REVIEW OF THE 20 AUGUST 2005 LANDSLIDE ON SLOPE NO. 15NE-A/C152 AT MA HANG PRISON, STANLEY

GEO REPORT No. 247

Fugro Scott Wilson Joint Venture

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

REVIEW OF THE 20 AUGUST 2005 LANDSLIDE ON SLOPE NO. 15NE-A/C152 AT MA HANG PRISON, STANLEY

GEO REPORT No. 247

Fugro Scott Wilson Joint Venture

This report is largely based on GEO Landslide Study Report No. LSR 3/2008 produced in June 2008

First published, September 2009

Prepared by:

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

Table of Contents

Table of Contents

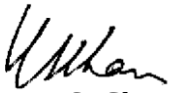
Table of Contents

Table of Contents

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. These include guidance documents and results of comprehensive reviews. These 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.



R.K.S. Chan
Head, Geotechnical Engineering Office
September 2009

FOREWORD

This report presents the findings of the review of a landslide (Incident No. 2005/08/0493) that occurred on 20 August 2005 on slope No. 15NE-A/C152 behind a staff quarters building, which was vacant at the time of the incident, at Ma Hang Prison, Stanley. The incident involved a shallow failure of the soil nailed slope with an estimated failure volume of about 35 m^3, which was deposited on the ground at the slope toe. No casualties were reported as a result of the incident.

The key objectives of the review were to document the facts about the incident, the site history and pertinent observations. The scope of the review does not include any ground investigation. Recommendations for follow-up actions are reported separately.

The report was prepared as part of the 2006/2007 Landslide Investigation Consultancy (LIC) for Hong Kong Island and Outlying Islands, for the Geotechnical Engineering Office (GEO) of the Civil Engineering and Development Department (CEDD), under Agreement No. CE 49/2005 (GE). This is one of a series of reports produced during the consultancy by Fugro Scott Wilson Joint Venture (FSW).

V C Koo
Project Director
Fugro Scott Wilson Joint Venture

Agreement No. CE 49/2005 (GE)
Study of Landslides Occurring in Hong Kong Island and Outlying Islands in 2006 and 2007

CONTENTS

1. INTRODUCTION

In the morning of 20 August 2005, a landslide (Incident No. 2005/08/0493) occurred on slope No. 15NE-A/C152 behind a staff quarters building within the Ma Hang Prison complex at Stanley (Figure 1 and Plate 1). An Amber Rainstorm Warning and a Landslip Warning were in force at the time of the failure. Debris from the landslide, with an estimated volume of about 35 m^3, was deposited on the level ground between the slope toe and the staff quarters building. No casualties were reported as a result of the failure.

Following the incident, Fugro Scott Wilson Joint Venture (FSW), the 2006 and 2007 Landslide Investigation Consultants for Hong Kong Island and Outlying Islands, carried out a review of the landslide for the Geotechnical Engineering Office (GEO) of the Civil Engineering and Development Department (CEDD), under Agreement No. CE 49/2005 (GE).

This review report documents the facts about the incident, the site history and pertinent observations made by FSW in respect of the subject area. The scope of the review does not include any ground investigation. Recommendations for follow-up actions are reported separately.

2. SITE DESCRIPTION

2.1 Site Description

The general landform in the vicinity of the 20 August 2005 landslide comprises a southeasterly-trending spur ridge containing a number of ephemeral drainage lines extending below Stanley Gap Road, which is situated at an elevation of about 90 mPD, to the Ma Hang Prison complex at Stanley. The prison complex is constructed on cut and fill platforms of varying elevation on and within the spur ridge, and it extends over a distance of about 80 m on plan to the southeast to the border of the adjacent 'Stanley Knoll' residential complex at an elevation of around 50 mPD.

Slope No. 15NE-A/C152 (Figure 2 and Plate 1) comprises a 40 m long southeast-facing soil and rock cut with a maximum height of about 12 m. The slope is situated above a two-storey high staff quarters building at the northwestern extent of the complex. The building structure is located about 2 m beyond the slope toe, and the intervening ground is paved with concrete. The natural hillsides comprising the spur ridge extend above the slope crest at an angle of about 25°. East- and south-trending ephemeral drainage lines are located to the northeast and southwest of the slope respectively. A concrete water tank, with dimensions of about 3 m by 3 m on plan, is located at the slope crest in the central portion of the feature. Two exposed water pipes of 35 mm in diameter are connected to the water tank at the slope crest and laid on the slope face, and another 35 mm in diameter exposed pipe extends along the slope toe (see Figure 2).

The geometry of slope No. 15NE-A/C152 comprises a maximum 4 m high upper batter inclined at about 30° and an 8 m high lower batter inclined at between 35° and 56°, but typically steeper than 45°. The two slope batters are separated by an 800 mm wide berm, creating an overall inclination of about 38° to 40°. Rock outcrop is exposed in the lower batter up to about 4 m above the slope toe. The soil portion of the slope face has a surface

cover of vegetation comprising mostly grass with isolated small trees. The intermediate berm is covered by a concrete slab incorporating a 230 mm wide U-channel, and a 300 mm wide stepped channel extends along the slope crest. Slope upgrading works involving the installation of soil nails, replacement of chunam surfacing with vegetation and provision of surface drainage system were completed on the slope under the Landslip Preventive Measures (LPM) Programme in 2001 (see Section 5.5).

2.2 Water-carrying Services

Records of the Water Supplies Department and Drainage Services Department indicate that there are no buried water-carrying services in the immediate vicinity of slope No. 15NE-A/C152.

Two exposed water pipes of 35 mm in diameter are connected to the water tank at the slope crest and laid on the slope face, and another 35 mm diameter exposed pipe extends along the slope toe (see Section 2.1).

3. LAND STATUS AND MAINTENANCE RESPONSIBILITY

According to the Slope Maintenance Responsibility Information System of the Lands Department, slope No. 15NE-A/C152 falls within the government land GLA-HK401, which has been allocated to the Correctional Services Department (CSD). The maintenance responsibility of the slope rests with the Architectural Services Department (Arch SD).

4. SITE DEVELOPMENT AND PREVIOUS INSTABILITIES

4.1 Site Development

The site development history has been established from a review of file records in the GEO, which include a Stage 3 Study Report under the LPM Programme incorporating an aerial photograph interpretation (API) for slope No. 15NE-A/C152 prepared by the LPM Consultant, Halcrow Asia Partnership Limited (HAP), in 2001 (see Section 5.5). A review of the aerial photographs has been carried out as part of the present study to verify the information from the previous API. A detailed account of the API for the present review is given in Appendix A, and the salient information relevant to the history of the site is presented in Figure 3.

Stanley Gap Road and the original Ma Hang Prison complex were constructed at some time prior to the 1949 aerial photographs. Stanley Gap Road has maintained essentially the same alignment up to the present day. The Ma Hang Prison complex in 1949 comprised the present reception block, the adjacent three dormitories and dining hall, together with the associated access roads. Two footpaths extended upslope from the dormitories to Stanley Gap Road.

In 1949, the present-day location of slope No. 15NE-A/C152 and the adjacent staff quarters building remained undeveloped, and comprised natural hillsides with easterly

flowing ephemeral streamcourses located to the north and south. An area of cultivated ground was located upslope, adjacent to the eastern-most of the two footpaths.

The 1963 aerial photographs indicate further development of the Ma Hang Prison complex, which included construction of the staff quarters building at the toe of slope No. 15NE-A/C152 and the site formation works incorporating the formation of the cut slope. The crest line of the slope face does not extend as far upslope as the present-day arrangement. The water tank presently located at the slope crest is visible. The slope face appears to be mostly bare and the lower portion of the slope face is irregular, probably indicating the rock exposure. The cultivated area above slope No. 15NE-A/C152 appears to be abandoned at this time, being heavily overgrown with vegetation. The adjacent footpath is similarly overgrown. A linear feature, probably comprising an above-ground pipeline, extends from Stanley Gap Road to the staff quarters access road immediately to the east of slope No. 15NE-A/C152.

The 1977 aerial photographs indicate further development of the Ma Hang Prison complex, although not in the vicinity of slope No. 15NE-A/C152. The slope face has a cover of vegetation, including trees in the upper portion, and a drainage channel is visible along the slope crest. A footpath extends down the western side of slope No. 15NE-A/C152 from the water tank to the adjacent access road.

The 1980 aerial photographs show the face of slope No. 15NE-A/C152 to have been cut back to the present-day geometry, extending the crest line upslope to the water tank. The slope face is mostly bare, with sparse, shrub-sized vegetation present. A dark-toned area is visible on the lower portion of the slope face, possibly indicating seepage on the exposed rock. The footpath associated with the water tank identified in the 1977 aerial photographs is no longer visible. No major changes are observed at slope No. 15NE-A/C152 or the hillside above between 1980 and 1983, except that the vegetation on the slope face becomes heavier with time and a surface drainage channel traversing the feature at mid-height is visible in the 1981 aerial photographs.

From 1984 to 1996, heavy trimming of vegetation on the man-made slopes and natural hillsides within the Ma Hang Prison complex was periodically carried out (visible in the 1984, 1990, 1992, and 1996 aerial photographs). This included trimming of the vegetation on slope No. 15NE-A/C152 and the hillside above over a distance of about 10 m to 20 m on plan upslope (Figure 3). The vegetation progressively recovered after each trim. The natural hillsides extending above the area of trimming to Stanley Gap Road have remained essentially unchanged up to the present day.

The above-ground pipeline first identified in the 1963 aerial photographs is no longer visible from 1987 onwards. Possible repair works on the lower eastern portion of slope No. 15NE-A/C152 are visible in the 1990 aerial photographs, and a recently applied hard surface cover on the face of slope No. 15NE-A/C152 above the rock exposure is visible in the 1991 aerial photographs. The surface cover on the upper portion of slope No. 15NE-A/C152 was replaced a short time prior to the 1996 aerial photographs, and was observed to have progressively deteriorated with time. The upper batter has a cover of unplanned vegetation in the 1999 aerial photographs.

Ground investigation associated with the upgrading of slope No. 15NE-A/C152 under the LPM Programme was completed in 2000 (see Section 5.5), and a reinstated surface strip is

Table of Contents
Table of Contents
Table of Contents
Table of Contents

visible on the slope face in the 2000 aerial photographs. The 2001 aerial photographs show the completed upgrading works, comprising a hydroseeded surface cover and new surface drainage channels at the slope crest and the berm at mid-height. No major changes are observed in the vicinity of slope No. 15NE-A/C152 from 2001 up to the present.

4.2 Previous Instabilities

According to the GEO's landslide database, no previous landslides have been recorded at or in the vicinity of slope No. 15NE-A/C152.

No previous landslides were identified in the vicinity of the August 2005 landslide from the aerial photograph records, except that two areas of erosion, which are located on the hillsides about 40 m (on plan) to the northwest of the crest of slope No. 15NE-A/C152, were identified in the 1993 aerial photographs (Figure 3).

A single relict landslide is shown in the GEO's Enhanced Natural Terrain Landslide Inventory (ENTLI) situated in a drainage line below Stanley Gap Road about 40 m to the west of the 20 August 2005 failure (Figure 3). No relevant landslide data in the vicinity of the failure are shown in the GEO's Large Landslide Database.

5. PREVIOUS ASSESSMENTS AND SLOPE UPGRADING WORKS

5.1 Study by Binnie & Partners in 1977/78

In April 1978, slope No. 15NE-A/C152 was inspected by Binnie & Partners (B&P) under the "Phase 1 Re-appraisal of Cut & Natural Slopes & Retaining Walls Study" and was subsequently registered in the 1977/78 Catalogue of Slopes (Plate 2). The field sheet for this feature reported the slope angle as 50° and recorded no signs of seepage or distress. B&P also recommended the clearance of U-channels, the clearance of vegetation and protection of the slope.

5.2 SIFT and SIRST Studies

In June 1995, under GEO's "Systematic Inspection of Features in the Territory" (SIFT) project, slope No. 15NE-A/C152 was categorised as a Class 'C1' feature, i.e. slopes that "have been formed or substantially modified before 30.6.78 or have been illegally formed after 30.6.78".

In December 1996, slope No. 15NE-A/C152 was inspected under the "Systematic Identification and Registration of Slopes in the Territory (SIRST)" project initiated by the GEO. The SIRST field sheet noted that the chunam surface was in a fair condition, and that no signs of seepage and no potentially leaky services or distress were observed. The slope was recorded as having no inferred past instability. The consequence-to-life category of the subject slope was rated as '1'. The slope angle was recorded as 50°.

5.3 Routine Maintenance Inspections

Routine Maintenance Inspections (RMI) of slope No. 15NE-A/C152 were carried out by the in-house staff of Arch SD in August 1994, December 1994, December 1995, November 1996, February 1998, April 1998, December 1998, June 1999, January 2000, November 2000, September 2001, December 2002, January 2005 and September 2005 respectively. A RMI was carried out by Au Posford Consultants Limited (Au Posford), the RMI Consultant to the Arch SD, in February 2004.

The inspection records for the August 1994 RMI indicated that the condition of slope surfacing on slope No. 15NE-A/C152 was "satisfactory", and recommended that drainage channels be cleared and weepholes be unblocked. The December 1994 RMI made recommendations for the clearance and repair of drainage channels, and the clearance of weepholes. The works were recorded as having been completed under a Works Order in January 1995. The December 1995 RMI made similar recommendations for the clearance and repair of drainage channels, and the clearance of weepholes (Plate 3).

The inspection records of the November 1996 RMI indicated that action was required in respect of clearance and repair of drainage channels, repair of the surface cover, removal of surface debris and vegetation and unblocking of weepholes.

The February 1998 RMI recorded that the general condition of the slope was acceptable, and that no action was necessary. The previously recommended "remedial works" were reported as having been completed in 1997 (Plate 4). Subsequently, the April 1998 RMI made recommendations for the clearance and repair of drainage channels, the removal of surface vegetation and the clearance of weepholes. The December 1998 RMI records made similar recommendations, which were recorded as having been completed in February 1999.

The June 1999 RMI again made recommendations for the clearance and repair of drainage channels, the repair of the surface cover, removal of surface vegetation and the clearance of weepholes. Records from the January 2000 RMI made recommendation for removal of surface vegetation, which was recorded as having been completed in February 2000, and noted slight seepage issuing from joints in the rock exposed on the slope face.

The November 2000 RMI made recommendation for the clearance of weepholes, which was recorded as having been completed in December 2000, and noted "slight" seepage issuing from rock joints on the slope face, as well as "modification" of the slope being carried out by the GEO at the time of the inspection. The September 2001 RMI made a recommendation for the clearance of drainage channels, which was recorded as having been completed in December 2001.

The December 2002 RMI recorded that no action was necessary in respect of slope maintenance. The February 2004 RMI completed by Au Posford made recommendations for the clearance of blocked drainage channels and a blocked catchpit, which were recorded as having been completed in April 2004.

The January 2005 RMI recorded recommendations for clearance of drainage channels and trimming of undesirable vegetation. The records from the Arch SD indicated that these works were completed in June 2005.

5.4 Engineer Inspections

Engineer Inspections (EI) of slope No. 15NE-A/C152 were undertaken by Fugro (Hong Kong) Ltd. (FHK), the EI Consultant to the Arch SD, in August 1996 and August 2002, and by the Arch SD in June 2000.

Records from the August 1996 EI completed by FHK indicated that the rigid surface cover was in fair condition, and that weepholes and U-channels were partially blocked with vegetation. No obvious indication of recent movement or tension cracks was observed. Seepage was identified emanating from joints in the rock exposure on the lower third of the slope face. Minor works were recommended in relation to the clearance and repair of surface channels, the removal of unplanned vegetation from the cracked surface cover and weepholes, and the sealing of cracks in the surface cover. A Maintenance Manual for slope No. 15NE-A/C152, which was issued by FHK in January 1998, presented similar information to that in the August 1996 EI Report.

Records from the June 2000 EI completed by the Arch SD indicated that the rigid surface cover was in fair condition, and that weepholes and U-channels were partially blocked with vegetation. The channels were recorded as exhibiting a moderate degree of cracking. Moderate seepage was observed issuing from rock joints at about 3 m above the slope toe (Plate 5). Signs of leakage from water-carrying services were also recorded and a recommendation for leakage testing was made, but the location and nature of the leakage was not indicated in the EI Report. The EI records noted that slope No. 15NE-A/C152 was included in the LPM Programme under Schedule of Rates Contract No. GE/99/18, and that ground investigation works were underway at the time of the inspection. Minor works were recommended in relation to the removal of unplanned vegetation and repair of cracks in the surface cover, the clearance of unplanned vegetation and sediment from channels and repair of cracking in channels, and the removal of unplanned vegetation from weepholes. The Maintenance Manual for the slope was subsequently updated by the Arch SD in July 2000 and presented similar information to that in the EI Report.

Records from the August 2002 EI completed by FHK reported that the previous routine maintenance works were only partially completed and that drainage channels had not been cleared of debris. The overall condition of slope No. 15NE-A/C152 was recorded as "fair" and no signs of distress were observed. Seepage was observed at the soil/rock interface in the central portion of the slope (Plate 6). The situation was considered "fair", and to have been addressed by the LPM Consultant in the LPM Stage 3 Study (HAP, 2001a), which was completed in 2001 (see Section 5.5). The updated Maintenance Manual for slope No. 15NE-A/C152, subsequently completed by FHK in March 2003, presented information similar to that in the August 2002 EI Report, as well as the results of a water leakage detection survey completed by BUDA Engineers and Consultants Ltd, engaged as leakage detection survey consultants, in October 2001. The report recorded that no additional freshwater main had been constructed and no leakage was detected from the existing exposed water pipes (see Section 2.1).

5.5 LPM Stage 3 Study

Slope No. 15NE-A/C152 was included in the LPM Programme in 1998/1999. A LPM Stage 3 Study (HAP, 2001a) was completed for the slope by the LPM Consultant, HAP, under Agreement No. CE 26/98 in 2001. The slope upgrading works were carried out by Gammon Construction Ltd. under Contract No. GE/99/18 between November 2000 and March 2001.

Site-specific ground investigation, which included four trial pits (TP1 to TP4) to a depth of 3 m below ground and three surface strips (CS1 to CS3) (Figure 2) completed as part of the LPM Stage 3 Study, together with previous ground investigations within the prison complex (including eight drillholes some 70 m to the east of the slope), indicated that slope No. 15NE-A/C152 mainly comprised completely decomposed tuff (CDT), which was generally described as very stiff, slightly clayey, sandy silt with occasional angular, fine- to medium-sized gravel rock fragments. The decomposed tuff was overlain by an approximately 1.5 m thick layer of colluvium in the upper portion of the slope, comprising brown, slightly gravelly, slightly sandy silt and clay. A thin layer of fill up to 1 m in thickness was encountered at the slope crest, beyond the feature boundary.

The rock exposure present in the lower central portion of the slope (Plate 7) was described as moderately to slightly decomposed tuff. No adversely orientated joints were identified by HAP. Slight seepage was observed to be issuing from the rock joints. The rockhead behind the slope face could not be determined from the available ground investigation data, and the extent of the exposed rock assumed for the LPM Stage 3 Study is shown in Figure 4. The overall slope angle was reported as "45°" in the LPM Stage 3 Report.

No site-specific groundwater monitoring was carried out. The assumed design groundwater condition for stability assessment in the LPM Stage 3 Study report (HAP, 2001a) comprised a base groundwater table at a height corresponding to half of the overall slope height (i.e. approximately 6 m above the slope toe), which was reported as "to represented [represent] at least a 1 in 10 year rainfall event and any potential leakage from the water tank at the crest of the slope". A 0.5 m high perched water table within the colluvium layer in the upper portion of the slope was also assumed for the slope stability analyses in the study (Figure 4).

The adopted shear strength parameters for the colluvium and CDT were based on the results of laboratory testing completed as part of the site-specific ground investigation on block samples recovered from trial pits as well as from the previous ground investigation using mazier samples recovered from drillholes. These were $c' = 4$ kPa and $\phi' = 32°$, and $c' = 5$ kPa and $\phi' = 36°$ respectively. As the extent of the exposed rock outcrop could not be confirmed, a "conservative" assumption was made by the LPM Consultant that the entire slope comprised CDT for the assessment of the overall stability of the slope. The results of the stability analyses indicated that the calculated factors of safety for critical slip surfaces (Figure 5) of the slope did not meet the minimum required safety standards.

The slope upgrading measures proposed in the LPM Stage 3 Study report comprised a total of 62 soil nails (18 on the upper batter and 44 on the lower batter), which consisted of 9 m long and 25 mm in diameter steel bars installed in 100 mm diameter holes inclined at 15° to the horizontal, with up to five rows at 2 m horizontal centres and 1 m and 2 m vertical centres on a staggered grid in the upper and lower batters respectively (Figure 6). The

400 mm by 400 mm soil nail heads were to be recessed into the slope. In addition, a hydroseeded surface cover with Tensar-type erosion control mats was recommended as a replacement of the existing chunam cover (without the provision of prescriptive raking drains), as well as an upgraded surface drainage system and maintenance access stairways. The upgraded surface drainage system arrangement was essentially the same as the original arrangement, except that the 250 mm crest U-channel was replaced by a 300 mm stepped channel and the 220 mm U-channel along the intermediate berm was replaced by a 230 mm U-channel.

As-built drawings for the upgrading works to slope No. 15NE-A/C152 indicate that 16 out of the 18 soil nails on the upper batter were deleted (Figure 7). The associated construction records obtained from HAP indicate that the 16 soil nails on the upper batter were deleted because of the presence of underground utilities (i.e. fibre optic cables), which had not been identified during the Stage 3 Study, traversing the upper batter from east to west. The soil nailing pattern installed in the lower batter was in general agreement with the LPM Stage 3 Study report, comprising three rows of nails (viz. Row 2, Row 3 and Row 4 on Figure 7) with the addition of a row of six soil nails across the rock exposure in the central portion of the slope face in line with nails from Row 4. The resulting total of 52 soil nails is consistent with the Maintenance Manual prepared by HAP for slope No. 15NE-A/C152 after the completion of the LPM works (HAP, 2001b).

According to the construction records for soil nail installation, the formation of the soil nail drillholes was carried out using percussive type drills with air as the flushing medium. Details of the drilling rigs used are not available. The drilling records for the row of soil nails installed across the rock exposure indicate a uniform penetration rate of drilling (i.e. about 18 min/m) throughout the 9 m drilled length of the soil nail hole, which would suggest that no major change in material type occurred over the length of the nails and that the rock mass at the rock exposure area extended further back into the slope than that previously inferred by HAP (see Figure 4). The average drilling rate for the individual soil nails located within the rock exposure was around 18 min/m penetration, whilst for the soil nails located outside the extent of the rock exposure, the average drilling rate was around 6 min/m penetration.

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

6.1 Description of the 20 August 2005 Incident

The landslide occurred on the lower batter of slope No. 15NE-A/C152. The exact timing of the failure is not known and is estimated to be around 10:00 a.m. on 20 August 2005, based on the account of a CSD staff stationed at Ma Hang Prison, who reported the incident to the GEO on 29 August 2005. At the time of the failure, the staff quarters building at the toe of the slope was vacant. No casualties were reported as a result of the landslide.

A plan view of the landslide is presented in Figure 2. Elevation and sectional views are presented in Figure 8.

The source area of the landslide (Plates 8 and 9) was located in the central portion of the lower batter of the slope below the berm slab. The main scarp, with a maximum height of about 1 m, undermined the berm slab by about 700 mm. The scar, with dimensions of about

6 m (width) by 7 m (max.) (length) by 1.5 m (max.) (depth), extended downslope to the top of the rock exposure.

The landslide affected two soil nails from Row 2 (see Figure 7) installed in the lower batter of the slope. The two affected nails were exposed in the scar (see Figure 8). The surface of rupture daylighted at the toe of the scar and the main debris trail passed between two soil nails from Row 3 (see Figure 7) immediately below (see Figure 8), leaving these two lower nails unaffected.

Debris from the landslide, with an estimated volume of about 35 m^3 and comprising soil, vegetation and erosion control mat, was mostly deposited on the open space between the toe of slope No. 15NE-A/C152 and the adjacent staff quarters building, blocking the toe drainage provisions (Plate 10). A portion of the debris was deposited within the scar and on the slope face, obscuring the lower portion of the surface of rupture. The debris mound at slope toe was of about 0.6 m maximum depth, and spread laterally over a distance of about 18 m. The travel angle of the debris (Wong & Ho, 1996), as measured from the berm slab to the staff quarters building perpendicular to the strike of the slope face (i.e. not to the lateral extent of the debris mound), was about 38°.

6.2 Post-failure Observations

Several parties visited the site after the landslide incident. The CSD officer who first noticed the landslide scar and debris in the morning of 20 August 2005 advised that he did not inspect the berm above the landslide scar on the day of the failure. He also noted that the berm channel had not been cleared by any party prior to the commencement of urgent protection works by the Arch SD's contractor, Chee Cheung Hing & Co. Ltd. (CCH) on 29 August 2005.

CCH was instructed to carry out urgent protection works to the landslide scar by the Arch SD on 29 August 2005. A CCH staff advised that a tarpaulin was used to cover the landslide scar in the afternoon of 29 August 2005, and that no clearance works had been carried out at the crest channel of slope No. 15NE-A/C152 at that time. The CCH staff further advised that the channel at the crest of the landslide scar was clear at the time when they first arrived at the site on 29 August 2005.

A joint site inspection by the Arch SD and the Island Division of the GEO was carried out in the afternoon of 29 August 2005. The inspecting geotechnical engineer from the Island Division verbally confirmed that the berm channel was clear at the time of the inspection. The GEO inspection report indicates that no seepage could be observed from the landslide scar.

FSW inspected the landslide site on 30 August and 2 September 2005. The landslide debris was wet at the time of the inspections, and comprised brown mottled white clayey sandy SILT with some gravel-/cobble-sized rock fragments. The debris mass also contained vegetation and erosion control mats.

The main scarp of the landslide scar exposed brown clayey sandy silt (colluvium) with some rootlets (Plate 11), which was underlain by CDT in the lower portion of the scarp and

along the surface of rupture. Some fine-grained soils, comprising yellowish-brown silt, were also observed. No seepage was observed at the main scarp at the time of site inspection, and the exposed material was dry at the time of the inspections. Seepage was noted at the soil/rock interface immediately adjacent to both sides of the scar (Plate 9). No soil pipes could be observed at the main scarp. Adversely orientated joint sets, with dip/dip direction of 32°/144° (Joint Set 2) and 81°/278° (Joint Set 4), were noted on the rock exposed at slope toe (Figure 9). No obvious adverse relict joints were observed on the landslide scarp.

The flanks of the scar were generally poorly defined and bordered by the damaged erosion control mat on the adjacent portions of the slope face. No obvious signs of distress were observed on the upper batter of the slope.

Two soil nails from Row 2 within the lower batter (see Figure 7), with heads measuring about 400 mm and 500 mm square respectively and located about 3 m below the intermediate berm, were situated within the landslide scar (Figure 8, Plates 12 and 13). The exposed portions of these two soil nails were bent downward at about 30° to the horizontal, at approximately 0.5 m behind the slope face (Plate 14). The cement grout underneath the nail bars was found to have spalled and hence the nail reinforcement was exposed.

It did not appear that nails from Row 3 (see Figure 7), which were situated lower on the slope face immediately above the soil/rock interface, were affected by the failure, as the debris trail and the daylight of the surface of rupture passed between the locations of two soil nails in Row 3 (see Figure 8). A third soil nail head was observed within the debris trail on the rock outcrop below the scar, approximately 2.5 m above the slope toe (Plate 15). This nail head, which was one of the six additional soil nails installed across the rock outcrop (see Section 5.5), was noted to be intact and unaffected by the failure.

The remaining portions of the lower batter adjacent to the landslide scar were observed to be in a satisfactory maintenance condition and the three rows of soil nails as shown in the as-built drawings were identified in these areas (Figure 7). The slope face angle was measured at a number of locations and was found to lie between 35° and 56°, but typically steeper than 45°. This is broadly consistent with the typical range of 45° to 55° previously reported by B&P (Section 5.1) and the SIRST Study (Section 5.2).

The 230 mm surface U-channel along the slope berm immediately above the landslide scar was clear at the time of the inspections and was in fair condition (Plate 16). No signs of overland flow were observed on the slope face above this channel.

The mains-fed concrete water tank located at the slope crest was found to have an overflow pipe located about 2 m above ground level extending over the slope crest (Plate 17). A minor flow from the pipe was observed at the time of the inspections. The ground surrounding the tank, and extending to the slope crest channel, is concrete paved.

6.3 Review of LPM Stage 3 Study Laboratory Test Results

The laboratory test results presented in the LPM Stage 3 Study report were reviewed by FSW as part of the present review, notably the particle size distribution and triaxial tests results. The results are summarized in Table 1.

The available particle size distribution plots for the CDT indicate a relatively well-graded material. The majority of the CDT samples exhibited a dilative behaviour during shearing, with the exception of one sample (viz. sample from 3 m depth at trial pit No. TP11, which is some 100 m away from the August 2005 landslide) that showed contractive behaviour (see Table 1).

6.4 Urgent Repair Works

On 29 August 2005, GEO advised Arch SD to carry out urgent repair works to slope No. 15NE-A/C152, which comprised the trimming of the landslide scar and construction of a no-fines concrete buttress to match with the adjacent slope profile. The works were completed by the end of September 2005.

7. RAINFALL RECORDS

Rainfall data were obtained from GEO automatic raingauge No. H15, which is the nearest raingauge to the landslide site and located at St Stephen's College, Tung Tau Wan Road, about 1.1 km to the south-east of the landslide (Figure 1). The raingauge records and transmits rainfall data at 5-minute intervals to the Hong Kong Observatory (HKO) and the GEO.

According to the witness account, the landslide was first observed at about 10:00 a.m. on 20 August 2005. For the purpose of rainfall analysis, the time of the landslide was assumed to be at 10:00 a.m. An Amber Rainstorm Warning was issued at 8:35 a.m. on 20 August 2005 and was still in force at the time of the August 2005 incident.

The daily rainfall recorded by raingauge No. H15 over the month preceding the landslide, together with the hourly rainfall readings for the period between 10:00 a.m. on 18 August 2005 and 10:00 p.m. on 20 August 2005, are presented in Figure 10. The maximum 24-hour and 12-hour rolling rainfall before the landslide was 168.5 mm and 104.5 mm respectively.

Table 2 presents the estimated return periods for the maximum rolling rainfall for various durations recorded by raingauge No. H15 with reference to historical rainfall data at the HKO in Tsim Sha Tsui (Lam & Leung, 1994). The results show that the 31-day rolling rainfall of 745.5 mm before the landslide was the most severe, with a corresponding return period of about 3 years. The results also show that the 7-day rolling rainfall of 408.5 mm had a corresponding return period of about 3 years. For rainfall durations of less than 2 hours, the corresponding return periods were less than 2 years.

The return periods were also assessed based on the statistical parameters derived by Evans & Yu (2001) for rainfall data recorded by local raingauge No. H15 between 1984 and 1997 (Table 2). The estimated return period of the 7-day rolling rainfall was 3 years. It is noted that the estimated return periods of the August 2005 rainstorm based on rainfall data at the local raingauge are similar to those estimated by the historical rainfall data at the HKO.

The maximum rolling rainfall for the rainstorm on 20 August 2005 has been compared with the past major rainstorms between the mid-1980's and 2005 recorded by raingauge No. H15, which came into operation in August 1979 (Figure 11). The maximum rolling rainfall for the rainstorm on 20 August 2005 was not the most severe for any duration when compared to the full data set of rainfall records.

The maximum rolling rainfall for the rainstorm on 20 August 2005 has also been compared with the past major rainstorms since the LPM slope upgrading works were completed in March 2001 (Figure 12). This indicates that the maximum rolling rainfall for the rainstorm on 20 August 2005 was the highest for the 7-day and 31-day durations, but was not particularly severe for short durations.

8. DISCUSSION

The timing of the 20 August 2005 landslide on slope No. 15NE-A/C152 suggests that the failure was probably rain-induced. Although the landslide was not a major failure, the incident was of significance in that it occurred on an engineered slope about four years after completion of upgrading works using robust measures (i.e. soil nails), during a rainfall not particularly severe (return period of about 3 years).

There were no reported failures on the approximately 45° to 55° steep soil cut prior to the LPM works in 2001, which was shotcreted since 1991. The hard surface cover was replaced with a vegetated cover under the LPM works, and soil nails were installed with a pattern that is consistent with the prevailing practice at the time (viz. 400 mm square recessed soil nail heads at not more than 2 m centre spacing).

The landslide comprised an 'internal' failure of the soil-nailed system, with the detachment occurring within the active zone in CDT. The soil nails in the vicinity were evidently called into action and two of them were bent as a result of the instability. The lower end of the basal slip plane of the sliding failure was confined to the soil-rock interface. The detachment was not particularly mobile. It is not certain whether the soil nails, although they were unable to prevent the local failure, contributed to the ductility of the failure mode.

There is as yet no satisfactory method of analytical design against active zone failures in soil-nailed slopes. Steep soil-nailed slopes with a vegetated cover are liable to be susceptible to shallow failures in the active zone, particularly given relatively small size nail heads, as reflected by the failure being triggered by a rainstorm that was not particularly severe. However, it is noteworthy that the failure volume was of a moderate scale (35 m^3) and that two of the nails were notably deformed.

The local failure occurred near the top of the lower slope batter, at a section through the location of a locally extensive moderately decomposed rock mass that measures 18 m across and 4 m high (see Figure 8). The ground investigation undertaken under the LPM Stage 3 Study comprised trial pits and surface strips, with no boreholes, and no groundwater monitoring was undertaken. In the LPM design, this rock mass was judged to be a "boulder". In the stability analysis of this section, the LPM design ground model assumed a soil profile, ignoring the large "boulder". The corresponding groundwater condition adopted in the LPM Study was generally commensurate with the above assumed ground model (see Figure 5).

The observed moderate size local failure, which is not common in the performance history of vegetated soil-nailed slopes in Hong Kong, could be a result of either the presence of weak ground mass of low shear strength, or the transient build-up of high local groundwater pressure, or both. Field observations did not reveal any relict joints or weak geological features on the landslide scarp. Furthermore, a detailed review of the available laboratory triaxial test results revealed that the majority of the CDT samples exhibited a dilative behaviour during shearing, with the exception of one sample (which was obtained at some 100 m away from the August 2005 landslide) that showed contractive behaviour (see Table 1). The laboratory test results, together with the geological descriptions by the LPM consultants and the field observations by FSW, suggest that the CDT at this site is 'typical', i.e. with no obvious geological weaknesses and no unusually low mass strength. As such, it is probable that a locally high transient groundwater regime contributed to the 2005 failure.

Past inspections during RMI and EI, and by the LPM consultants revealed persistent seepage from the soil/rock interface and from rock joints in the moderately decomposed rock mass below the failure. This suggests the possibility of a preferential flowpath and concentrated subsurface flow at this section, and the local hydrogeological setting may not be fully reflected by the surface topography, which has a relatively small catchment. Furthermore, the extensive moderately decomposed rock mass, which was judged to be a "boulder" by the LPM consultant, may actually be rock outcrop. The relative drilling rates of the nails installed through the moderately decomposed rock mass as well as in the overlying saprolite tend to support this postulation (see Section 5.5). If this were the case, then the site setting in this locality could be conducive to the build-up of transient seepage pressure or a local perched water table in the soil mass above, where the failure occurred. The shallow gradient of the upper slope batter (about 30°) directly above the location of the landslide is also favourable to enhance direct infiltration, thereby contributing to development of groundwater pressure in the soil mass.

The replacement of the hard surface cover with a vegetated cover, with no prescriptive raking drains provided, represents an adverse change in the hydrogeological setting. The occurrence of the landslide within a fairly short time after completion of the slope upgrading works suggests that the above probably played a contributory role in the failure by adversely changing the infiltration characteristics of the slope. More generous provision of subsurface drainage (e.g. prescriptive raking drains) is generally called for where slopes are subject to adverse infiltration. One should, however, bear in mind that prescriptive raking drains may not be always effective to avoid possible adverse build-up of groundwater pressure, especially in a relatively thin surface mantle (which is liable to rapid and large build-up of the pore water pressure ratio, r_u) or where local preferential flowpaths are not intercepted by the raking drains.

9. REFERENCES

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

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.

Halcrow Asia Partnership Ltd. (2001a). Feature No. 15NE-A/C152, North of Staff Quarters, Ma Hang Prison, Stanley (Stage 3 Study Report No. S3R 107/99). Halcrow Asia Partnership Ltd, Hong Kong.

Halcrow Asia Partnership Ltd (2001b). Feature No. 15NE-A/C152, North of Staff Quarters, Ma Hang Prison, Stanley (Maintenance Manual No. MM 51/2001). Halcrow Asia Partnership Ltd, Hong Kong.

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

LIST OF TABLES

Table 1 - Summary of LPM Stage 3 Study Laboratory Test Results (Sheet 1 of 2)

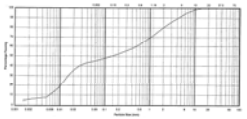
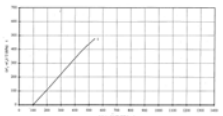
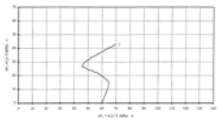
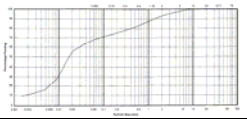
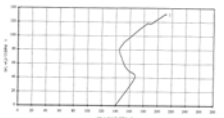
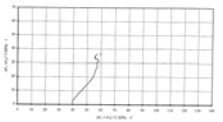
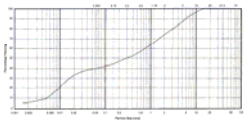
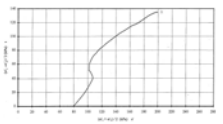
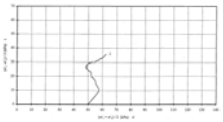
Trial Pit No.	Sample Depth (m)	Material	Testing Results										
			Particle Size Distribution					Triaxial Compression Test					
			Clay (%)	Silt (%)	Sand (%)	Gravel (%)	PSD Curve	Type of Test	Dry Density (Mg/m^3) (before test)	Confining Pressure (kPa)	Pore Pressure Coefficient at Failure	s' – t' plot	Behaviour upon Shearing
TP2	1.5	CDT	-				-	CUS	1.39	30	0.23		Dilative
	2.0		5	40	35	1.43		CUS	1.43	100	0.04		Dilative
TP3	1.5	CDT	-				-	CUS	1.44	60	0.40		Dilative
	3.0		11	57	25	1.41		CUS	1.41	140	0.23		Dilative
TP4	1.5	CDT	-				-	CUS	1.30	40	0.26		Dilative
	3.0		6	34	34	1.43		CUS	1.43	80	0.06		Dilative
TP6	1.5	CDT	-				-	CUS	1.60	50	0.32		Dilative

Table of Contents
Table of Contents
Table of Contents

Table 1 - Summary of LPM Stage 3 Study Laboratory Test Results (Sheet 2 of 2)

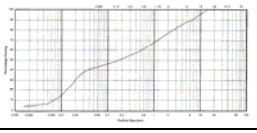
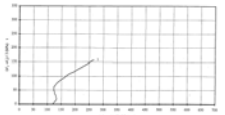
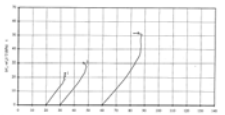
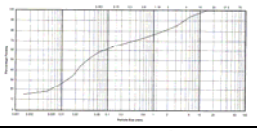
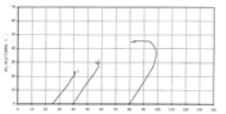
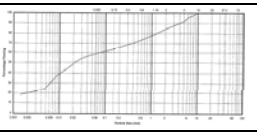
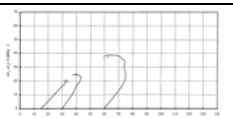
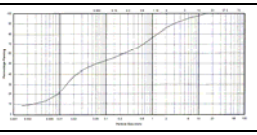
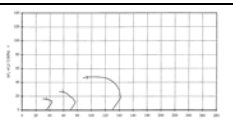
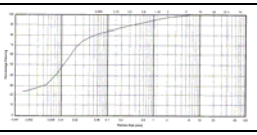
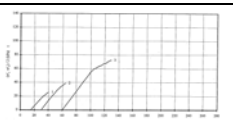
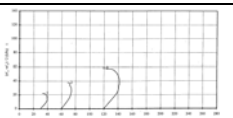
Trial Pit No.	Sample Depth (m)	Material	Testing Results										
			Particle Size Distribution					Triaxial Compression Test					
			Clay (%)	Silt (%)	Sand (%)	Gravel (%)	PSD Curve	Type of Test	Dry Density (Mg/m^3) (before test)	Confining Pressure (kPa)	Pore Pressure Coefficient at Failure	s' – t' plot	Remarks
TP6	3.0	CDT	4	40	33	23		CUS	1.52	120	0.04		Dilative
TP7	1.5	Fill	-				-	CUM	1.55	20	0.22		Dilative
									1.57	30	0.23		
									1.59	60	0.30		
TP8	3	Colluvium	16	42	24	18		CUM	1.64	25	0.17		Dilative
									1.66	40	0.25		
									1.68	80	0.49		
TP11	1.5	Colluvium	20	39	25	16		CUM	1.38	15	0.07		Dilative
									1.41	30	0.35		
									1.42	60	0.49		
	3	CDT	9	41	36	14		CUM	1.27	35	0.65		Contractive
									1.32	70	0.80		
									1.35	130	0.94		
TP12	1.5	Residual Soil	26	56	16	2		CUM	1.56	15	0.02		Dilative
									1.61	30	0.07		
									1.61	60	0.09		
	3	CDT	-				-	CUM	1.40	30	0.43		Dilative
									1.45	60	0.39		
									1.47	120	0.51		

Table 2 - Maximum Rolling Rainfall at GEO Raingauge No. H15 for Selected Durations Preceding the Landslide on 20 August 2005 and the Estimated Return Periods

Duration	Maximum Rolling Rainfall (mm)	End of Period (See Notes 3)	Estimated Return Period (Years) (See Notes 2)	
			Lam & Leung (1994)	Evans & Yu (2001)
5 Minutes	7.0	01:30 hours on 19 August 2005	< 2	< 2
15 Minutes	17.5	01:30 hours on 19 August 2005	< 2	< 2
1 Hour	26.5	02:00 hours on 19 August 2005	< 2	< 2
2 Hours	32.5	03:05 hours on 19 August 2005	< 2	< 2
4 Hours	43.0	22:50 hours on 19 August 2005	< 2	< 2
12 Hours	104.5	05:45 hours on 20 August 2005	< 2	< 2
24 Hours	168.5	08:20 hours on 20 August 2005	< 2	< 2
48 Hours	241.0	10:00 hours on 20 August 2005	< 2	< 2
4 Days	301.5	10:00 hours on 20 August 2005	< 2	< 2
7 Days	408.5	10:00 hours on 20 August 2005	3	3
15 Days	491.5	10:00 hours on 20 August 2005	2	< 2
31 Days	745.5	10:00 hours on 20 August 2005	3	2

Notes:

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

(2) Return periods were derived from Table 3 of Lam & Leung (1994) and Evans & Yu (2001).

(3) The landslide is assumed to have occurred at 10:00 hours on 20 August 2005 for the purpose of rainfall analysis.

(4) The nearest GEO raingauge to the landslide site is raingauge No. H15, which is located about 1,100 m to the south of the 20 August 2006 landslide site and is operational since August 1979.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

LIST OF FIGURES

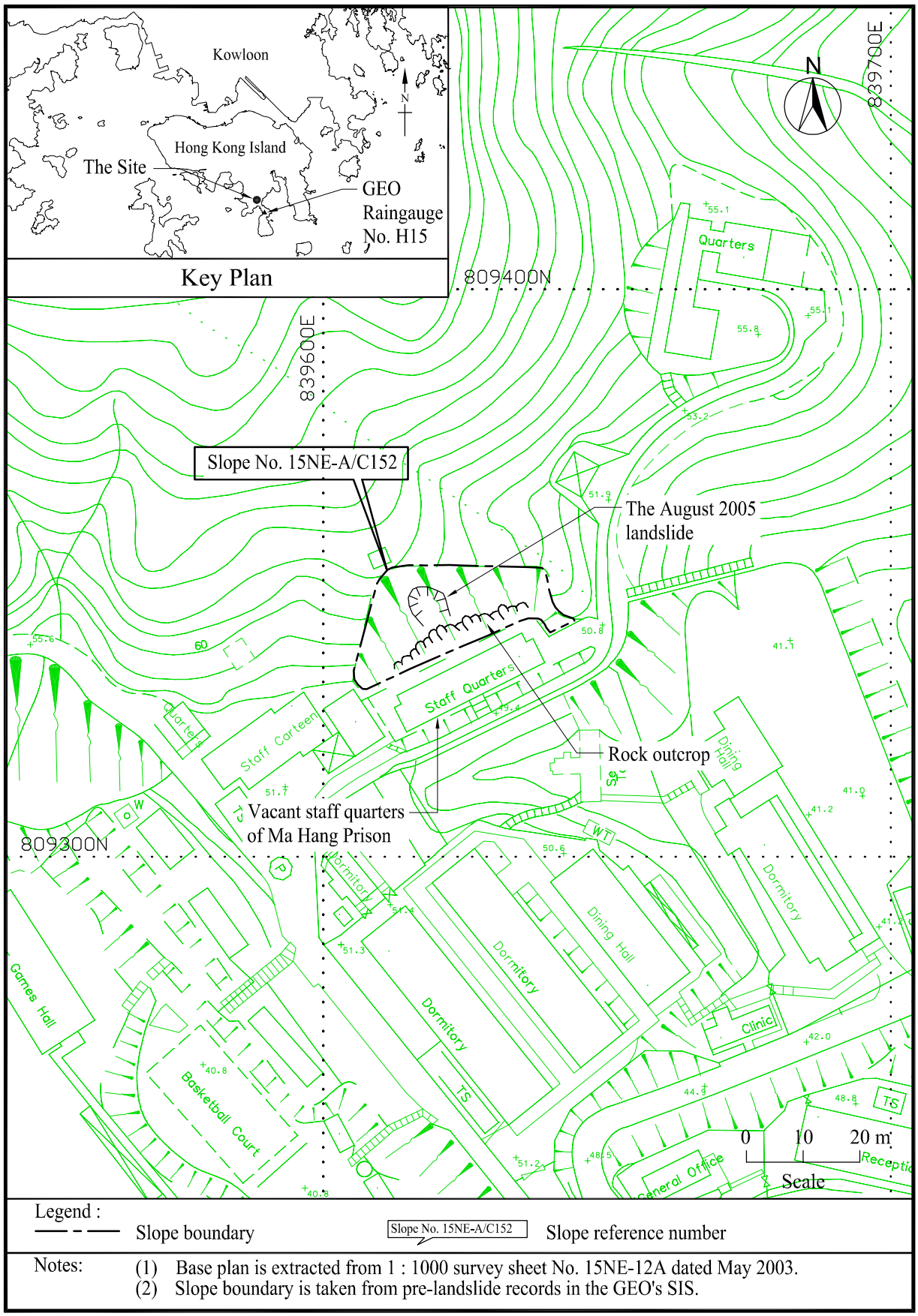


Figure 1 - Site Location Plan

Table of Contents
Table of Contents
Table of Contents
Table of Contents

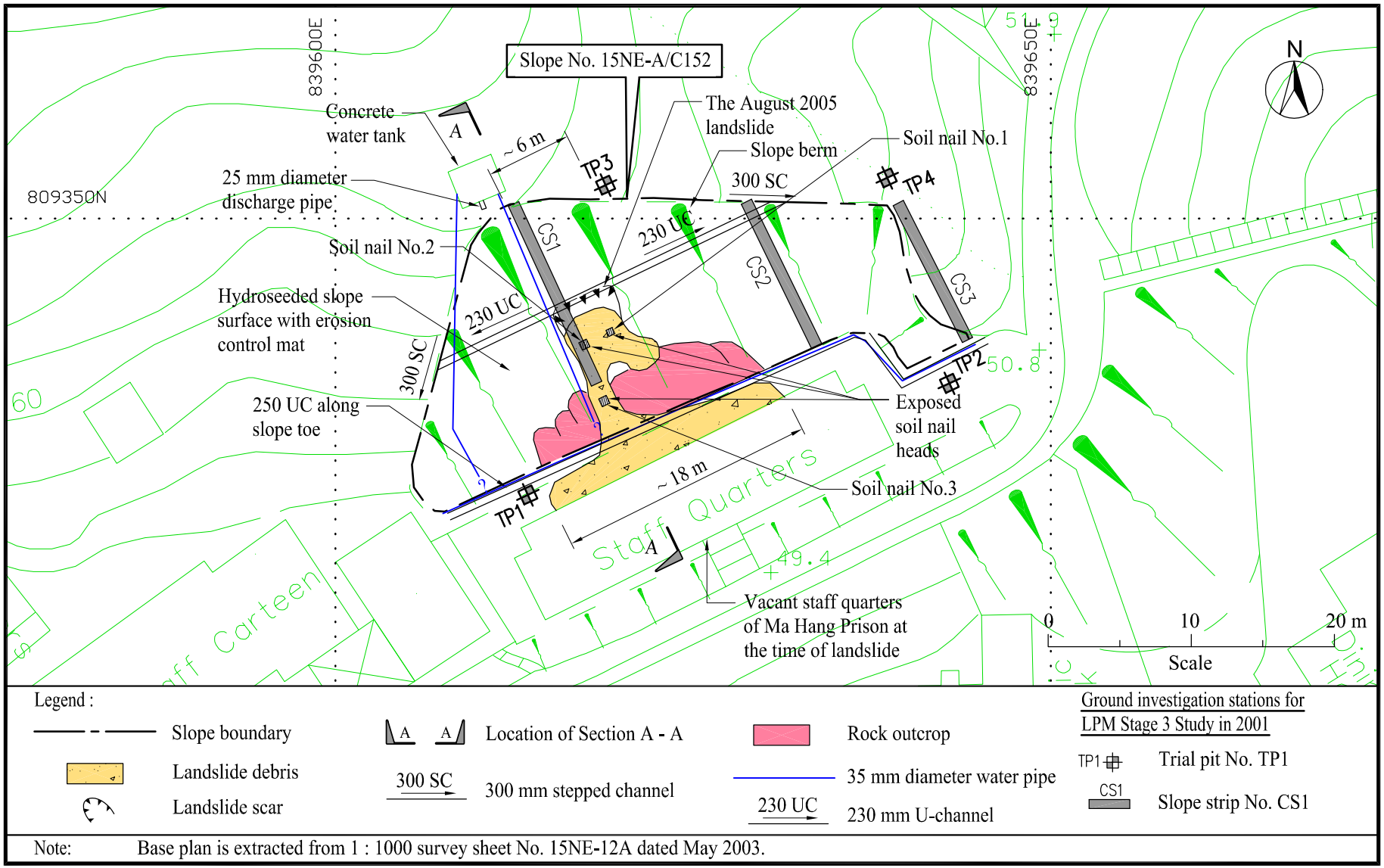


Figure 2 - Site Plan

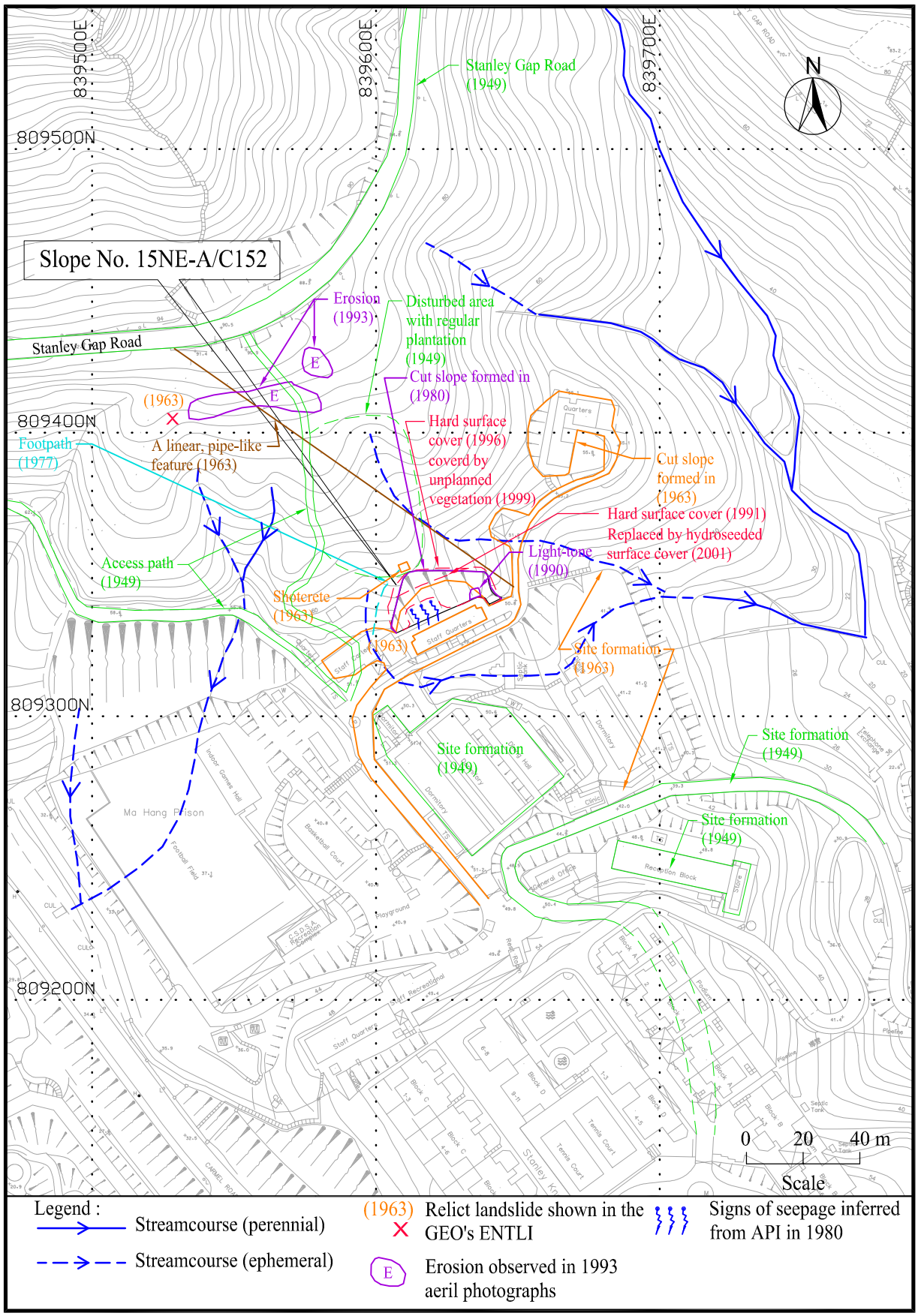


Figure 3 - Site Development Plan

Table of Contents
Table of Contents
Table of Contents
Table of Contents

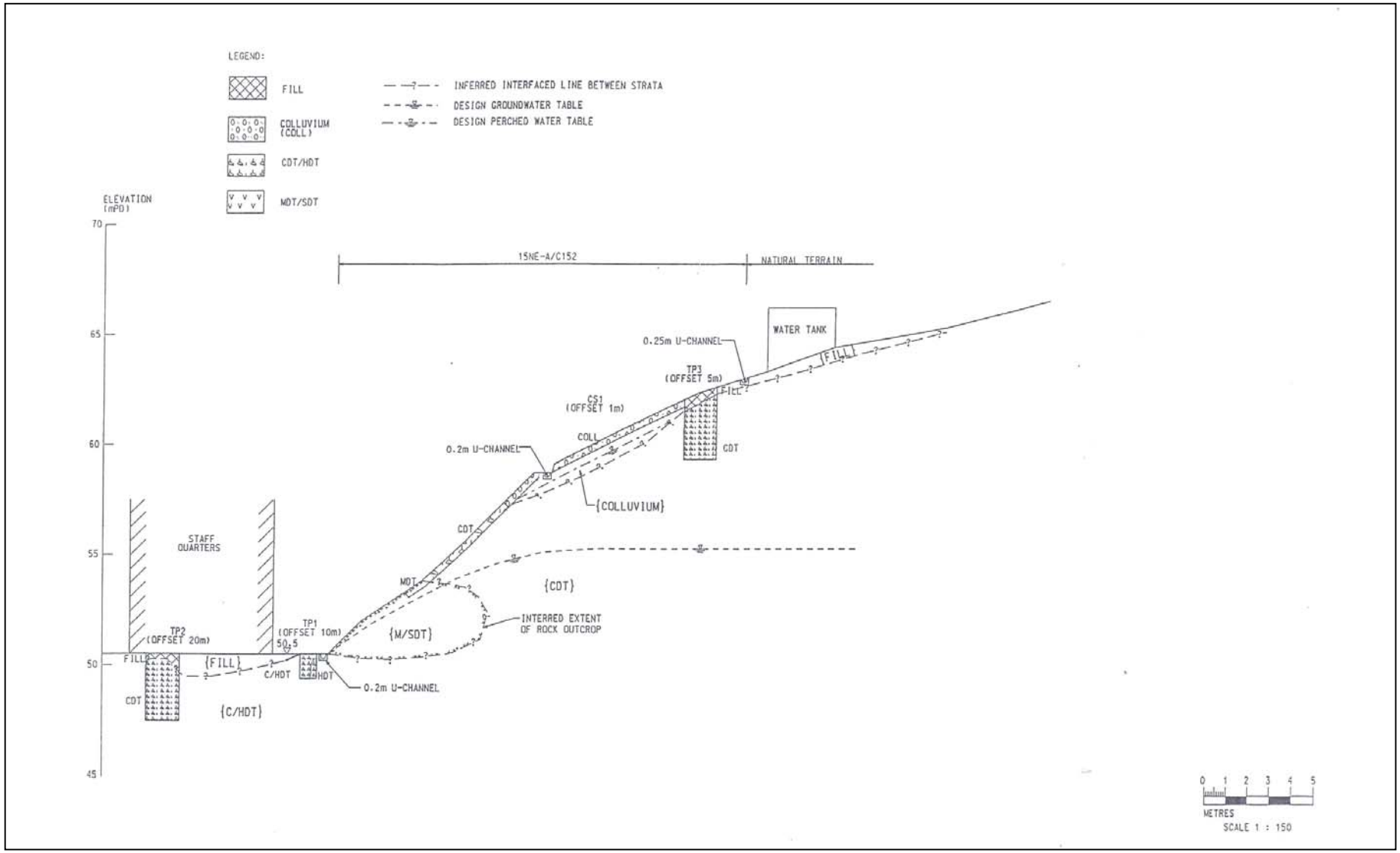


Figure 4 - Geological Section 1-1 through Slope No. 15NE-A/C152
(Extracted from Figure 4 of LPM Stage 3 Study Report No. S3R 107/99)

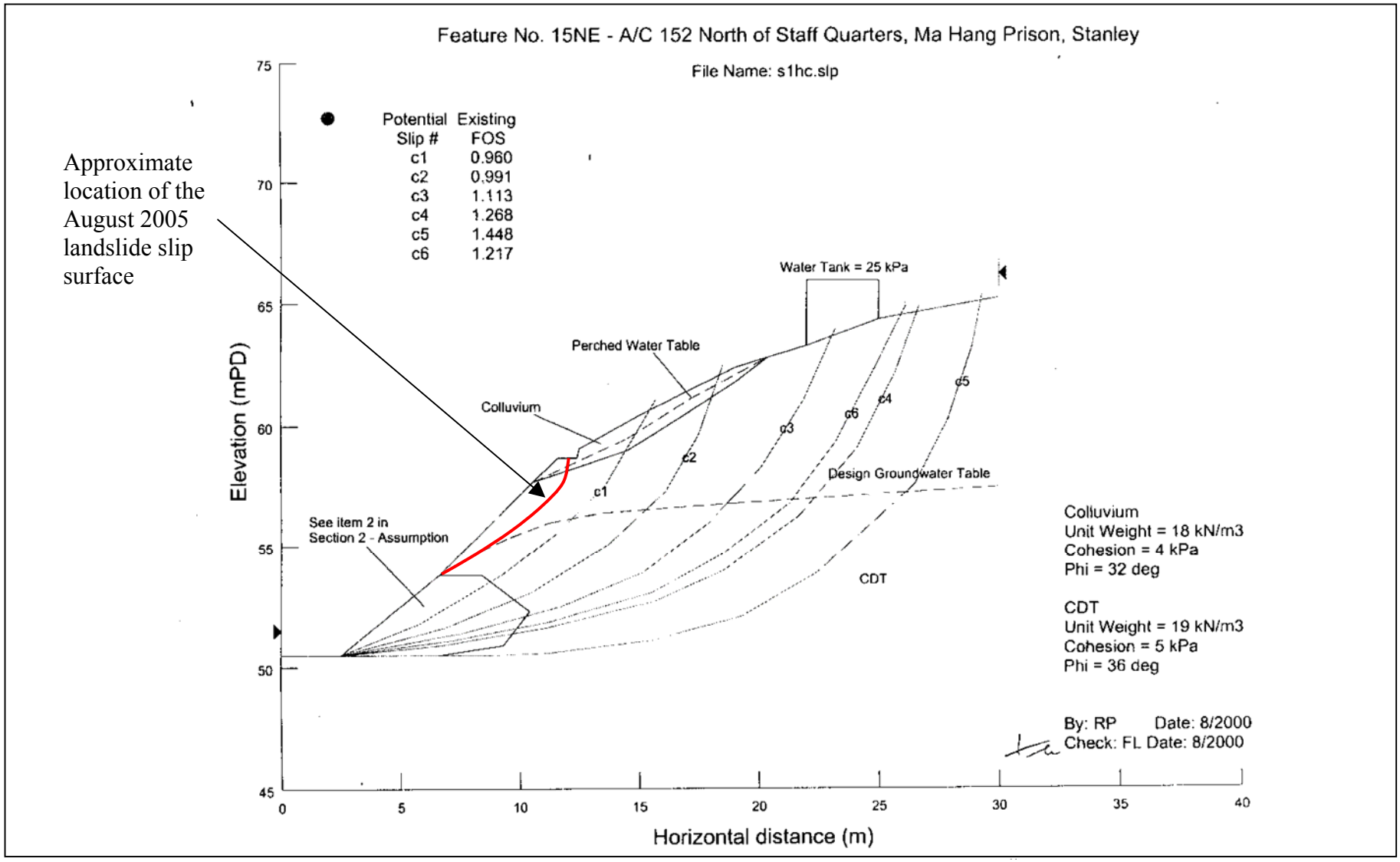


Figure 5 - Results of Stability Analyses for Critical Slip Surfaces in Section 1-1
(Extracted from Appendix D (Figure A4) of LPM Stage 3 Study Report No. S3R 107/99)

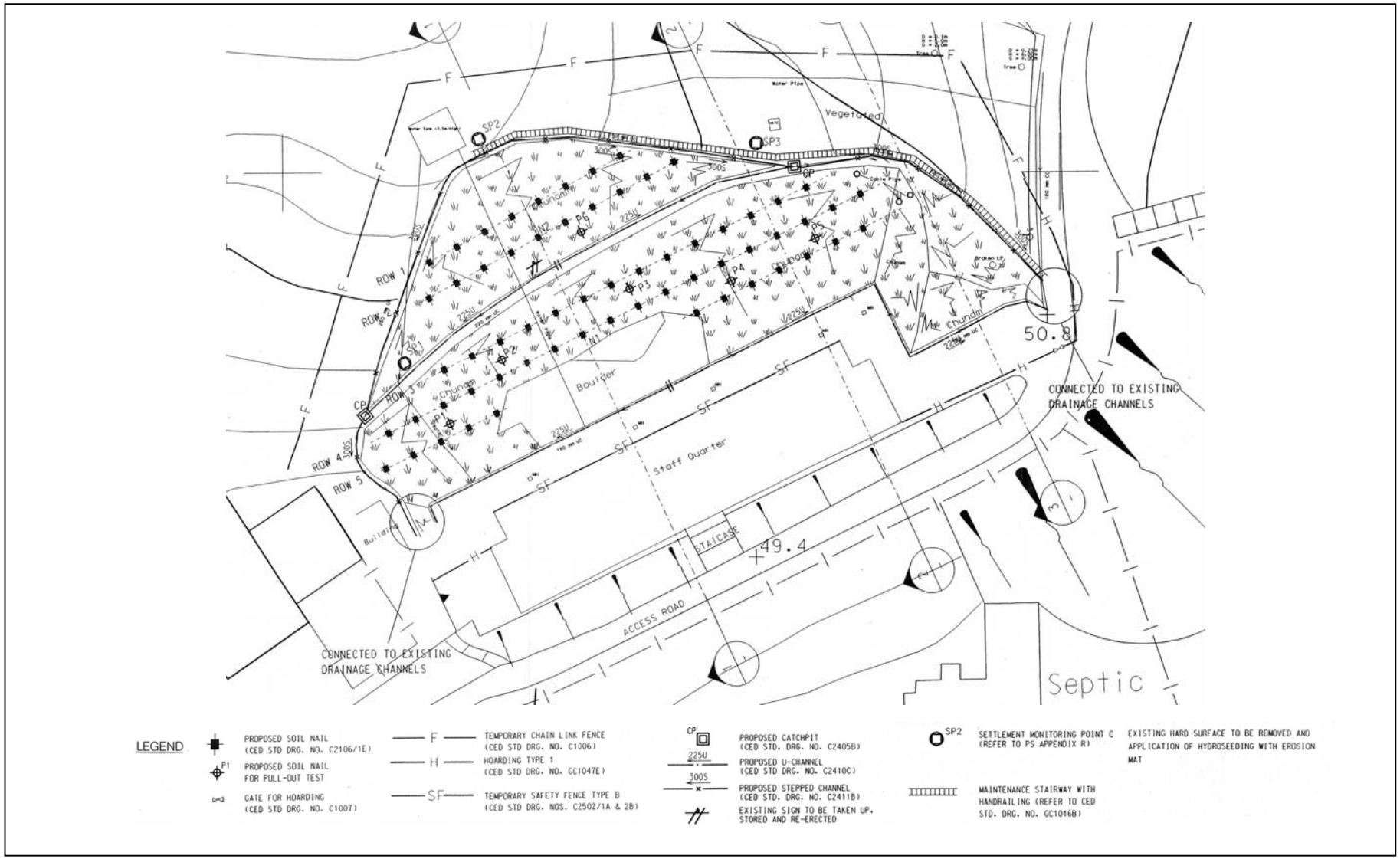


Figure 6 - Proposed Arrangement of Soil Nails (Extracted from Drawing No. LPM9918/1622 (Version 0) of LPM Stage 3 Study Report No. S3R 107/99)

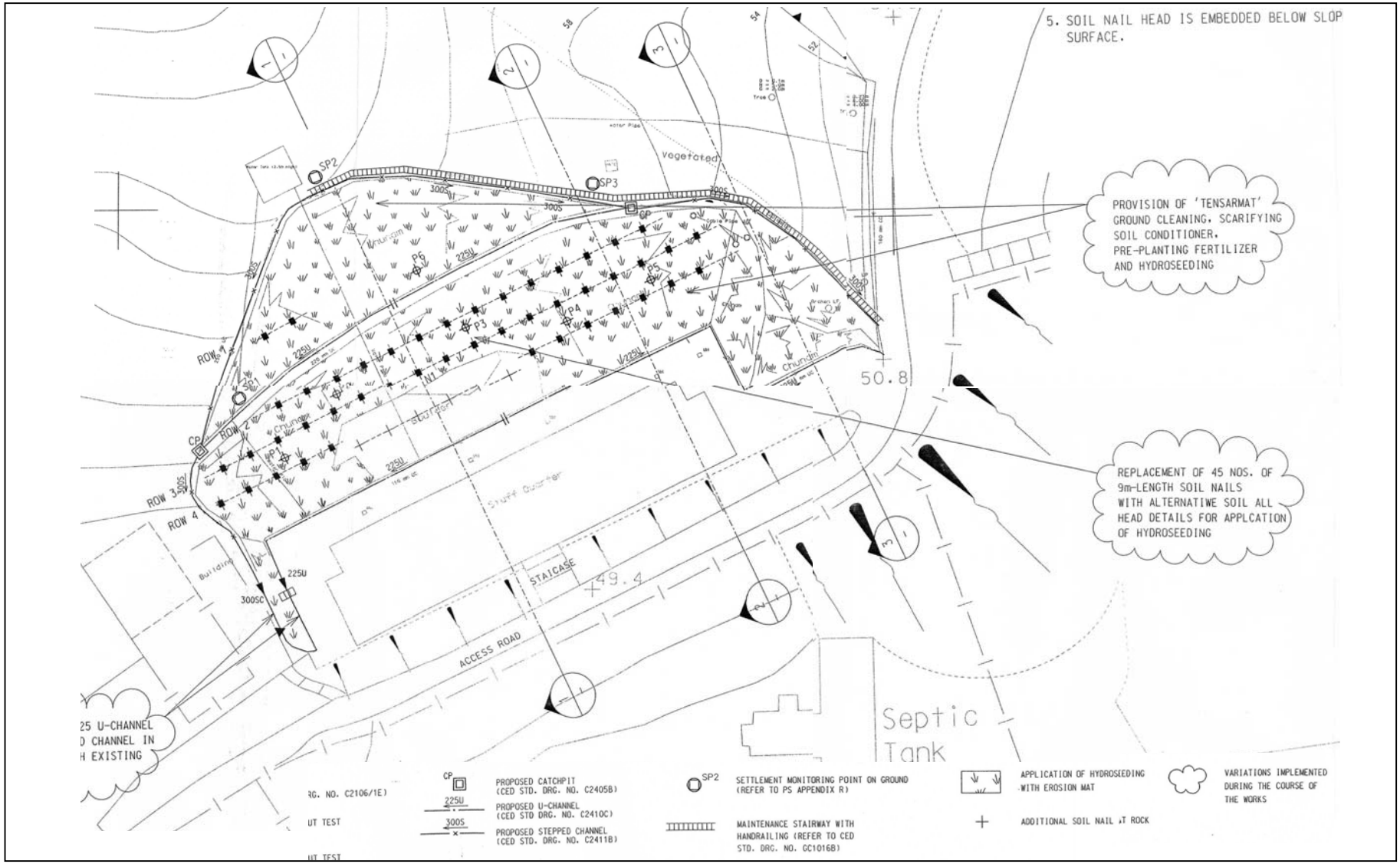


Figure 7 - As-built Arrangement of Soil Nails (Extracted from Drawing No. LPM9918/1622 (Revision A) of LPM Stage 3 Study Report No. S3R 107/99)

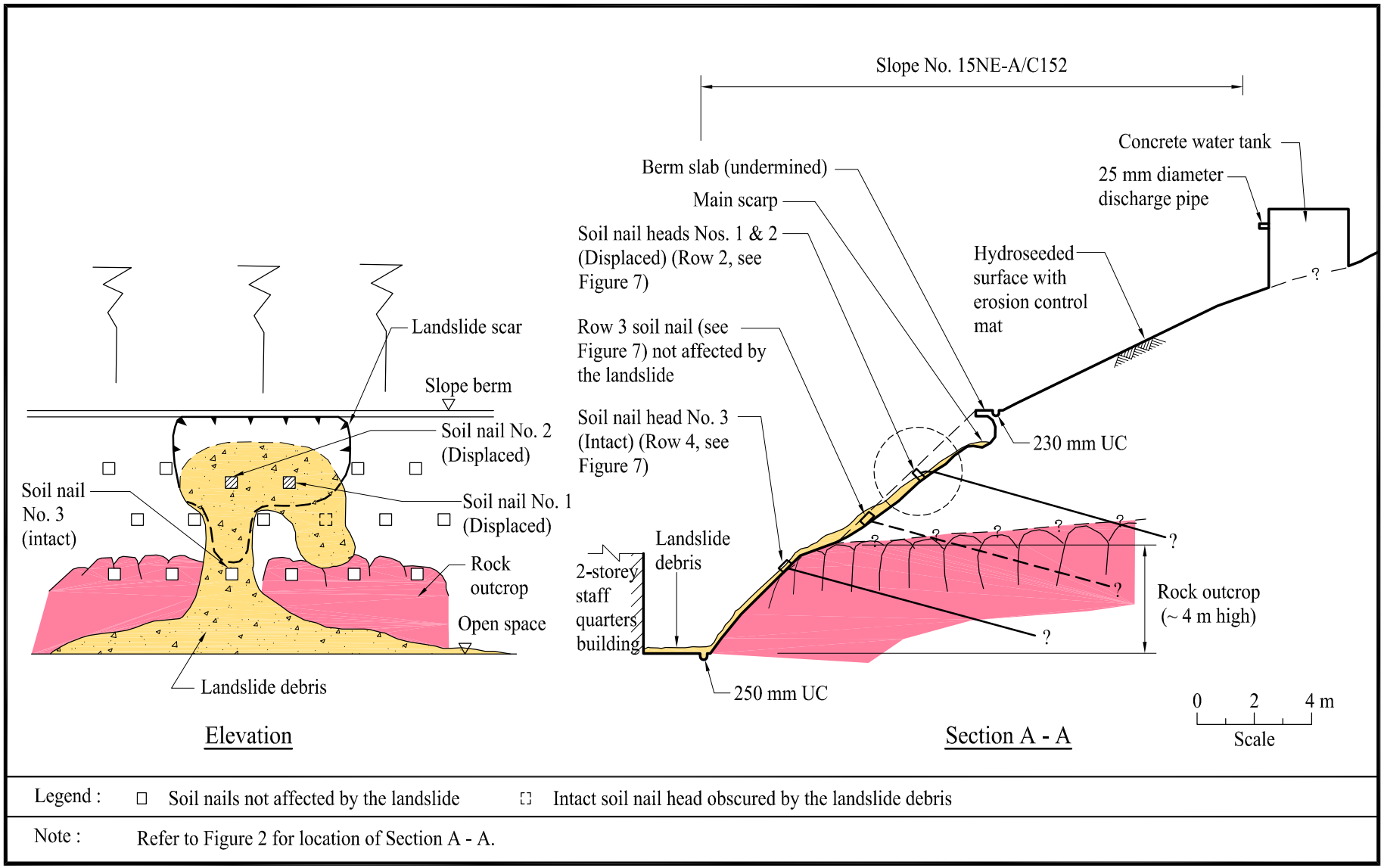
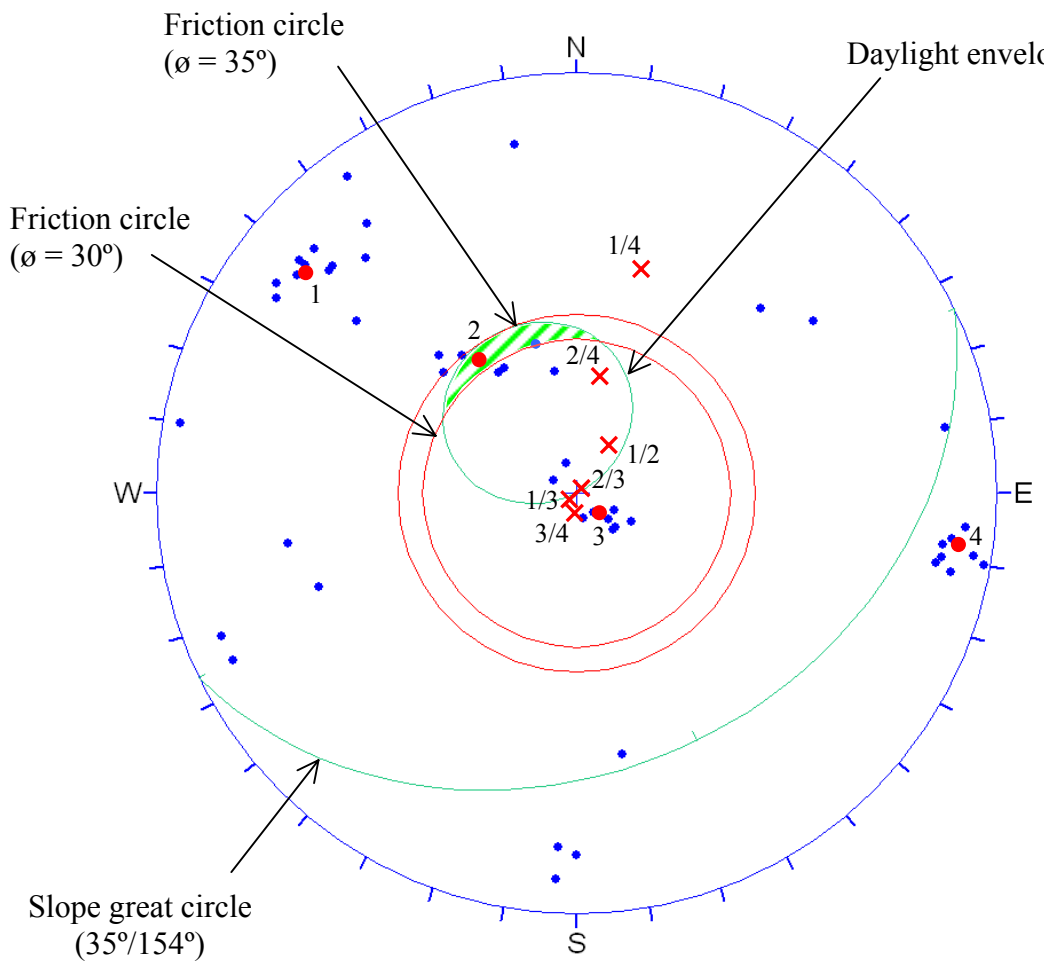


Figure 8 - Elevation of and Cross-section A - A through the 20 August 2005 Landslide Scar



LEGEND

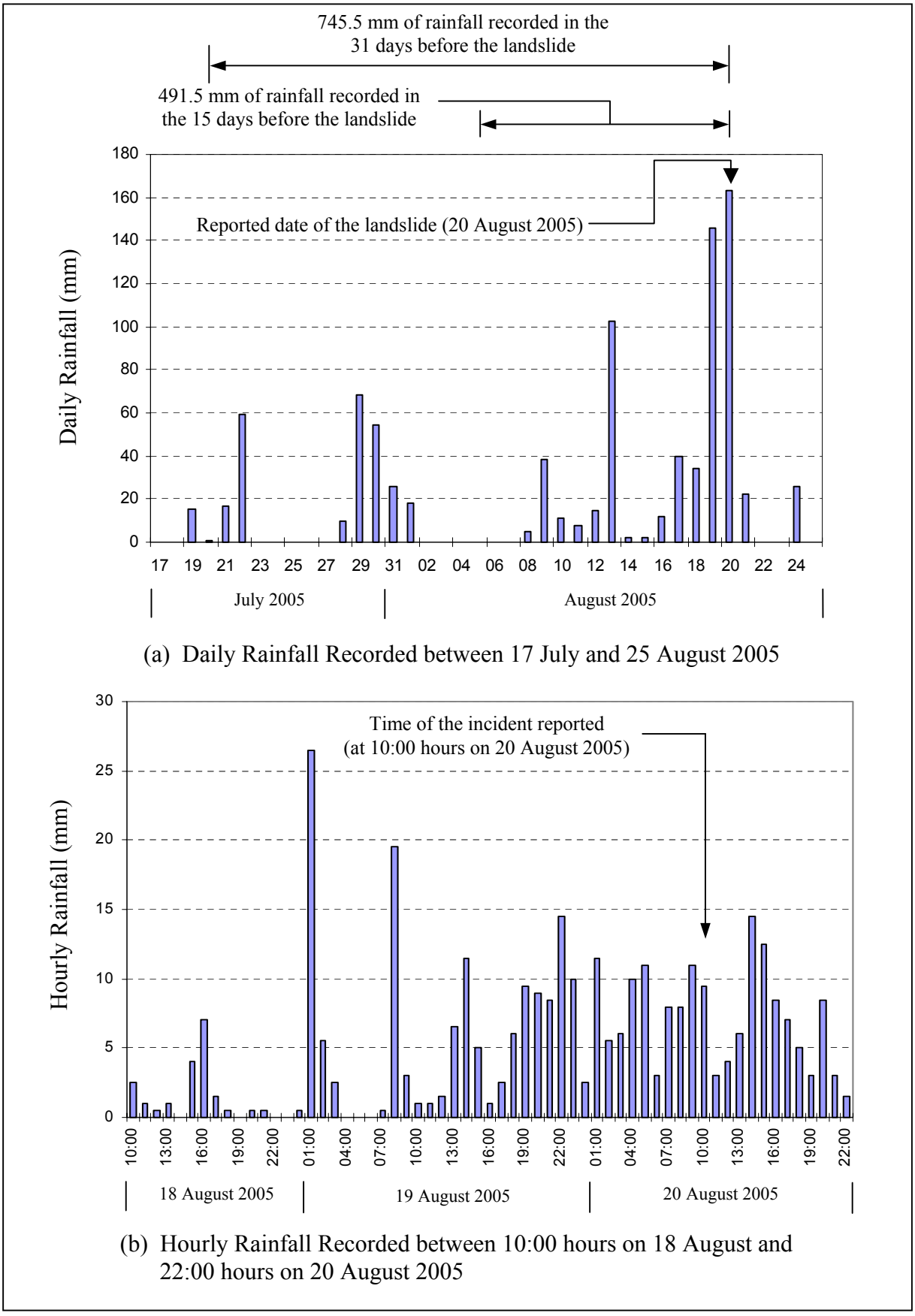
- Pole of joint set (plane 1)
- Pole of intersection of joint sets 1 and 2
- Pole of individual joint plane from discontinuity survey
- Planar/wedge sliding is kinematically feasible along some joints/line of intersection

Joint set	Dip (º)	Dip direction (º)
1	71	129
2	32	144
3	6	314
4	81	278

Note: Joint sets interpreted from pole data based on contouring of pole concentrations using Fisher Concentrations Method.

Figure 9 - Stereographic Projection of Discontinuity Survey Data

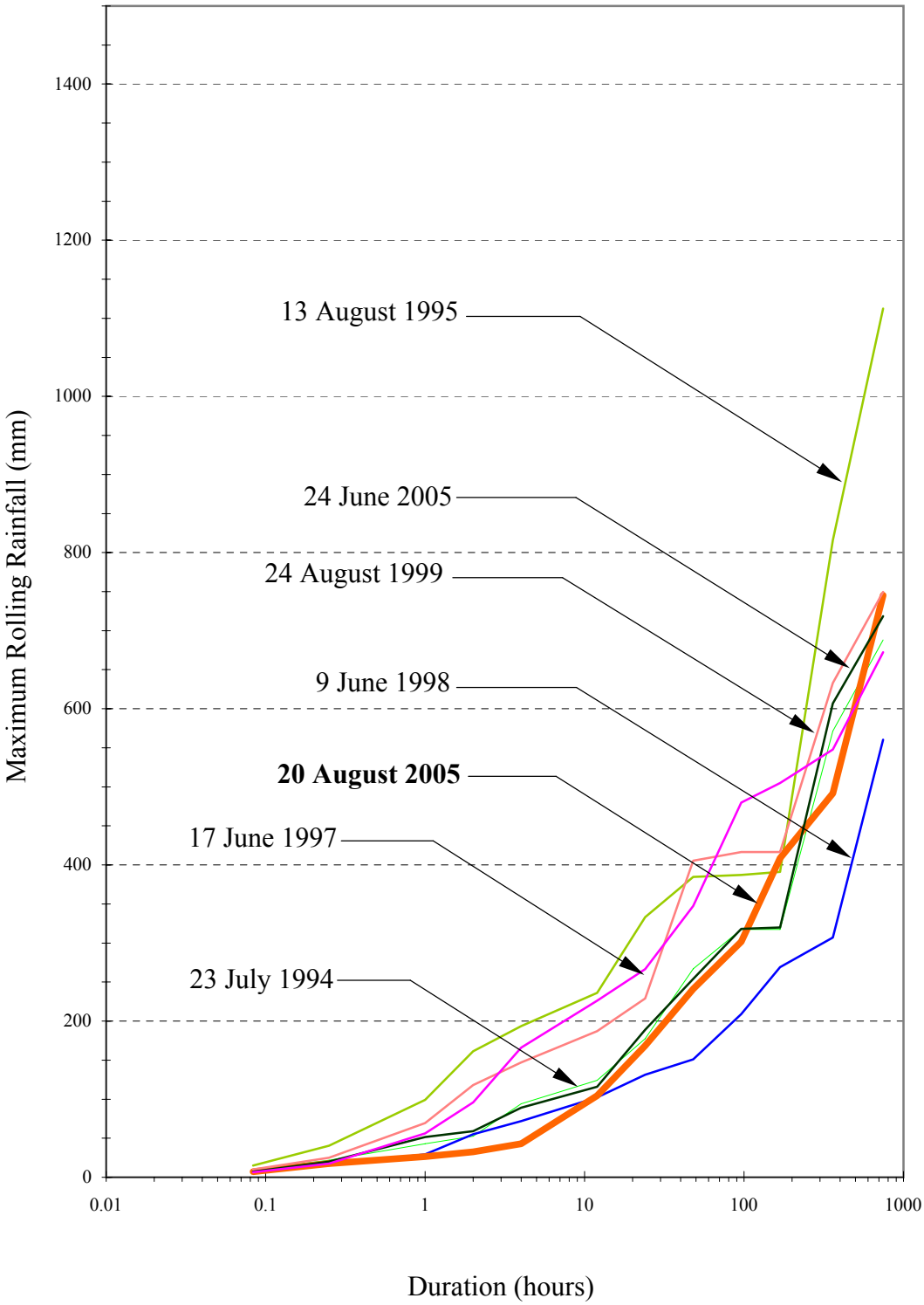
Table of Contents
Table of Contents
Table of Contents
Table of Contents



(a) Daily Rainfall Recorded between 17 July and 25 August 2005

(b) Hourly Rainfall Recorded between 10:00 hours on 18 August and 22:00 hours on 20 August 2005

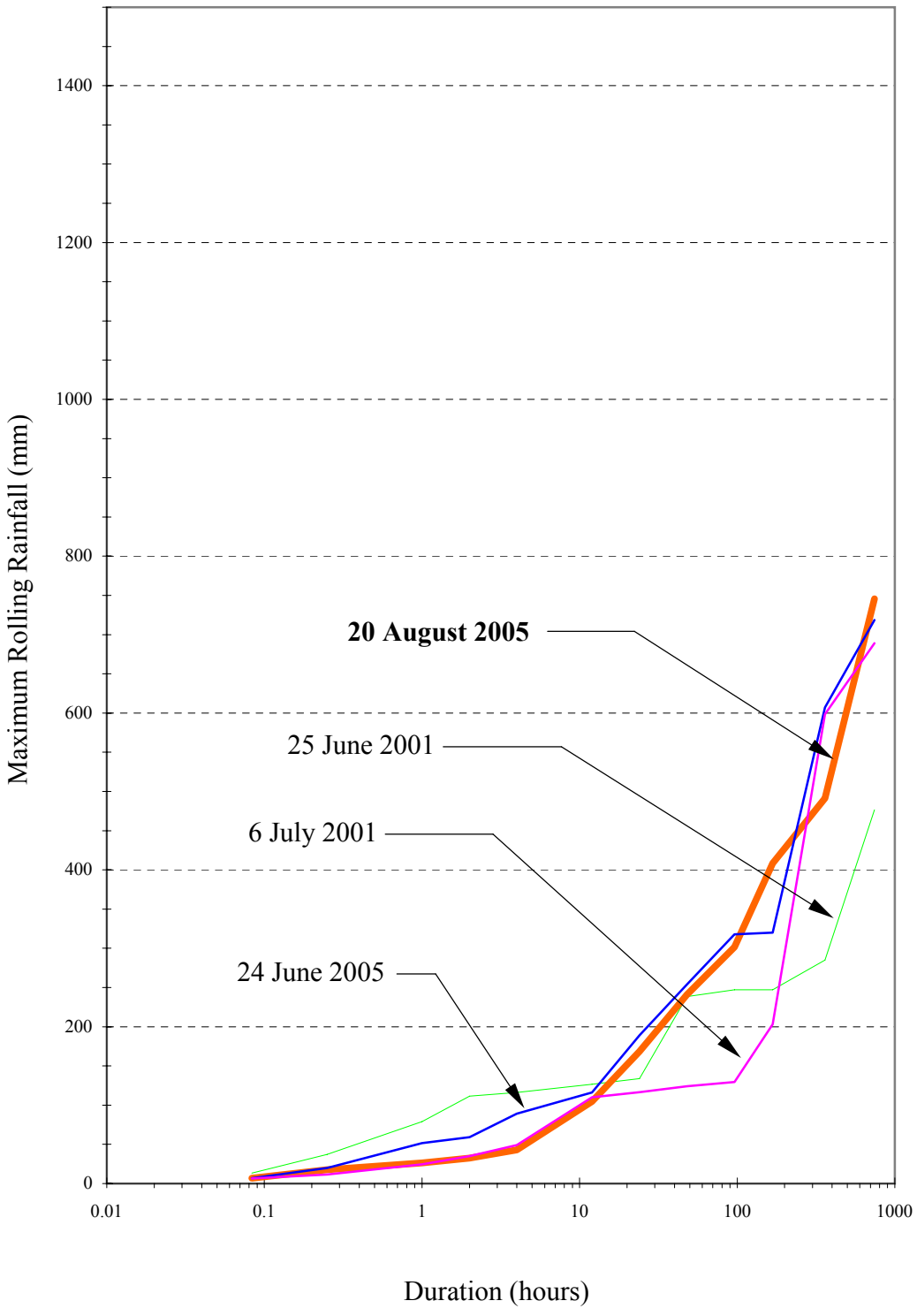
Figure 10 - Rainfall Recorded at GEO Raingauge No. H15 Preceding the 20 August 2005 Landslide



Note : Rainfall data are 5-minute statistics from GEO raingauge No. H15

Figure 11 - Maximum Rolling Rainfall Preceding the 20 August 2005 Landslide and Selected Previous Major Rainstorms Recorded at GEO Raingauge No. H15

Table of Contents
Table of Contents
Table of Contents
Table of Contents



Note : Rainfall data are 5-minute statistics from GEO raingauge No. H15

Figure 12 - Maximum Rolling Rainfall Preceding the 20 August 2005 Landslide and Selected Previous Major Rainstorms Recorded at GEO Raingauge No. H15 since Completion of LPM Works in March 2001

Table of Contents
Table of Contents
Table of Contents
Table of Contents

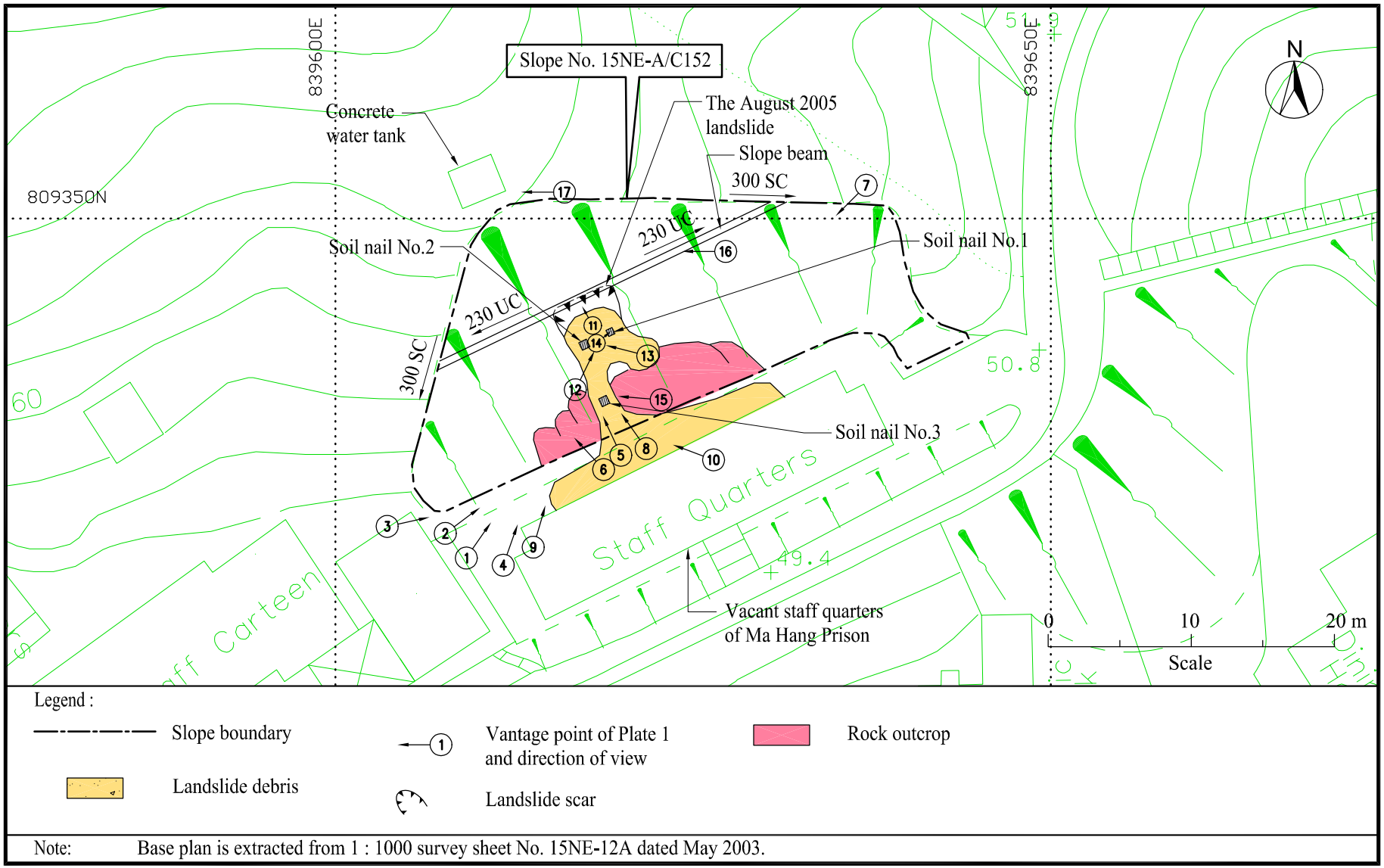


Figure 13 - Locations and Directions of Photographs

LIST OF PLATES

Plate 1 – General View of the 20 August 2005 Landslide (Photograph taken on 2 September 2005)

Note: See Figure 13 for the location and direction of photograph.

Plate 2 – Photographic Record of Slope No. 15NE-A/C152 in 1978 (Photograph taken by Binnie & Partners (HK) on 13 April 1978)

Note: See Figure 13 for the location and direction of photograph.

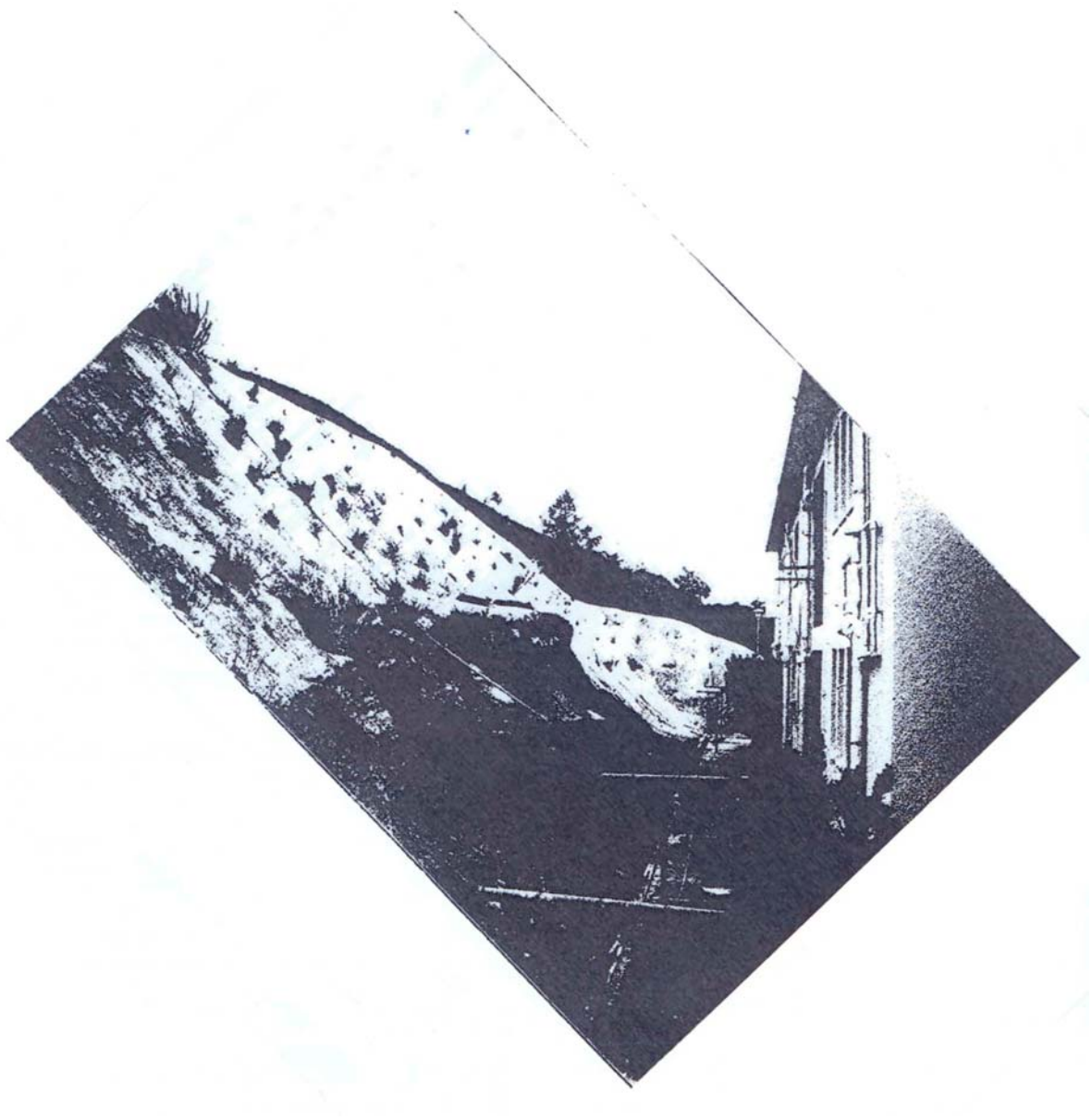


Plate 3 – Photographic Record of Slope No. 15NE-A/C152 in 1995
(Photograph taken by ArchSD on 13 December 1995)

Note: See Figure 13 for the location and direction of photograph.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Plate 4 – Photographic Record of Slope No. 15NE-A/C152 in 1998
(Photograph taken by ArchSD on 20 February 1998)

Note: See Figure 13 for the location and direction of photograph.

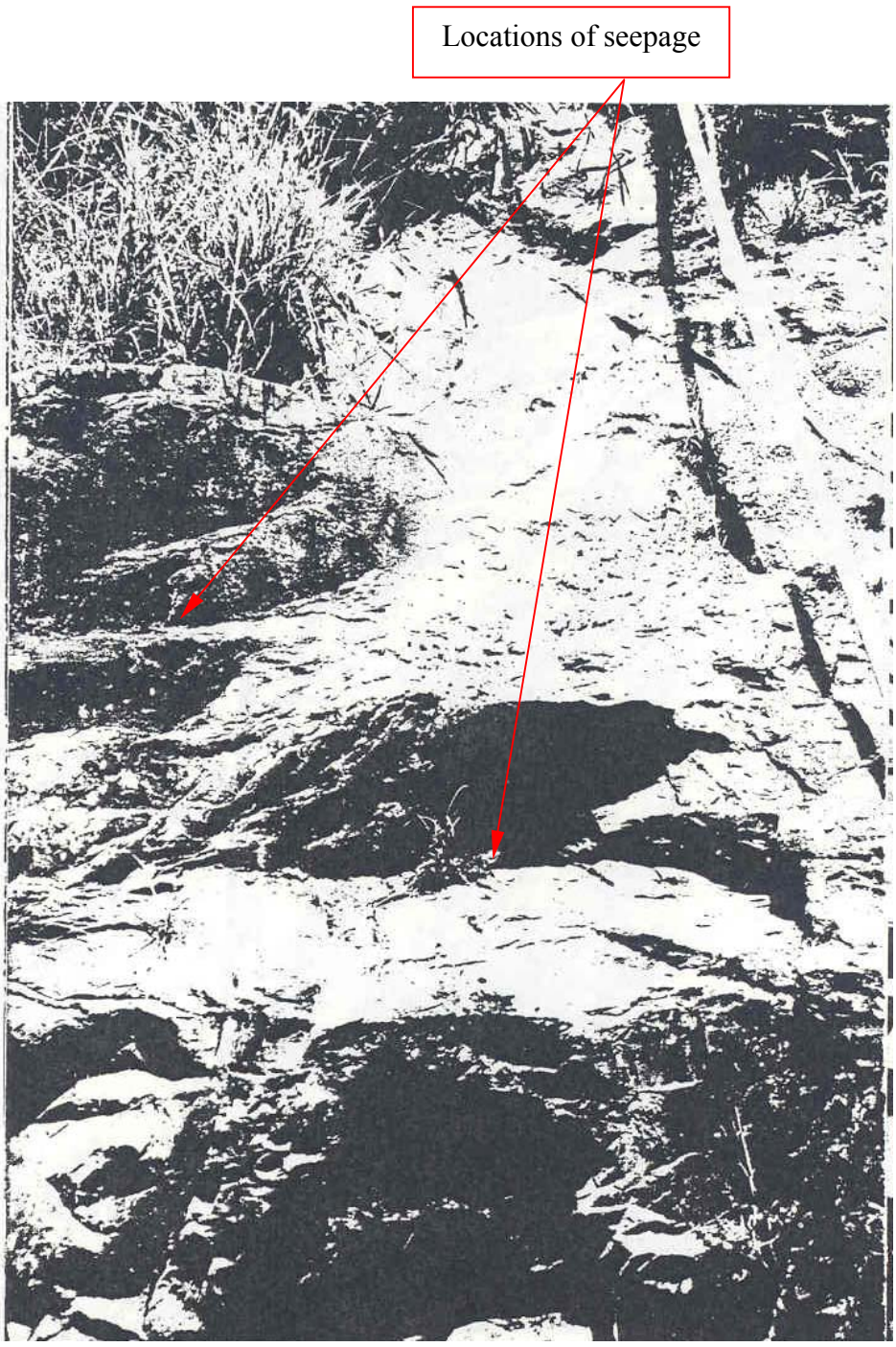


Plate 5 – Photographic Record of Seepage from Joints in Rock Exposure at Slope Toe (Photograph taken by ArchSD on 30 June 2000)

Note: See Figure 13 for the location and direction of photograph.

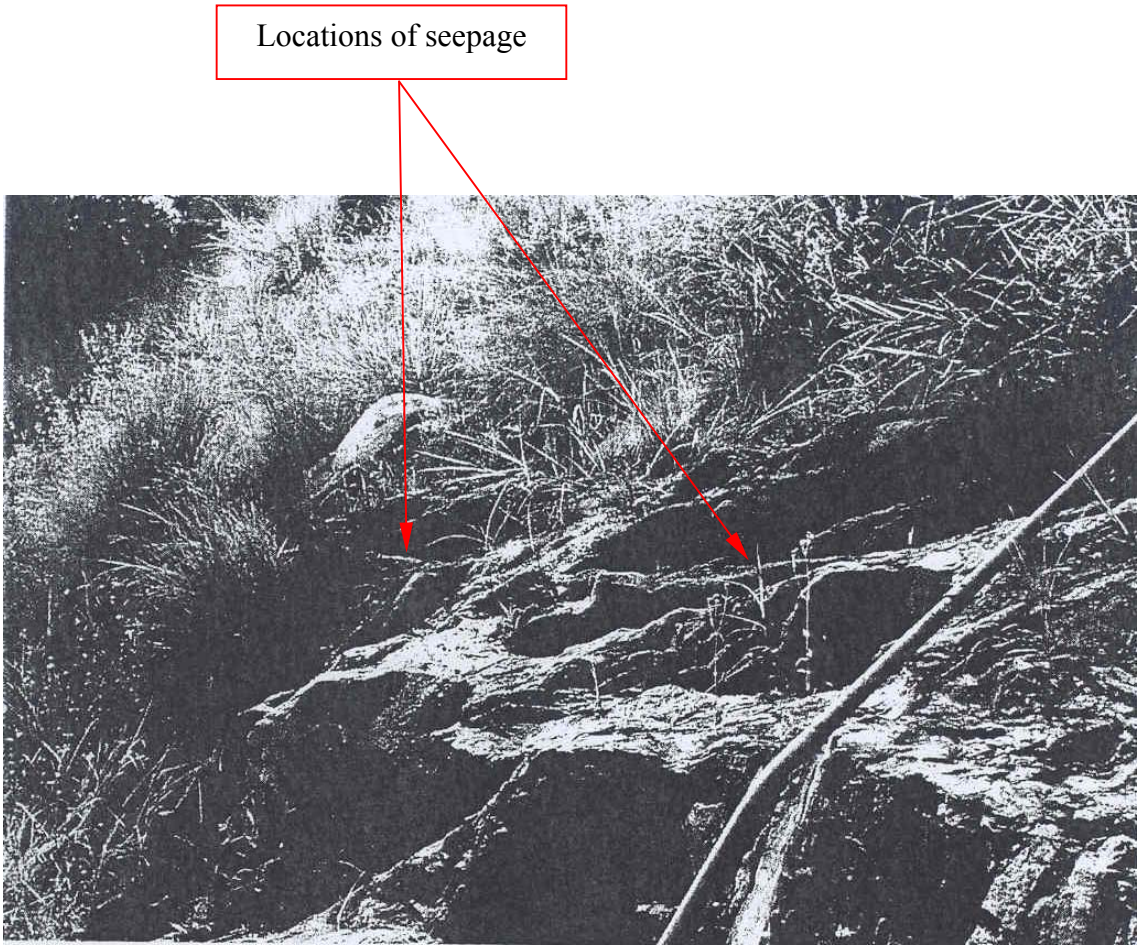


Plate 6 – Photographic Record of Seepage from Joints in Rock Exposure at Slope Toe (Photograph taken by Fugro (HK) Ltd. on 27 August 2002)

Note: See Figure 13 for the location and direction of photograph.

Plate 7 – General View West Across Slope No. 15NE-A/C152 (Photograph taken by HAP in 1999)

Note: See Figure 13 for the location and direction of photograph

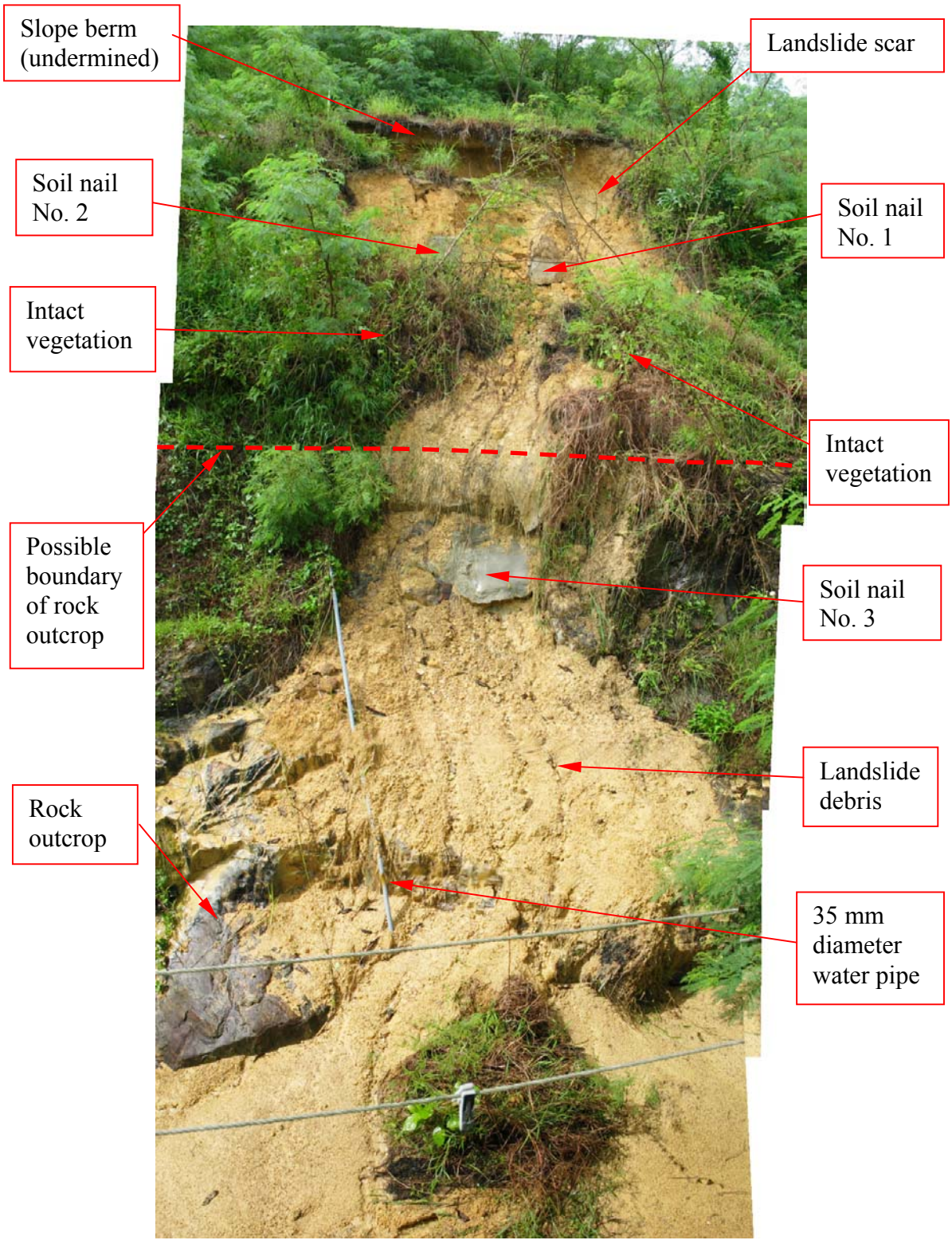


Plate 8 – View from Toe of Slope No. 15NE-A/C152 - Looking Northwest Towards the 20 August 2005 Landslide Scar (Photograph taken by GEO on 29 August 2005)

Note: See Figure 13 for the location and direction of photograph.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Plate 9 – View from Toe of Slope No. 15NE-A/C152 - Looking Northeast Towards the 20 August 2005 Landslide Scar (Photograph taken on 2 September 2005)

Note: See Figure 13 for the location and direction of photograph

Table of Contents
Table of Contents
Table of Contents
Table of Contents

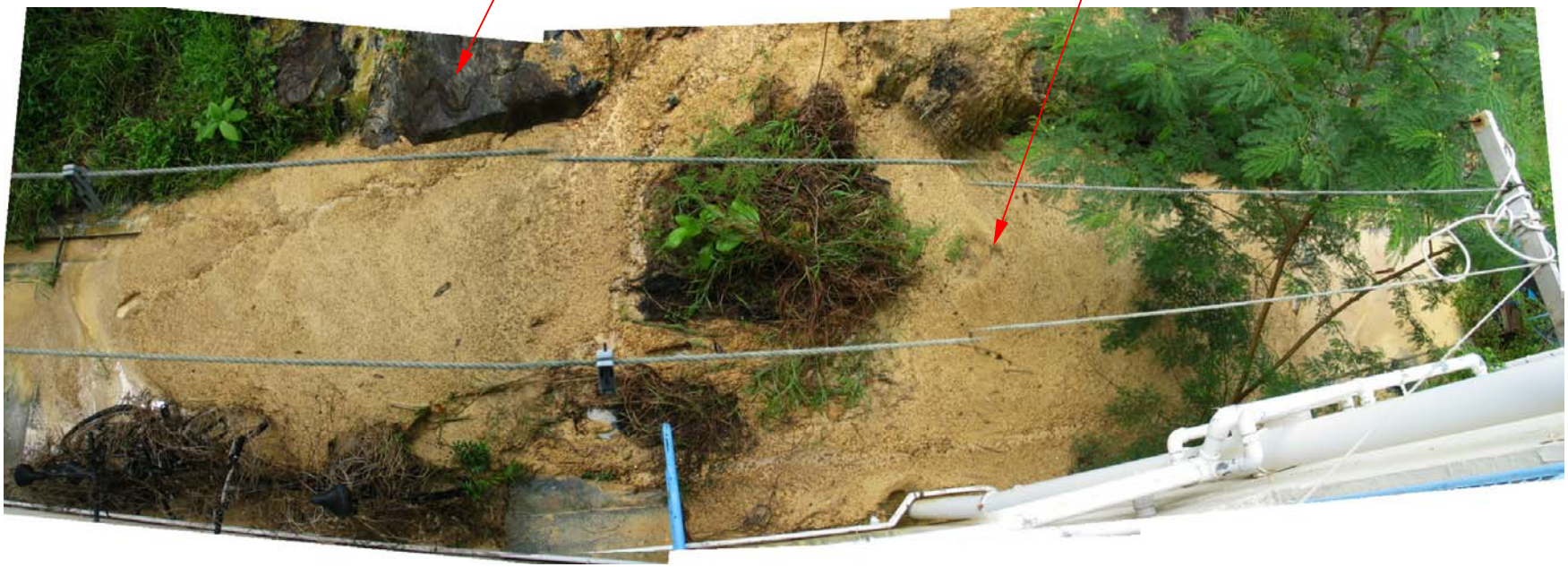


Plate 10 – View of Landslide Debris from Roof of Staff Quarters Building (Photograph taken by GEO on 29 August 2005)

Note: See Figure 13 for the location and direction of photograph

Table of Contents
Table of Contents
Table of Contents
Table of Contents

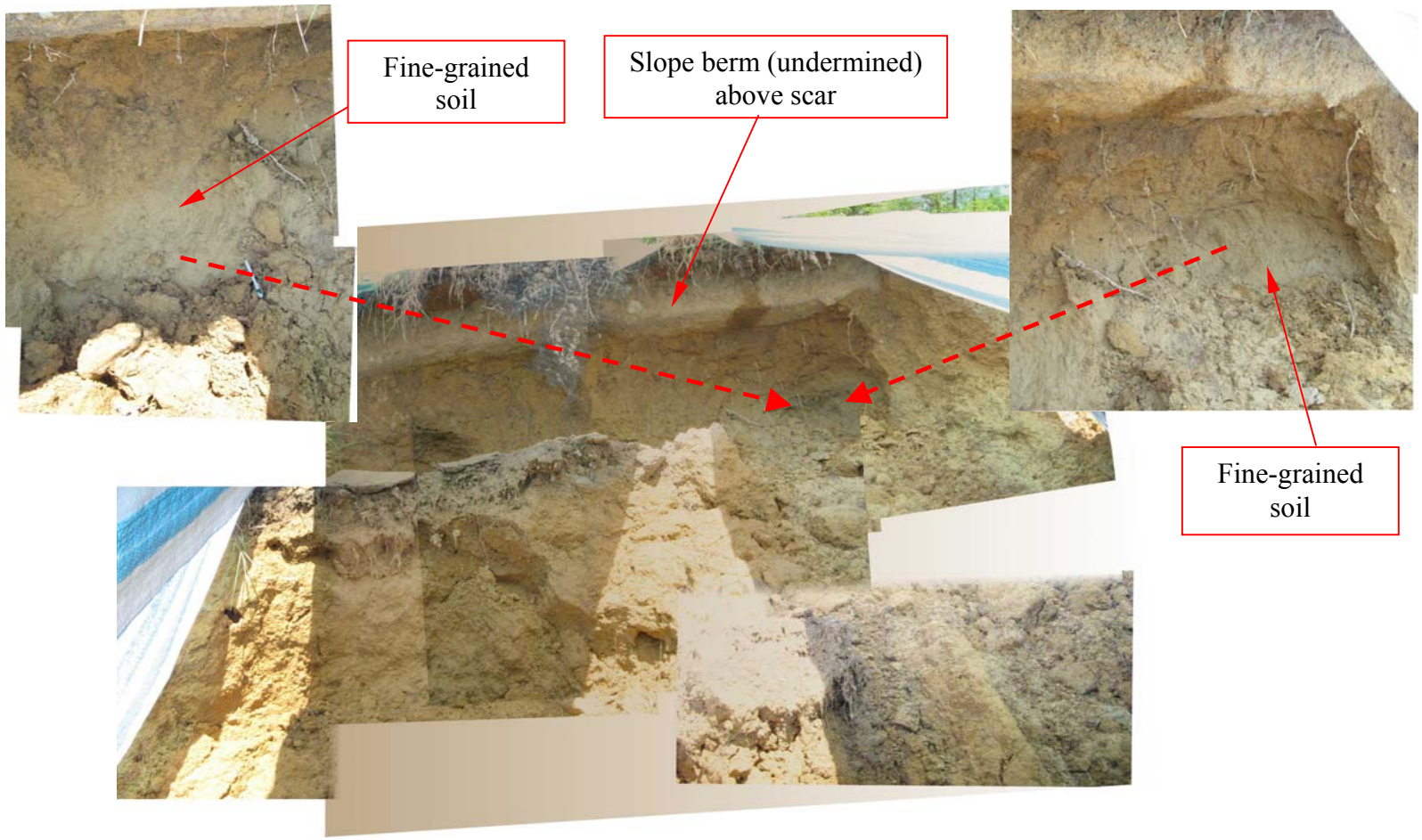


Plate 11 – Close View of the Main Scarp of the Landslide Scar (Photograph taken on 30 August 2005)

Note: See Figure 13 for the location and direction of photograph

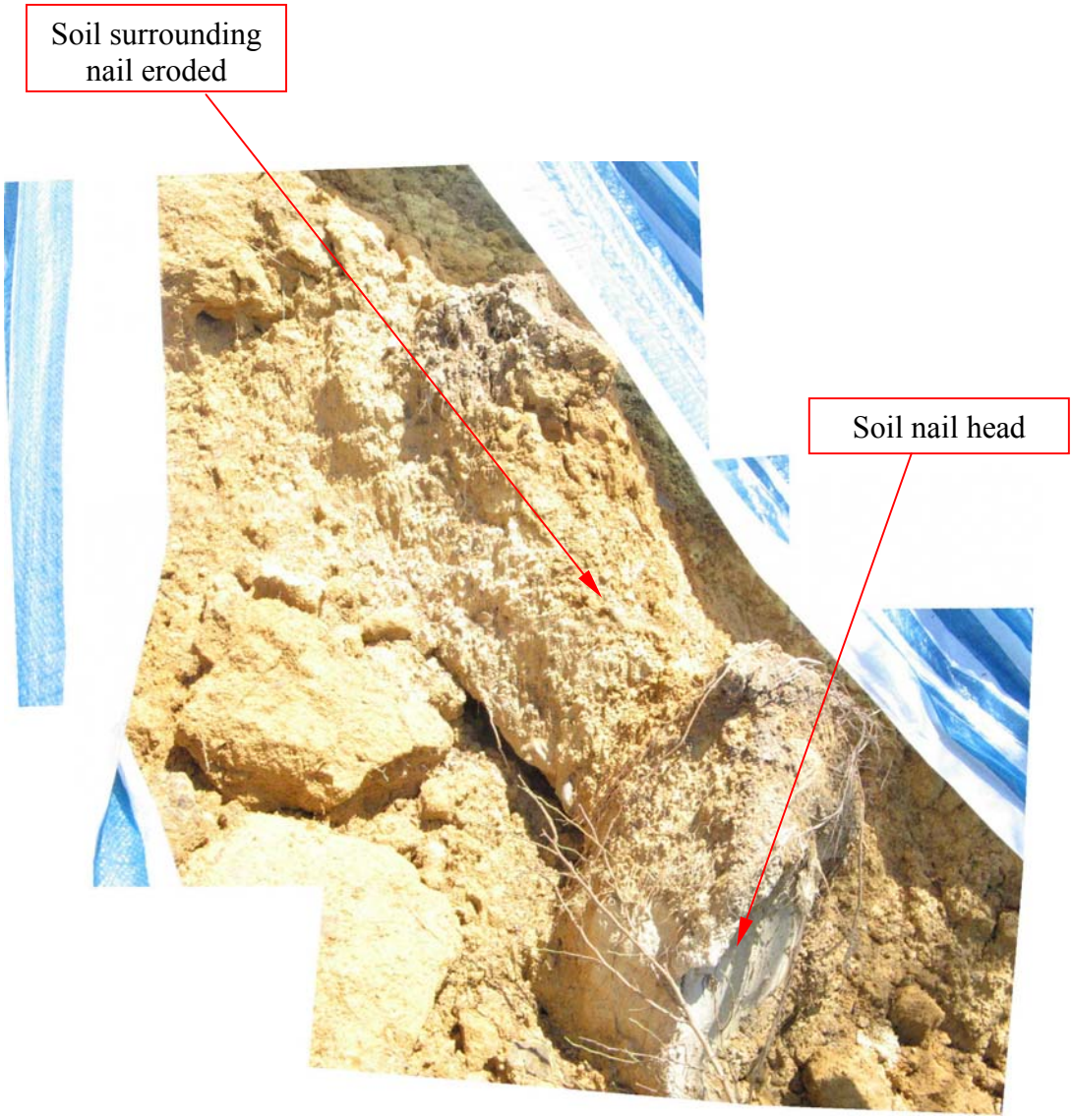


Plate 12 – Close View of Soil Nail No. 1 (Photograph taken on 30 August 2005)

Note: See Figure 13 for the location and direction of photograph.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Plate 13 – Close View of Soil Nail No. 2 (Photograph taken on 30 August 2005)

Note: See Figure 13 for the location and direction of photograph.

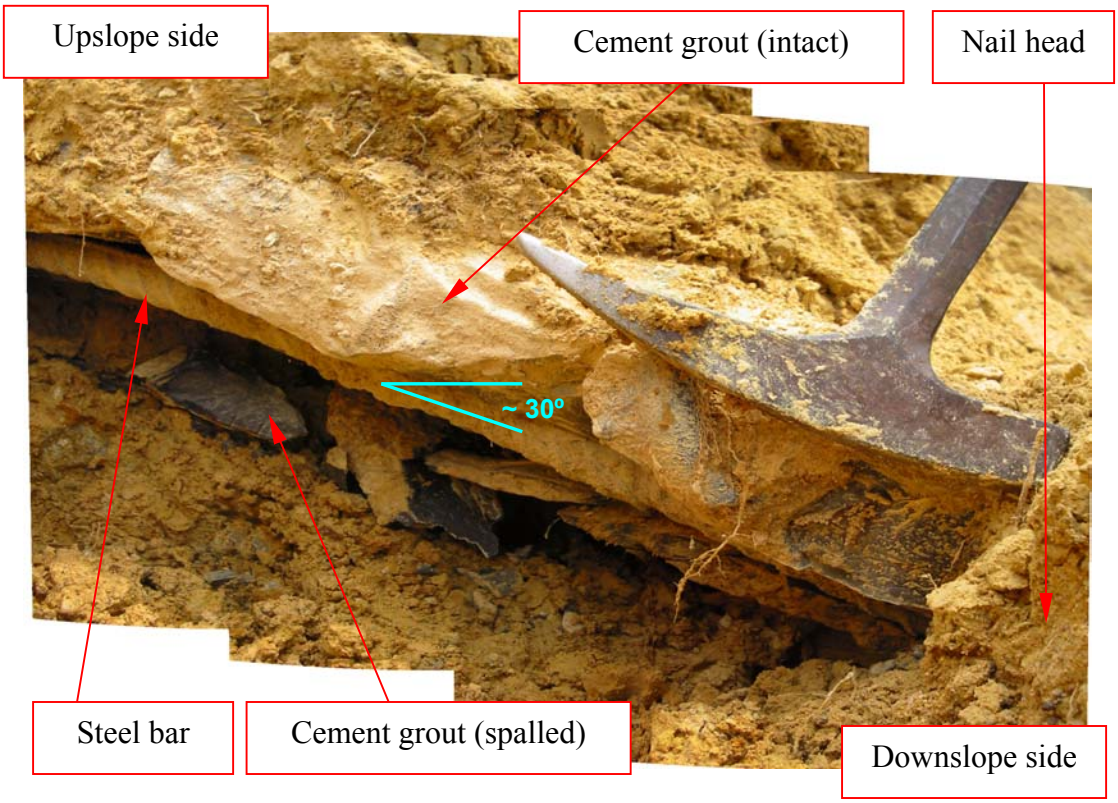


Plate 14 – Close View of Exposed Portion of Soil Nail No. 1 (Photograph taken on 2 September 2005)

Note: See Figure 13 for the location and direction of photograph.

Plate 15 – Close View of Soil Nail No. 3 (Photograph taken on 30 August 2005)

Note: See Figure 13 for the location and direction of photograph.

Plate 16 – Surface Channel above Landslide Scar (Photograph taken on 30 August 2005)

Note: See Figure 13 for the location and direction of photograph.

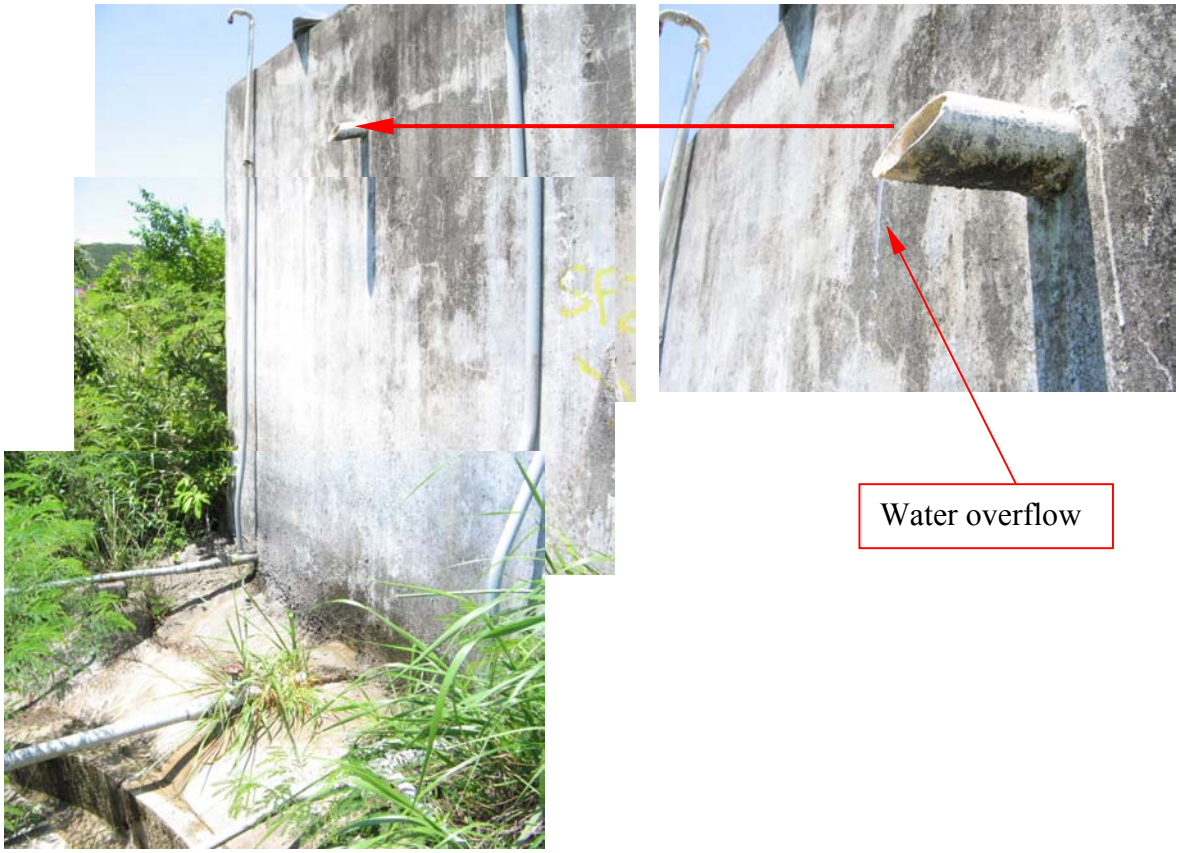


Plate 17 – Water Tank above Slope Crest (Photograph taken on 30 August 2005)

Note: See Figure 13 for the location and direction of photograph.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

APPENDIX A

AERIAL PHOTOGRAPH INTERPRETATION

A.1 DETAILED OBSERVATIONS

The following comprise the detailed observations made from the aerial photographs studied (see Figure A1). A list of aerial photographs used in this study is given in Section A.2.

Year	Observations
1949	The aerial photographs are of poor quality. The landform within the general area, comprising the foothills of Ma Hang Shan (Stone Hill) is generally undulating and is characterised by a number of gentle spurs and valleys trending in the east, southeast and south. Stanley Gap Road traverses across the natural hillside above the Ma Hang Prison at about 90 mPD and generally conforms to the present day alignment. The Ma Hang Prison complex, including the present reception block at the southeastern corner, the three dormitories and dining hall in the central area, and associated access roads, is visible further downslope of Stanley Gap Road at about 50 mPD. Some agricultural terraces are evident to the west of the dormitories. Site formation work within the area presently occupied by the football field, gymnasium and recreation complex situated to the west is underway. Two access paths extend upslope from the dormitories to the Stanley Gap Road. A small hut is situated at the downslope section of the eastern access path. Further upslope is a large area of disturbed terrain with regular planting along the eastern access path, which is situated immediately above the present day location of slope No. 15NE-A/C152. Slope No. 15NE-A/C152 and the present staff quarter at the slope toe have not been constructed and the area comprises natural landform. Two ephemeral streamcourses bound the northern and southern boundaries of slope No. 15NE-A/C152 respectively and generally trend towards the east and merging with a major drainage line. There are another two ephemeral stream courses to the west of the study area.
1963	Ma Hang Prison has been further developed. The development includes the construction of the present-day clinic building between the reception block and dining hall, staff canteen to the west, general office and three staff quarters together with associated slopes and access roads, including the present-day structure to the northeast of slope No. 15NE-A/C152. The agricultural terrace to the west of the dormitories is still evident. The site formation works at the present-day location of the football field and recreation facilities adjacent to the terrace identified in the 1949 aerial photographs appear to be still underway.

Year	Observations
1963 (cont'd)	To the north, the disturbed area and part of the eastern access path identified in the 1949 aerial photographs are covered with dense vegetation. Trees are observed in local depressions and valley areas. A linear, pipe-like feature extends from Stanley Gap Road to the access road immediately to the east of the present-day location of slope No. 15NE-A/C152. Slope No. 15NE-A/C153 situated to the northeast of slope No. 15NE-A/C152 has been formed. Site formation work in the area to the east of dining hall has been completed. Slope No. 15NE-A/C321 is formed, however it extends further west from the present-day slope boundary to the dormitory. The ephemeral streamcourses bounding both northern and southern areas of slope No. 15NE-A/C152 are no longer evident. The initial geometry of slope No. 15NE-A/C152 has been formed, probably in association with the construction of the staff quarter below. An irregular slope surface, possibly a rock outcrop, is evident in the lower part of the slope face. No surface protection appears on the slope, except some sparse shrubs. A structure about 3 m x 3 m on plan is present at about 10m above the crest of the slope. No relict landslide scars are evident in the vicinity of the study area.
1964	High altitude photographs. No major changes observed at slope No. 15NE-A/C152. No further development of the Ma Hang Prison has been identified except slope No. 15NE-A/C328 is formed. A strong, north-south trending photolineament, which is in line with the valley, is evident to the east of the study area.
1977	Site formation work within the area presently occupied by the football field and other recreational facilities to the west continues. Three new footpaths are evident; two from Stanley Gap Road and one from the structure immediately above slope No. 15NE-A/C152. There is a de-vegetated area immediately adjacent to the structure at the slope crest identified in the 1963 aerial photographs. A linear feature, possibly a footpath, is visible on the face of slope No. 15NE-A/C321. A structure is presented on the platform in front of slope No. 15NE-A/C153. The Ma Hang Prison continues to develop. A new dormitory has been constructed on the platform to the east of the dining hall. The agricultural terrace to the west identified in the 1949 aerial photographs appears to be abandoned. Site Formation for Stanley Knoll, which is situated to the south of Ma Hang Prison, is in progress.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Year	Observations
1977 (cont'd)	Slope No. 15NE-A/C152 and most of the formed slopes within the Ma Hang Prison complex are covered with vegetation. Trees are present on the upper portion of slope No. 15NE-A/C152 with its crest line apparently bounded by a surface channel.
1978	No major changes observed at slope No. 15NE-A/C152 or the natural hillside above, except an increased cover of trees is present on the slope face. Site formation work for the present football field and other recreational facilities within the prison complex to the west continues. Building works for Stanley Knoll development to the south are in progress.
1980	Slope No. 15NE-A/C152 has been further cut back to form the present slope geometry, extending the crest line further upslope and closer to the structure identified in the 1963 aerial photographs. The slope surface is mostly bare with sparse shrubs. A dark-tone area, possibly seepage on rock exposure, is evident on the lower batter of the slope face. The footpath extending below the structure above the feature is no longer evident. Some slope improvement works are evident on slope Nos. 15NE-A/C153 and C154. Construction of Stanley Knoll is complete. Site formation work for the football field and other recreational facilities appears on hold.
1981	The vegetation cover on slope No. 15NE-A/C152 is slightly heavier. A surface channel is evident traversing the slope at mid-height. The area of possible seepage is still evident on the lower portion of the slope. Otherwise, no major changes in the general area.
1983	High altitude photographs. No major changes observed at slope No. 15NE-A/C152 or the adjacent area.
1984	No major changes observed at slope No. 15NE-A/C152 or the adjacent area. Further development of the Ma Hang Prison complex is evident, with the recent construction of the present-day gymnasium, basketball court and other facilities in the southeastern portion. Heavy trimming of vegetation has been carried out on the man-made slopes and the natural hillside within the complex area.
1986	No major changes observed at slope No. 15NE-A/C152 or the adjacent area. Vegetation cover is slightly heavier. A new staff quarters building has been constructed to the west of the staff canteen.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Year	Observations
1987	No major changes observed at slope No. 15NE-A/C152 or the adjacent area. The linear feature first observed in 1963 aerial photographs is no longer visible.
1988	High altitude photographs. No major changes observed at slope No. 15NE-A/C152 or the adjacent area. Vegetation cover is generally heavier.
1990	The current recreation complex has been constructed to the southwest of the study area. Heavy trimming of vegetation has been carried out on the man-made slopes and the natural hillside within the prison compound. A small light-tone patch, possibly minor repair work on slope cover, is evident on the lower eastern portion of slope No. 15NE-A/C152.
1991	Slope upgrading work has been carried out on slope No. 15NE-A/C152. A recently applied hard surface cover is evident on lower batter of the slope excluding the area with possible seepage identified in the 1980 aerial photographs. The upper batter of the slope remains covered with vegetation. Otherwise no major changes observed in the general area.
1992	No major changes observed at slope No. 15NE-A/C152 or the adjacent area. Heavy trimming of vegetation has been carried out on the man-made slopes and natural hillside within the prison compound.
1993	No major changes observed at slope No. 15NE-A/C152 or the adjacent area. The footpath between Stanley Gap Road and staff canteen building is still evident. Areas of surface erosion are evident on the natural hillside immediately below Stanley Gap Road.
1994	No major changes observed at slope No. 15NE-A/C152 or the adjacent area.
1995	High altitude photographs. No major changes observed at slope No. 15NE-A/C152 or the adjacent area.
1996	Heavy trimming of vegetation has been carried out on the man-made slopes and natural hillside within the prison compound. A hard surface cover has been recently applied to the upper portion of slope No. 15 NE-A/C152.
1997	High altitude photographs. No major changes observed at slope No. 15NE-A/C152 or the adjacent area.
1998	No major changes observed at slope No. 15NE-A/C152 or the adjacent area. The new hard cover on the upper batter of slope No. 15NE-A/C152 has deteriorated.

Table of Contents
Table of Contents
Table of Contents
Table of Contents

Year	Observations
1999	No major changes observed at slope No. 15NE-A/C152 or the adjacent area. The hard surface cover on the upper batter of slope No. 15NE-A/C152 has been removed and replaced by vegetation cover.
2000	No stereopair is available. A reinstated surface strip is evident on the slope face of slope No. 15NE-A/C152.
2001	Slope upgrading works have been carried out on slope Nos. 15NE-A/C152 and 15NE-A/C328. The hard surface cover has been removed and replaced by hydroseeding. A new crest channel and a mid-slope channel are evident on slope No. 15NE-A/C152, which has retained the overall face geometry.
2002	No major changes observed at slope No. 15NE-A/C152 or the adjacent area. Some areas of erosion are evident on the face of slope No. 15NE-A/C328. Otherwise vegetation continues to increase over the general area.
2003	No major changes observed at slope No. 15NE-A/C152 or the adjacent area, except that the areas of erosion observed in the 2002 aerial photographs have been repaired.

A.2 LIST OF PHOTOGRAPHS

Date	Reference No.	Altitude
24/04/1949	Y1067, Y1068	8,000’
25/05/1949	Y1086, Y1087	8,600’
1/02/1963	Y6699, Y6700	2,700’
13/12/1964	Y12800, Y12801	12,500’
15/09/1977	19456, 19457	4,000’
24/01/1978	21014, 21015	4,000’
7/11/1980	32650, 32651	4,000’
18/05/1981	37544, 37545	4,000’
1/12/1983	51729, 51730	20,000’
2/03/1984	53818, 53819	4,000’
22/10/1984	56783, 56784	4,000’
20/09/1986	A6144, A6145	4,000’
9/09/1987	A10445, A10446	4,000’
3/11/1988	A15290, A15291	10,000’
30/03/1990	A20587, A20588	4,000’
4/10/1991	A28041, A28042	4,000’
13/05/1992	A31128, A31129	4,000’
11/11/1992	A33097, A33098	10,000’
5/12/1993	A37095, A37096	4,000’
17/11/1994	CN7960, CN7961	4,000’
23/11/1995	CN12102, CN12103	10,000’
23/10/1996	CN15410, CN15411	4,000’
31/10/1997	CN18701, CN18702	10,000’
23/10/1998	CN20983, CN20984	4,000’
8/09/1999	CN23919, CN23920	4,000’
9/08/2000	CN27592	4,000’
21/11/2001	CW36214, C36215	8,000’
25/10/2002	CW45687, CW45688	8,000’
25/11/2003	CW53309, CW53310	4,000’

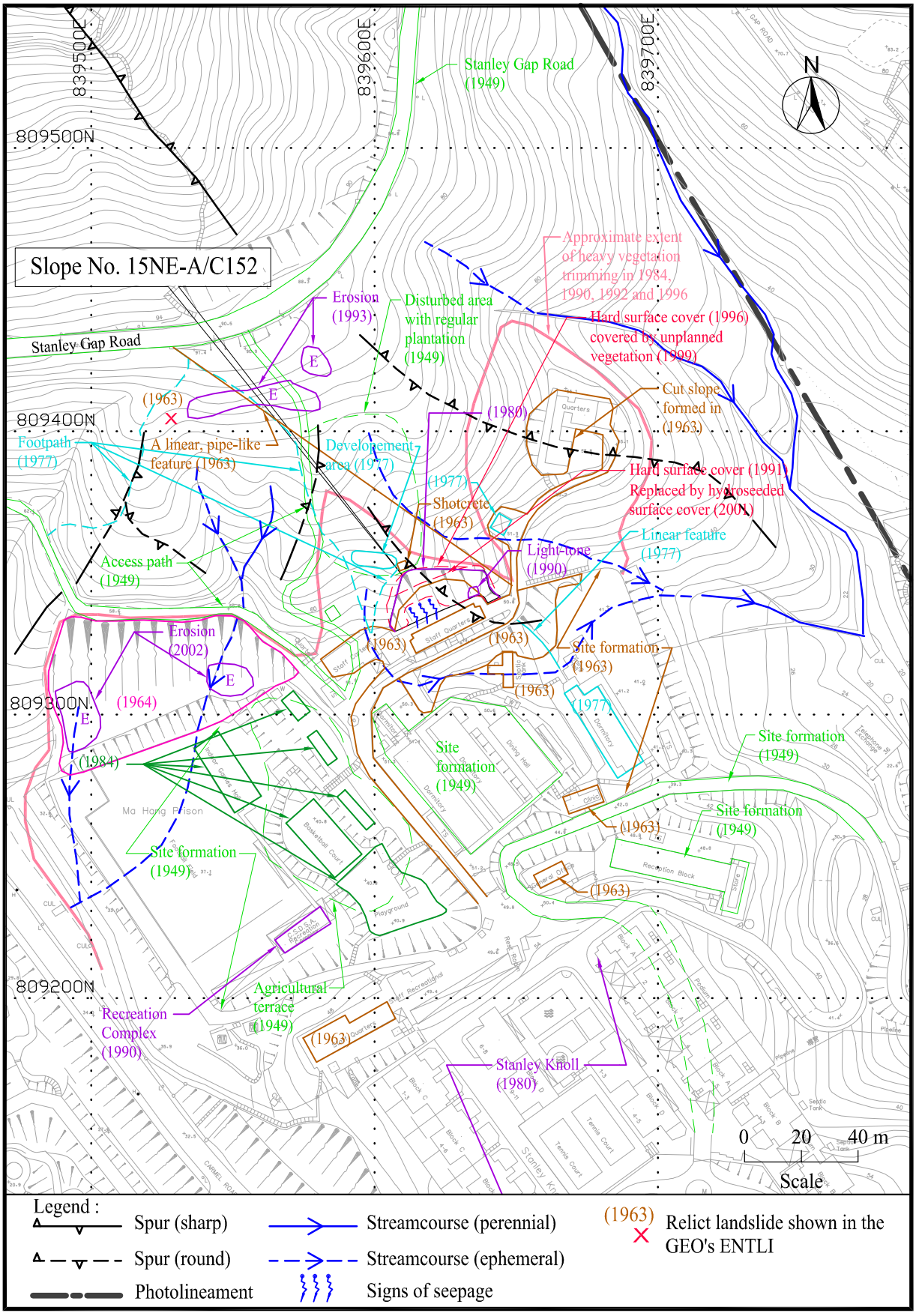


Figure A1 - Site Development Plan

GEO PUBLICATIONS AND ORDERING INFORMATION
土力工程處刊物及訂購資料

A selected list of major GEO publications is given in the next page. An up-to-date full list of GEO publications can be found at the CEDD Website http://www.cedd.gov.hk on the Internet under "Publications". Abstracts for the documents can also be found at the same website. Technical Guidance Notes are published on the CEDD Website from time to time to provide updates to GEO publications prior to their next revision.

部份土力工程處的主要刊物目錄刊載於下頁。而詳盡及最新的土力工程處刊物目錄，則登載於土木工程拓展署的互聯網網頁 http://www.cedd.gov.hk 的"刊物"版面之內。刊物的摘要及更新刊物內容的工程技術指引，亦可在這個網址找到。

Copies of GEO publications (except maps and other publications which are free of charge) can be purchased either by:

writing to
Publications Sales Section,
Information Services Department,
Room 402, 4th Floor, Murray Building,
Garden Road, Central, Hong Kong.
Fax: (852) 2598 7482

or
- Calling the Publications Sales Section of Information Services Department (ISD) at (852) 2537 1910
- Visiting the online Government Bookstore at http:// www.bookstore.gov.hk
- Downloading the order form from the ISD website at http://www.isd.gov.hk and submit the order online or by fax to (852) 2523 7195
- Placing order with ISD by e-mail at puborder@isd.gov.hk

讀者可採用以下方法購買土力工程處刊物(地質圖及免費刊物除外):

書面訂購
香港中環花園道
美利大廈4樓402室
政府新聞處
刊物銷售組
傳真: (852) 2598 7482

或
- 致電政府新聞處刊物銷售小組訂購 (電話：(852) 2537 1910)
- 進入網上「政府書店」選購，網址爲 http://www.bookstore.gov.hk
- 透過政府新聞處的網站 (http://www.isd.gov.hk) 於網上遞交訂購表格，或將表格傳真至刊物銷售小組 (傳真：(852) 2523 7195)
- 以電郵方式訂購 (電郵地址：puborder@isd.gov.hk)

1:100 000, 1:20 000 and 1:5 000 maps can be purchased from:

Map Publications Centre/HK,
Survey & Mapping Office, Lands Department,
23th Floor, North Point Government Offices,
333 Java Road, North Point, Hong Kong.
Tel: 2231 3187
Fax: (852) 2116 0774

讀者可於下列地點購買1:100 000，1:20 000及1:5 000地質圖：

香港北角渣華道333號
北角政府合署23樓
地政總署測繪處
電話: 2231 3187
傳真: (852) 2116 0774

Requests for copies of Geological Survey Sheet Reports, publications and maps which are free of charge should be sent to:

For Geological Survey Sheet Reports and maps which are free of charge:
Chief Geotechnical Engineer/Planning,
(Attn: Hong Kong Geological Survey Section)
Geotechnical Engineering Office,
Civil Engineering and Development Department,
Civil Engineering and Development Building,
101 Princess Margaret Road,
Homantin, Kowloon, Hong Kong.
Tel: (852) 2762 5380
Fax: (852) 2714 0247
E-mail: jsewell@cedd.gov.hk

For other publications which are free of charge:
Chief Geotechnical Engineer/Standards and Testing,
Geotechnical Engineering Office,
Civil Engineering and Development Department,
Civil Engineering and Development Building,
101 Princess Margaret Road,
Homantin, Kowloon, Hong Kong.
Tel: (852) 2762 5346
Fax: (852) 2714 0275
E-mail: wmcheung@cedd.gov.hk

如欲索取地質調查報告、其他免費刊物及地質圖，請致函：

地質調查報告及地質圖:
香港九龍何文田公主道101號
土木工程拓展署大樓
土木工程拓展署
土力工程處
規劃部總土力工程師
(請交:香港地質調查組)
電話: (852) 2762 5380
傳真: (852) 2714 0247
電子郵件: jsewell@cedd.gov.hk

其他免費刊物:
香港九龍何文田公主道101號
土木工程拓展署大樓
土木工程拓展署
土力工程處
標準及測試部總土力工程師
電話: (852) 2762 5346
傳真: (852) 2714 0275
電子郵件: wmcheung@cedd.gov.hk

Table of Contents
Table of Contents
Table of Contents
Table of Contents

MAJOR GEOTECHNICAL ENGINEERING OFFICE PUBLICATIONS
土力工程處之主要刊物

Table of Contents

GEOTECHNICAL MANUALS

Geotechnical Manual for Slopes, 2nd Edition (1984), 300 p. (English Version), (Reprinted, 2000).

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).
Geoguide 3	Guide to Rock and Soil Descriptions (1988), 186 p. (Reprinted, 2000).
Geoguide 4	Guide to Cavern Engineering (1992), 148 p. (Reprinted, 1998).
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.

Table of Contents

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.

GEO PUBLICATIONS

GCO Publication No. 1/90	Review of Design Methods for Excavations (1990), 187 p. (Reprinted, 2002).
GEO Publication No. 1/93	Review of Granular and Geotextile Filters (1993), 141 p.
GEO Publication No. 1/2000	Technical Guidelines on Landscape Treatment and Bio-engineering for Man-made Slopes and Retaining Walls (2000), 146 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.

Table of Contents

GEOLOGICAL PUBLICATIONS

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

TGN 1	Technical Guidance Documents

Table of Contents