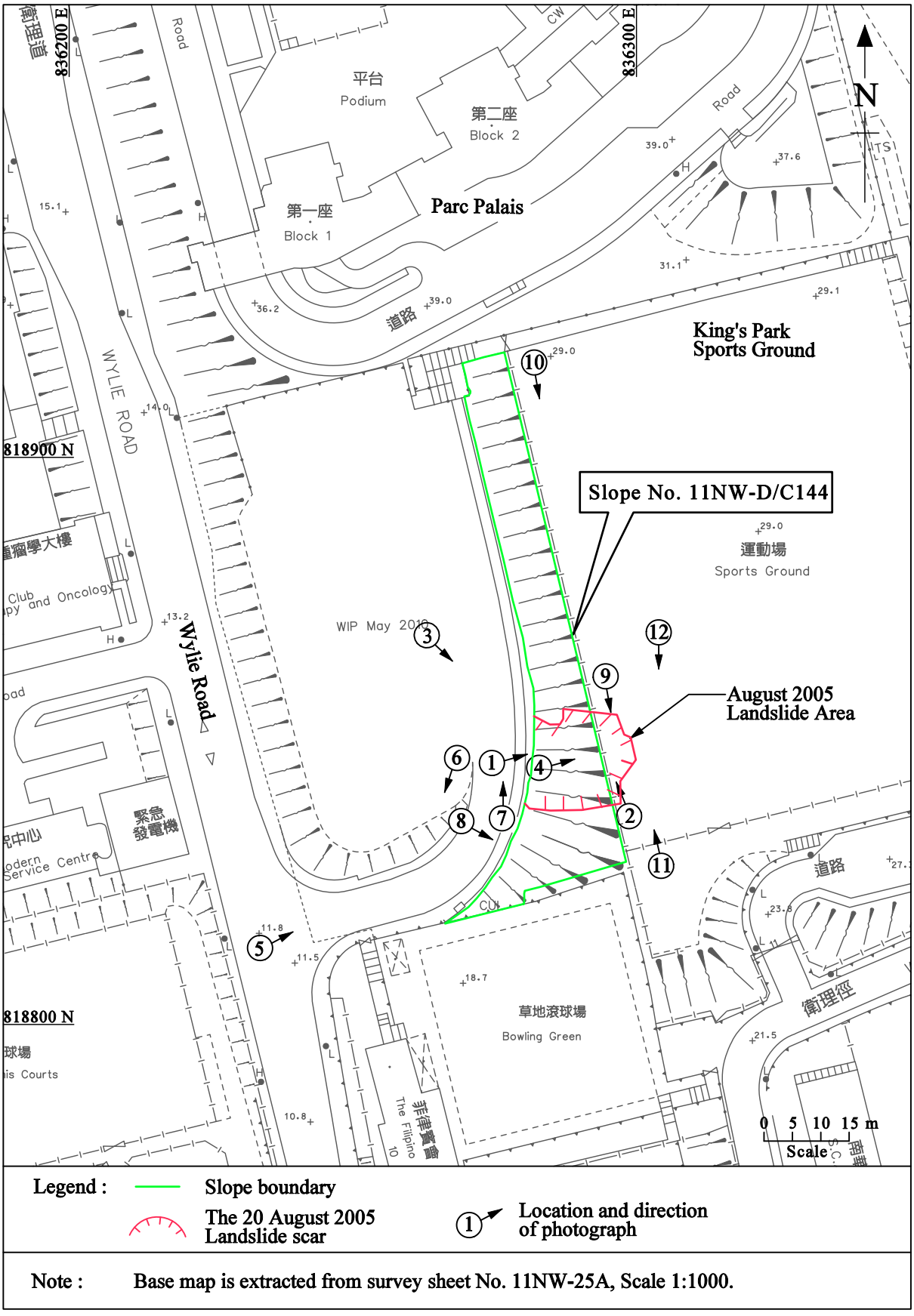

Figure 18 - Locations and Directions of Photographs Taken

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Plate 1 – General View of the August 2005 Landslide Area
(Photograph taken by MGSL on 20 August 2005)

Plate 2 – View of the Landslide Scar Extending into the Grassed Sports Ground above Slope No. 11NW-D/C144
(Photograph taken by GEO on 22 August 2005)

Note : See Figure 18 for locations and directions of photographs.

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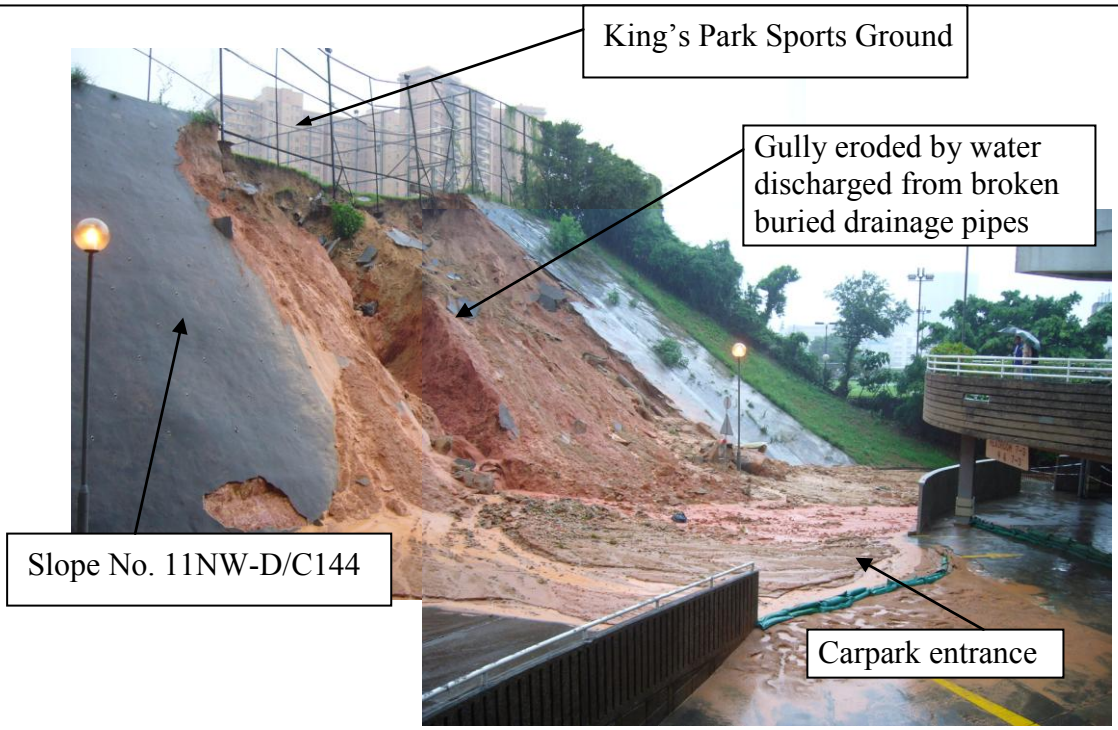

Plate 3 – Landslide Debris Deposited on the Carpark Entrance of Canterbury Court (Photograph taken by MGSL on 20 August 2005)

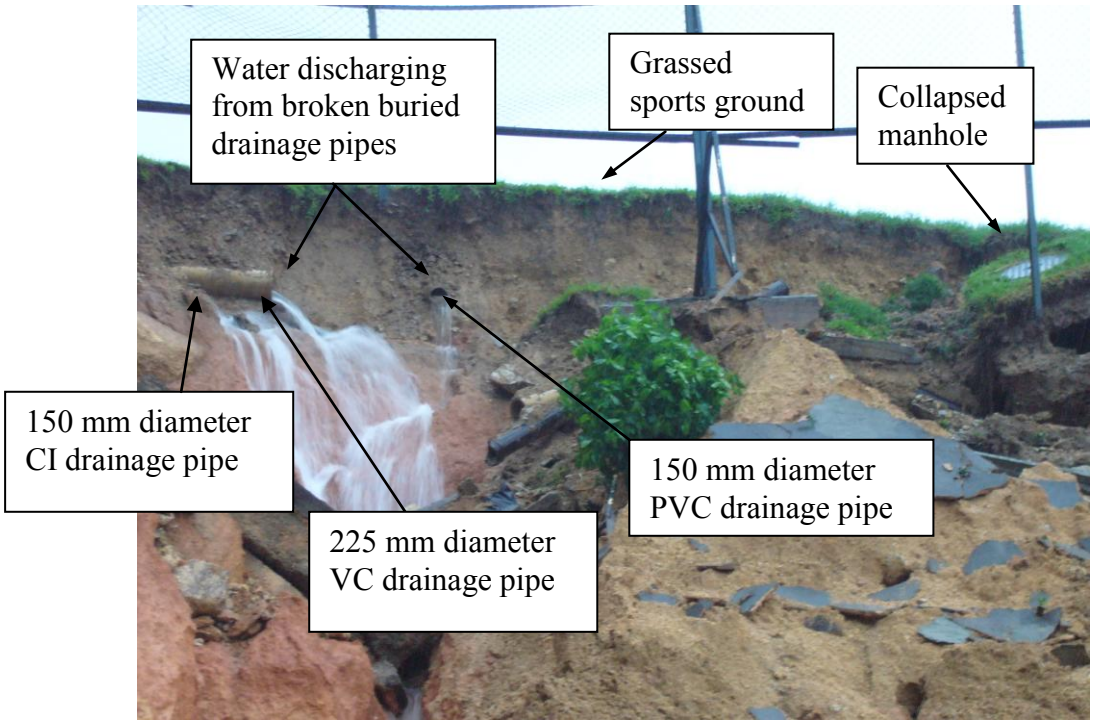

Plate 4 – Close-up View of the Crest of the Failure Scar (Photograph taken by MGSL on 20 August 2005)

Note : See Figure 18 for locations and directions of photographs.

Plate 5 – Landslide Debris with Muddy Water on the Inclined Access Road
(Photograph taken by MGSL on 20 August 2005)

Plate 6 – Landslide Debris Deposited on the Entrance of the Access Road at Wylie Road
(Photograph taken by MGSL on 20 August 2005)

Note : See Figure 18 for locations and directions of photographs.

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Plate 7 – Northern Portion of Slope No. 11NW-D/C144 after LPM Works
(Photograph taken by HCL on 12 November 2007)

Plate 8 – Southern Portion of Slope No. 11NW-D/C144 after LPM Works
(Photograph taken by HCL on 12 November 2007)

Note : See Figure 18 for locations and directions of photographs.

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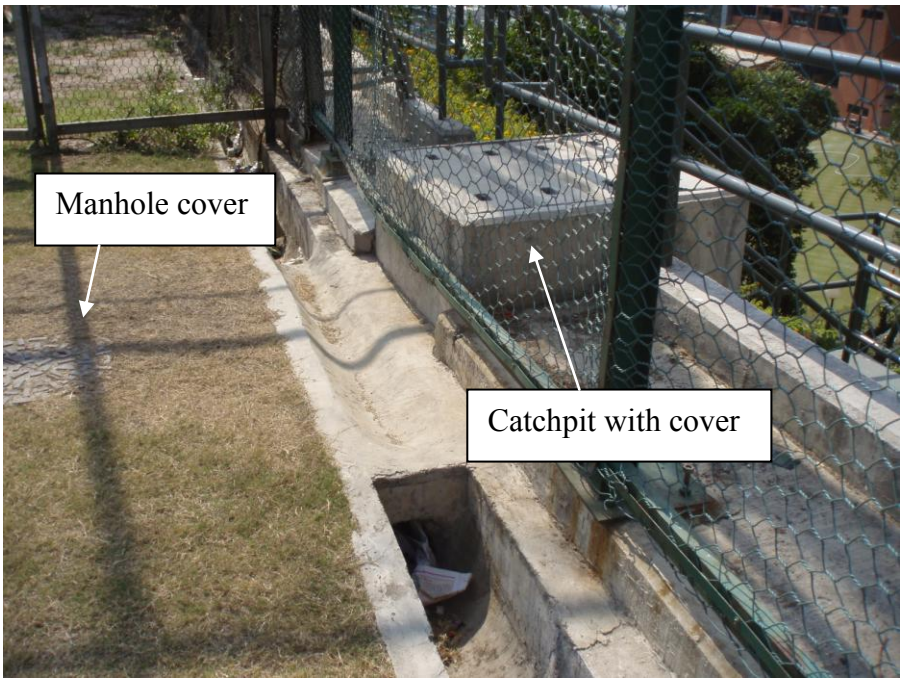

Plate 9 – Manhole and Catchpit Constructed behind the August 2005 Landslide Area after LPM Works
(Photograph taken by HCL on 12 November 2007)

Plate 10 – Crest Condition of Slope No. 11NW-D/C144 after LPM Works
(Photograph taken by HCL on 12 November 2007)

Note : See Figure 18 for locations and directions of photographs.

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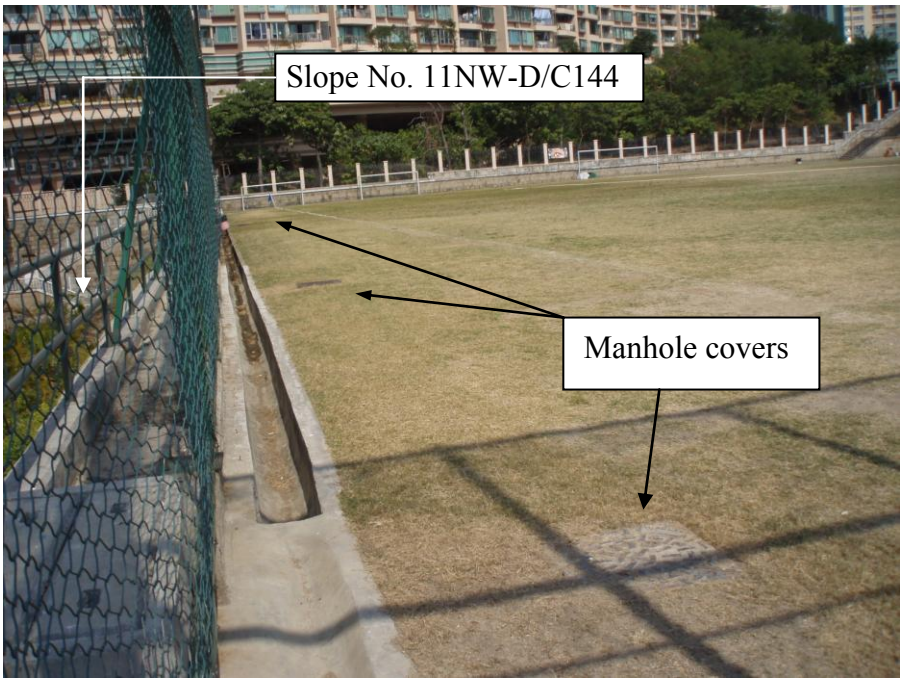

Plate 11 – Manhole Covers on the King's Park Sports Ground above Slope No. 11NW-D/C144
(Photograph taken by HCL on 12 November 2007)

Plate 12 – Repaired Grassed Sports Ground above the August 2005 Landslide Area
(Photograph taken by HCL on 12 November 2007)

Note : See Figure 18 for locations and directions of photographs.

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APPENDIX A

AERIAL PHOTOGRAPH INTERPRETATION

CONTENTS

A1. DETAILED OBSERVATIONS

The following report comprises the detailed observations from the examination of aerial photographs taken between 1945 and 2006. A list of aerial photographs examined in this study is presented in Table A1 and the main observations of the API are shown in Figure A1 and Figure A2.

YEAR	OBSERVATIONS
1945	Monograph only. Poor quality, high flight aerial photograph. The study area is located on the southwest-facing hillside with a shallow slope gradient of about 30° - 40°. The subject Slope No. 11NW-D/C144 is not yet formed. The hillside is generally covered with a thin veneer of vegetation comprising grass and sporadic shrubs. Severe sheet and gully erosion affecting the ridgeline extending across the upper catchment area towards the lower lying terrain near the foothill can be identified. Wylie Road which trends northwest to southeast was already formed along the lower reaches of the subject foothill. There does not appear to be any slope cutting works at the subject hillside. Worcester Heights is not yet constructed. To the south of the subject slope location, the bowling green and the tennis courts of the Hong Kong Chinese Civil Servants' Association and King's Park Hockey Ground already existed.
1949	High elevation stereo pairs of fair quality. The subject hillside suffered from severe sheet and gully erosion giving a general appearance of a barren and hummocky terrain. There is no prominent valley or stream course developed within the study area. Preferential ephemeral drainage lines are apparent and run along the incised erosion gullies which drain from the northeast to southwest. Tor stones are predominantly located along the northwestern ridgeline indicating shallow rockhead within this area. Subangular colluvial boulders are mainly deposited at the low-lying sloping ground near the toe of the subject hillside. A deep excavated borrow area is identified at about 50 m to the east of the subject slope location near the ridgeline. Slope No. 11NW-D/C144, King's Park Sports Ground and Worcester Heights are not yet formed.
1959	Monograph only. Fair quality and high altitude aerial photograph. The subject hillside still appears to be undeveloped. Slope No. 11NW-D/C144 is not yet formed. No observable significant change except the tennis courts and the King's Park Hockey Ground has been renovated to the present-day extent to the south of the subject slope location.

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YEAR	OBSERVATIONS
1963	High resolution stereo pairs. The aerial photographs only cover the northern part of the subject hillside. The subject hillside has been trimmed to form two level platforms at the top. King's Park Sports Ground is still under construction on the platforms. Construction of a subsoil drainage system can be clearly observed on the platforms. The subject Slope No. 11NW-D/C144 is formed in association with the construction of the Sports Ground. The slope gradient of the subject cut slope appears to be about 50°. Bare soil with individual subangular boulders, probably colluvium/corestone, appears at the northern portion of the cut slope. A thin veneer of short grass appears on the slope surface near the southern boundary. Crest and toe channels at the subject slope are under construction. To the west and in front of the subject slope toe, a new vehicular access road connecting the elevated platform for Worcester Heights and Canterbury Court adjoining Wylie Road is built. The elevated platform and the associated Slope No. 11NW-D/FR138 have been formed by the emplacement of fill materials. The British Military Hospital immediately adjacent to the northern end of the subject slope is under construction. Slope Nos. 11NW-D/R246 and 11NW-D/R61 are also formed adjoining the northern boundary of the subject slope. Slope Nos. 11NW-D/R233 and 11NW-D/R244 are constructed adjoining the southern boundary of the subject slope.
1964	Monograph only. Fair quality and high altitude aerial photograph. There is no observable significant change to the subject slope. Most of the surface is still in bare condition except that shallow grass cover is observed at the lower southern portion and a small portion of chunam/shotcrete cover is also discerned in the middle portion of the slope. Worcester Heights and Canterbury Court are not yet constructed. Construction of the British Military Hospital was still in progress. Slope Nos. 11NW-D/FR90 and 11NW-D/R30 have been formed to the southeast of the subject slope. Construction of Wylie Path which connected Wylie Road to the eastern locality of the subject feature has been completed.

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YEAR	OBSERVATIONS
1967	Good quality, low flight stereo pairs. A possible shallow failure is observed at the lower southern portion of the subject slope. The highly reflective soil surface contrasts greatly with the previous grass surface cover in 1964 at this location. The northern portion of the subject slope is still in bare soil condition. A cluster of temporary structures occupy the elevated platform to the west in front of the subject slope toe. Construction of the British Military Hospital immediately adjacent to the north of the subject slope has been completed.
1969	Low elevation high quality stereo pairs. A strip of hard slope surface, probably shotcrete/chunam, has been applied at the lower southern portion of the subject slope as a remedial measure for the landslide identified in 1967. Thin vegetation growth is observed on the rest of the slope surface. The temporary structures at the elevated platform to the west of the subject slope has been cleared.
1972	Low elevation high quality stereo pairs. Shallow grass and sporadic shrubs are observed growing on the subject slope surface. Neither sign of distress nor water seepage are observed in the vicinity of the subject slope. The elevated platform to the west of the subject slope is occupied by an open carpark.
1973	Low elevation high quality stereo pairs. No observable changes except the general area of the subject slope has been covered by a thin layer of grass and scattered trees and shrubs.
1974	High altitude monograph. No significant changes are observed except the vegetation density continues to increase within the subject area.
1975	Low elevation high quality stereo pairs. There is a slight increase in vegetation growth on the subject slope surface. Construction of Worcester Heights and Canterbury Court is in progress on the elevated platform in front of the subject slope.

YEAR	OBSERVATIONS
1977	Low altitude and good quality stereo pairs. Individual patches of possibly chunam cover appears at the northern portion of the subject slope. Slope maintenance works including sealing cracks and vegetation clearance possibly has been carried out at the slope. A young tree is also observed growing at the lower southern portion of the subject slope near the previous failure location. The buried drainage system is seen to be exposed, which suggests that maintenance works are probably being carried out. Construction of Worcester Heights and Canterbury Court is completed.
1978	Low altitude monograph. No significant change since 1977.
1980	Low elevation high quality stereo pairs. A renovated hard slope surface is applied to the subject slope. The young tree identified in 1977 at the lower southern portion of the slope has also been cleared. Only the southern end portion of the subject slope remains covered with grass.
1981	Low elevation high quality stereo pairs. No significant change since 1980.
1982	Low elevation high quality stereo pairs. No observable significant change except a thin veneer of vegetation growth is observed on the entire subject slope surface.
1983	Low elevation high quality stereo pairs. Vegetation clearance appears to have been carried out at the subject slope. No sign of distress is identified in the vicinity of the slope.
1984	Good quality stereo pairs. No significant change.
1985	High elevation stereo pairs. A slight increase in vegetation growth on the subject slope surface is observed.

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YEAR	OBSERVATIONS
1986	Good quality stereo pairs. Vegetation clearance has been carried out at the subject slope except for the lower southern portion at which several young trees and shrubs remain indicating possibly high groundwater table at that location.
1987	High elevation stereo pairs. Vegetation starts growing again on the subject slope surface indicating possibly high groundwater table at the slope.
1988	Low elevation monograph. An area of high reflectivity is discerned at the lower southern portion of the subject slope, possibly a new shotcrete/chunam cover indicating that slope works might have been carried out at that location, possibly installing/repairing underground pipes. A young tree is evident at the mid-slope of the lower southern portion.
1989	High elevation stereo pairs. No changes can be observed. Part of the slope is obscured by buildings owing to the orientation of the photographs.
1990	Good quality stereo pairs. No significant change on the subject slope. Part of the slope is obscured by the shadows of buildings.
1991	High resolution stereo pairs. The middle and the northern part of the slope are obscured by the shadows of buildings. Linear grey tone features from the upslope to the downslope are clearly observed at the new hard surface cover which has been applied in 1988, possibly indicating signs of water seepage at that area.
1992	Good quality stereo pairs. No significant change since 1991.
1993	Good quality stereo pairs. No significant changes except that a layer of grass cover appears at the subject slope surface.

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YEAR	OBSERVATIONS
1994	Good quality stereo pairs. No significant changes except that vegetation density continues to increase within the general area of subject slope.
1995	Good quality stereo pairs. Routine slope maintenance work, vegetation clearance, appears to have been carried out at the subject slope. Neither sign of distress nor water seepage is observed in the vicinity of the subject slope.
1996	Good quality stereo pairs. No significant change since 1995.
1997	Low altitude monograph. No significant change.
1998	Good quality stereo pairs. No significant change on the subject slope.
1999	High resolution monograph. The subject slope surface appears as a very clean hard slope cover indicating that slope maintenance works have been carried out at the slope.
2000	High elevation stereo pairs. No significant change observed.
2001	Good quality stereo pairs. No significant changes are apparent on the subject slope except that the large-scale site clearance for the construction of Parc Palais has been undertaken immediately to the north of the subject slope. The former British Military Hospital has been demolished.
2002	Good quality stereo pairs. No change observed except that the construction of Parc Palais is still in progress and part of the subject slope is obscured by the shadows of buildings.

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YEAR	OBSERVATIONS
2003	Low altitude monograph. No change observed except that the construction of Parc Palais is still in progress and part of the subject slope is obscured by the shadows of buildings.
2004	Low altitude monograph. No observable change to the subject slope. Construction of Parc Palais has been completed.
2005	High resolution stereo pairs. The lower southern portion of the subject slope appears lighter in tone, possibly indicating localised shotcreted surface protection which suggests that the location has been recently affected by localised instability. The landslide probably corresponds to the location of the reported incident (2005/08/0327). The failure source appears to extend backwards and affect the profile of King's Park Sports Ground. The landslide source and debris trail cannot be delineated as the area has been fully shotcreted. The remaining parts of the slope are densely covered with grass and shrubs.

LIST OF TABLES

Table A1 - List of Photographs

Date taken	Altitude (ft)	Photograph Number
11 Nov1945	20,000	Y00517
24 Apr 1949	8,000	Y1619 – Y1620
5 Oct 1959	40,000	Y4610
1963	2,700	Y07751,Y07753
13 Dec 1964	12,500	Y12902
1967	6,250	Y13331-2, Y13350
1969	1,800	Y15081 – Y15082
1972	1,800	2381-2
23 Oct 1973	5,000	5281-3
28 Feb 1974	12,500	8266
2 December 1975 1 December 1975	2,000 4,000	11453 11302-3
21 December 1977	4,000	20372 – 20373
15 June 1978	2,000	21949
17 April 1980	4,000	30068-9
26 October 1981 26 November 1981	10,000 4,000	39043 39932,39934
6 October 1982	4,000	44101 – 44102
3 January 1983 28 September 1983	4,000	46897-8 49876
3 March 1984	4,000	54061 – 54062
4 October 1985	15,000	A02658 – A2659
3 March 1986	4,000	A04278 – A04279
5 January 1987 11 June 1987	20,000 4,000	A08404 – A08405 A09566
19 January 1988 4 June 1988	6,000 10,000	CN2097 A13669
13 November 1989	10,000	A19245 – A19246
13 November 1990	4,000	A23689 – A23690
29 October 1991	10,000	A27362-3 A28901 – A28902
26 August 1992 11 November 1992	3,000 10,000	CN3096-7 A33198

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Date taken	Altitude (ft)	Photograph Number
4 October 1993 2 November 1993	20,000 4,000	CN4394 A36177-8
6 May 1994 20 October 1994	4,000	A38059 A39188 – A39189, A39167
27 September 1995	3,500	CN11261 – CN11262
18 November 1996	5,000	CN15639 – CN15639
14 November 1997	4,000	CN18860
31 October 1998	4,000	CN21349 – CN21350
11 December 1999	4,000	CN25189
26 February 2000	20,000	CN25923 – CN25924
21 November 2001	8,000	CW36487 – CW36488
9 October 2002	8,000	CW45244 – CW45245
25 November 2003	4,000	CW53331
5 October 2004	4,000	CW60299 – CW60300
24 October 2005	4,000	CW65674 – CW65675
Note: All aerial photographs are in black and white except for those prefixed with CN or CW.		

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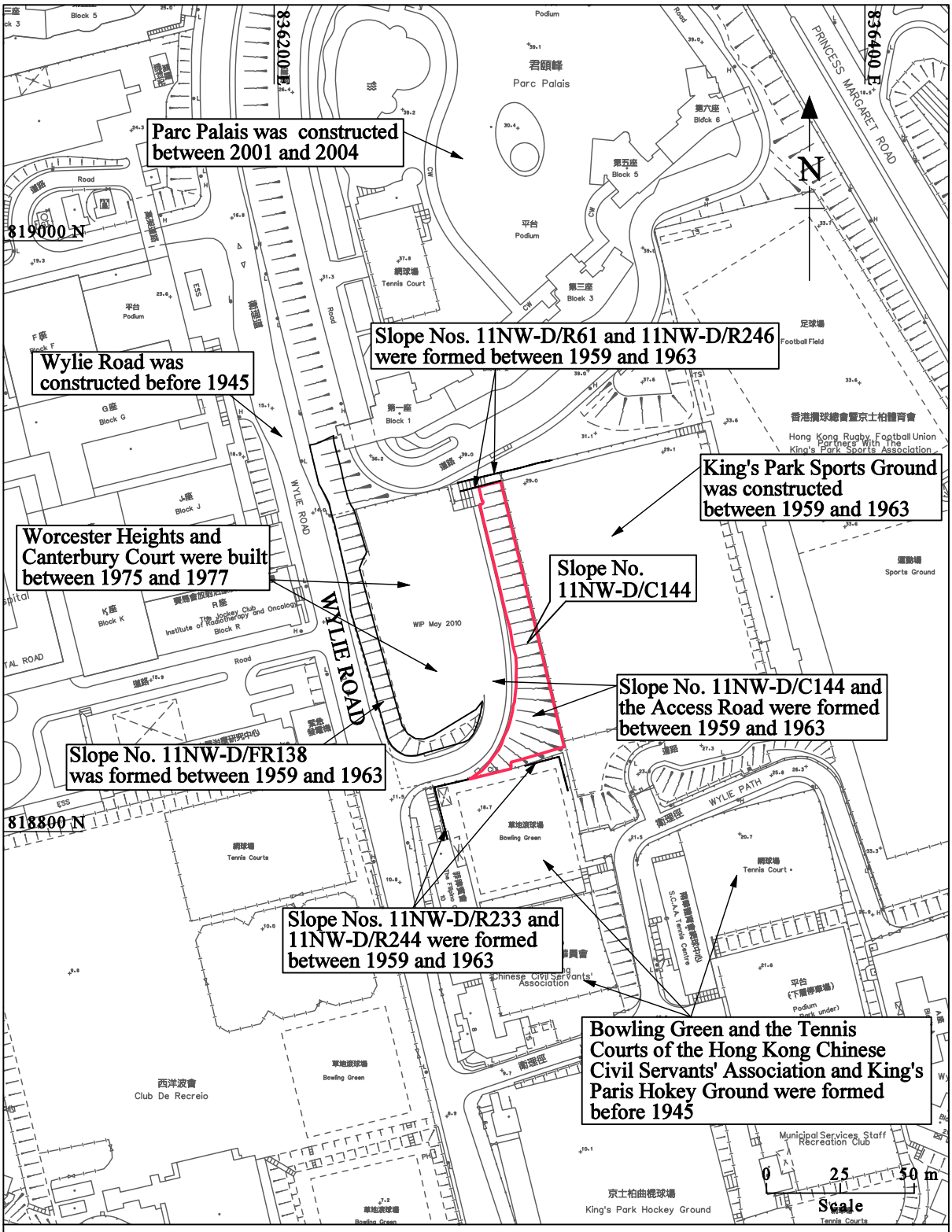

Figure A1 - Site Development History

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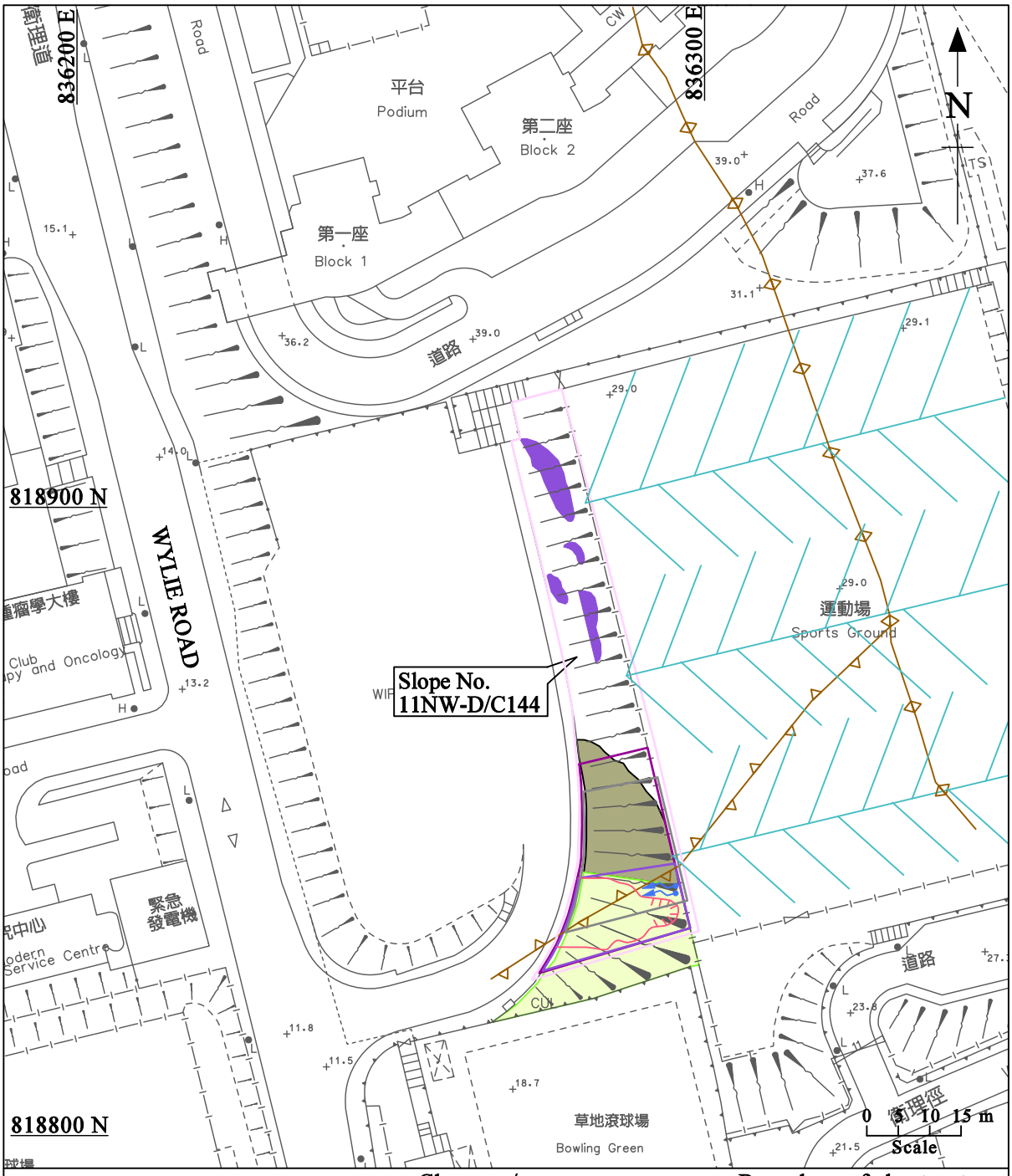

Figure A2 - Aerial Photograph Interpretation

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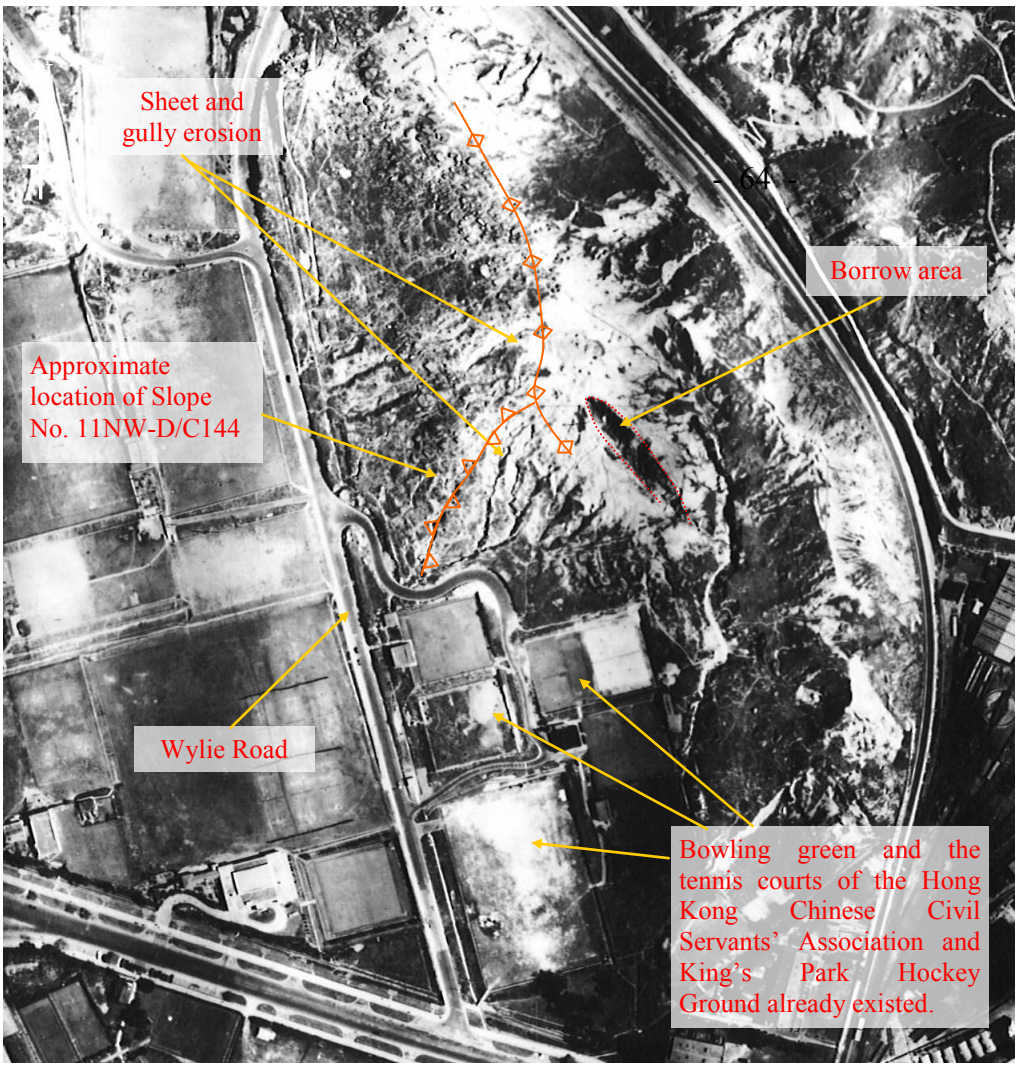

Legend:

Ridgeline

Spurline

Possible borrow area

Plate A1 – Interpretation of 1949 Aerial Photograph

Note: Aerial Photograph No. Y01620 taken on 24 April 1949.

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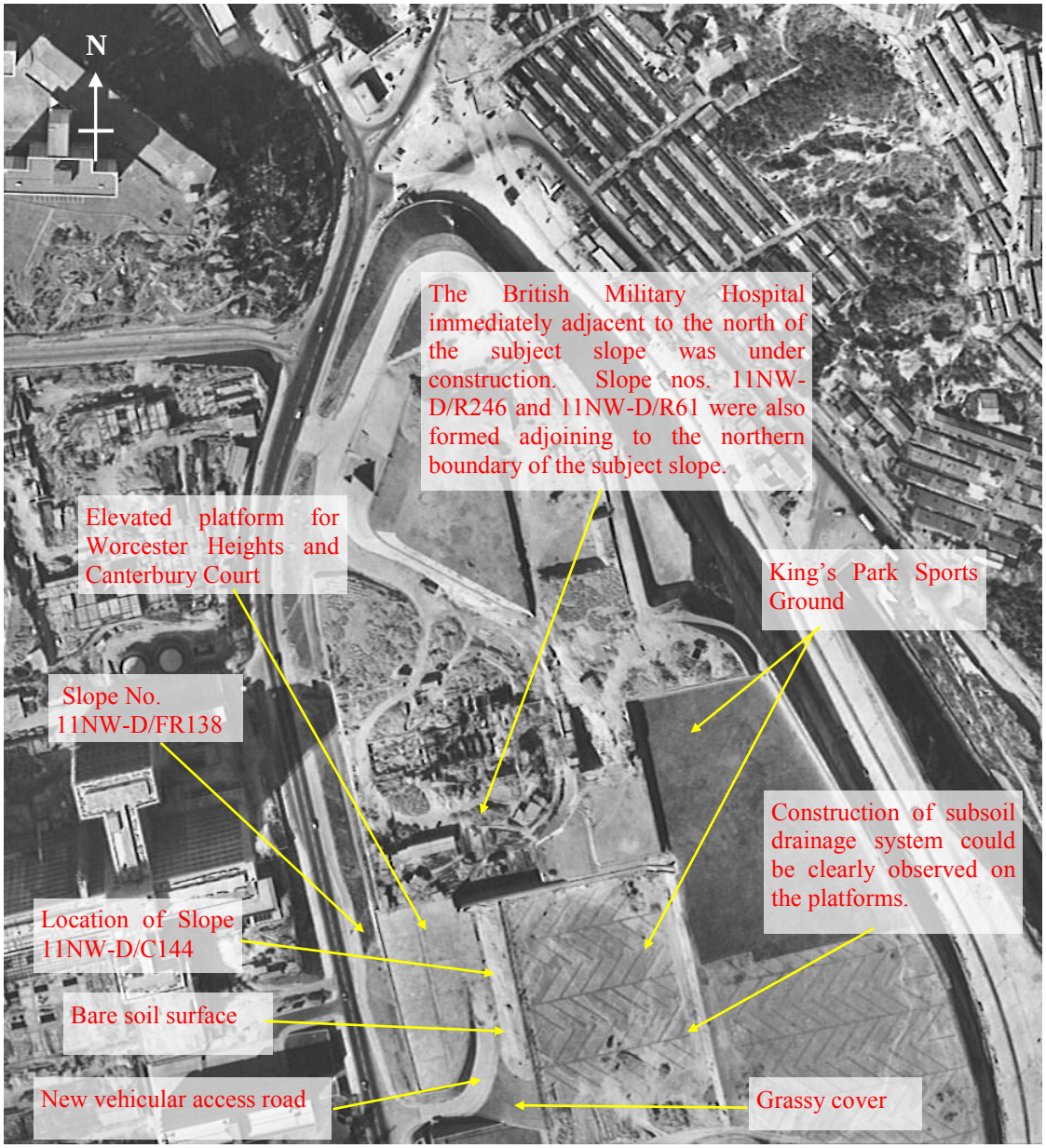

Plate A2 – Interpretation of 1963 Aerial Photograph

Note : Aerial Photograph No. Y07751 taken on 25 January 1963.

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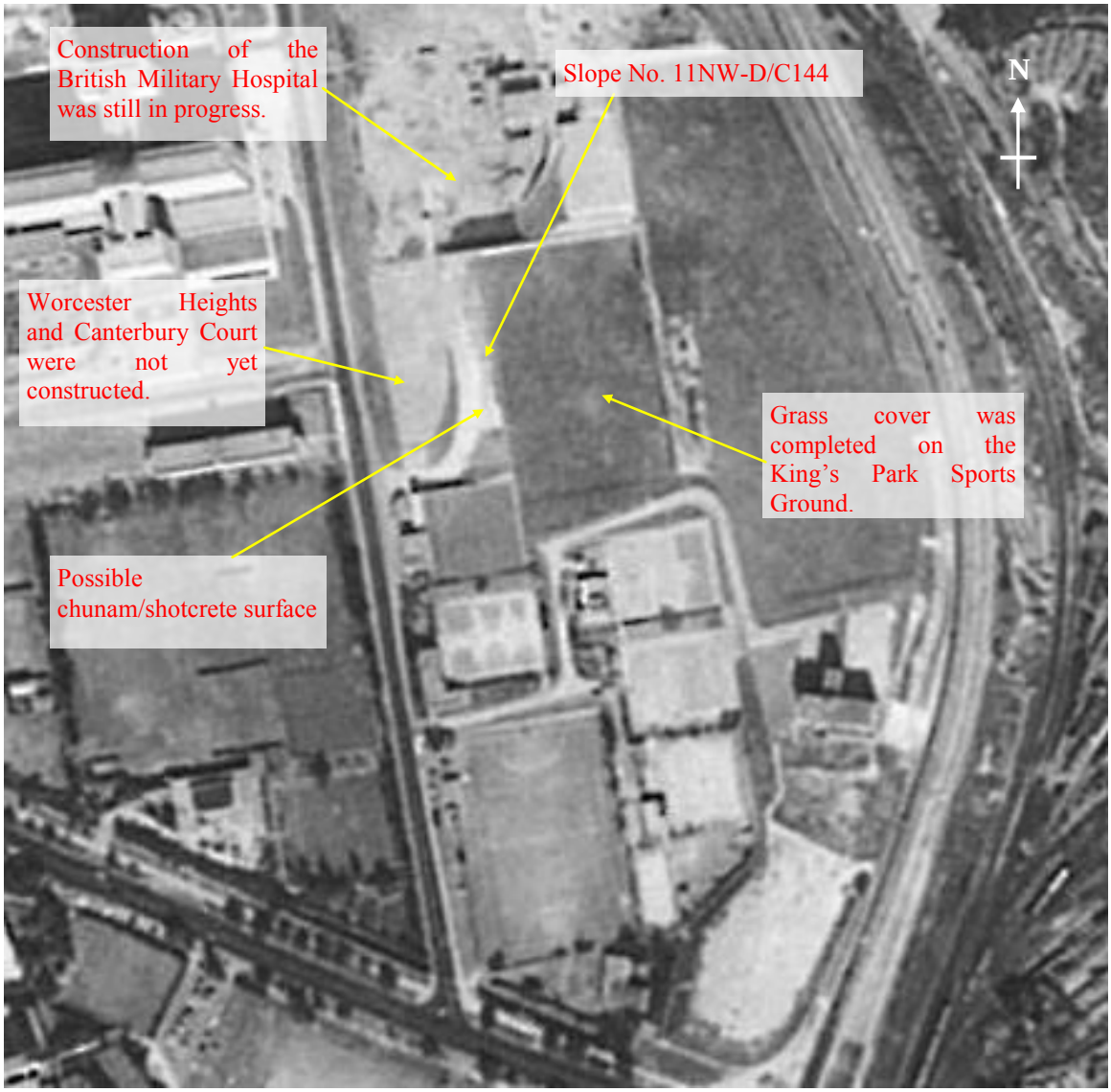

Plate A3 – Interpretation of 1964 Aerial Photograph

Note : Aerial Photograph No. Y12902 taken on 13 December 1964.

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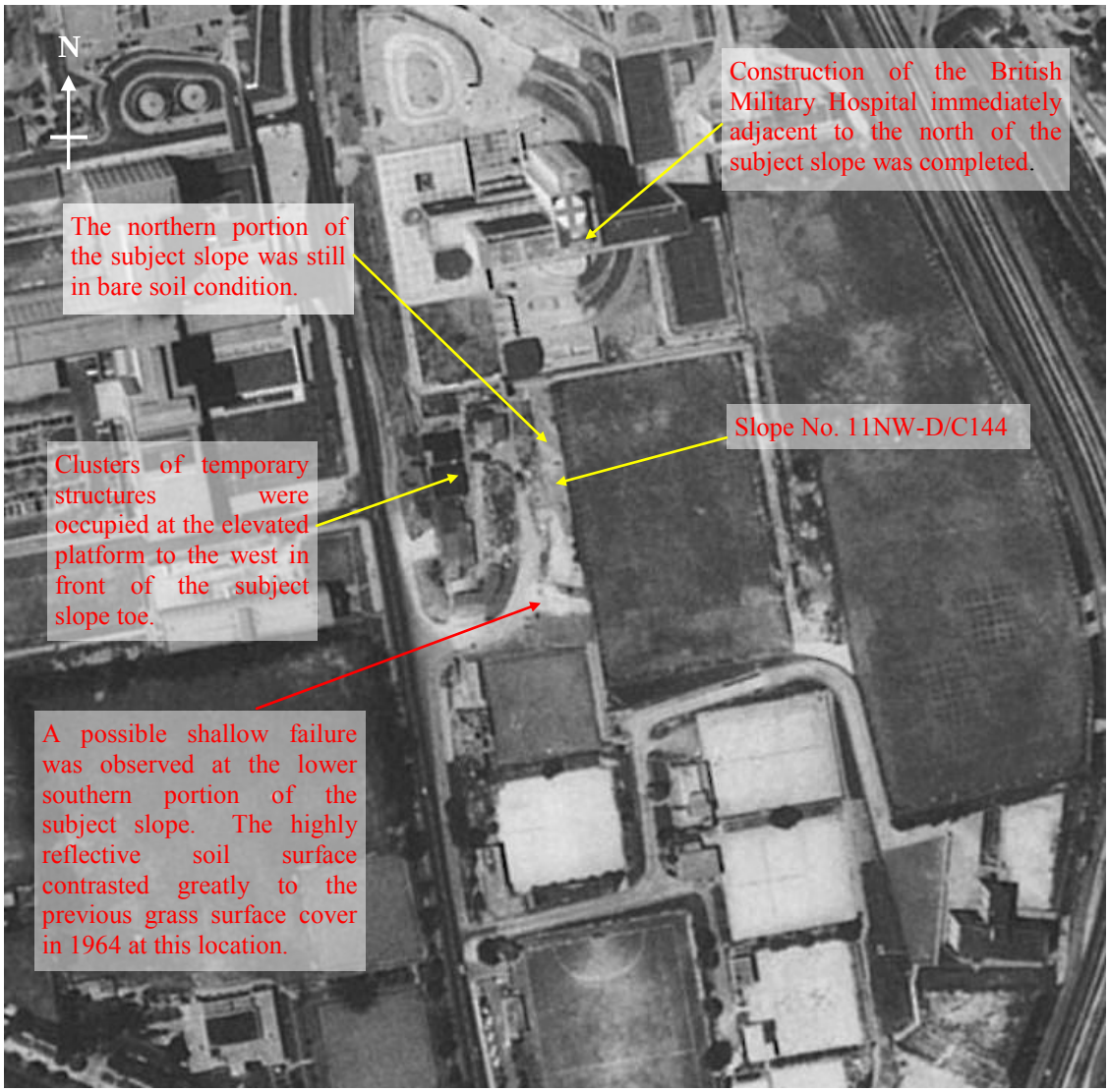

Plate A4 – Interpretation of 1967 Aerial Photograph

Note : Aerial Photograph No. Y13350 taken in 1967.

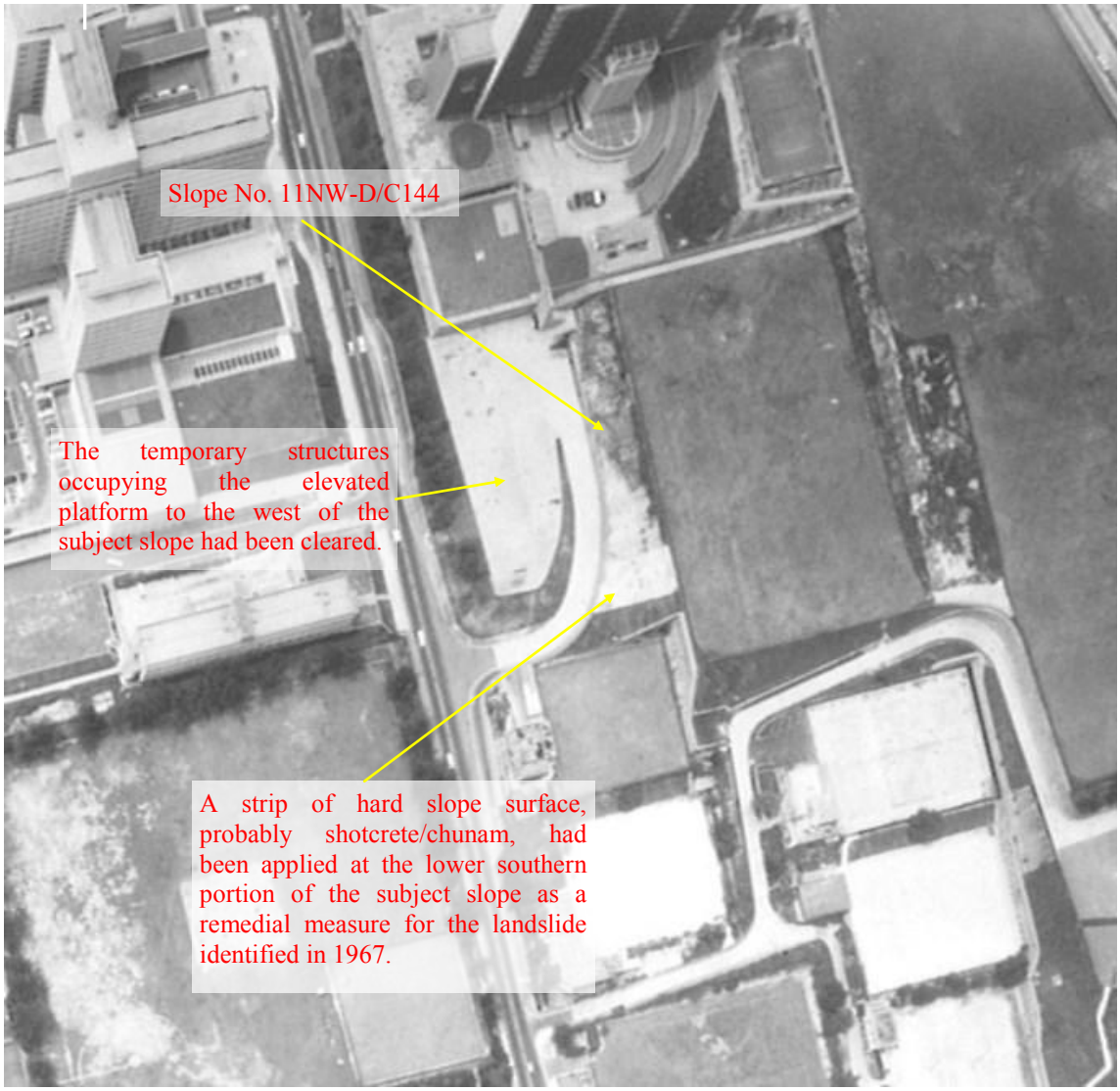

Plate A5 – Interpretation of 1969 Aerial Photograph

Note : Aerial Photograph No. Y15082 taken in 1969.

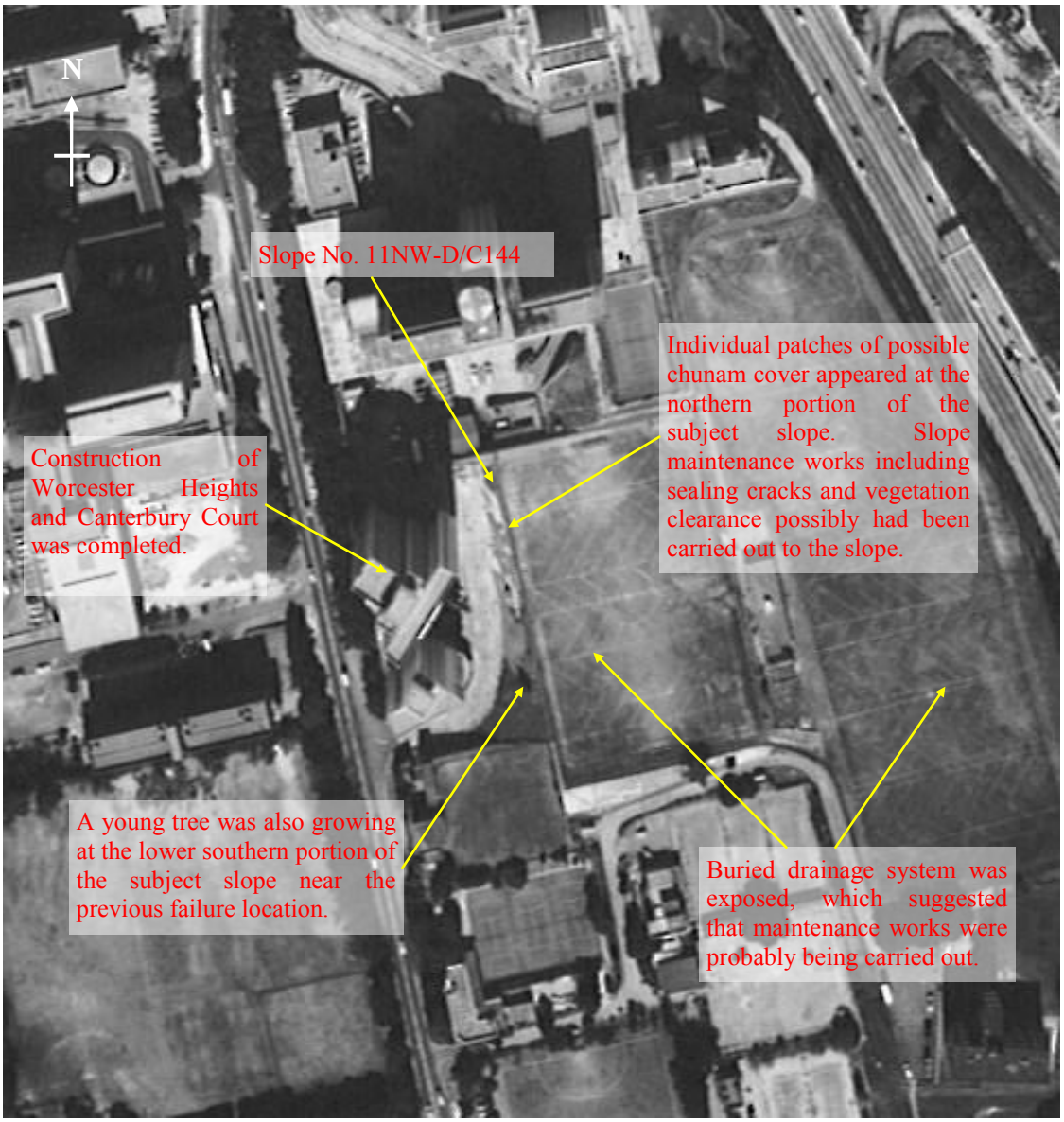

Plate A6 – Interpretation of 1977 Aerial Photograph

Note : Aerial Photograph No. 20373 taken on 21 December 1977.

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Plate A7 – Interpretation of 1980 Aerial Photograph

Note : Aerial Photograph No. 32764 taken on 12 November 1980.

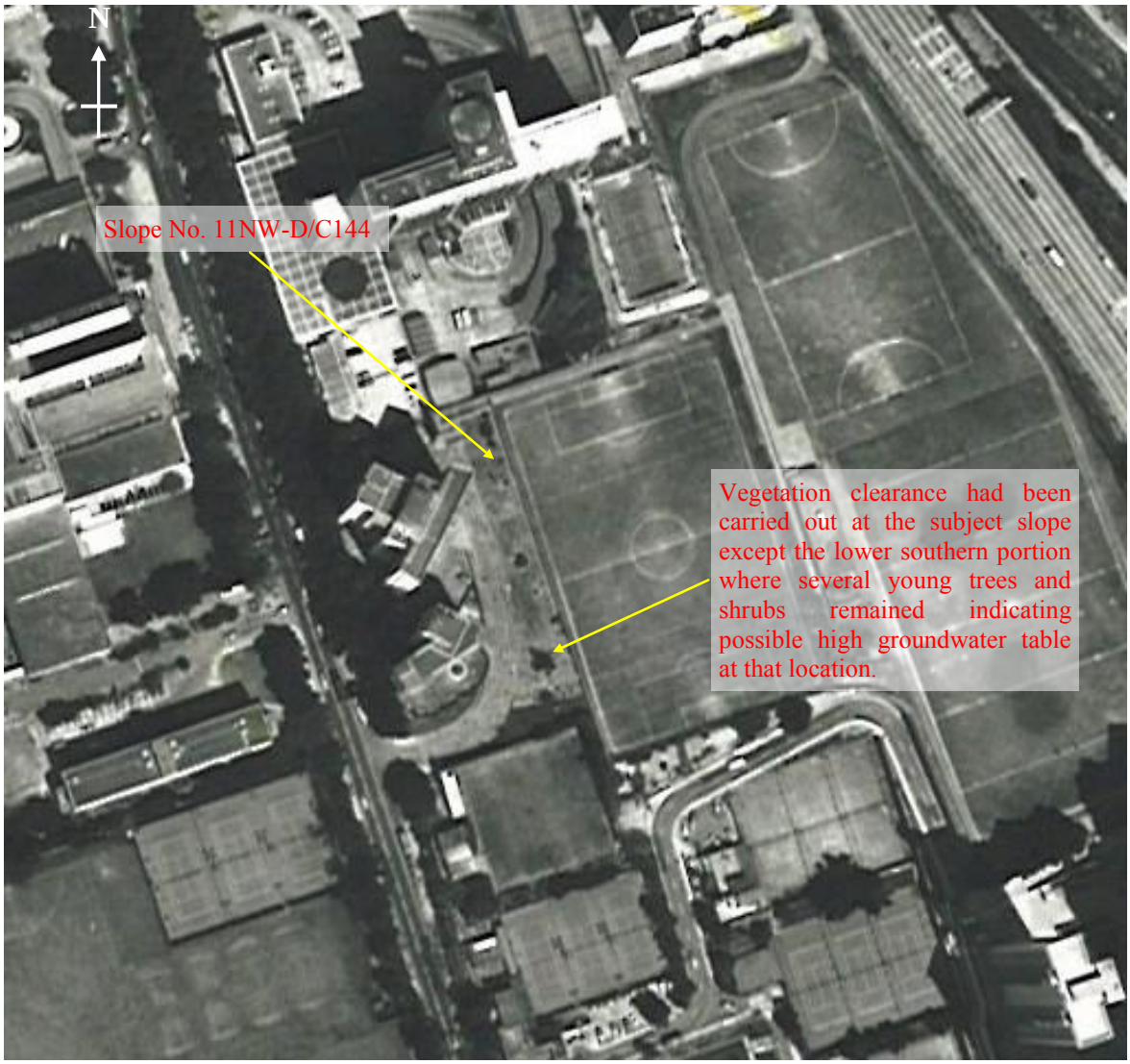

Plate A8 – Interpretation of 1986 Aerial Photograph

Note : Aerial Photograph No. A04278 taken on 3 March 1986.

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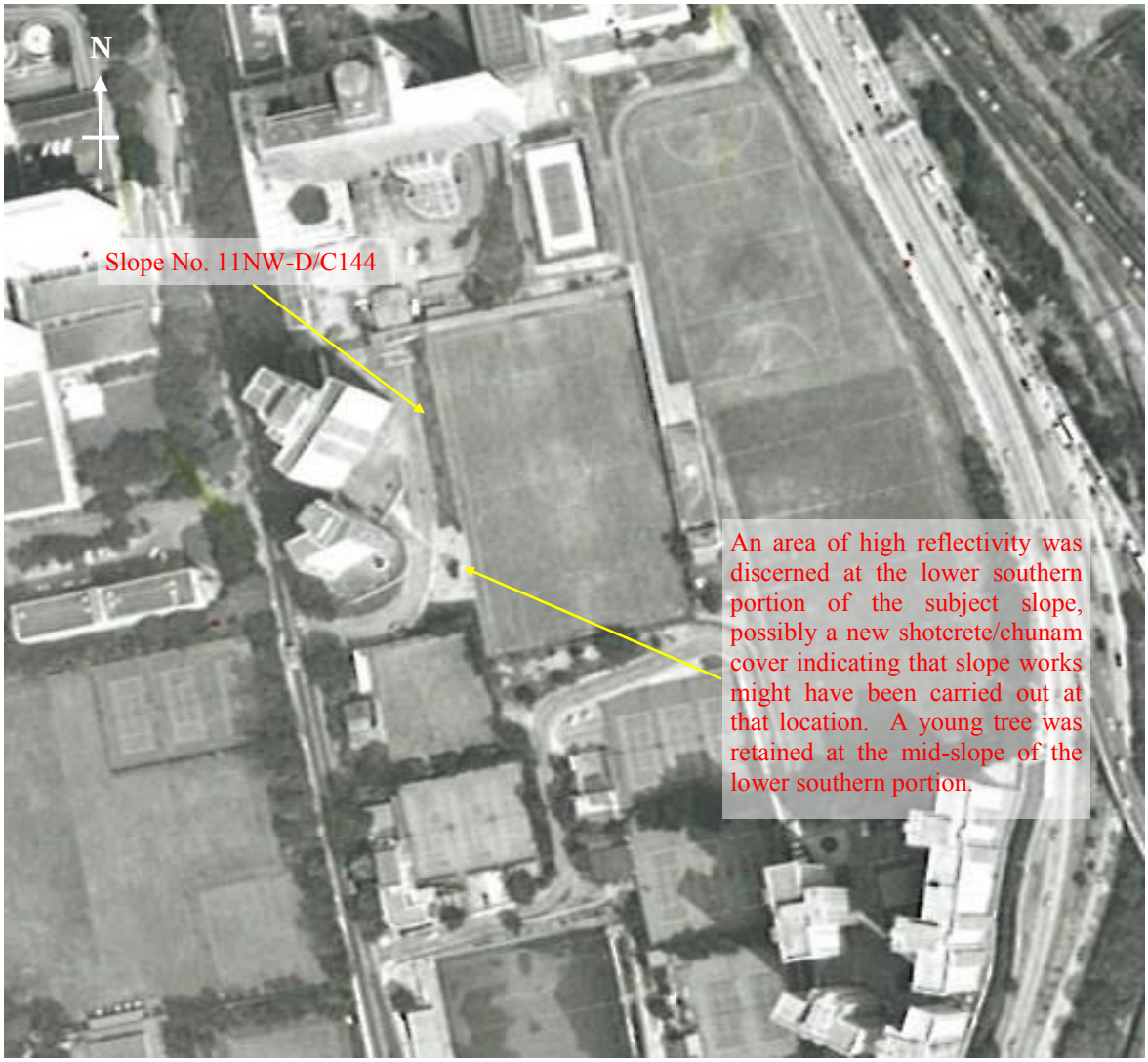

Plate A9 – Interpretation of 1988 Aerial Photograph

Note : Aerial Photograph No. A14618 taken on 5 October 1988.

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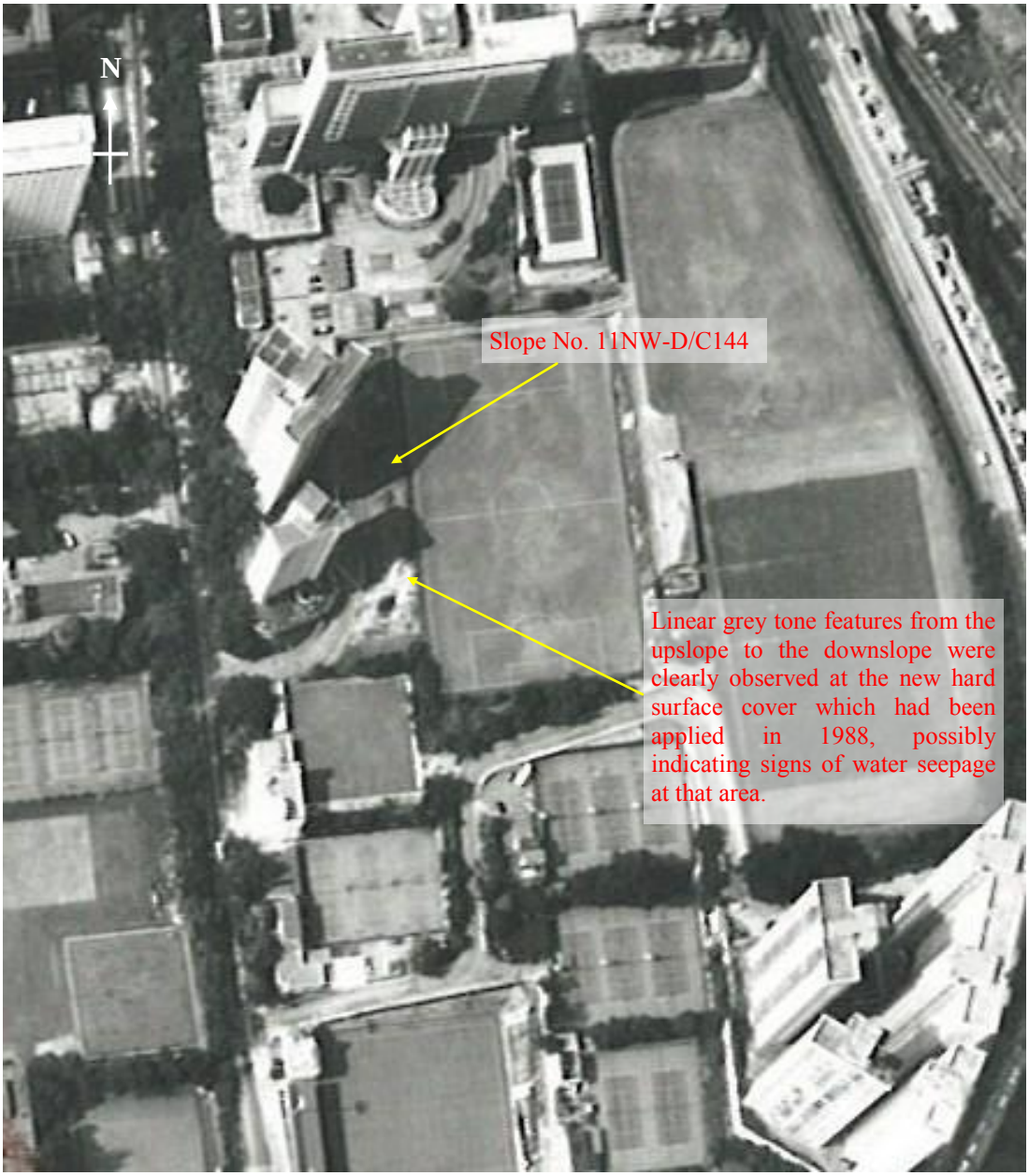

Plate A10 – Interpretation of 1991 Aerial Photograph

Note : Aerial Photograph No. A27363 taken on 20 September 1991.

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Plate A11 – Interpretation of 2005 Aerial Photograph

Note : Aerial Photograph No. CW65675 taken on 24 October 2005.

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Geotechnical Manual for Slopes, 2nd Edition (1984), 302 p. (English Version), (Reprinted, 2011).

斜坡岩土工程手冊(1998)，308頁(1984年英文版的中文譯本)。

Highway Slope Manual (2000), 114 p.

GEOGUIDES

Geoguide 1	Guide to Retaining Wall Design, 2nd Edition (1993), 258 p. (Reprinted, 2007).
Geoguide 2	Guide to Site Investigation (1987), 359 p. (Reprinted, 2000).
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Geoguide 5	Guide to Slope Maintenance, 3rd Edition (2003), 132 p. (English Version).
岩土指南第五冊	斜坡維修指南，第三版(2003)，120頁(中文版)。
Geoguide 6	Guide to Reinforced Fill Structure and Slope Design (2002), 236 p.
Geoguide 7	Guide to Soil Nail Design and Construction (2008), 97 p.

GEOSPECS

Geospec 1	Model Specification for Prestressed Ground Anchors, 2nd Edition (1989), 164 p. (Reprinted, 1997).
Geospec 3	Model Specification for Soil Testing (2001), 340 p.

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GEO Publication No. 1/93	Review of Granular and Geotextile Filters (1993), 141 p.
GEO Publication No. 1/2006	Foundation Design and Construction (2006), 376 p.
GEO Publication No. 1/2007	Engineering Geological Practice in Hong Kong (2007), 278 p.
GEO Publication No. 1/2009	Prescriptive Measures for Man-Made Slopes and Retaining Walls (2009), 76 p.
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The Quaternary Geology of Hong Kong, by J.A. Fyfe, R. Shaw, S.D.G. Campbell, K.W. Lai & P.A. Kirk (2000), 210 p. plus 6 maps.

The Pre-Quaternary Geology of Hong Kong, by R.J. Sewell, S.D.G. Campbell, C.J.N. Fletcher, K.W. Lai & P.A. Kirk (2000), 181 p. plus 4 maps.

TECHNICAL GUIDANCE NOTES

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