DETAILED STUDY OF THE 14 DECEMBER 2001 WASHOUT INCIDENT BELOW POKFIELD ROAD, KENNEDY TOWN

GEO REPORT No. 152

Fugro Maunsell Scott Wilson Joint Venture

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

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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. 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 last page of this report.

R.K.S. Chan
Head, Geotechnical Engineering Office
December 2004

FOREWORD

This report presents the findings of a detailed study of a washout incident (GEO Incident No. 2001/12/0123), which occurred on 14 December 2001 on a slope below Pokfield Road opposite University Heights, Kennedy Town. The incident involved the washout of about 30 m^3 of soil underneath the shotcrete cover of the slope. There were no reported casualties as a result of the incident.

The key objectives of the study were to document the facts about the washout incident, present relevant background information and establish the probable causes of the incident. The scope of the study comprised a review of relevant documents relating to the history of the site, topographical survey, detailed site observations and field measurements, aerial photograph interpretation, analysis of rainfall records, engineering analyses and diagnosis of the probable causes of the incident. Recommendations for follow-up actions are reported separately.

The Landslide Study Report No. LSR 7/2002 was prepared as part of the 2000 and 2001 Landslide Investigation Consultancy for Hong Kong Island and Outlying Islands, for the Geotechnical Engineering Office, Civil Engineering Department, under Agreement No. CE 1/2000. This report is one of a series of reports produced during the consultancy by Fugro Maunsell Scott Wilson Joint Venture.

Y C Koo
Project Director
Fugro Maunsell Scott Wilson Joint Venture

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

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1. INTRODUCTION

On 14 December 2001, a washout incident (GEO Incident No. 2001/12/0123) caused by a burst watermain occurred on a slope below Pokfield Road opposite University Heights, Kennedy Town (Figure 1 and Plate 1). The incident involved the erosion of approximately 30 m^3 of soil underneath the shotcrete cover to the slope (referred to as the 'subject slope' in this report). Some of the outwash material cascaded down the face of slope No. 11SW-A/C747 above Rock Hill Street (Plate 2). Most of the debris was deposited on a platform at the toe of the subject slope whilst some was deposited on the pedestrian pavement of Rock Hill Street. No casualties were reported as a result of the incident.

Fugro Maunsell Scott Wilson Joint Venture (FMSW), the 2000/2001 Landslide Investigation Consultants for Hong Kong Island and Outlying Islands, carried out a detailed study of the incident for the Geotechnical Engineering Office (GEO), Civil Engineering Department (CED), under Agreement No. CE 1/2000. The key objectives of the study were to document the facts about the washout incident, present relevant background information and establish the probable causes of the incident. Recommendations for follow up actions are reported separately.

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

(a) a review of relevant documentary records relating to the history of the site,

(b) topographical survey,

(c) detailed site observations and field measurements,

(d) aerial photograph interpretation (API),

(e) analysis of rainfall records,

(f) engineering analyses, and

(g) diagnosis of the probable causes of the incident.

2. THE SITE

2.1 Site Description

The location of the incident site is shown in Figure 1. The washout incident occurred on a northeasterly facing slope which is bounded to the south by a curved section of Pokfield Road at its crest, to the northwest by slope No. 11SW-A/C747, to the southeast by slope No. 11SW-A/FR23 and to the north by a platform at the slope toe. The subject slope is about 45 m long, maximum 20 m high and is inclined at about 35°. The entire slope is covered with shotcrete, which is provided with weepholes and tree rings.

Along the eastern crest of the subject slope is an 11.5 m long, 2.3 m to 3.2 m high reinforced concrete retaining wall (Figure 1), which is provided with 75 mm diameter weepholes at 1 m spacing. This retaining wall was not registered in the New Catalogue of Slopes at the time of the incident. A 150 mm U-channel runs along the toe of the wall and connects to a 350 mm stepped-channel via a catchpit. Another 300 mm U-channel exists near the crest of subject slope below the wall and also connects to the same 350 mm stepped-channel. Details of the surface drainage provisions on the subject slope are shown in Figure 2.

Pokfield Road is located immediately above the crest of the subject slope at an elevation of about 53 mPD. An open platform area with an average width of 5 m is located at the toe of the slope at a level of about 33.5 mPD (Plate 3). Below the platform is a 1.5 m high, 45° steep shotcreted slope which is supported by a 3.2 m high, 85° steep masonry retaining wall No. 11SW-A/R1083 (Figure 1). There is a row of residential buildings at a minimum distance of 2 m from the toe of this masonry wall.

2.2 Water-carrying Services

Record plans from the Water Supplies Department (WSD) and the Drainage Services Department (DSD) indicate that water-carrying services are present at the crest of the subject slope along Pokfield Road. Details of the water-carrying services are shown in Figure 1.

Based on WSD's record, a 250 mm diameter pressurised fresh watermain runs along the curved section of carriageway of Pokfield Road at a distance of about 6 m from the crest of the subject slope. A 75 mm diameter watermain branches off from the 250 mm diameter watermain to a fire hydrant on the pedestrian pavement of Pokfield Road near the western end of the subject retaining wall. The presence of the burst watermain in the 14 December 2001 washout incident was not indicated on WSD's record plan entitled "FRESH WATER MAINS RECORD PLAN(S) No. W67880/11-SW-6D & 7C". Based on WSD's report on main burst and leakage, the watermain that burst was an 80 mm diameter galvanized iron pipe. According to WSD, the burst watermain probably branches off an uncharted watermain (of an unknown diameter), which in turn probably branches off the above 75 mm watermain (see Figure 2). The 80 mm screw-jointed watermain is located about 1 m below the pedestrian pavement and the end of the pipe closest to the retaining wall is about 3 m away (Figure 2). WSD advised that the burst watermain was probably operating at a working pressure of about 390 kPa when the bursting occurred on 14 December 2001.

According to WSD, visual inspection and leakage detection test were carried out on the 250 mm diameter watermain along the crest of the subject slope in August 2000. The leakage test involved the use of a leak noise correlator and was carried out by Ming Hing Waterworks Engineering Company under the supervision of Maunsell/CDM Joint Venture, under Agreement No. CE 49/96 on "Leak Detection of Buried Watermains Affecting Slopes". No leakage was detected during the test. The inspection by WSD also indicated no signs of leakage.

According to WSD's records, their Leak Detection Unit carried out "day sounding visual inspections" (DSVI) leakage detection tests on 17 February 2001, 3 April 2001, 14 May 2001, 7 July 2001, 1 September 2001 and 17 October 2001 respectively on the

watermains in the Kennedy Town Area, which covers Pokfield Road. No leakage was found at the time of the above inspections.

Stormwater drains and foul sewers up to 375 mm in diameter, with invert levels at between 1.2 m and 2.4 m below ground level, run along the section of Pokfield Road above the incident site at a minimum distance of about 5 m from the crest of the retaining wall.

2.3 Maintenance Responsibility

The subject slope involved in the washout incident, including the crest retaining wall, was not registered in the New Catalogue of Slopes at the time of the incident. Following the December 2001 incident, the subject slope, together with the reinforced concrete retaining wall at its crest (Figure 1), was registered as feature No. 11SW-A/FR230. The maintenance responsibility of this feature was subsequently assigned to the Highways Department (HyD) by the SIMAR unit of the Lands Department.

2.4 Site History

The development history of the site has been compiled from a review of the available aerial photographs, old topographic maps and relevant documentation, together with site observations made by FMSW (Figure 3). Details of the pertinent observations from aerial photographs are given in Appendix A.

The 1924 aerial photographs show an area that appears to be a reflective patch at the upper part and beyond the crest of the subject slope, covering the full width of the present Pokfield Road above (Figure A1 of Appendix A). This indicates the possibility of a shallow fill or cut platform being formed in this area. An API carried out by the GEO in 1992 in association with the Rock Hill Street Extension project also revealed the presence of pre-1945 fill at the upper part and beyond the crest of the subject slope.

Old topographic maps indicate that a platform existed within the reflective patch as early as 1901 (Figure 3). A zigzag footpath was first observed in the 1949 aerial photographs on the subject slope, extending from a group of buildings constructed on the platform down to the toe of the slope and leading to the buildings at Sands Street. By 1956, another platform with two small cut slopes was formed at the toe of the subject slope (Figure 3). Squatter huts were built on the platform (which was formed in 1956 close to the two cuts) sometime between 1956 and 1961. Another large reflective patch (see Figure A1 in Appendix A) covering the eastern part of the subject slope was noted on the 1961 aerial photographs. This possibly indicates that either vegetation had been removed or that fill material had been placed onto the subject slope. Some modification works, possibly for the formation of cultivation terraces, at the toe of the subject slope took place in 1963. By 1976, the area immediately northwest of the subject slope, at the location of the present slope No. 11SW-A/C747, had been cut back and areas of exposed soil existed on the upper portion of the adjacent slope. The vegetation on the subject slope subsequently involved in the washout incident had been cleared locally, probably during the works on slope No. 11SW-A/C747. Further local clearance of vegetation on the subject slope took place in 1982 and large trees were removed in 1984.

Slope upgrading works on the adjacent slope No. 11SW-A/FR23 were carried out between August 1985 and November 1987 under Contract No. GC/84/03 GCO Package B of the LPM Programme. The subject slope was located between the works site and the works area allocated for the project. Slope 11SW-A/FR23 was then registered as a 33 m wide, 18 m high fill slope supporting Pokfield Road at the southwest. The northern boundary of the slope was defined by a stairway. The LPM works comprised the construction of a caisson wall at the slope crest and removal of loose fill from the slope surface. During the works, the loose fill was found to be much more extensive than that originally anticipated. The upgrading works were subsequently extended beyond the northern slope boundary. The old stairway was demolished and a new one was constructed along the extended northern feature boundary. Upon completion of the works, the boundary of the feature in the Slope Catalogue was updated. Following the LPM works, the plan area of feature No. 11SW-A/FR23 increased by about 90% as compared to the original one (see Figure 4).

Slope No. 11SW-A/C747 (Figure A1 in Appendix A) was modified to its present configuration between 1995 and 1996 as part of HyD's "Rock Hill Street Extension Project" (HY/93/41). The feature was further cut back to form a 40 m high soil/ rock cut. The lower rock cut portion is inclined at 70° and the upper soil cut portion is inclined at 40°. The 1995 aerial photographs show a bare reflective patch at the western end of the subject slope adjoining slope No. 11SW-A/C747.

Following a landslide incident in August 1999 (see Section 2.5), GEO recommended HyD on 27 August 1999 to "apply temporary hard surface protection with the provision of weepholes" to the landslide scar and to "construct a mass concrete to replace the damaged portion of the footpath and the associated abutment wall". A reinforced concrete retaining wall was subsequently constructed by HyD at the crest of the subject slope. Shotcrete cover, tree rings and surface drainage channels were also provided by HyD to the subject slope.

In 2000, the Architectural Services Department (Arch SD) proposed to build a school at the subject slope. Geotechnical advisory service for the proposed school project was provided by the Advisory Division of the GEO. Between April and June 2001, ground investigation was carried out on and adjacent to the subject slope (see Section 3). Prior to the commencement of site formation works, Arch SD advised the Advisory Division of the GEO on 8 January 2003 that the proposed school development at this site had been suspended.

During FMSW's post-failure inspections in December 2001, there was indication that additional fill might had been placed near the toe of the subject slope between 1994 and 2001. This was evidenced by the reduction in the size of the platform at the toe of the subject slope and the disappearing of the two associated small cut slopes that were shown in the 1994 topographic maps. The above observation is corroborated by the topographic survey, which was carried out by the Survey Division of CED after the 2001 washout incident. The survey shows that the toe line of the subject slope has extended northward by up to 8 m (Figure 3) since 1994, indicating that filling and localised minor cutting had taken place at the toe of the subject slope.

2.5 Past Instability

A burst watermain affecting the subject slope was reported to have occurred on 5 January 1980 in the report entitled "Special Investigation into Fill Slopes - Detailed Studies for Slope No. 11SW-A/FR23", which was prepared by GCO (Geotechnical Control Office, GCO, renamed GEO in 1991) consultant Binnie & Partners in 1980. The incident resulted in the formation of cracks on Pokfield Road and a local failure of the subject slope below (see Figure 1). Details of the slope failure were not given in the report and no other information on this incident could be found in other GEO's records.

The GEO's landslide database indicates a past landslide incident (GEO Incident No. HK 1999/8/17) on the subject slope. The incident occurred on 24 August 1999 at the slope crest involving a volume of about 20 m^3. The failure resulted in the collapse of a section of a 1.5 m wide footpath at its crest (Figure 1). The landslide was recorded in the GEO Incident Report as having been caused by heavy discharge from "an old 200 mm diameter stormwater drain underneath the footpath". The failed feature was recorded in the GEO Incident Report as a fill slope comprising very loose to loose silty sand. Based on the cross section shown in the GEO Incident Report, the footpath prior to failure appears to rest on top of a 2 m high step with a "natural slope (?)" below. The GEO Incident Report also indicates the presence of a trench being excavated by the DSD as part of a drainage improvement project on Pokfield Road behind the 1999 landslide location.

Following the August 1999 incident, HyD constructed an L-shaped reinforced concrete retaining wall at the slope crest (see also Section 3.4). According to HyD, there are no records of any signs of distress observed for the section of the pedestrian pavement and the road above the retaining wall during their routine road maintenance inspections after wall construction.

3. PAST ASSESSMENTS AND SLOPE WORKS

3.1 Inspection by Binnie & Partners (HK) Ltd (B & P)

In June 1977, B & P inspected the subject slope together with the area covering the majority of the present slopes Nos. 11SW-A/C565 and 11SW-A/C747, under the project entitled "Landslides, Phase I Re appraisal, Cut & Natural Slopes and Retaining Walls" to prepare the 1977/78 Catalogue of Slopes. The area was registered as natural slope No. 11SW-A/N11 in the 1977/78 Catalogue of Slopes (see Figure 4). The field sheet prepared by Binnie and Partners recorded the subject slope as being about 30 m high by 200 m long and standing at an angle of up to 40°.

3.2 SIFT and SIRST Records

In 1992, the GEO commenced the consultancy entitled "Systematic Inspection of Features in the Territory" (SIFT). This assignment aimed to search systematically for sizeable man made slope features not included in the 1977/78 Catalogue of Slopes and to update information on previously registered features, by studying aerial photographs together with limited site inspections. Under the SIFT project in May 1995, the area covering the subject slope and other adjoining slopes, including part of the present slope

No. 11SW-A/C747, was collectively assigned a "WIP" (i.e. works in progress) status and noted that registerable features may be present (Figure 5). The SIFT report also recorded that "Excavation of a cut slope evident in 1994 air photos. Work continuing as at May 1995 and appears that it will include several old low cut slopes and low retaining walls along eastern side of hill slope". The above work is likely to be that associated with slope No. 11SW-A/C747 under the HyD's project (see Section 2.4). No inspection record of the subject slope by the consultant under the "Systematic Identification and Registration of Slopes in the Territories" (SIRST) project, which was commenced by the GEO in July 1994 to update the 1977/78 Catalogue of Slopes, was found in the GEO.

Following the December 2001 washout incident, the subject slope, together with the reinforced concrete retaining wall at the crest, was registered in the New Catalogue of Slopes as feature No. 11SW-A/FR230 in April 2002 (Figure 3).

3.3 LPM Works on Slope No. 11SW-A/FR23

According to GEO file records, slope upgrading works on the adjacent fill slope (No. 11SW-A/FR23) were carried out between August 1985 and November 1987 under the LPM Programme. The works included the construction of a cantilevered caisson wall at the slope crest to support Pokfield Road and removal of most of the loose fill. Detailed design of the upgrading works was prepared by the Design Division of the GEO and the site works were undertaken by Tai Hing (Engineers and Builders) Ltd.

The associated ground investigation (GI) works were carried out by Bachy Soletanche Group between March and April 1984 under Contract No. 2/GCO/1983. The works comprised 3 vertical drillholes and 9 trial pits. Based on the GI, the ground profile of the slope consisted of fill (about 3 m thick) overlying decomposed tuff. In situ density tests indicated that the fill material had a relative compaction of about 90%. During the LPM works, the fill was found to be much more extensive than that originally anticipated from the desk study and GI. The upgrading works were subsequently extended to the north beyond the previous slope boundary, which was then bounded by a stairway. The stairway was demolished and a new one was constructed along the new northern boundary of the feature. Upon completion of the upgrading works, the boundaries of the feature in the slope catalogue were updated and the plan area of the new feature is about twice the area of the original one.

3.4 L-shaped Reinforced Concrete Retaining Wall

After the August 1999 landslide incident on the subject slope, an L-shaped reinforced concrete retaining wall was constructed by HyD at the slope crest to support the pedestrian pavement of Pokfield Road. The retaining wall was essentially a temporary measure to enable the opening of Pokfield Road in an expeditious manner following the landslide.

On 20 October 1999, a set of design calculations for the retaining wall (which has a 3.4 m high stem and 0.6 m thick base slab) was forwarded by HyD to GEO for comment. The calculated factors of safety against sliding and overturning were 1.71 and 2.40 respectively. The maximum bearing pressure of the wall was calculated to be 88 kPa but the factor of safety against bearing failure was not determined.

In a memo addressed to HyD dated 22 October 1999, the GEO noted that "the proposed wall is constructed on the crest of a slope but the design calculation is assumed to be founded on a levelled platform". The GEO also suggested to HyD that "if the wall is considered as a permanent geotechnical feature, you may wish to review the design in accordance with the second edition of Geoguide 1 as stipulated in WBTC 7/94" and that "the overall stability of the wall should be checked with regard to the finished slope profile at its front". The GEO also requested for the submission of the as built records of the wall. In March 2003, the HyD provided the GEO with an as constructed drawing No. HHM20200-EW0001Z for the retaining wall.

Record photographs in HyD's files indicate that the reinforced concrete retaining wall was under construction in November 1999. The stop valve to the 80 mm watermain that subsequently burst in December 2001 could be seen to be protruding from the sloping ground behind the retaining wall (Plate 4). The stop valve was subsequently embedded within the backfill to the retaining wall. Record photographs taken by HyD at the time of wall construction show that a small vibratory roller was used to compact the backfill.

The 3.2 m high reinforced concrete retaining wall was not registered in the Slope Catalogue at the time of the 2001 washout incident. Following the December 2001 washout incident, the retaining wall, together with the slope below, was registered as feature No. 11SW-A/FR230. The maintenance responsibility of the feature was subsequently assigned to HyD by the SIMAR unit of the Lands Department.

Routine maintenance inspections of the retaining wall had not been carried out by HyD following its construction. As advised by HyD, the inspection records for the section of road carriageway and pedestrian pavement above the retaining wall do not indicate any significant signs of distress after wall construction in December 1999.

3.5 Site Formation Design for the Proposed Primary School

In 2000, Arch SD proposed to build a primary school on the subject slope and its vicinity at Pokfield Road. The boundary of the school development project is shown in Figure 6. The Advisory Division of the GEO was requested by Arch SD to carry out the geotechnical design of the site formation works.

The proposed site formation works included the construction of a bored pile wall at the slope crest (which was to replace the existing L-shaped retaining wall within the subject slope), formation of soil and rock cut slopes, installation of soil nails, together with recompaction of loose fill or replacement of loose fill with no fines concrete. On 8 October 2002, the Advisory Division submitted a geotechnical report on the proposed site formation works to the Island Division of the GEO for checking. The design submission was accepted by the Island Division on 20 November 2002.

Prior to the commencement of the site formation works, the proposed school project was suspended by the Secretary for Education and Manpower in January 2003.

4. PREVIOUS GROUND INVESTIGATIONS

In 1984, ground investigation (GI) works comprising three drillholes and nine trial pits were carried out for the design of LPM works on slope No. 11SW-A/FR23 which is located adjacent to the subject slope (Figure 6). The GI works were carried out by Bachy Soletanche Group under Contract No. 2/GCO/1983 and supervised by the Design Division of the GEO. Trial pits Nos. F1, F2 and F5 excavated along the southeastern boundary of the subject slope indicate fill of 0.5 m to 1.2 m in thickness, comprising fine to coarse silty sand. An insitu density test carried out at 1 m depth in trial pit No. F2 indicates that the fill tested has a relative compaction of 91%.

In 1992, six drillholes were put down by Bachy Soletanche Group over the area corresponding to the present slope No. 11SW-A/C747 for the geotechnical design in connection with the Rock Hill Street Extension project (Figure 6). None of these drillholes encountered fill.

Arch SD's contractor, Vibro (H.K.) Limited, carried out a ground investigation within the proposed school site from March to April 2001. The works included 11 vertical drillholes, six trial pits and two surface strips, which were mainly located on slope No. 11SW-A/FR230 (Figure 6). Standpipe piezometers with Halcrow buckets were installed in selected drillholes to monitor the groundwater levels. Mazier samples were taken and Standard Penetration Tests (SPT) were carried out at 2 m intervals in all drillholes. The GI indicates that the subject slope has a surface mantle of fill ranging from 1 m to 3 m in thickness and comprising generally firm sandy silt/clay with some gravel and in places cobbles and concrete fragments. Four in situ density tests were carried out. Two of these tests were within the fill material at 1 m below the slope surface and recorded dry densities of between 1.15 Mg/m^3 and 1.30 Mg/m^3. No standard compaction test was carried out in the laboratory and hence the relative compaction of the fill cannot be assessed. No SPT or GCO probes were carried out in the fill material.

In March and April 2001, GEO Materials Division's contractor, Enpack (Hong Kong) Limited, carried out a GI on slope No. 11SW-A/C565 to the west of the subject slope under the LPM Programme (Figure 6). The GI was carried out under the supervision of Fugro (Hong Kong) Limited. The investigation comprised four vertical drillholes, four trial pits and two surface strips. Seven standpipe piezometers with Halcrow buckets were installed in the four of the drillholes to monitor the groundwater levels. Fill was encountered in trial pits Nos. 34-TP4 and 34-TP5 near the crest of the slope.

The results of the groundwater monitoring carried out between April 2001 and August 2002 are shown in Figures B1 to B4 in Appendix B. The base groundwater level varied between 5 m and 23 m below the ground surface. The groundwater level was higher at the eastern portion of the proposed school site and lower within the middle and western portions of the site.

A geological cross section through the location of the 2001 washout incident based on the available GI information is given in Figure 7.

5. THE WATERMAIN BURST INCIDENT ON 14 DECEMBER 2001

The GEO Incident Report (No. 2001/12/0123) recorded that the 14 December 2001 washout was caused by a burst pressurised watermain located above the crest of the subject slope. About 30 m^3 of soil underneath the shotcrete cover of the subject slope is estimated to have been eroded by concentrated water flow during the incident.

The outwash material from the failure was largely deposited on the platform at the toe of the subject slope, although some of the outwash material cascaded down the surface of slope No. 11SW-A/C747 and reached Rock Hill Street (see Plate 2).

According to WSD's record, the watermain burst was reported to them at 8:40 a.m. on 14 December 2001. The watermain was isolated by the WSD at 10:00 a.m. As advised by WSD, the burst watermain involved an 80 mm diameter galvanized iron pipe located about 1 m below the pedestrian pavement (Figure 8), which was operating at a working pressure of about 390 kPa, burst at the time of the incident.

The subsequent investigation by WSD revealed that "external corrosion of the pipe body leading to subsequent main burst is the main cause of burst incident" and that "cracks appears on the defective pipe body". The location of the burst was within the pipe section behind the stop valve. WSD further confirmed that the burst fresh water main was constructed over 20 years ago and as such the corresponding as built record drawings could no longer be located. It is also noted that the old water main that burst on 14 December 2001 was not included in the WSD's master record plans on fresh water mains and salt water mains underneath Pokfield Road above the crest of the subject slope.

Record photograph taken by WSD (Plate 5) during the repair works shows a section of the watermain that burst on 14 December 2001. The damaged section of the watermain, together with the stop value, was removed and the remaining pipe was capped off by WSD on the same day (Plate 6).

6. FIELD OBSERVATIONS BY FMSW

FMSW inspected the site on 15 December 2001, i.e. one day after the washout incident was reported to the GEO. The burst watermain had been repaired at the time of the inspection, as evidenced by the lack of water flow on site and the presence of a newly cast section of concrete pavement at Pokfield Road. The location of the newly cast concrete on the pavement matches approximately with the location of the burst 80 mm diameter watermain.

The subject slope below the burst watermain was covered with shotcrete, which was provided with weepholes and tree rings. A 2.3 m to 3.2 m high reinforced concrete retaining wall with 75 mm diameter weepholes at 1 m spacing is present along the eastern crest of the subject slope. No signs of seepage from the weepholes of the retaining wall were observed.

A gap of about 20 mm wide was observed along the construction joint between the concrete wall stem and the pedestrian pavement of Pokfield Road near the western end of the retaining wall in the vicinity of the location of the burst watermain (see Plates 7 and 8). As a

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result of the movement, part of the mastic sealant of the construction joint had dropped into the gap (see Plate 9). No movement of the retaining wall was observed apart from this locality. No other conspicuous signs of distress or cracking were observed on the retaining wall or the pavement above.

The above observations indicate that some minor movement of the wall following completion of the construction. There was no evidence from detailed inspection of the small open gap that it had existed some time prior to the watermain burst.

Cracking of the shotcrete surface, up to 20 mm wide, was observed at several locations along the toe of the subject slope (Plate 10). Voids (subsequently found to be erosion gullies, the extent of which is shown in Figure 2) were detected underneath the shotcrete cover at the time of the inspection. There were signs of material having been washed out underneath the shotcrete cover through some weepholes and through the cracks on the shotcrete cover (Plate 10). Most of the eroded soil debris was deposited on the platform at the toe of the subject slope, covering an area of about 200 m^2 with an average thickness of about 100 mm (Plate 3). The outwash cascaded down the face of slope No. 11SW-A/C747 (Plate 2). Some of the debris was carried further down by the water from the burst watermain to Rock Hill Street via surface drainage channels and footpaths (Plate 11).

Following the 2001 incident, GEO recommended HyD on 28 December 2001 to strip off the cracked shotcrete cover to expose the extent of the erosion gully beneath. The surface stripping and the subsequent reinstatement works, comprising a new layer of 75 mm thick shotcrete cover, were carried out by HyD between January and February 2002.

The erosion gully on the surface of the subject slope is shown in Figure 2. The gully starts from the crest of the subject slope near the western end of the reinforced concrete retaining wall (i.e. opposite the location of the burst watermain section). The gully continued to the toe of the slope (Plate 12), with a maximum depth of about 1 m and a width of up to 5 m. The material exposed by the erosion gully was generally fill including some concrete fragments and boulders (Plate 13).

Based on the relative positions of the burst watermain section and the erosion gully, uncontrolled water flow resulting from the burst watermain appeared to have flowed underneath the base of the retaining wall causing erosion of the slope below (Figure 2). The lowest row of weepholes on the retaining wall (located about 0.2 m above the ground surface in front of the wall) is at an elevation of about 2 m below that of the burst watermain and it was noted that these weepholes exhibited no signs of seepage or water stain. Following the stripping of the shotcrete cover, the section below the base of the wall immediately above the erosion gully was exposed. No major signs of significant washout below the base of the retaining wall were observed by FMSW.

Based on field measurements, it is estimated that about 30 m^3 of material was eroded from underneath the shotcrete cover as a result of the watermain burst.

7. ANALYSIS OF RAINFALL RECORDS

The nearest GEO automatic raingauge (No. H02) to the subject slope is located at Kwun Lung Lau Estate, Lun Wah Street, about 300 m to its southwest. The daily rainfall for the period six weeks preceding and two weeks following the incident is presented in Figure 9. The records show that there was very little rainfall in the month before the incident. No rainfall was recorded in the three days before the burst of the old watermain.

Analysis of the return periods of the rainfall intensities between December 1999 (i.e. after construction of the L-shaped retaining wall) and the date of the washout incident using the rainfall data recorded by raingauge No. H02 has been carried out with reference to the historical rainfall data at the Hong Kong Observatory (Lam & Leung, 1994). The results are given in Table 1. The analyses show that during the above period, the maximum 31 day rolling rainfall of 1237 mm was the most severe (the end date being 6 July 2001), with a corresponding return period of about 61 years. Based on the available groundwater monitoring records (see Section 4), the rise in the groundwater level at the subject shotcreted slope was not significant, with a maximum storm response of about 1 m.

8. ENGINEERING ANALYSES

Engineering analyses were carried out by FMSW to assist in the diagnosis of whether possible slope or wall instability, or excessive ground movement, could have contributed to the watermain burst incident. Both retaining wall stability calculations and displacement calculations were undertaken.

The stability of the L-shaped retaining wall was checked for different potential modes of failure, viz. sliding, overturning, bearing capacity and overall slope stability for the period after wall construction and before the watermain burst incident. Further calculations were carried out to assess the likely stability condition at the time of the watermain burst. Displacement calculations were also carried out for the same two scenarios.

The geometry of the L-shaped wall and the ground profile in front was based on the as-built records of the retaining wall, past GI information and post failure topographic survey arranged by FMSW. The wall stability and wall displacement analyses adopted the range of shear strength parameters previously used by the Advisory Division for the design of the bored pile wall based on site specific GI data (Section 4). Sensitivity analyses were also carried out under the present study and it was found that the results of the wall displacement analyses were not sensitive to the variation of the strength parameters within the expected range.

The assumption on the groundwater level before the watermain burst was based on the groundwater monitoring records for the subject slope, which show that the groundwater level is below the base of the retaining wall. Following the watermain burst, the groundwater level was assumed to have elevated up to the level of the lowermost row of weepholes behind the wall (see Section 6) and that a perched water table was taken to have built up within the fill mantle to the slope in front.

Factors of safety against sliding, overturning and bearing capacity failure of the L-shaped wall were calculated in accordance with the First Edition of Geoguide 1 (GCO, 1982). The overall slope stability analyses were carried out using the rigorous solution of Morgenstern & Price (1965) using the computer program SLOPE/W.

The calculated factors of safety are summarised in Table 2. It can be seen from Table 2 that prior to the watermain burst, the safety margins are well above the minimum required standards. Following the watermain burst, the calculated factors of safety for the various failure modes have reduced due to the adverse groundwater condition but they remain well above unity, i.e. the wall and the slope was not close to instability for the failure modes considered. The washout failure mode is not amenable to conventional calculations.

In the retaining wall calculations, the resultant force was found to be within the middle third of the wall base for both conditions, i.e. before and after the watermain burst. Thus, the incremental wall movement due to the more adverse groundwater condition following the watermain burst is not expected to be significant. As an independent check, the likely wall movement was also quantified using an analytical framework based on the assumption of a simplified plastic deformation mechanism (Sun, 1990). Ground movements underneath spread footings can be related to the mobilisation of shear strength and the corresponding strain level in the founding material via the assumed plastic deformation mechanism. The approach has been shown by Bolton & Sun (1991) to give realistic ground movement predictions for abutment walls or embankment on stiff ground. Figure 10 shows the assumed plastic deformation mechanism of the founding material in the calculation of the movement of the L-shaped wall.

The calculations show that the movement of the retaining wall prior to the watermain burst was negligible (i.e. 1 to 2 mm movement of the top of the wall stem). Following the watermain burst, the calculations predict that the top of the wall stem would move forward by a further 15 mm to 20 mm. The above is consistent with the post failure site observations for the wall section close to the location of the burst watermain.

9. DIAGNOSIS OF THE PROBABLE CAUSES OF THE INCIDENT

The watermain burst and washout incident occurred in the dry season. The burst watermain below the pedestrian pavement to Pokfield Road was about 3 m behind the L-shaped retaining wall and the slope in front of the wall was shotcreted. In view of this, the potential for direct surface infiltration is low. Also, there was practically no rainfall preceding the incident. There were also no signs of any leakage from the other water carrying services in the vicinity. Hence, the soil behind and in front of the retaining wall was likely to be in a partially saturated state and had higher shear strength than that in a saturated state. The wall was constructed in December 1999 following a landslide and since then no major signs of distress of the area above the wall were observed by HyD during their road maintenance inspections. Also, there were no signs of water seepage or water stain from the weepholes of the retaining wall. Stability calculations demonstrate that the calculated factors of safety of the wall and the slope exceed the minimum required standards, taking into account the results of site specific ground investigation and groundwater monitoring results. Movement calculations also show that the likely wall displacement given the most severe rainstorm (return period about 60 years) experienced after construction

was negligible. Thus, it can be concluded that the watermain burst was not triggered by impending instability or excessive movement of the retaining wall in front.

The end of the concerned watermain was exposed following the August 1999 landslide during the construction of the L-shaped retaining wall (Section 3.4). As the end of the watermain with a stop valve was embedded within the compacted backfill to the retaining wall, there would have been some compaction induced stresses on the watermain. However, the compaction-induced stresses to the watermain would not have been significant as only a small vibratory roller was used for compaction. The pressurised watermain did not suffer any damage (leakage or bursting) at the time of the landslide or during wall construction. The 14 December 2001 watermain burst incident occurred some two years after wall construction. The above suggests that the watermain burst incident was unrelated to the previous landslide and the subsequent backfilling work.

The investigation carried out by WSD after the incident indicated that watermain burst was caused by external corrosion of the pipe body which was more than 20 years old. Leakage detection tests carried out by WSD on their installations at different times (see Section 2.2) indicated that there was no leakage in the period after construction of the L-shaped retaining wall and before the burst of the pressurised watermain.

Following the watermain burst, uncontrolled water flow took place for more than an hour before the water supply was isolated. During this time, significant erosion of the material in front of the wall was caused by the concentrated subsurface water flow, leading to a washout of about 30 m^3 of material. The water ingress into the ground would also have led to wetting up of the soil and local transient build up of water pressure. This would have a destabilising effect on the retaining wall. Calculations suggest that the reduction in the factors of safety of the wall would not be significant and that the top of the affected wall portion could move forward by about 15 mm to 20 mm. This is consistent with the field observations made for the wall section close to the burst watermain.

Given that the burst watermain involved a galvanised iron pipe, WSD considered that "for this type of pipe burst due to corrosion, water would first escape from the corroded section of the pipe body long before its ultimate failure. Consequently, water seepage should be seen coming out from the weepholes of the adjacent retaining wall and/or from the shotcrete slope before the main burst incident in December 2001". However, as there were no signs of water seepage or water stain from the weepholes of the retaining wall, WSD opined that "It is very rare for metal pipe with rigid joint failure due to corrosion without first displaying any signs of water leakage".

Based on the advice of the WSD, leakage from the corroded watermain probably occurred for some period of time before the burst. As there is a shotcrete cover to the temporary cut face behind the retaining wall and that the compacted soil fill in front of the shotcreted cut face is likely to be less permeable than the loose fill where the abandoned watermain was embedded, leakage from the watermain would tend to flow through the loose fill and probably underneath the retaining wall towards the slope in front, which also has loose fill (see Figure 8). The water ingress would have wetted up the ground below and behind the retaining wall and probably resulted in local build up of water pressure behind the compacted fill to the retaining wall. This in turn led to wall displacement and bursting of the

watermain. The above postulation would explain why no signs of seepage were seen from the weepholes in the retaining wall (see Section 6).

10. DISCUSSION

The section of the pressurised watermain that burst during the dry season on 14 December 2001 was not included in WSD's master record plans. Based on a review of the site development history, it is possible that the watermain used to supply water to the squatters below this section of Pokfield Road, which were cleared in the late 1970's. The abandoned watermain, which is close to the crest of the slope, was not removed in entirety. This would pose a hazard to slope stability in the event of leakage or bursting.

Prior to the 2001 washout incident, there were two past instabilities of the slope in the same locality in 1980 and 1999 respectively. According to the available records, the causes of these previous incidents were associated with leakage or bursting of water carrying services. The incidents occurred below a bend of Pokfield Road. There are no records to indicate whether or not any thrust blocks are present to secure the pipes in place along the bend. It is not certain whether this played a contributory role to the previous incidents or not.

The 14 December 2001 washout incident exposed fill material on the subject slope. The fill mantle is about 2 m thick. During the upgrading of the adjacent registered fill slope (No. 11SW-A/FR23) under the LPM Programme in the mid 1980's, the slope registration boundary was extended because the fill extent was found to be much more extensive during the construction stage. The extended boundary of feature No. 11SW-A/FR23 did not cover the subject slope where fill is also present. The presence of fill on the subject slope was also noted in the API carried out by GEO in 1992 for the Rock Hill Street Extension project. Under the SIFT study, the subject area was designated as "work in progress". The GI carried out in early 2001 on the subject slope as part of the proposed school development project also identified fill and insitu tests were carried out. At the time of the 14 December 2001 washout incident, the fill slope and the crest retaining wall (which was more than 3 m in height and constructed in December 1999) were not registered in the Slope Catalogue.

11. CONCLUSIONS

The 14 December 2001 washout incident was caused by uncontrolled subsurface water flow resulting from a burst pressurised watermain behind the slope crest, which was more than 20 years old and not included in WSD's master record plan. According to WSD's investigation, the watermain burst was caused by external corrosion of the pipe body.

The burst watermain was about 3 m behind a crest retaining wall to a shotcreted slope. The study has established that there was probably negligible movement of the slope or the retaining wall prior to the 14 December 2001 incident. Based on the advice of the WSD, leakage from the corroded watermain probably occurred for some period of time before the burst. In this instance, water ingress arising from the leakage from the corroded and abandoned watermain would have wetted up the ground and probably resulted in local build up of water pressure behind the retaining wall. This led to wall displacement and bursting of

the watermain. It is likely that progressive deterioration of the condition of the old pressurised watermain, as evidenced by dilapidated state of the corroded pipe, played a key role in the burst of the watermain.

12. REFERENCES

Bolton, M.D. & Sun, H.W. (1991). The behaviour of bridge abutments on spread foundations. Proceedings of the 10th European Conference on Soil Mechanics and Foundation Engineering, Florence, vol. 1, pp 319-322.

Geotechnical Control Office (1982). Guide to Retaining Wall Design (Geoguide 1). Geotechnical Control Office, Hong Kong, 153 p.

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

Morgenstern, N.R. & Price, V.E. (1965). The analysis of the stability of general slip surfaces. Geotechnique, vol. 15, pp. 79-93.

Sun, H.W. (1990). Ground Deformation Mechanisms for Soil-Structure Interaction. PhD Dissertation, Cambridge University, 250 p.

LIST OF TABLES

Table 1 - Maximum Rolling Rainfall at GEO Raingauge No. H02 from 1 December 1999 to 4 December 2001 and the Estimated Return Periods

Duration	Maximum Rolling Rainfall (mm)	End of Period	Estimated Return Period (Years) (See Note 2)
5 Minutes	15.5	22:10 hours on 12 August 2001	5
15 Minutes	37.0	05:55 hours on 12 June 2000	8
30 Minutes	62.0	06:00 hours on 12 June 2000	9
1 Hour	97.0	06:00 hours on 12 June 2000	25
2 Hours	144.5	04:10 hours on 24 August 2000	16
4 Hours	202.5	04:20 hours on 24 August 2000	13
8 Hours	203.0	04:20 hours on 24 August 2000	4
12 Hours	206.0	04:20 hours on 24 August 2000	3
24 Hours	206.0	04:20 hours on 24 August 2000	2
48 Hours	276.5	14:10 hours on 9 June 2001	2
4 Days	448.5	13:15 hours on 9 June 2001	5
7 Days	596.5	11:15 hours on 12 June 2001	11
15 Days	727.5	09:55 hours on 9 September 2001	9
31 Days	1237.0	18:45 hours on 6 July 2001	61

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 statistical parameters from Evans & Yu (2000). The return periods obtained by the two methods do not show a significant difference.

Table 2 - Factors of Safety Against Various Modes of Failure of the L-shaped Retaining Wall

	Condition before the 14 December 2001 Watermain Burst Incident	Condition at the 14 December 2001 Watermain Burst Incident
Sliding	1.82	1.39
Overturning	4.55	2.77
Bearing Capacity	4.0	2.2
Overall Slope Stability	1.53	1.36

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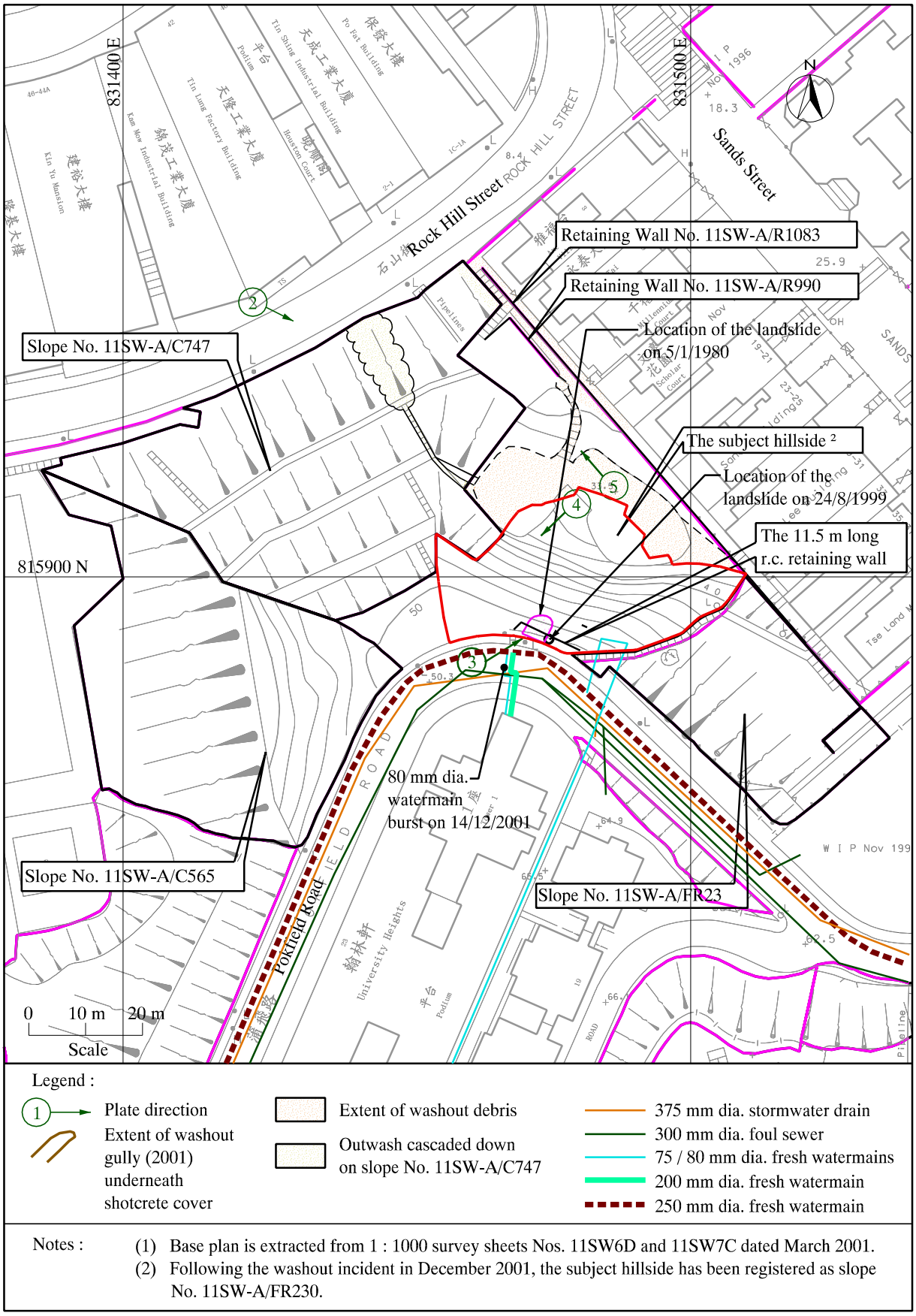

Figure 1 - Site Plan

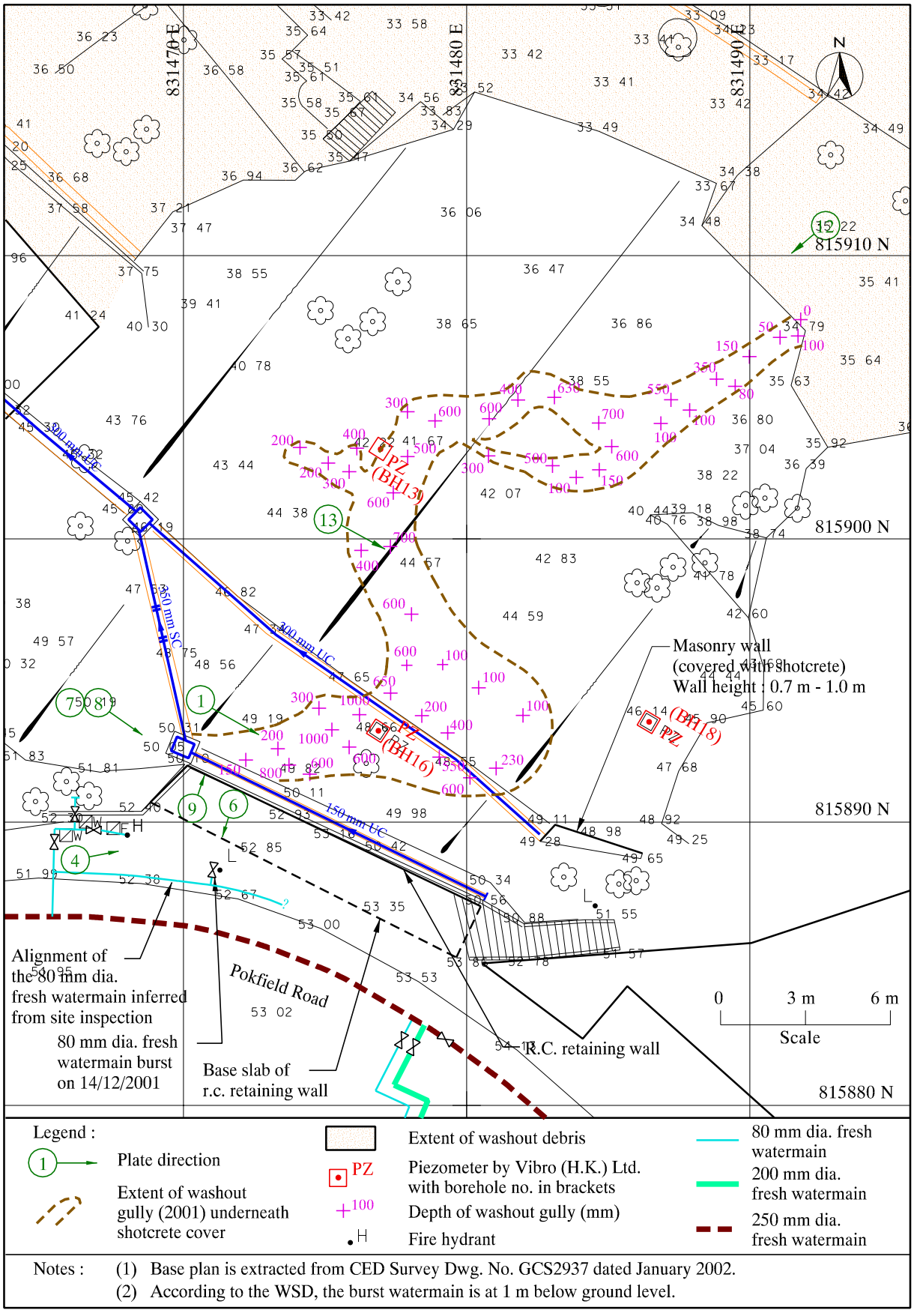

Figure 2 - Plan of the Washout Scar

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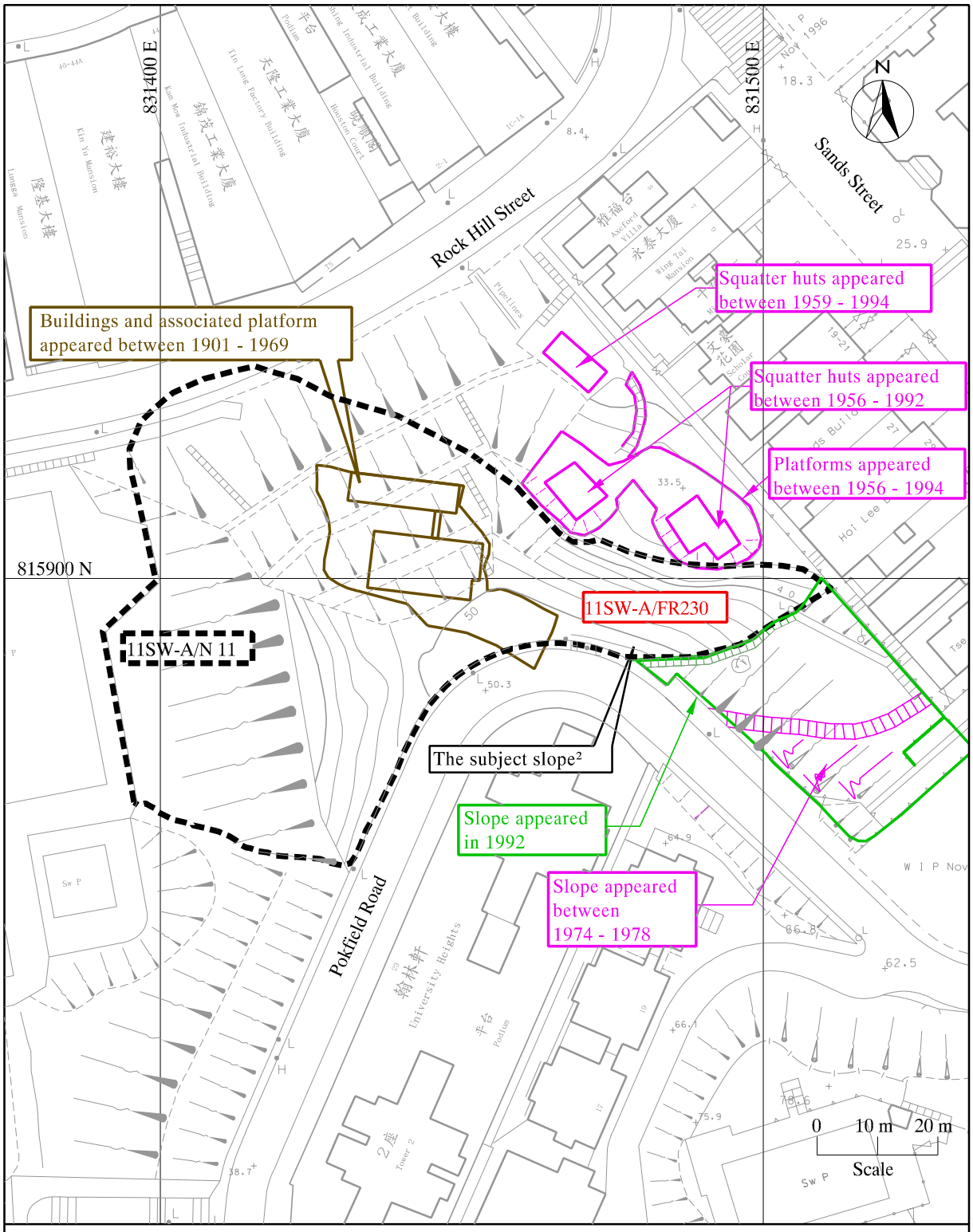
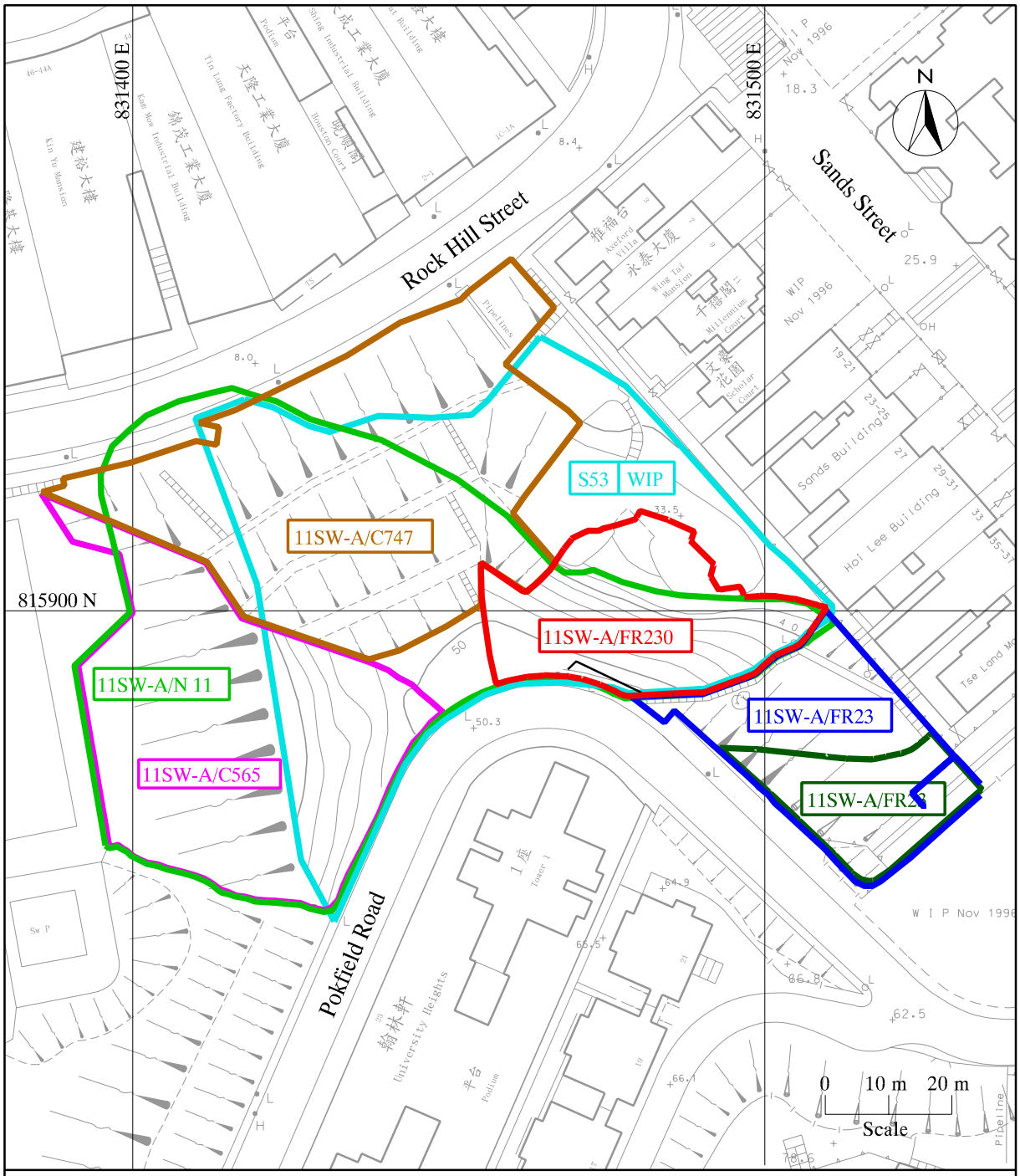


Figure 3 - Site History



Legend :

- 11SW-A/N11 in 1978
- SIFT Feature 11SW-6D/S53 in 1995
- 11SW-A/C747 in 1998
- 11SW-A/C565 in 1997
- 11SW-A/FR230 in 2002[2]
- 11SW-A/FR23 Pre - '1985/87 LPM'
- 11SW-A/FR23 Post - '1985/87 LPM'

Notes :

(1) Base plan is extracted from 1 : 1000 survey sheets Nos. 11SW-6D and 11SW-7C dated March 2001.
(2) Following the washout incident in December 2001, the subject slope has been registered as slope No. 11SW-A/FR230.

Figure 4 - Slope Registration History

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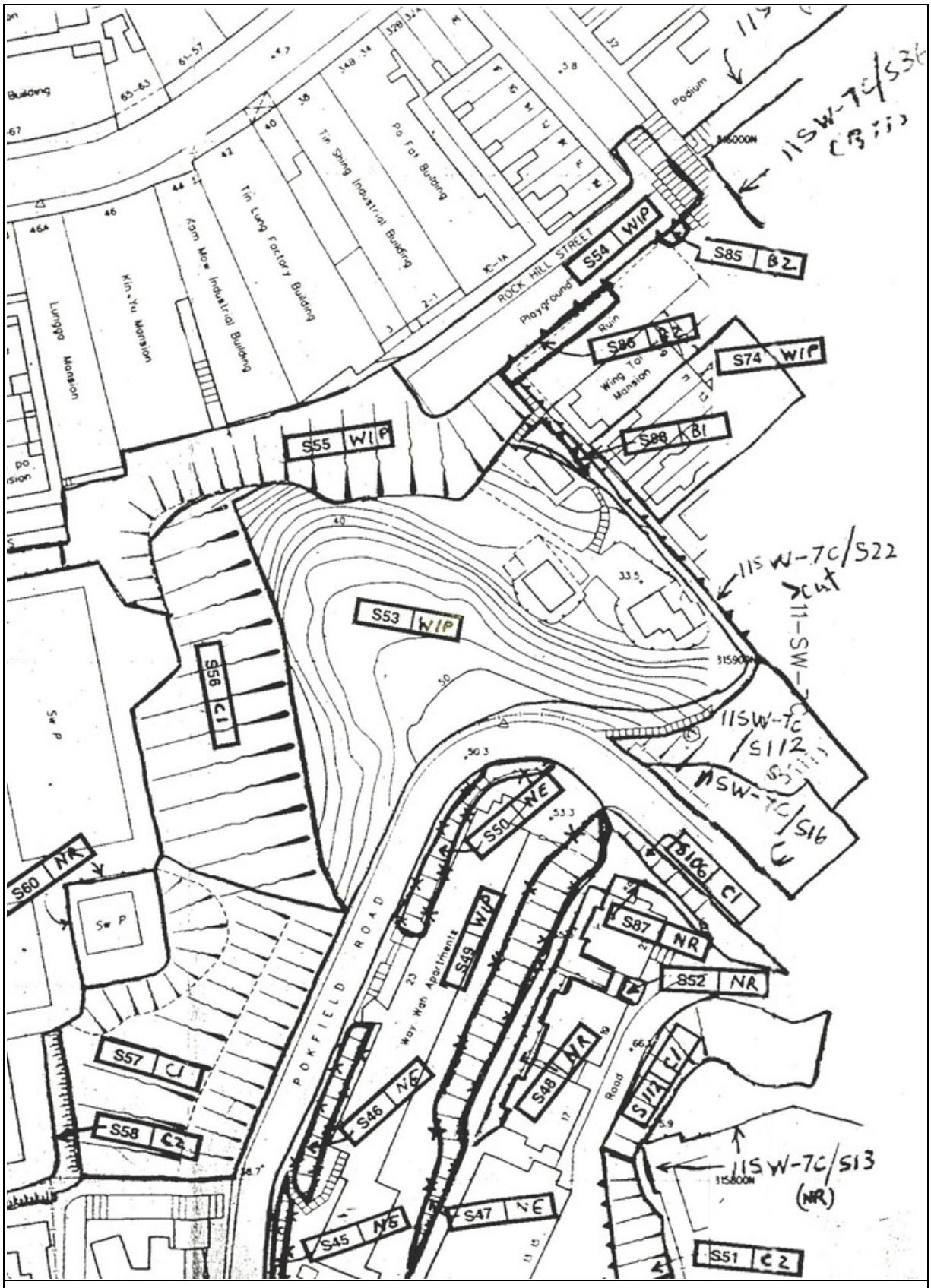


Note Plan is extracted from SIFT Report No. 11SW-7C.

Figure 5 - Part-copy of Related SIFT Plan

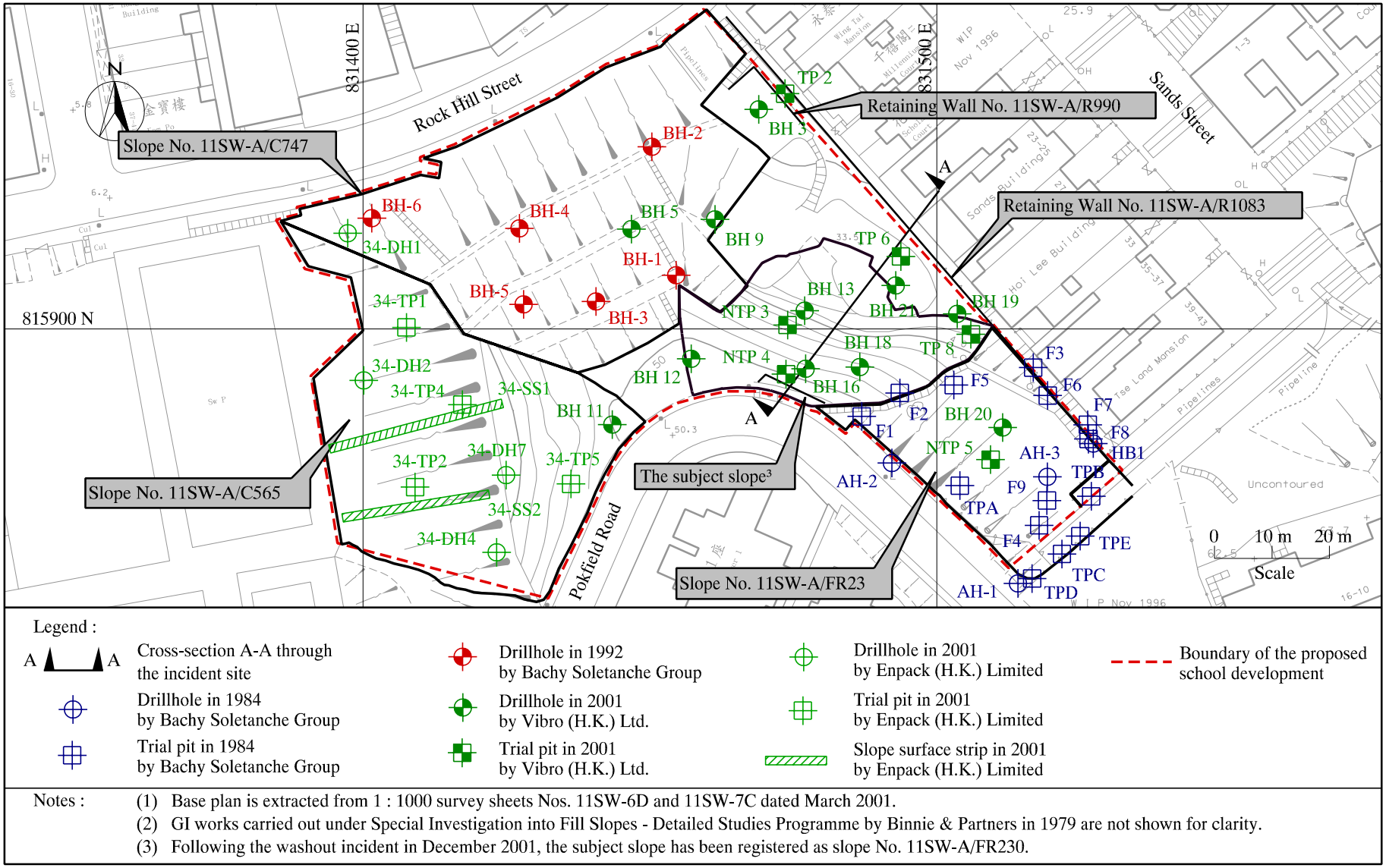
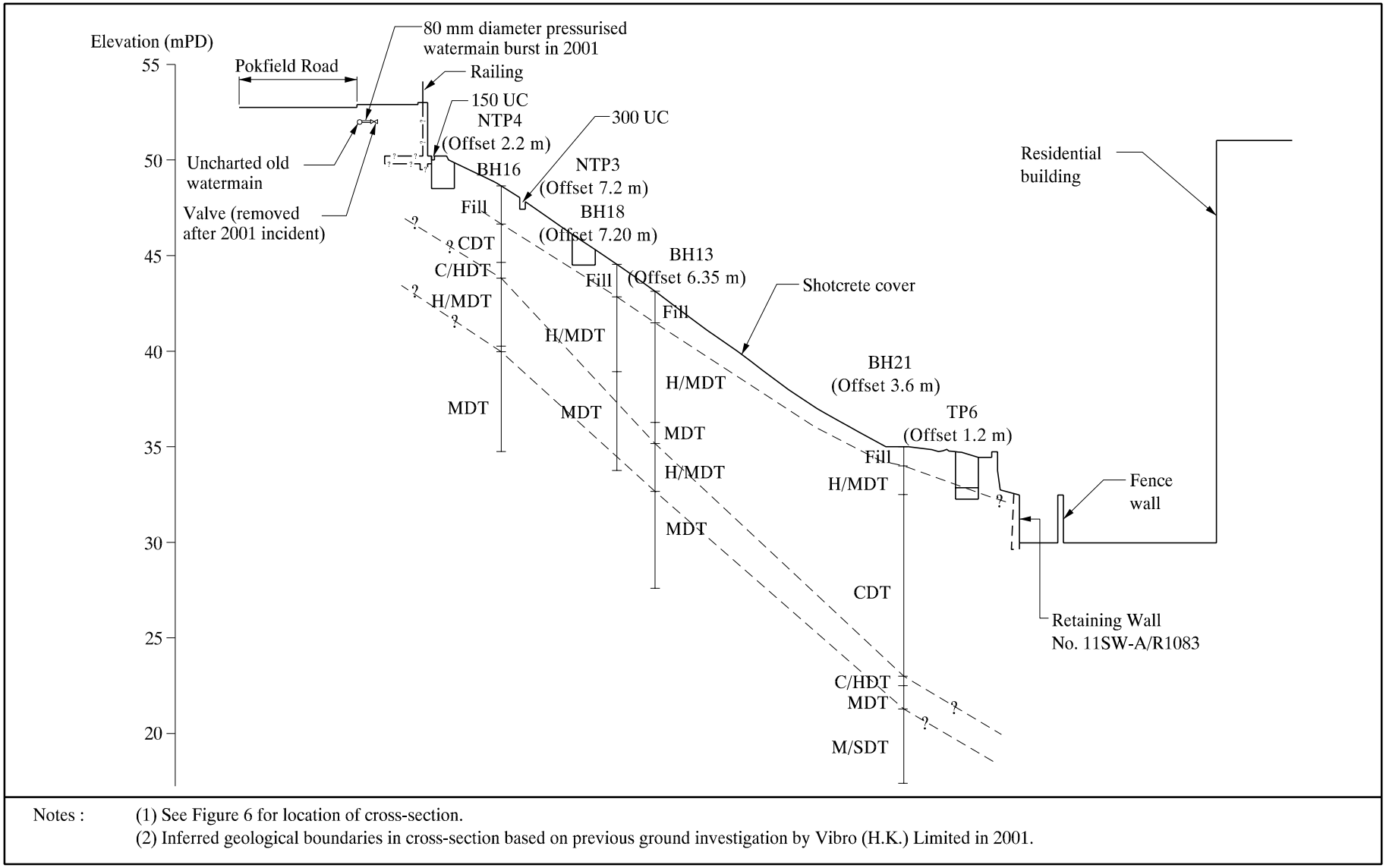
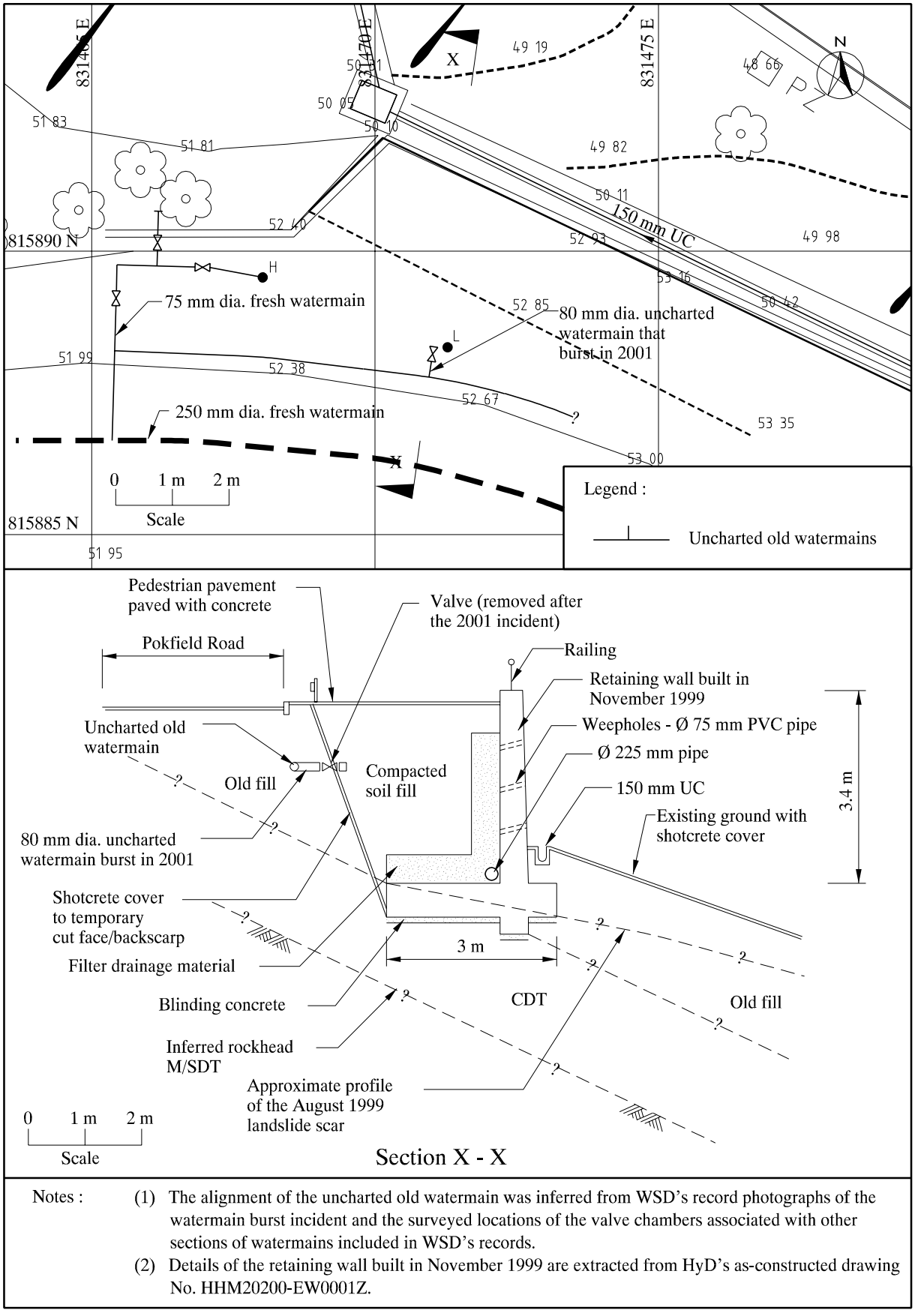


Figure 6 - Plan of Previous Ground Investigation



Notes : (1) See Figure 6 for location of cross-section.
(2) Inferred geological boundaries in cross-section based on previous ground investigation by Vibro (H.K.) Limited in 2001.

Figure 7 - Cross-section A-A through the Incident Site



Notes :

(1) The alignment of the uncharted old watermain was inferred from WSD's record photographs of the watermain burst incident and the surveyed locations of the valve chambers associated with other sections of watermains included in WSD's records.

(2) Details of the retaining wall built in November 1999 are extracted from HyD's as-constructed drawing No. HHM20200-EW0001Z.

Figure 8 - Location of the Burst Watermain

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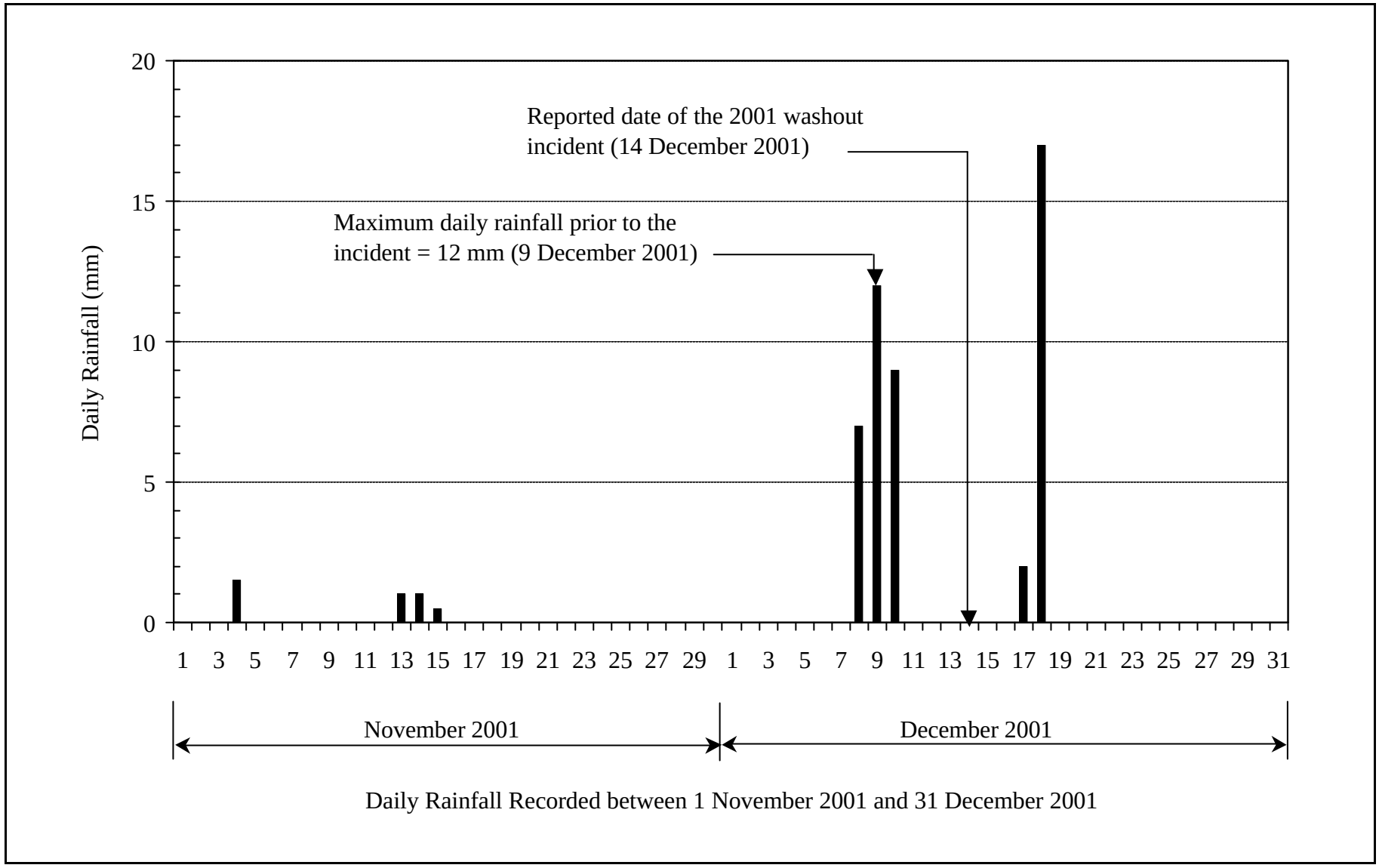

Figure 9 - Rainfall Recorded at GEO Raingauge No. H02

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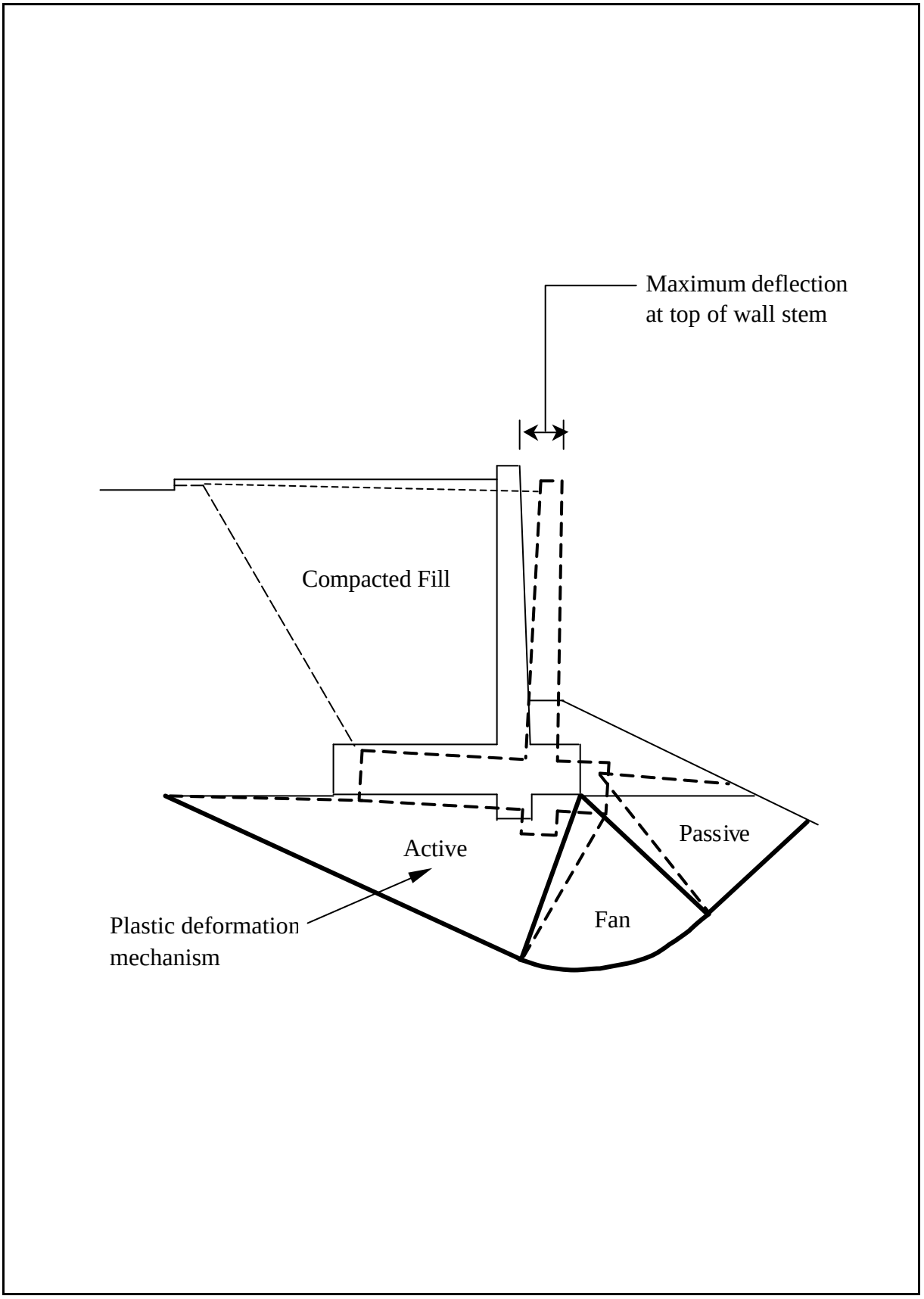

Figure 10 - Ground Deformation and Wall Movement Calculation using Plastic Deformation Mechanism Calculations

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Plate 1 - Washout of Soil from underneath the Shotcrete Cover at the Subject Slope
(Photograph taken on 4 February 2002)

Plate 2 - Outwash Cascaded down the Face of Slope No. 11SW-A/C747
(Photograph taken on 15 December 2001)

Note: See Figures 1 & 2 for locations of photographs.

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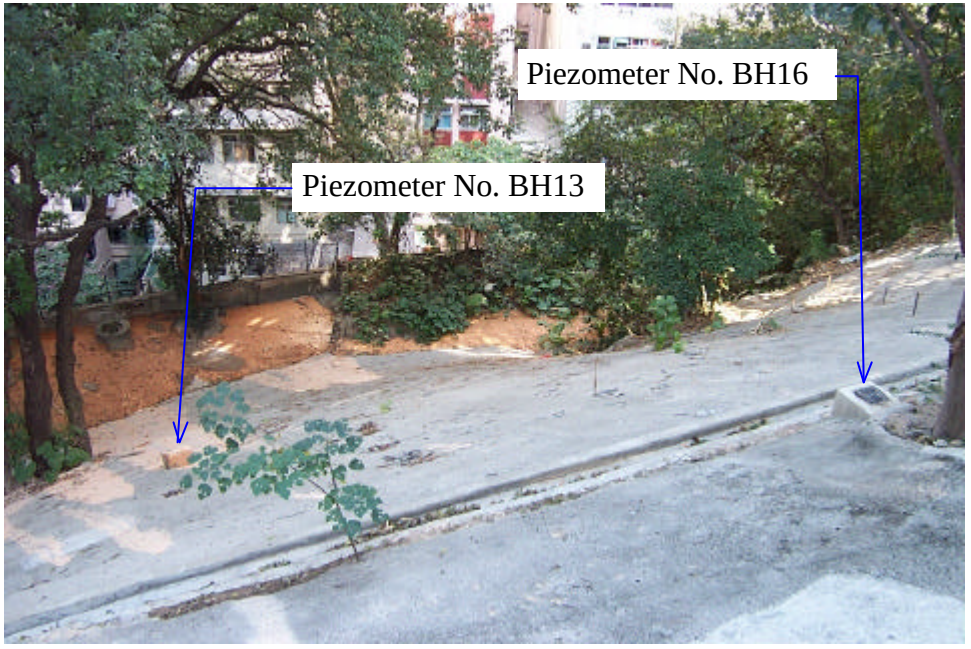

Plate 3 - Washout Debris Deposited on the Platform at the Toe of the Subject Slope
(Photograph taken on 15 December 2001)

Note: See Figure 1 for location of photograph.

Plate 4 - L-shaped Retaining Wall being Constructed After the August 1999 Landslide Incident
(Photograph taken in November 1999 by HyD)

Plate 5 - Corroded Watermain and Stop-valve Removed
(Photograph taken on 14 December 2001 by WSD)

Note: See Figure 2 for locations of photographs.

Plate 6 - The Burst Watermain Capped
(Photograph taken on 14 December 2001 by WSD)

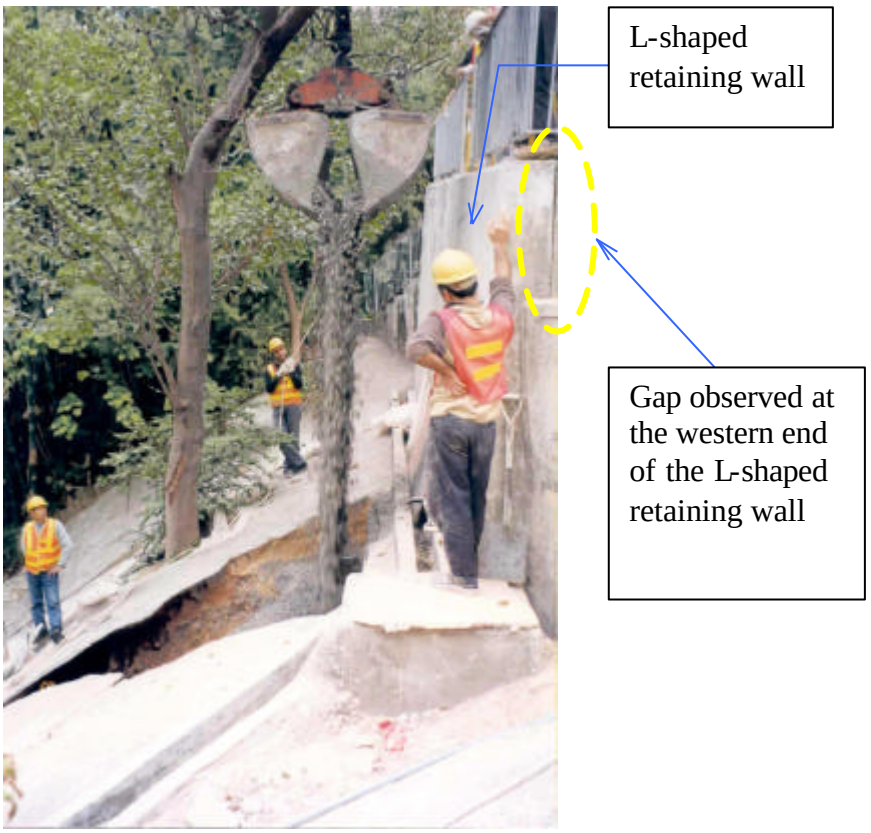

Plate 7 - Filling of No-fines Concrete After the December 2001 Washout Incident
(Photograph taken after the 14 December 2001 watermain burst)

Note: See Figure 2 for locations of photographs.

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Plate 8 - Gap Observed at the Western End of the Wall
(Photograph taken after the 14 December 2001 watermain brust)

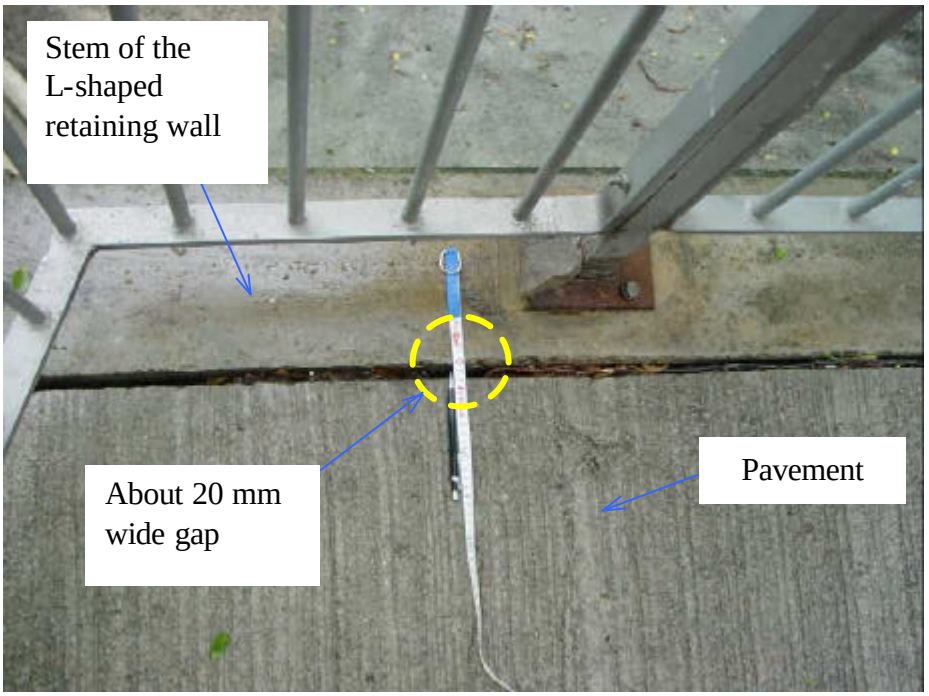

Plate 9 - Gap Observed at the Western End of the Wall Crest
(Photograph taken after the 14 December 2001 watermain brust)

Note: See Figure 2 for locations of photographs.

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Plate 10 - Washout of Soil at the Subject Slope through Weepholes and Cracks on the Shotcrete Cover
(Photograph taken on 15 December 2001)

Note: See Figure 1 for location of photograph.

Plate 11 - Washout Debris Deposited along a Footpath Leading to Rock Hill Street (Photograph taken on 15 December 2001)

Plate 12 - Erosion Gully at the Subject Slope (Photograph taken on 25 February 2002)

Note: See Figures 1 & 2 for locations of photographs.

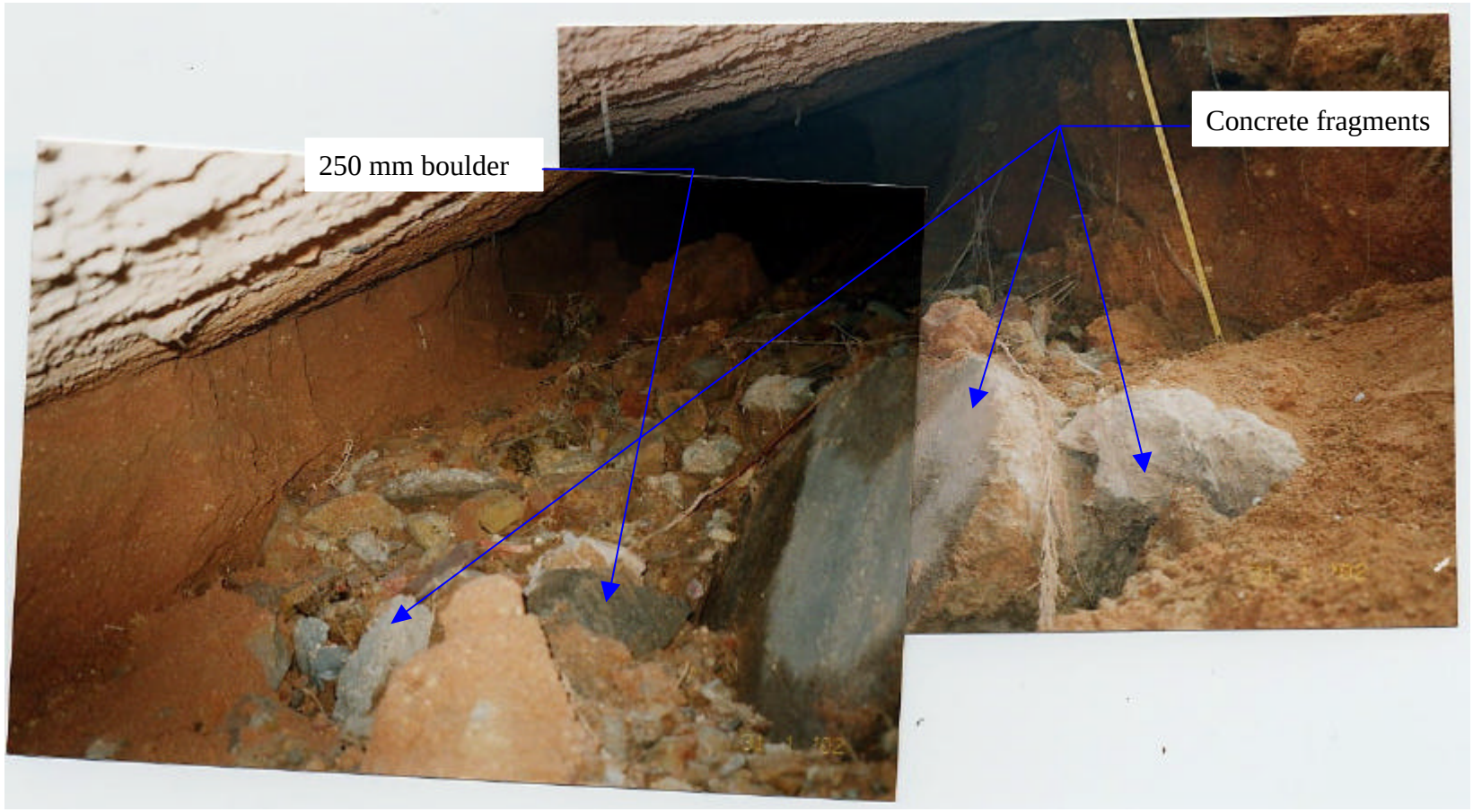

Plate 13 - Concrete Fragments and Boulders Exposed within the Erosion Gully
(Photograph taken on 31 January 2002)

Note: See Figure 2 for location of photograph.

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APPENDIX A

AERIAL PHOTOGRAPH INTERPRETATION

CONTENTS

A1. DETAILED OBSERVATIONS

The following report comprises the detailed observations made from an aerial photographic review. A list of the aerial photographs studied and a location plan (Figure A1) are also attached.

YEAR	OBSERVATIONS
1924	The study area is located on a northeasterly facing hillside on a north-south trending spur that is predominantly covered with dense vegetation. A footpath/unpaved road (probably Pokfield Road before realigned to its present form) was noted extending from Pok Fu Lam Road westward towards Smithfield Road. Buildings (shown as B1 in Figure A1) are observed at a small distance from the toe of the study area. A reflective patch was noted at a site immediately above the study area. Due to the poor (over exposed) quality photograph it is difficult to ascertain the precise nature of the material. Possibly the reflective area indicates the formation of a shallow fill or cut platform on top of the spurline as it is the location of a house observed in the 1949 photographs.
1945	A rectangular building (shown as B2 in Figure A1) has been constructed just above the footpath (Pokfield Road). Immediately adjacent to the footpath (southwest of the study area), what appears to be a cultivation terrace (shown as CT1 on Figure A1) can be observed.
1949	A small group of buildings (shown as B3 in Figure A1) have been constructed directly above and to the west of the study area. A new zigzag footpath has been formed through the study area extending from these buildings (B3) down to the toe of the study area and leading to the buildings at Sands Street. There appears to be two spoon-shaped topographic depressions at the toe of the hillside immediately northwest of the study area, they appear to have terminated behind the buildings that are situated at the present Rock Hill Street.
1956	The vegetation on the study area appears to have become denser, possibly obscuring the zigzag footpath that was previously observed in the 1949 photographs. A squatter hut with a square roof has been constructed immediately below the study area.
1961	Pokfield Road has now been realigned and paved. A large multi-storey residential building (Way Wah Apartments) has been constructed above Pokfield Road in the location of the building B2 shown in Figure A1. A large reflective patch is noted on the study area, possibly indicating that vegetation has been removed or that fill material has been placed onto the slope. Two buildings (B4 and B5), possibly squatter huts have been erected on the terraces below the study area.

YEAR	OBSERVATIONS
1963	A footpath appears to have been formed between Pokfield Road and the buildings at the toe of the slope (at Sands Street). The squatter hut observed the 1956 photographs could not be seen and probably obscured by vegetation. Some modification works, possibly for the formation of cultivation terraces, at the toe of the subject hillside were observed. Two smaller squatter huts have been erected at the elevation higher than the 1956 squatter hut.
1967	A relatively large portion of the hillside on the eastern flank of the spur (at approximately the location of the present slope No. 11SW-A/FR23) appears to have been covered with chunam. The vegetation on the study area appears to have become more dense, with trees obscuring the squatter huts observed in 1963.
1969	The large house (B3) directly above the study area observed in the 1949 photographs has been demolished leaving a large bare surface above the study area. No other significant changes are observed, except some building works at Sands Street.
1972	Poor visibility of the study area, due to the flight height of the aerial photograph, is noted. The large bare surface that was observed in the 1969 photographs has now been overgrown with vegetation. The area (at the location of the present slope No. 11SW-A/C747) immediately northwest of the study area has had the toe area cutback.
1975	These photographs are of very poor quality (appears out of focus) and are high flight, no observable changes noted.
1976	The slope (at the location of the present slope No. 11SW-A/C747) immediately northwest of the study area has been recently cutback. Areas of exposed soil are visible on the upper portion of the slope. Vegetation on the study area has been partially cleared, probably during the works on the slope (at the location of the present slope No. 11SW-A/C747).
1978	Only one squatter hut is visible below the study area, due to the dense vegetation and trees growing on the study area. No other significant changes observed.
1980	All squatter huts have now disappeared underneath the trees. No other significant changes observed.
1982	Vegetation has been removed from the area (at the location of the present slope No. 11SW-A/C747) north of the study area. Vegetation has also been partially cleared from the study area and its adjoining toe platform (approximately 30%). No other significant changes observed.
1984	Large trees have been removed from the study area and its adjoining toe platform, leaving only shrubs and sparse vegetation on the slope. No other significant changes observed.

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YEAR	OBSERVATIONS
1986	The area on which the large house (shown as B1 in Figure A1) observed between 1949 and 1969 has been cleared of vegetation again. A retaining wall appears to have been recently constructed adjacent to Pokfield Road, immediately above slope No. 11SW-A/FR23.
1987	The majority of the vegetation (approximately 90%) that was covering slope No. 11SW-A/FR23 has been removed. Possibly due to the upgrading works, after the construction of the retaining wall in 1986. No other significant changes observed.
1988	Slope No. 11SW-A/FR23 has now been covered with shotcrete. Tree rings are visible on the slope surface. No other significant changes observed.
1989	No significant changes observed.
1990	The area directly above the study area has been overgrown with vegetation again. No significant changes observed.
1992	The large rectangular residential building (B2) above Pokfield Road constructed in 1945 has now been demolished. Work appears to be in progress at the site. No other significant changes observed at the study area.
1993	No significant changes observed.
1994	No significant changes observed.
1995	Two new residential buildings have been constructed at the site where the building was demolished in 1992. The cut slope (No. 11SW-A/C747) directly northwest of the study area is in the process of being modified and appears to be nearly completed. The two lowermost batters of slope No. 11SW-A/C747 have been shotcreted, while the top two batters have been hydroseeded. A bare reflective patch at the western portion of the study area appears to have been formed, possibly indicating the formation of a cut slope.
1996	The study area has now become overgrown with vegetation.
1997	No visible changes have occurred to the study area. Vegetation has begun to grow on slope No. 11SW-A/C747.
1998	No noticeable changes observed at the study area (the view of study area is partially obscured due to an unfavorable viewing angle of the photographs).
1999	No observable changes are noted at the study area.
2000	The study area appears to have been shotcreted.

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Table A1 - List of Aerial Photographs

Date Taken	Flight Height (feet)	Aerial Photograph	Coverage
1924	11100	Y00023-5	V. Poor
11-Nov-1945	20000	Y0422-4	V. Poor
25-May-1949	8600	Y01498-9	Good
27-Dec-1956	16700	Y03180-1	Poor
17-Jan-1961	30000	Y04792-3	V. Poor
2-Feb-1963	2700	Y07527-8	Good
1-Feb-1963	2700	Y07600	Not Stereo
16-May-1967	6250	Y13299	Not Stereo
Nov-1969	Unspecified *	Y14655	Not Stereo
3-Oct-1972	13000	2303	Not Stereo
23-Nov-1975	10000	Y16398-9	V. Poor
28-Jan-1976	4000	12599	Not Stereo
5-Dec-1978	4000	23931	Not Stereo
4-Nov-1980	5500	32060-3	Excellent
28-Jul-1982	3500	43073-4	Good
2-Mar-1984	4000	53624-6	Good
20-Sep-1986	4000	A05941-2	No overlap
9-Sep-1987	4000	A10279-80	Good
27-Sep-1988	4000	A14381-2	Excellent
15-Aug-1989	4000	A17608	Not Stereo
14-Nov-1990	4000	A23752	Not Stereo
15-Oct-1992	4000	A32490-1	Excellent
9-Jul-1993	4000	A35379-80	Excellent
5-May-1994	4000	CN6846-7	Excellent
7-Dec-1995	3500	CN12596-7	Good
18-Nov-1996	5000	CN15690-1	Good
16-May-1997	4000	CN17065-6	No overlap
26-May-1997	4000	CN17075-7	Good
26-May-1997	4000	CN17067-8	Poor
31-Oct-1998	4000	CN22119-20	Good
4-Aug-1998	2500	CN20931-2	Good
3-Nov-1999	5000	CN23998	Not Stereo
3-Nov-1999	5000	CN23992-3	Poor
4-Jun-1999	2500	CN22921-2	Poor
19-Apr-2000	2500	CN26307-8	Excellent
26-Jul-2000	2500	CN27544-5	Excellent

Notes: (1) All aerial photographs are in black and white except those denoted with a CN prefix besides the photograph number.

(2) The flight height of the 1969 aerial photograph is not specified and estimated to be less than 4000 feet.

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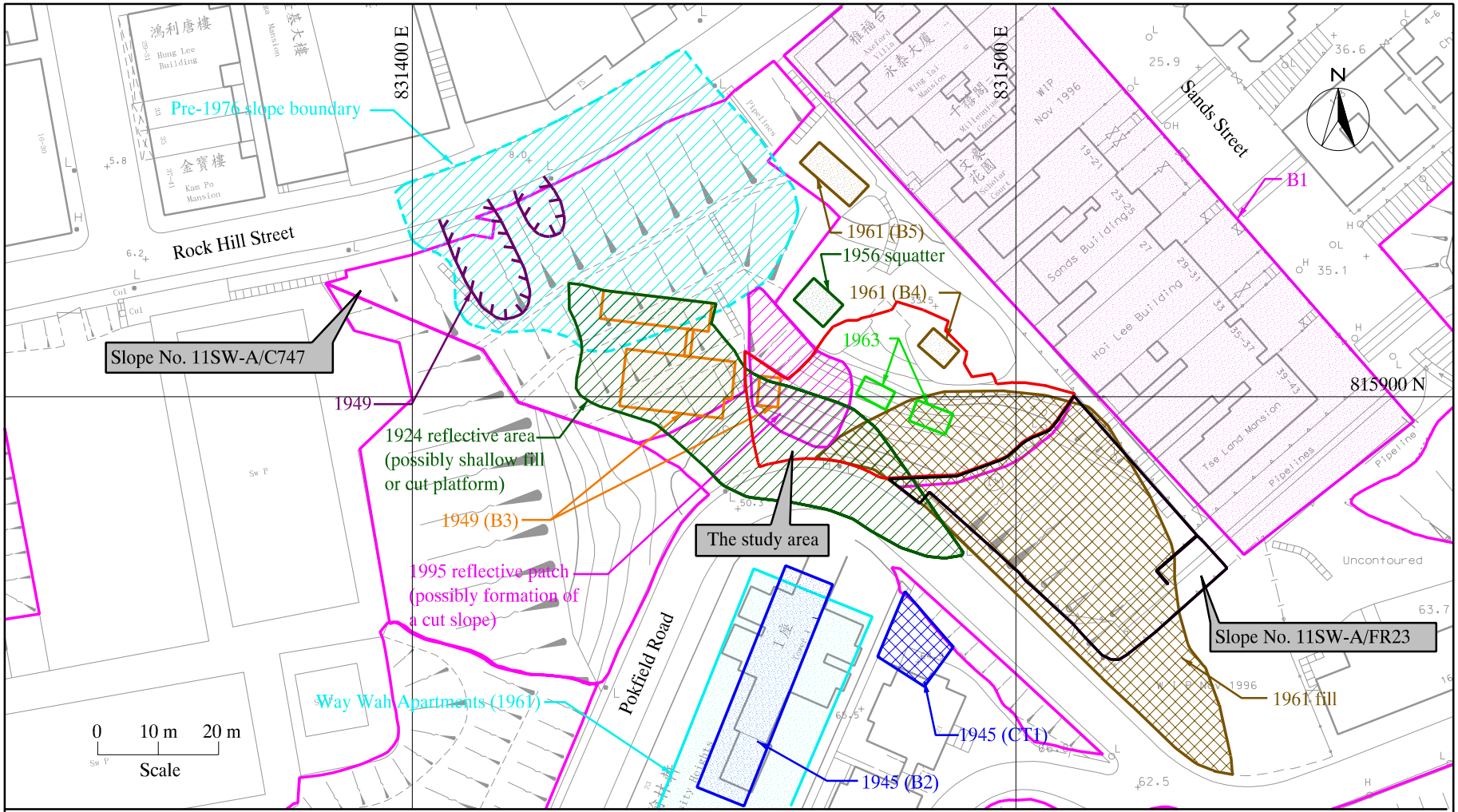

Figure A1 - API Plan

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APPENDIX B

GROUNDWATER MONITORING RECORDS

(Abstracted from the Geotechnical Report on the Proposed School Development (Site Formation Works) Prepared by the Advisory Division, GEO)

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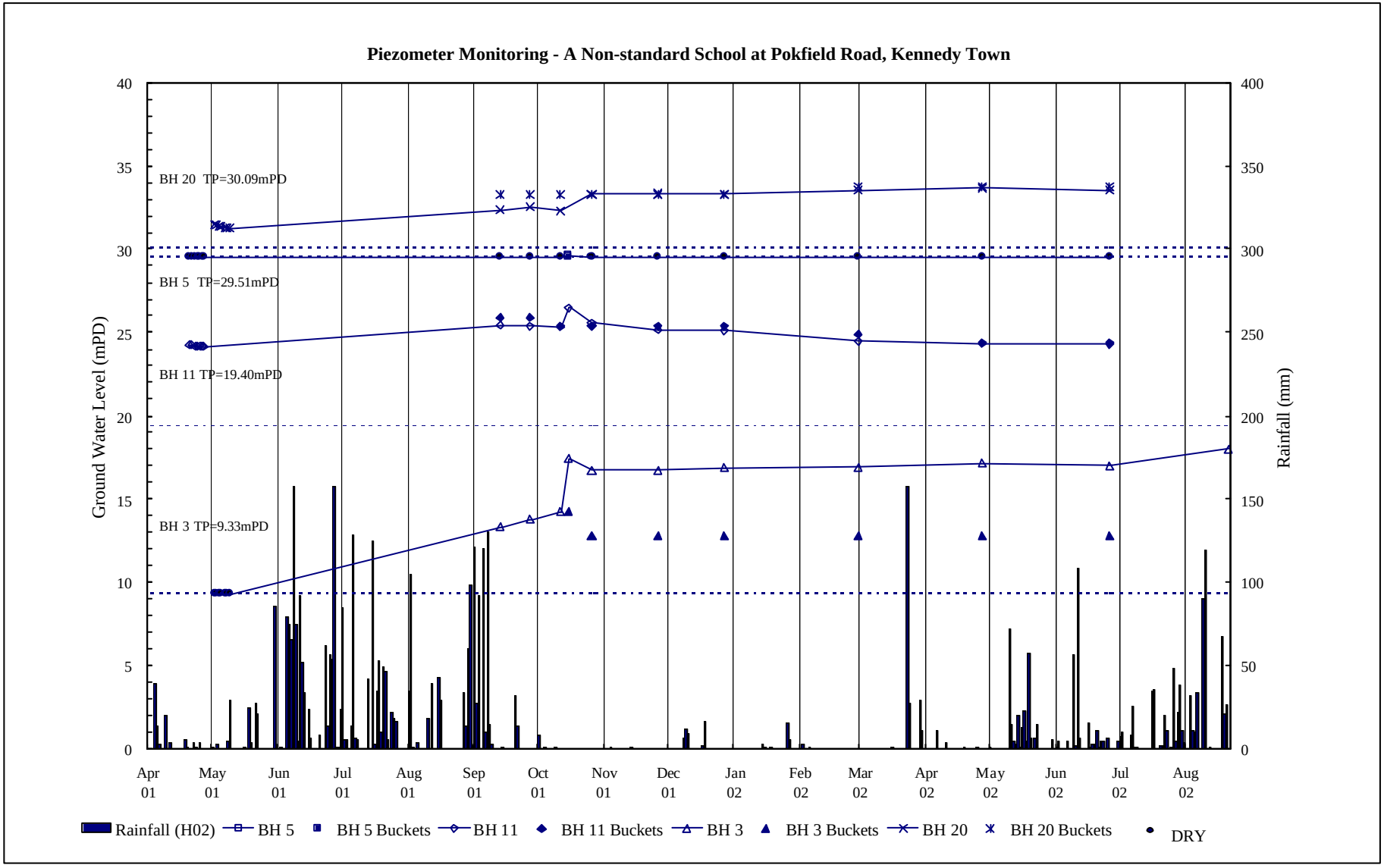

Figure B1 - Groundwater Monitoring Records for Piezometers within Drillholes Nos. BH3, BH5, BH11 and BH20

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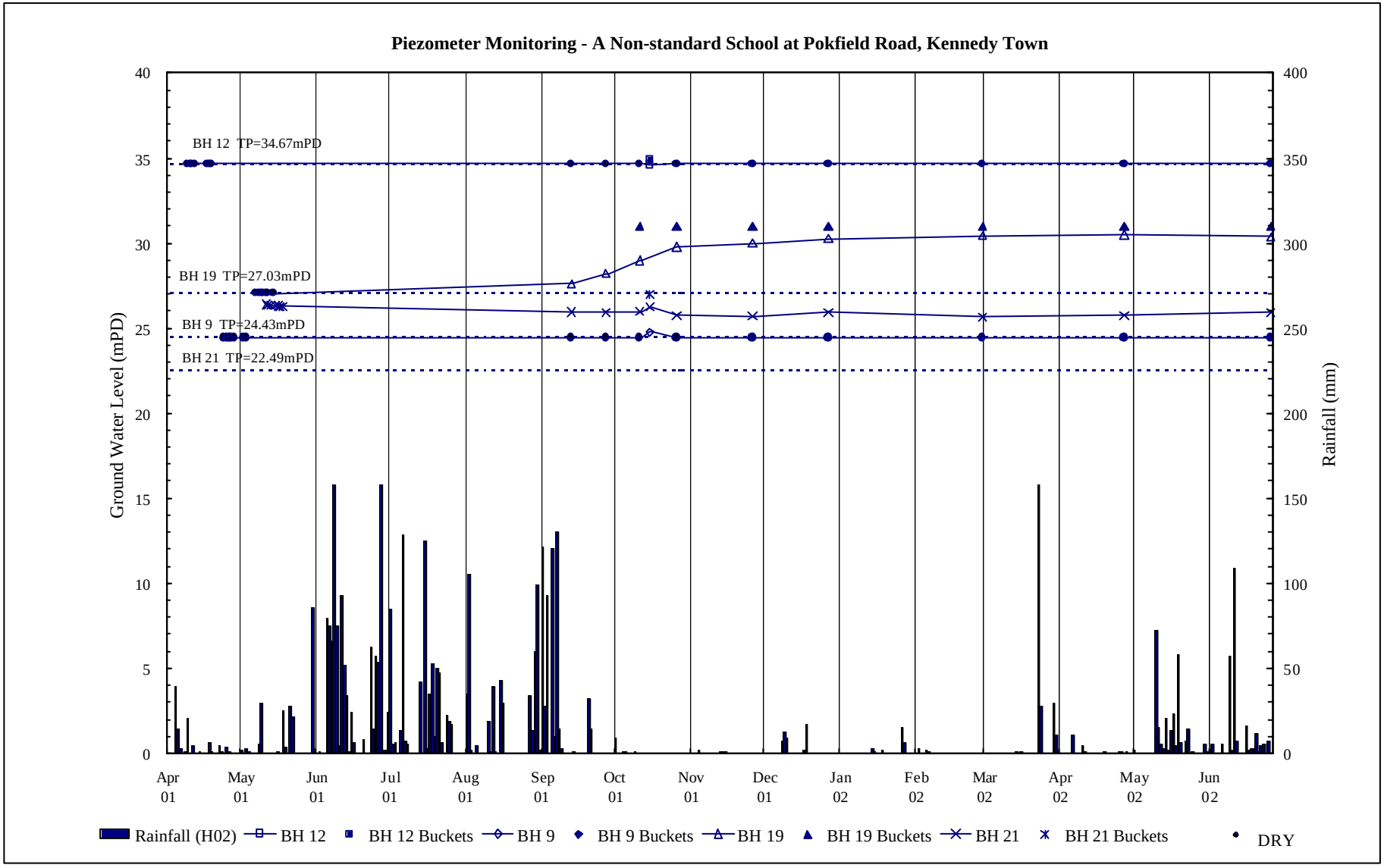

Figure B2 - Groundwater Monitoring Records for Piezometers within Drillholes Nos. BH9, BH12, BH19 and BH21

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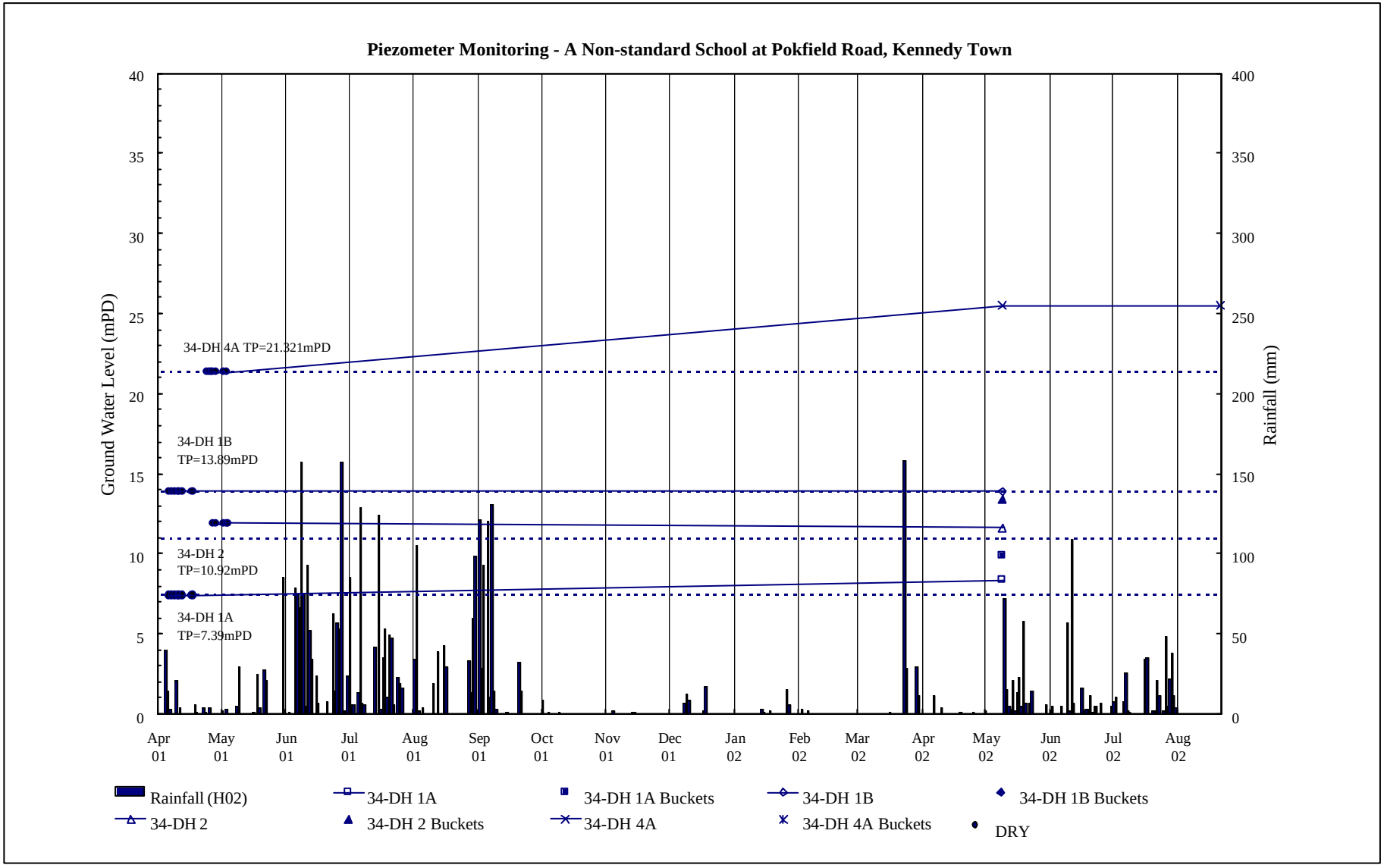

Figure B3 - Groundwater Monitoring Records for Piezometers within Drillholes Nos. 34-DH1A, 34-DH1B, 34-DH2 and BH34-DH4A

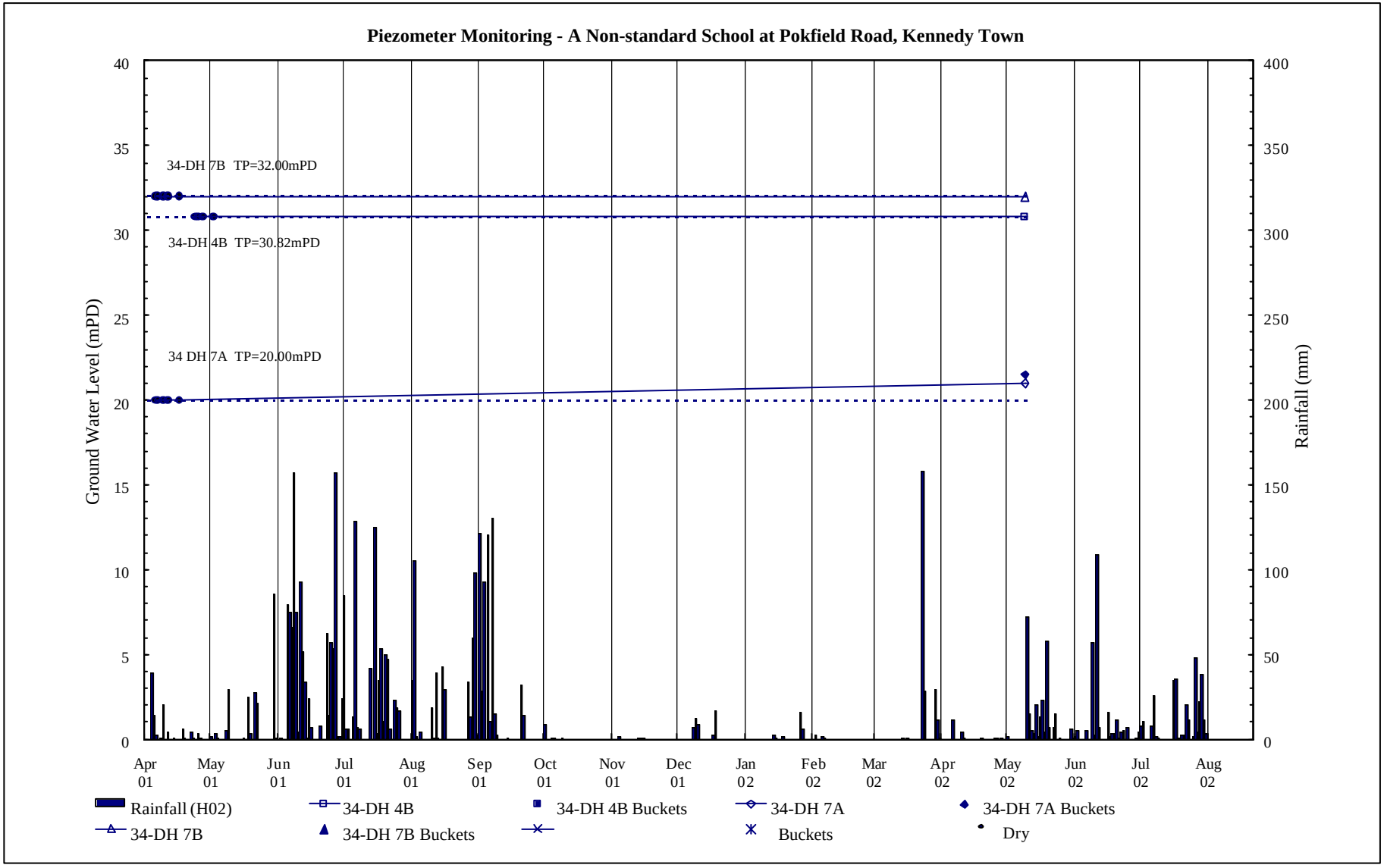

Figure B4 - Groundwater Monitoring Records for Piezometers within Drillholes Nos. 34-DH4B, 34-DH7A and 34-DH7B

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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.

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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.

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Geospec 1	Model Specification for Prestressed Ground Anchors, 2nd Edition (1989), 164 p. (Reprinted, 1997).
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GEO Publication No. 1/96	Pile Design and Construction (1996), 348 p. (Reprinted, 2003).
GEO Publication No. 1/2000	Technical Guidelines on Landscape Treatment and Bio-engineering for Man-made Slopes and Retaining Walls (2000), 146 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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