HIGH-LEVEL COASTAL DEPOSITS IN HONG KONG

GEO REPORT No. 243

J.C.F. Wong and R. Shaw

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.

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R.K.S. Chan
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March 2009

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FOREWORD

This report summarises the findings of a comprehensive review of the high-level coastal deposits in Hong Kong, which was carried out by members of the Geological Survey Section of Planning Division as part of the current 1:20,000 scale map updating and digitisation programme. The study, which includes a re-assessment of the previously mapped high-level coastal deposits and an associated literature review, re-evaluates the elevation, geographical location and morphology of the previously mapped features with the parallel objectives of revising the classification and of standardising the terminology that is used both on the updated geological maps and in the associated reports.

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ABSTRACT

The Geotechnical Engineering Office is currently updating the series of 1:20,000 scale geological maps of Hong Kong (published between 1986 and 1996), using the wealth of additional borehole, survey and analytical data that has been gathered over subsequent years. A systematic re-examination of the high-level coastal deposits that have been mapped around the coastline of Hong Kong prompted a re-evaluation of the significance of these sandy and bouldery deposits. These deposits, which occur between +3 mPD to +11 mPD, are located above and behind the active, contemporary beaches that fringe the coastline in many parts of Hong Kong. Several terms have been used on the maps and in the memoirs, namely, “back beach deposits”, “backshore beach deposits”, “storm beach deposits” and “raised beach deposits”. Because each of these terms has a distinct meaning and, more importantly, a genetic implication, this inconsistency in terminology has been addressed by re-examining the various characteristics of the individual deposits. Archaeological, meteorological, oceanographical and geological factors have been considered, in order to establish criteria for the identification and characterisation of the various deposits, and to develop a standardised nomenclature.

Current literature suggests that the evidence for higher Holocene sea levels in this region is equivocal. Meteorological records of large storm surges affecting Hong Kong point to the fact that high-level coastal deposits around Hong Kong could have been formed during major storms. In certain instances, the high-level coastal deposits could also have developed as wind-blown features, or by the winnowing action of waves. However, further detailed field investigations are still required to determine the true mode of origin of the deposits. Consequently, it is recommended that, for the present purposes, the non-genetic term “backshore deposit” be adopted to designate these high-level coastal deposits. It is also concluded that further detailed fieldwork is required to verify the exact geographical distribution, altitudinal range and sedimentary characteristics of these valuable indicator deposits.

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1. INTRODUCTION

The Hong Kong Geological Survey (HKGS) is currently updating the HGM20 series of 1:20,000 scale geological maps of Hong Kong, which were originally published between 1986 and 1996. This revision has been necessitated by the large amount of borehole data, tunnel logs, geochemical data, and associated geological information that has been gathered since the first editions of the maps were compiled, and by the need to convert the geological databases to GIS format for more flexible manipulation and release of the geological data. This updating exercise has necessitated a re-examination, and in many cases a revision, of some of the previous geological classifications and map legends.

During a systematic review of the superficial deposits that are shown on the published 1:20,000 scale geological maps, it was observed that a variety of terms, including "backshore beach deposits", "back beach deposits", "storm beach deposits" and "raised beach deposits" were used on different map sheets to describe high-level coastal deposits that are located behind and above active contemporary beaches. This report re-examines these features, assessing them in the context of standard beach profiles, accepted terminology, Holocene sea level history, and modern coastal processes.

1.1 Beach Profiles

The coastal zone is commonly sub-divided into three sections, namely the nearshore zone, the foreshore zone and the backshore zone (Figure 1). The nearshore zone is the shallow water, submerged area close to the beach. This zone is commonly characterised by sand bars, which result from the movement of loose sediment by both waves and currents. The foreshore zone is the seaward-sloping portion of the beach within the normal range of tides. The backshore zone is generally above the level of normal high spring tides. This zone is usually dry, wave action affecting this area only during exceptionally high tides or storms. The term "backshore" is synonymous with "back beach". A glossary of coastal geomorphology terms is presented in Appendix I.

1.2 Contemporary Beaches

Beaches are located in the transitional zone between land and sea. They are subject to dynamic conditions, with wave energy varying diurnally, seasonally and during storms. In Hong Kong, contemporary beaches are, with a few exceptions, generally laterally restricted, and usually narrow, deposits of loose sand and gravel that have accumulated in the back of coastal embayments. Beaches extend landwards from the low water mark to the inland limit of wave influence (Figure 1). The upper limit of wave action under commonly prevailing tidal and weather conditions is usually up to about 3 m above Hong Kong Principal Datum (+3 mPD) (Fyfe et al., 2000).

Tides in Hong Kong are mixed and mainly semi-diurnal (Wong et al., 2003). There are two high tides and two low tides on most days of the month. Large tidal ranges occur twice a month during spring tides, when the moon is new or full. However, on days around neap tides when the moon is at its first or last quarter, tidal ranges decrease and sometimes only one daily high and one daily low tide is observed. According to the Hong Kong

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Observatory's (HKO) tidal records from the Tai Po Kau tide gauge station, the highest sea level measured between 1995 and 2004 was 3.13 m above Chart Datum (CD) (+2.98 mPD) (see Section 2.1 below) in 1995, which is consistent with the upper limit of wave action described by Fyfe et al. (2000).

1.3 High-level Coastal Deposits

High-level coastal deposits, described variously as backshore beach, back beach, raised beach and storm beach deposits, have been depicted on the published HKGS geological maps behind active contemporary beaches at various localities around the coastline of Hong Kong. These high-level coastal deposits occur between +2.7 to +9.2 mPD (Appendix II) in various forms such as berms, bars, tombolos and dunes (Figure 1), which are mostly above the upper limit of normal wave action.

Definitions of the four terms (after Bates & Jackson, 1980), available at the time the original mapping was initiated in 1982, are listed below. A fuller glossary of beach terminology is presented in Appendix I, and the typical features are graphically illustrated on Figure 1:

(a) Backshore beach or back beach - (i) the upper or inner, usually dry, zone of the shore or beach, lying between the high-water line (HWL) of mean spring tides and the upper limit of shore-zone processes; it is acted upon by waves or covered by water only during exceptionally severe storms or unusually high tides. It is essentially horizontal or slopes gently landward, and is divided from the foreshore by the crest of the most seaward berm; and (ii) the area lying immediately at the base of a sea cliff.

(b) Storm beach or storm terrace - (i) a low, rounded ridge of coarse gravel, cobbles, and boulders, piled up by powerful storm waves behind or at the inner margin of a beach, above the level reached by normal high spring tides or by ordinary waves; and (ii) a beach as it appears immediately after an exceptionally violent storm, characterised either by removal or deposition of beach materials.

(c) Raised beach - an ancient beach occurring above the present shoreline and separated from the present beach, having been elevated above high-water mark, either by local crustal movements (uplift), or by lowering of sea level, and often bounded by inland cliffs.

From the foregoing, it is apparent that each term has a distinct meaning, and each carries a genetic implication. The use of these terms to categorise high-level coastal deposits on different map sheets has resulted in inconsistencies and, in several cases, the terms have been used inappropriately. Accordingly, this study, which includes a literature review and data analysis (Appendix II), was carried out in order to establish criteria for the recognition

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and characterisation of these high-level coastal deposits in Hong Kong, and to standardise the nomenclature.

2. SEA LEVEL AND SURVEY DATUM POINTS

Before the geological evidence for former higher sea levels can be objectively interpreted, it is first necessary to examine the survey datums used in Hong Kong, how they were established, and how they relate to the concept of "Sea Level". In addition, it is necessary to determine the maximum tidal range that is observed in Hong Kong waters and the expected height of extreme wave events, factors that are of fundamental importance to an understanding of the normal variations in the modern sea surface, and thus the height to which marine processes can affect the contemporary coastline.

2.1 Geodetic Datum Levels in Hong Kong

Triangulation stations first appeared on the 1845 topographical map of Hong Kong produced by Lt. Collinson of the British Royal Engineers (Mugnier, 1998). However, the first recorded benchmark for topographical surveying in Hong Kong was not established until 1866, being placed by the crew of Her Majesty's Survey Vessel "Rifleman" (Survey and Mapping Office, 1995). This benchmark was a copper bolt, known as "Rifleman's Bolt", driven into the wall of Storehouse No. 12 on Tamar Street in the Hong Kong Naval Dockyard, Victoria Harbour.

Hong Kong Principal Datum (HKPD), which was originally called Ordnance Datum, was established twenty-two years later, being determined from tidal observations carried out between 1887-1888 (see Section 2.2). HKPD then became the survey datum for all heights and levels on land. The reduced level of "Rifleman's Bolt" was, at that time, determined to be 17'10" (or 5.435 m) above HKPD.

During subsequent major triangulations, beginning with the surveys for the territory-wide maps of 1899/1900, HKPD was transferred from "Rifleman's Bolt" to other benchmarks. Today there are about 1600 benchmarks established across the Hong Kong SAR as part of the triangulation network, each with an accurately determined height value in metres above HKPD. All intermediate heights on the land are fixed by reference to these benchmarks. Hence, Hong Kong Principal Datum does not now exist as an identifiable monument or mark, but as a concept that is enshrined in the network of benchmarks across Hong Kong. Beginning in 1990, GPS techniques are now used for position fixing in Hong Kong, with differential GPS (DGPS) stations currently being set up for altitudinal measurements.

Storehouse No. 12 was demolished in 1962, and "Rifleman's Bolt" was re-set, reportedly at its original level, into the eastern wall of Blake Block in H.M.S. Tamar. During a re-survey in May 1984 the level of the Bolt in its new location was determined to be about 5.42 m above HKPD, as opposed to the originally surveyed level of +5.435 mPD (Survey and Mapping Office, 1995).

Chart Datum (CD), which was originally known as Admiralty Datum, is the survey datum for all offshore surveys. Chart Datum is approximately the level of the Lowest

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Astronomical Tide, which was fixed in 1917 at 0.146 metres below HKPD (Survey and Mapping Office, 1995). Since 1917, Chart Datum has been adopted as the zero point for the Hong Kong Tide Tables and for all offshore bathymetrical surveys.

2.2 Tide Gauges and Mean Sea Level

"Sea Level" is generally synonymous with the term Mean Sea Level (MSL), which is the mean height of the sea measured at a convenient and stable location on the coast. MSL is calculated from hourly tide gauge readings taken over a period of at least five years.

Hong Kong MSL, and HKPD, was originally calculated by a one Dr Doberck from tidal observations taken over the period between 1887-1888. MSL was then fixed at 1.125 metres above HKPD (Survey and Mapping Office, 1995). More recently, MSL was re-calculated by the Royal Observatory (now the Hong Kong Observatory, HKO) using the records from the North Point Automatic Tide Gauge in Victoria Harbour. Observations were taken over a full metonic cycle (a period of 19 years (235 lunar months), after which the various phases of the Moon fall on approximately the same days of the year as in the previous cycle (Tver, 1979)), for 18.6 calendar years from 1965-1983 (Mugnier, 1998). From these observations, MSL was determined to be 1.23 metres above HKPD and 1.38 metres above CD (Survey and Mapping Office, 1995).

Today there are eleven tide gauge stations in Hong Kong, six managed by the HKO, four by the Marine Department, and one by the Hong Kong Airport Authority (Chan, 2006). The HKO tide gauge station at North Point/Quarry Bay, which is registered on the Global Sea Level Observing System (GLOSS), is a float-type gauge accurate to 1 cm. All Hong Kong tide gauges take 128 samples each second, from which are derived 1-second average and the 1-minute average sea levels.

It is well known that sea level fluctuates periodically in a cyclical manner, over short- and long-periods (see Section 3.1 below). Recent warnings about global warming indicate that world sea levels are currently on a rising trend. A study of long-term sea level change in Hong Kong by the HKO (Ding et al., 2004) concluded that the MSL in Hong Kong had risen at an annual rate of 2.3 millimetres a year in the 50 years between 1954 and 2003, suggesting that the currently accepted value for MSL should be re-examined.

3. LITERATURE REVIEW

Published literature on Holocene sea level changes has been reviewed to establish the current theories with regard to Holocene sea level highstands. In addition, a range of publications from the pertinent fields of archaeology, meteorology, oceanology, and geology that describe high-level coastal deposits in Hong Kong have been consulted. Finally, detailed descriptions of the deposits presented in the HKGS geological memoirs were also re-examined to determine the locations and characteristics of the previously mapped features.

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3.1 Holocene Sea Level Changes

Although there is general agreement on the evidence for cyclical sea level changes throughout the Quaternary (Shackleton, 1987; Fyfe et al., 2000), there appears to be less agreement on the evidence for a Holocene sea level highstand. Work by Peltier (1998, 2002, 2004) indicated that there is considerable spatial variation in both the timing and the maximum amplitude of the Holocene sea level rise recorded around the world. These variations are noted not only globally, but also within individual ocean basins. Thus, the magnitude of the maximum Holocene sea level rise ranges from zero metres, or even below present sea level, to the largest recorded amplitude of 5-6 metres above present sea level along the coast of Patagonia (Peltier, 2004).

Recent work has refined the chronology and amplitude of the last-glacial and post-glacial changes in sea level. Mathematical modelling of global glacial isostatic re-adjustment (Peltier, 2004) has confirmed that at the Last Glacial Maximum, which occurred about 21,000 years ago, sea level had fallen by about 125 m. Following deglaciation, sea level began to rise. However, global variations in the absolute amount of sea level rise appear to depend upon a complex interplay of factors including the impacts of changing surface ice load upon both the Earth's shape and gravitational field (Peltier, 2004), the regional and local structural geological setting, ocean currents (Collins et al., 2006), the coastal morphology and its influence upon local hydrographic conditions, and the coastal lithology.

For example, Dickinson (2002) observed that dated archaeological sites in tectonically active Micronesia, which were located along or near the mid-Holocene palaeo-shoreline, are now found both underwater and up to 10-12 m above the present sea level. Collins et al. (2006) concluded that variations in palaeo-sea level indicators along the southwestern Australia coast probably resulted from the effects of the poleward-flowing Leeuwin Current.

The sea level history of the Pacific Ocean is the most pertinent to Hong Kong. Peltier (2004) modelled data from island locations in the equatorial Pacific and showed that all significant melting from both hemispheres had ceased by 4,000 years ago, at which time the sea level in the area stood at about 2 metres above the present level. Similarly, field observations reported by Dickinson (2000, 2002) suggest a highstand of 0.6-2.6 m in the tropical Pacific at between 4,750 to 2,250 years BP. In slight contrast, field data from emergent coral pavements in a tectonically stable coastal area of southwestern Australia indicate a smooth decline of sea level from a highstand of 2 metres that occurred 6,832 years ago (Collins et al., 2006).

A recent re-examination of the history of Holocene sea level changes along the southeast coast of China (Zong, 2004) concluded that the evidence is equivocal, but it does not, in general, confirm a regional mid-Holocene highstand. However, marked localised variations were noted, which fall into three categories. In the vicinity of the large river deltas, such as the Yangtze River Delta, the Han River Delta, and the Pearl River Delta, evidence of former sea level stands is recorded either close to or below the present sea level, a phenomenon attributed to geological subsidence. Highstands of between 1-2 m above the present sea level were found in areas close to plate boundaries that are experiencing tectonic uplift, such as along the Fujian coast and within the Taiwan Strait. In tectonically stable

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areas, such as along the South China coast, with the exception of the Pearl River delta, the highest recorded sea level corresponds with the modern sea level.

With regard to the timing of the Holocene marine transgression, Zong (2004) reported that sea level along the East Guangdong coast reached its present level at around 5,800 years BP, rising to between 1-1.5 m above present sea level at about 5,000 years BP. There then followed a gradual decline to the present level. In contrast, sea level in the Pearl River Delta region was reported to have risen rapidly during the early Holocene, but then experienced a rapid slowing at around 6,800 years BP. Sea level continued to rise, at a reduced rate, until it reached the present height by 3,000 years BP, by which time it had reached its maximum landward extent. During the last 2,000 years, the Pearl River delta plain has prograded seawards.

Overall, Hong Kong predominantly exhibits a drowned coastline, with the few recorded high level coastal deposits occurring in widely scattered localities as distinctive localised features. The area is generally considered to be relatively stable with no confirmed examples of neotectonic activity.

The coastline of Hong Kong is mostly formed in granitic and volcanic rocks that, being relatively erosion-resistant, would not readily record the erosive effects of transient highstands. Similarly, it is believed that the "elevated" coastal erosional platforms developed on the sedimentary rocks in the northeast of Hong Kong could not have been formed during the mid-Holocene (see Section 3.4 below). Consequently, they are probably pre-Holocene relict features. This situation contrasts markedly with the evidence from limestone areas in the Western and Southern Pacific Ocean (Dickinson, 2002), where mid-Holocene highstand wave-cut notches at 1.2 to 2.6 m above present sea level have formed in the more easily eroded carbonate rocks.

3.2 Archaeological Observations

The characteristics of the deposits in a feature described as a sand bar, or a local "raised beach", at Sham Wan, Lamma Island (Plate 1) were studied by Meacham (1978). Middle Neolithic (approximately 3800-3000 BC), late Neolithic (approximately 3000-1200 BC), Bronze Age (approximately 1200-400 BC) and early historical period cultural deposits (post-400 BC) were identified in the sand bar at +5.9 m to +6.8, +6.9, +7.5 and +7.8 mPD respectively. However, corresponding cultural deposits for each of the above major periods found at other sites along the adjacent coastline were located well below the levels of the Sham Wan sand bar. Meacham (1978) also described archaeologically sterile sandy layers (levels not given) at other sites in the area. These were interpreted as evidence of ancient flooding, or of abandonment. On the other hand, sand movements above the effective wave range were found to be common, and sporadic wind-blown sand was reported as accumulating in fields and villages adjacent to beaches after severe storms. Based on these findings, Meacham (1978) ruled out the possibility that the sand bar at Sham Wan was formed during a period of higher sea level. Instead, it was postulated that the observed feature was most probably formed by the combined effects of high waves and onshore winds.

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3.3 Meteorological and Oceanographical Observations

Hong Kong, situated at the northern coast of South China Sea, is affected by typhoons during the summer months. Storm surges are the product of abnormal weather conditions, such as during a tropical cyclone, creating sudden rises of sea level along open coasts. They are caused primarily by onshore-wind stresses, or less frequently by atmospheric pressure reduction, resulting in water being piled-up against the coast. The effects are most severe when accompanied by a high tide. If a storm surge occurs during an astronomical high tide, particularly the highest spring tide, the resultant sea level can be exceptionally high (HKO, 2005). According to the HKO's records, a storm surge related to a typhoon sweeping through Hong Kong on the 2nd September 1937 created tidal waves that were 13 feet (3.96 m) above CD (+3.81 mPD) in Hong Kong (Victoria) Harbour, 20 feet (6.10 m) above PD in Tai Po, and 30 feet (9.14 m) above CD (+8.99 mPD) in parts of Tolo Harbour, and the storm surge flood caused about 11,000 fatalities (Watts, 1959). However, there was no tide-gauge recording station in Tai Po in 1937. Another storm surge flood on the 1st September 1962 generated by Typhoon Wanda caused 127 fatalities, submerged around 3,000 huts, and inundated hundreds of hectares of farmland (Lau, 1980). The storm surge occurred an hour before the predicted high tide of 7.2 feet (2.19 m) above CD (+2.04 mPD), and the result was that the water levels in Tolo Harbour rose to approximately 10 feet (3.05 m) above the predicted high tide level.

Cheng (1965) pointed out that, in addition to storm surges, abnormally high ocean waves could be caused by tsunamis. He observed that the maximum rise in sea level in Hong Kong from a tsunami generated by the 1960 Chile earthquake (magnitude 8.5) was 2 feet and 2 inches (0.66 m), and that there was no record of Hong Kong being affected by a tsunami that was generated in South China Sea (18°N, 118°E) in 1934. The HKO (2005) reported that Hong Kong has never been affected by any significant tsunami, primarily because the Philippines and Taiwan act as natural barriers against tsunamis originating in the Pacific. Since the 1950s, four minor tsunamis, caused by earthquakes in Kamchatka (1952), Chile (1960 & 1985) and the Luzon Strait (1988), have been detected in Hong Kong, and all of which had amplitudes of less than 0.5 m.

3.4 Geological Observations

As discussed in Section 3.1 above, Holocene sea level changes in the South China region have long been the subject of scientific debate. Of particular concern is the question of whether the sea level has ever been higher than the present level during the past 6,000 years. The topics of sea level change, the existence of raised beaches, and the significance of buried coastal deposits, have all been debated by many authors over the years. However, the evidence in Hong Kong and the surrounding region is commonly conflicting.

Schofield (1943) described the presence of supposed raised beaches at between +5 mPD to +6 mPD, and also at approximately +15 mPD in Southeast Asia. Berry (1961) presented evidence of emerged beaches and erosion features at similar levels in Hong Kong. So (1968) identified two emerged beaches at Pui O. Huang (1984) discussed the results of field studies of reefs and sandbanks, dated at around 5000 to 6000 years B.P., that occur above the present sea level in different parts in China, which imply a higher sea level at that time. However, he conceded that the deposits may have resulted from variations in deltaic

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deposition rates and by tectonic movements in the coastal areas. Huang et al. (1984) pointed out that, based on the presence of marine units and transgression beds above the present sea level, a transgression appeared to have occurred along the coasts of the South China Sea in the middle Holocene (6,000 to 3,000 years ago). However, similar units were also found below the present sea level. Hence, the authors concluded that the deposits that are currently located above the present sea level could also be explained by crustal uplift.

Meacham & Yim (1983) and Yim (1984, 1999) concluded that there is no evidence in Hong Kong of oscillating Holocene sea levels, or of higher sea levels during the Holocene. Strange (1986) identified a high-level beach rock up to about 20 m above the present day sea level on Tau Chau near South Bay, Hong Kong Island. He concluded that the deposit was not definitive evidence of higher sea levels, but was most probably the result of severe storms, postulating that a combination of temporarily high water levels and strong wave action threw the material up to the higher level. Feng et al. (1988) described the sea level changes in the Pearl River Delta resulting from Quaternary glacial-interglacial cycles. He believed that a postglacial sea level high, possibly reaching +1 m to +3 m above present sea level, was attained at about 7,000 to 6,000 years BP., which was followed by a minor regression about 4,000 years BP, with evidence of a further minor transgression at about 2,000 years BP. Owen (1995) identified supra-tidal platforms at Kat O Chau, Double Island and along several coastal sections around Double Haven, which occur a few metres above the present day sea-level. Yim & Huang (2002) considered that, given the relatively slow rate of marine erosion, there was insufficient time during the Holocene to form the reported emergent wave-cut platforms in mechanically resistant rock.

Davis et al. (2000) dated a relict horizon of *Saccostrea* sp. shells at 1.7 m above the present day high tide levels in Big Wave Bay on Hong Kong Island. At present, the highest living growth position of isolated individuals of *Saccostrea* at that location was found to be 1.9 m below the relict shell bed. Radiocarbon dating of the high-level shells gave an uncorrected age of 5,140±50 BP. Referring to the findings of Berry (1961) and Owen (1995), the authors postulated that the sea-level in the South China area at 5,140±50 BP was 4-5 m higher than at present. Yim & Huang (2002) re-examined the evidence for higher Holocene sea levels presented by Davis et al. (2000) and concluded that sea level at that time was never higher than about 2 m above the present Mean Sea Level. Yim & Huang also noted that Big Wave Bay is an exposed, wave-dominated cove located between two headlands facing east and is prone to the influence of ocean swell, the frequently gusty northeast monsoon in the winter, and the approach of tropical cyclones from the southeast in the summer. They pointed out that Meacham & Yim (1983) and Meacham (1986a) have shown by archaeological dating of buried artifacts, and Wang (1997) showed by radiocarbon dating of beach rock, that the emerged beaches at Pui O represented beach-dune barriers that are no older than 1,660±75 years BP. In contrast, Baker et al. (2003) provided regional evidence of high-level fixed biomarkers from Malaysia, Indonesia, New Caledonia and Australia, to support the findings of Davis et al. (2000). Similarly, Dickinson (2000, 2002) provided evidence of a highstand in the tropical Pacific of 0.6-2.6 metres between 4,750 to 2,250 years BP.

3.5 Hong Kong Geological Survey Maps and Memoirs

Between 1986 and 1996, the Geotechnical Engineering Office (GEO) (formerly the

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Geotechnical Control Office (GCO)) produced six district memoirs to describe the geology of fifteen 1:20,000 scale geological maps. The maps and memoirs each used different nomenclature to describe the mapped high-level coastal deposits (Table 3).

Memoir No. 1 (Addison, 1986) describes Sheet 7 covering Sha Tin and the Tolo Harbour area. The author did not differentiate coastal deposits, with both beach and littoral sand occurrences being mapped as marine sand.

In Memoir No. 2 covering Sheets 11 and 15, beach sands were distinguished, and high-level storm beach deposits were identified on the eastern coast of Lamma Island (Strange & Shaw, 1986). The best known example is the sand bar at Sham Wan (discussed in Section 3.2), where Neolithic artefacts found up to 10 m above the present beach were described by Meacham (1978). Similar storm beaches, consisting of accumulations of large boulders, were also described along the coastline 300 m east of Tung O village and 200 m east of Yung Shue Ha village. East of Mo Tat, rounded boulders of granite, rhyolite and syenite, commonly up to 3 m across, have produced dams across the two valleys (see Section 5.5), both at heights of between +10 and +11 mPD (Plate 2) (Strange & Shaw, 1986). The authors presumed that the boulders could have been thrown up to considerable heights (up to 11 m above present day sea-level) by severe storm action. Similarly, sand deposits containing scattered pebbles up to 10 m above sea-level were regarded as storm beach deposits. Strange & Shaw (1986) concluded that there was no unequivocal evidence to support the existence of previous higher sea-levels.

In Memoir No. 3, covering the western part of the New Territories represented by Sheets 2, 5 and 6, Langford et al. (1989) used the term "raised beach deposits" to describe beach deposits behind a contemporary sand beach. The deposits, occur at heights of up to +6.5 mPD, are composed of gravelly coarse sand with scattered pebbles. Archaeological evidence indicates that these beaches are probably of Holocene age. Radiocarbon dating of a lime kiln found within raised beach deposits at Shek Kok Tsui, Tuen Mun gave an age of 1,370±100 years BP (Meacham, 1979), and archaeological material in the deposits of the Lung Kwu Chau tombolo gave an age of 5,800±500 years BP (Meacham, 1986b).

Strange et al. (1990) did not identify any high-level coastal deposits in the Sai Kung and Clear Water Bay areas covered by Sheets 8, 12 and 16 in Memoir 4. Consequently, deposits of beach sand found inland from the high water mark and tidal zone, which are up to 8 m above sea-level, were considered to be storm beach deposits. Therefore, no evidence of former higher sea levels was presented in the Memoir. The mapped beach ridges commonly form barriers across river mouths, resulting in the formation of freshwater lagoons and extensive alluvial tracts inland. One example occurs at Tai Wan in Tai Long Wan where the sand extends inland for 200 m and rises to 6.5 m, forming a barrier across the valley and creating a wide alluvial plain. Several of the features, particularly in the more exposed coastal locations, comprise boulders, cobbles and pebbles. Wherever possible, these were distinguished from the contemporary beach sands. An example of this kind of coarse storm beach deposit was mapped at the northern tip of Shelter Island (483 214).

Lai et al. (1996) adopted the term "backshore deposit" to describe deposits of gravelly coarse sand with scattered pebbles behind the contemporary sand beaches in Memoir No. 5. These features were identified in the sheltered bays around several islands in the northeastern New Territories, such as at Kat O Chau, Ap Chau, Ping Chau and Wong Wan Chau on map

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Sheets 3 and 4. “Storm beach deposits” were mapped on several islands in Tai Pang Wan (Mirs Bay). At Kang Lau Shek, accumulations of pebbles and boulders high on the shore were attributed to deposition by storm action. Large boulders of chert and siltstone, ranging from 1 m^3 to 2.6 m^3, were described as having been moved 150 m from the sea bed to the top of a promontory over +10 mPD.

Langford et al. (1995) employed the term “back beach deposits” in Memoir No. 6 for deposits of gravelly coarse sand with scattered pebbles that form “raised beach deposits” or “high level storm beach deposits” behind contemporary sand beaches on Sheets 9, 10, 13 and 14. The highest elevation of these beaches is +6 mPD. The memoir stated that there was no unequivocal evidence in the district for former high sea levels. These deposits form barriers across river mouths, resulting in the formation of freshwater lagoons with extensive alluvial tracts inland, such as the one at Yi Pak Wan, and another one at Sam Pak Wan. Boulders, cobbles and pebbles constitute the beach deposits on more exposed coasts. These coarse deposits were distinguished from the beach sands on the maps.

In the most recent comprehensive geological report “The Quaternary Geology of Hong Kong”, which is accompanied by a series of thematic 1:100,000 scale geological maps, Fyfe et al. (2000) stated that upper limit of wave action under prevailing conditions is usually up to about +3 mPD. However, the upper limit of beach deposits in some areas, most commonly along exposed southeasterly facing coasts, may extend up to about +6 mPD. These deposits commonly comprise gravelly coarse sand with scattered pebbles, suggesting that they were deposited in a high energy environment. Although several of these features were mapped as raised beaches on the 1:20,000 scale maps, the generally coarser grain size of the deposits supports the interpretation that they are probably storm beaches formed by strong wave surges associated with typhoon conditions. True raised beaches, resulting from deposition during a period of higher sea level or from tectonic uplift, have not been unequivocally identified in Hong Kong. Strictly, therefore, it was considered that the deposits should be regarded as storm beaches.

4. MAP AND AERIAL PHOTOGRAPH REVIEW

The mapped high-level coastal deposits of Hong Kong, namely “back beach deposits”, “backshore beach deposits”, “storm beach deposits” and “raised beach deposits”, have been re-examined to determine both their geographical setting and their common characteristics (Figure 2). The dimensions, elevation range, aspect, topographical setting and morphology were interpreted from the geological maps and from the 1964 aerial photographs (Appendix II). The elevations of these deposits were established from the published 1:1,000 scale topographical maps.

Based on the available information, the identified high-level coastal deposits range in elevation from +2.7 to +9.2 mPD. The highest mapped deposits at Tai Long Wan on the Chi Ma Wan Peninsula have an elevation of +9.2 mPD. Topographical data for contemporary beaches on the seaward side of some high-level beaches indicates that the elevation difference between the high-level coastal deposits and the contemporary beaches varies from between 1 m to 3 m. The data also reveal that there is no preferred aspect for the deposition of high-level coastal deposits, the features facing in several directions.

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The topographical characteristics of the high-level coastal deposits were examined on aerial photographs. Most of the beaches are situated in embayments with protruding headlands on each side, such as the one at Discovery Bay (Plate 3), or along concave sections of exposed coasts, such as Sha Po Kong, east of Tuen Mun (Plate 4). Some high-level beaches are situated on coastal alluvial plains, such as those at Sheung Pak Lai, Lau Fau Shan (Plate 5).

Most of the high-level coastal deposits occur as sand bars located between the high water mark and the toe of the adjacent hilly terrain. They are most common, and best developed, in the Kat O area, Cheung Sha and Tap Mun (Plate 6). Some of the high-level coastal deposits occur as raised bars on coastal alluvial flats, such as those in Sheung Pak Nai, Fan Lau, Pui O and Chi Ma Wan (Plate 7). The two "back beach deposits" originally mapped at northern Chek Lap Kok, have now been obliterated by the Chek Lap Kok International Airport. These occurred as small dunes upon an alluvial plain (Plate 8). Some high-level coastal deposits, such as the "raised beach deposits" in the middle of Cheung Chau and the "back beach deposits" at Siu A Chau, are tombolos (Plate 9).

5. MODES OF FORMATION

This section examines the possible modes of formation of the Hong Kong coastal deposits described in Section 4 above, with the objective of deciding upon an appropriate non-genetic term for the features.

5.1 Eustatic Changes of Sea Level

Eustatic changes of sea level should be distinguished from localised relative changes of sea level caused by tectonic elevation or subsidence, coastal progradation, coastal erosion, or changes in current and tidal regimes. Eustatic changes in sea level result from two primary causes. Glacio-eustatic change is largely controlled by the volume of terrestrial ice, which determines the amount of free water in the oceans. Tectono-eustatic changes occur due to an increase or decrease in the volume of the mid-oceanic spreading ridges (Walker & James, 1992). Eustatic sea level changes affect coastal processes globally and, if sufficiently prolonged, commonly leave evidence in the form of wave cut notches, raised beaches, or elevated wave-cut platforms.

Evidence of former higher sea levels has been described from numerous locations along the coastlines of China and Southeast Asia (see Section 3.1). In many cases, the Holocene glacio-eustatic rise of sea level can adequately account for the regional distribution of the observed high-level coastal deposits. However, regional or local tectonic activity can mask the effects of the global sea level rise. In the case of Hong Kong the evidence is equivocal and contradictory. In addition to the high level coastal deposits described in Section 3.4, some areas, such as the landscape in southeastern Hong Kong described by Fyfe et al. (2000), exhibit the characteristics of a drowned or ria-type coastline. It is clear that not all the coastline of Hong Kong or the South China region bears the same uniform evidence of a Holocene eustatic rise of sea level. Consequently, other mechanisms must be considered to explain the observed high-level coastal deposits.

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5.2 Local Variations in Sea Level

Despite the fact that, for topographical surveying purposes, MSL was fixed at North Point as +1.23 mPD, it is clear from Table 1 that the height of MSL in Hong Kong differs at other stations (HKO, unpublished data). At the four stations selected, MSL ranges between +1.27 to +1.38 mPD.

Also, Table 1 shows that the Mean Highest High Water level ranges between +2.03 and +2.30 mPD, and the Mean Lowest Low Water level ranges between +0.21 and +0.62 mPD. These levels have important implications for the geological interpretation of coastal deposits, indicating that depositional features that are up to +2.30 mPD are still within the range of normal annual sea surface fluctuations.

This picture is complicated still further when the highest tides are considered (Table 2). The highest Astronomical Tide (HAT) at the four stations ranges between +2.58 to +3.01 mPD, confirming that coastal features up to +3.01 mPD can still be affected by normal tidal rises and falls.

Extreme sea levels calculated for ten-year return periods at seven stations in Hong Kong (Civil Engineering Office, 2002, Tables 3 to 9) range between +2.9 mPD (at Waglan Island) and +3.6 mPD (at Tai Po Kau). When the highest tides coincide with storm surges, coastal water levels rise up to +4.18 mPD (Table 4).

These observations indicate that coastal deposits up to about +4 mPD may still periodically be influenced by marine waters, and deposits up to about +2.30 mPD could still be inundated annually, depending upon their location.

5.3 Extreme Wave Events

Hong Kong's weather pattern is influenced by winds of the northeasterly monsoon between the months of September and May, and by winds of the southwesterly monsoon between the months of June and August each year. During normal, stable weather conditions, wave heights are moderate over most of Hong Kong. However, when strong monsoon winds prevail, higher waves are experienced in exposed locations (Li & Wong, 2001).

Extreme wave conditions are generated during tropical cyclones. These winds are characterised by their high velocities and rapid changes of direction. During tropical cyclones the wave spectrum comprises long-crested offshore swells from the south and southeast, which are generated by the distant storm, reinforced by short-crested wind waves generated by very strong local storm winds. The two waves may not approach from the same direction.

In Hong Kong, storm surges have entered both Victoria Harbour and the Tolo Harbour, and reached Tai Po (see Section 3.3). The latest flooding due to a storm surge occurred in 2001 in association with Typhoon Utor (HKO, 2002). In Tai O, water was recorded as high as 3 metres, turning the main streets into rivers. The 2001 storm surge also caused flooding in the northwestern part of the New Territories. Sea water was flushed backwards through the drains and surged to ground level in Sheung Wan.

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Several studies have been carried out to predict extreme sea levels and extreme wave heights in Hong Kong waters (e.g. Civil Engineering Office, 1998; Hong Kong Polytechnic University, 2000), factors that are important to engineers designing offshore and coastal structures (Drainage Services Department, 1994; Civil Engineering Office, 2002). This work resulted in the development of a digital wave atlas (Li & Wong, 2001), which can be used to assess the extreme wave climate at several locations in Hong Kong waters. Using storm hindcasting, Significant Wave Heights (SWH) for return periods between 2 and 200 years were calculated (Table 5) (Civil Engineering Office, 1998). The results showed that waves of +5.99 m high can be expected every two years, and waves up to +10.03 m high every 10 years. Longer return periods, of up to 200 years, could bring waves of almost 15 m high.

Highly indented coastlines with a southeasterly aspect will be subjected to exceptionally high water levels during storm surges because the narrow bays funnel the incoming surges. Water levels will be increased still further during extreme tides. Since all the identified high-level coastal deposits are beneath the +15 m SWH of the 200-year return period storm, it is possible that extreme wave events could be responsible for the formation, or at least the periodic reworking, of some of the high-level coastal deposits.

5.4 High Waves and Wind Action at Sham Wan

Meacham (1978) postulated that high waves and wind played major roles in the formation of sand bar at Sham Wan. The archaeological findings suggested that, as the sea rose to its present level, wave action transported sand to the heads of new bays and sandy beaches were thus formed. Also, storm beaches would gradually have been built up above the high tide level by large waves occurring regularly each year. However, as the height of the sand bank increased, the deposition of wave-transported sand directly on top of the storm beach would have decreased as it approached the upper limit of storm wave activity.

Meacham (1978) also recognised that the strong winds experienced in Lamma could trigger sand movement above the effective wave range, and found that wind-blown sand was occasionally reported encroaching into fields and villages adjacent to the beach after severe storms. To explain the presence of a 0.2 to 0.3 m thick sand layer overlying Qing Dynasty material, the archaeological study postulated that this uppermost sand layer could have accumulated by wind action during the last 300 years. However, there was no detailed description of the stratigraphy of the sand deposit, nor any additional evidence provided to support this claim.

5.5 Winnowing

Strange & Shaw (1986) presumed that the coastal accumulation of boulders situated at elevations of up to +10 and +11 mPD in the exposed bays east of Mo Tat, Lamma Island, were associated with severe storm action. Alternatively, the boulder spreads may have originated as colluvial deposits derived from inland, or may represent the lag from an eroded weathered profile. Similar high level coastal bouldery deposits are not uncommon in Hong Kong, and may have been originally placed as colluvial sheets, fans, or lobes, or as alluvial tongues or spreads, which were subsequently winnowed by waves, or by storm wave action. Also, the winnowing of corestone- or boulder-bearing weathering profiles exposed

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along the coast could result in a zone of clast-supported boulders and cobbles.

5.6 Neotectonic Activity

The elevated position of high level coastal deposits could also be explained by localised, or more regional, neotectonic movements. Neotectonics is the study of recent movements of the Earth's crust. Although the term was originally applied to tectonic activity during the Neogene Epoch (Bates & Jackson, 1987), or since the beginning of the Miocene Period 26 million years ago, it is now more commonly used to refer to activity during the Quaternary Period, that is the last 2 million years. Dating of fault activity using thermoluminescence techniques is now well established (Ji & Gao, 1988; Ji et al., 1994; Singhvi et al., 1994), so neotectonic activity can, in principle, be detected.

In Hong Kong, Sewell et al. (2000) documented evidence of fault-related deformational events within rocks of all ages, including Early Tertiary sedimentary rocks. However, no direct evidence has so far been found of basement faults displacing either the offshore or onshore Quaternary superficial deposits.

Huang et al. (1984) suggested that marine units and transgressive deposits found above present sea level along the northern part of the South China coast could be explained by recent crustal movement. In Hong Kong, Ding & Lai (1997), and Duller & Wintle (1996) have dated alluvial sediments overlying bedrock faults and fault gouge using a combination of thermoluminescence, optically stimulated luminescence, and radiocarbon techniques. They concluded that movements along the faults occurred in the Middle to Late Pleistocene, with no evidence of extension into the Holocene.

More recently, Sewell & Wong (2006) identified possible fault traces within Quaternary superficial deposits in the Ho Lek Pui area in the New Territories, Hong Kong. Associated evidence included the displacement of streams by faults, and large landslides in adjoining catchments. Although detailed field studies are still being carried out, these observations indicate that the possibility of Holocene tectonic uplift of coastal deposits cannot be entirely ruled out.

6. SUMMARY AND CONCLUSIONS

High-level coastal deposits, mapped as “raised beach deposits”, “backshore deposits” or “back beach deposits” on HKGS geological maps, occur in many locations along the Hong Kong coastline. However, their mode of origin is in most cases uncertain. Several possible modes of origin have been discussed.

Archaeological findings have suggested that these high-level deposits are unlikely to have formed during sea-levels higher than present-day. Generally, the deposits consist of sand with scattered gravel-sized to boulder-sized materials, suggesting that they were formed, or are being formed, in a high energy environment. Large waves generated by storm surges appear to be the most likely mechanism, moving coarse materials to the backshore to locations as high as +11 mPD above the contemporary beach. Nevertheless, it is possible that the zone of clast-supported boulders and cobbles at Mo Tat (see Section 3.5) may be

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either a colluvial lag deposit, which resulted from wave action winnowing out the finer-grained matrix, or, a storm beach deposit, comprising coarse material thrown up by periodic large storm waves. Because coarse fragments occur within the deposit, most of the "sand bar" at Sham Wan, Lamma Island is believed to have formed by wave action, although it is possible that the uppermost sand layers may have been transported by wind action.

The results of a current study of neotectonic fault movement at Ho Lek Pui are not yet available. Hence, until further investigations are carried out, the possibility of uplift of coastal deposits by tectonic movements cannot be ruled out.

Throughout the Holocene, the coastal zones will have been periodically affected by extreme tidal levels and by extreme waves, alternately depositing or reworking sediments in locations up to at least +15 mPD (see Section 5.3), and higher during more extreme events. Thus, it is suggested that, depending upon their geographical location, only deposits above about +15 mPD are entirely above the influence of periodic marine influences and can be confidently classified as raised deposits. Because all the identified high-level coastal deposits above and behind contemporary beaches in Hong Kong are below +15 mPD, it is concluded that all the deposits described could have been formed under the extremes of the prevailing tidal and wave regime.

Thus it is concluded that there is no firm evidence to support any particular mode of formation of the observed high-level beach deposits. Consequently, until more detailed field surveys and analyses have been carried out, it is suggested that a non-genetic term "backshore deposit" be adopted to collectively refer to these elevated coastal deposits.

7. RECOMMENDATIONS

Based on this review, it is recommended that from among the various terms used on the existing 1:20,000 scale HKGS geological maps, the non-genetic term "backshore deposits (Qhbs)" is the most appropriate.

Storm surges appear to be the likely mechanism responsible for the formation of most of the high-level coastal deposits in Hong Kong. Nevertheless, further studies should be carried out to investigate the possibility that these deposits may alternatively have been formed by wind action, winnowing, or even by fault movements.

It is recommended that backshore deposits should be systematically searched for, mapped and investigated, and their significance should be taken into account in future coastal engineering and urban planning projects, particularly in view of the potential damage to structures that could result from extreme waves. Therefore, it is proposed that all "backshore deposits" in the Territory be identified and mapped during the current map updating project. For example, on Map Sheet 15, the newly identified backshore deposits at Shek O and Lamma should be depicted on the updated map. In addition, further field work, including field inspection, levelling, stratigraphy, and sedimentological studies, should be carried out to verify the detailed distribution and sedimentological characteristics of these valuable indicator deposits.

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Table 1 - Tidal Statistics for Four Tide Gauge Stations in Hong Kong, based on Hong Kong Observatory Data (1988 - 2006)

Station Name	Tidal Records Available to Derive Tidal Statistics	MHHW (mPD)	MLLW (mPD)	MSL (mPD)
Quarry Bay #	1988 - 2006	+ 2.03	+ 0.48	+ 1.28
Tai Po Kau	1988 - 2006	+ 2.03	+ 0.46	+ 1.27
Tsim Bei Tsui	1988 - 2006	+ 2.30	+ 0.21	+ 1.29
Waglan Island	1988 - 2006	+ 2.07	+ 0.62	+ 1.38

Legend:

MHHW Mean higher high water
MLLW Mean lower low water
MSL Mean sea level

Note: # Tidal statistics for Quarry Bay have not been corrected for ground settlement for the period 1988 to 1991.

Table 2 - The Highest Astronomical Tide (HAT) and Lowest Astronomical Tide (LAT) at Four Locations, based on Hong Kong Observatory Data (1988 - 2006)

Tide GaugeStation	HAT (mPD)	LAT (mPD)	MSL (mPD)
Quarry Bay	+ 2.63	- 0.11	+ 1.28
Tai Po Kau	+ 2.58	- 0.13	+ 1.27
Tsim Bei Tsui	+ 3.01	- 0.24	+ 1.29
Waglan Island	+ 2.68	+ 0.04	+ 1.38

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Table 3 - Nomenclature Used in HKGS Geological Memoirs for the Categorisation of High-level Coastal Deposits

Memoir No.	Mapsheet No.	Nomenclature		Level of the Deposits
		Used on Maps	Used in Memoir	
1	7	N/A	N/A	N/A
2	11	N/A	Storm Beach Deposits	Bouldery deposits - up to +11 mPD. Sandy deposits - up to +10 mPD.
	15			
3	2	Qrb-Raised Beach Deposits	Raised Beach Deposits	Sandy deposits - up to +6.5 mPD.
	5			
	6			
4	8	N/A	N/A	Bouldery deposits - up to 7 m above sea level. Sandy deposits - up to 8 m above sea-level.
	12			
	16			
5	3	N/A	N/A	Large boulders were moved 150 m from sea bed to the top of a promontory over +10 mPD.
	4	Qbs-Back Shore Deposits	Back Shore Deposits	
6	9	Qrb-Back Beach Deposits	Back Beach Deposits	Sandy deposits - up to +6 mPD.
	10			
	13	Qbs-Back Beach Deposits		
	14	Qrb-Raised Beach Deposits	Raised Beach Deposits	

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Table 4 - Lowest and Highest Sea Levels Recorded at Four Tide Gauge Stations in Hong Kong, based on Hong Kong Observatory Data (1988 - 2006)

Station Name	Data Period	Highest Sea Level* (mPD)	Lowest Sea Level (mPD)
North Point/ Quarry Bay	1954 - 2006	+ 3.81	- 0.31
Tai Po Kau	1963 - 2006	+ 4.18	- 0.48
Tsim Bei Tsui	1974 - 2006	+ 3.83	- 0.36
Waglan Island	1976 - 2006	+ 3.28	- 0.32
Note: * Combined level of astronomical tide and storm surge.			

Table 5 - Significant Wave Heights for Different Return Periods at Two Offshore Locations in Hong Kong Waters, based on Storm Hindcasting Data from Civil Engineering Office (1998)

Return Period (years)	Significant Wave Height (metres)		
	Point A 114° 09'E 21° 47'N	Point B 114° 40'E 21° 55'N	Average
2	6.01	5.96	5.99
5	8.50	8.62	8.56
10	9.93	10.13	10.03
20	11.15	11.43	11.29
50	12.57	12.93	12.75
100	13.53	13.95	13.74
200	14.42	14.90	14.66

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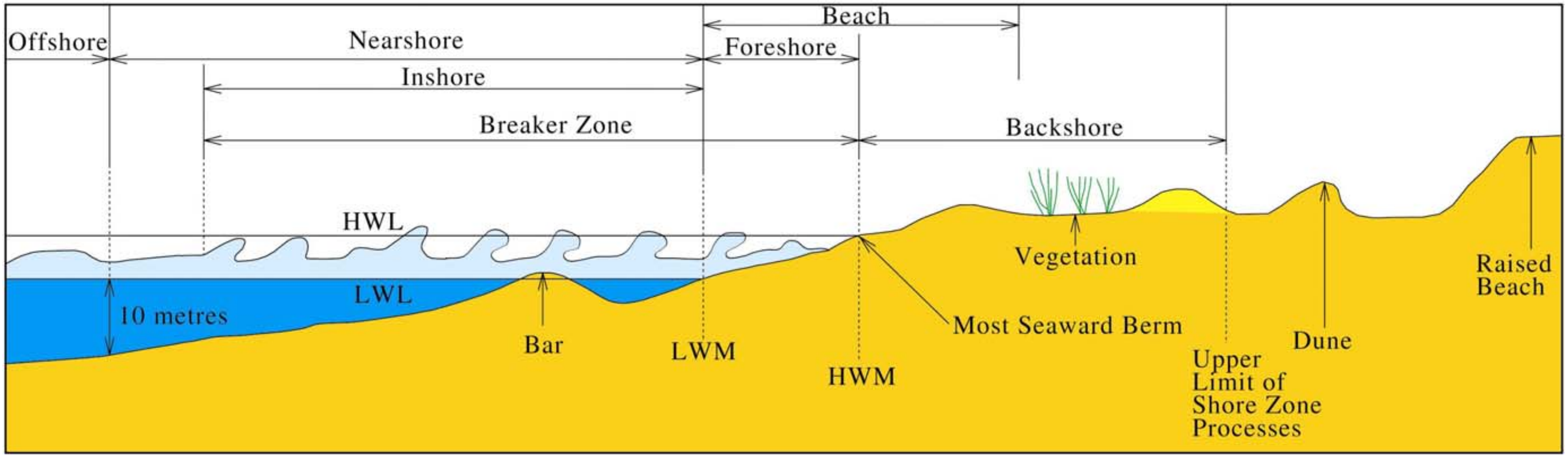

Figure 1 - Beach Profile Terminology

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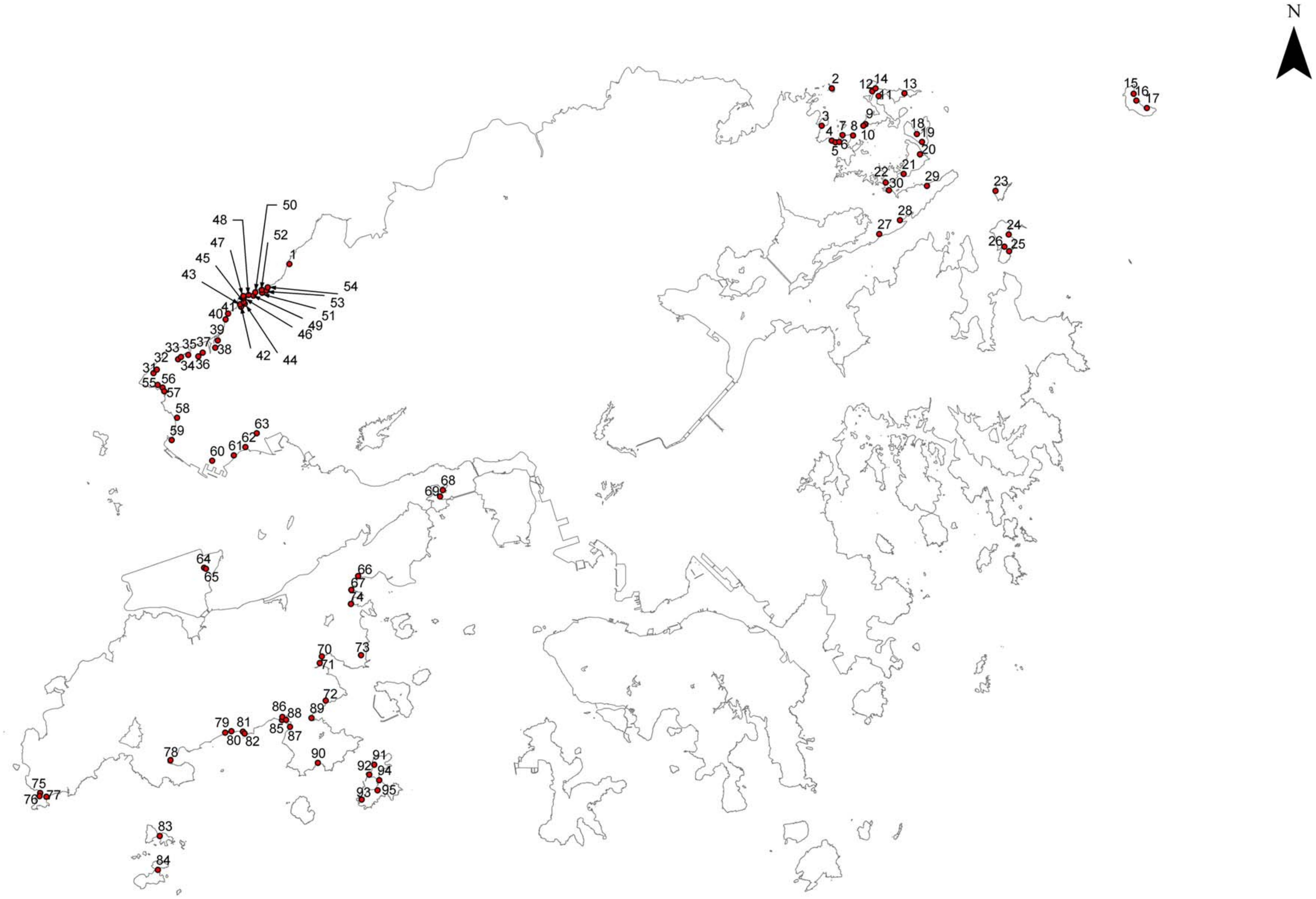

(Please refer to the table in Appendix II for details of the locations shown on the plan)

Figure 2 - Mapped High-level Coastal Deposits in Hong Kong

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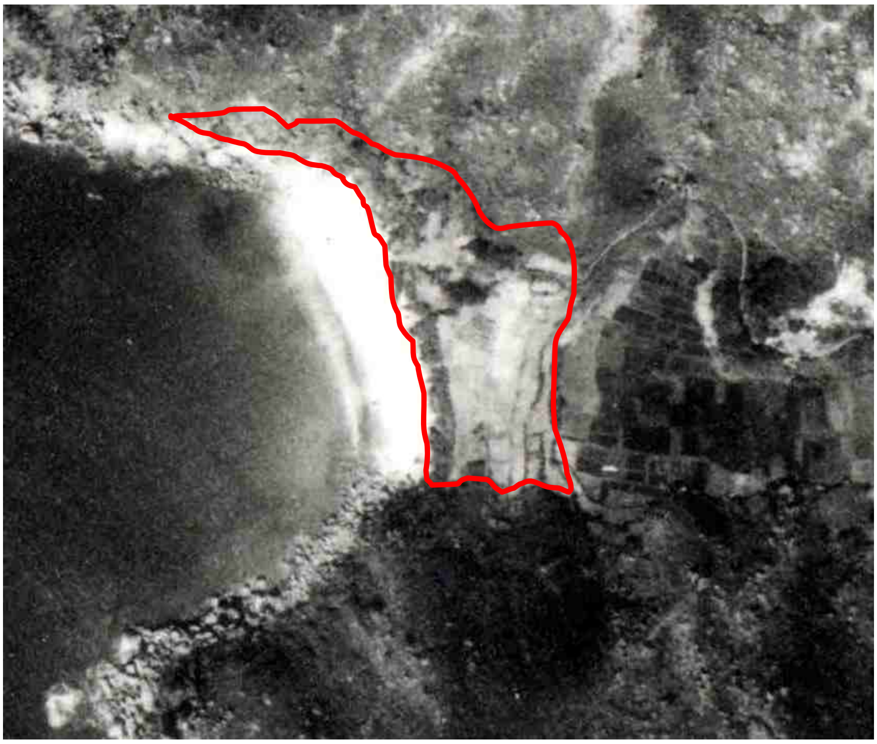

Plate 1 - High-level Coastal Deposits at Sham Wan, Lamma Island (extracted from aerial photo no. Y12763)

Plate 2 - Boulders at +11 mPD forming Dam across a Valley near Mo Tat, Lamma Island (extracted from Plate 46, Strange et al, 1986)

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Plate 3 - High-level Coastal Deposits at Discovery Bay (extracted from aerial photo no. Y12893)

Plate 4 - High-level Coastal Deposits at Sha Po Kong, East of Tuen Mun (extracted from aerial photo no. Y12960)

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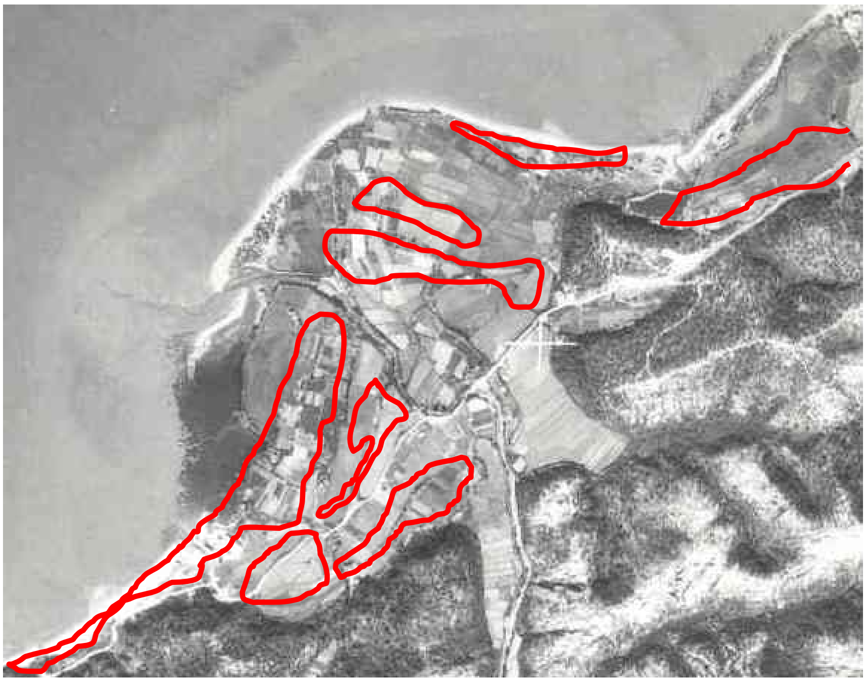

Plate 5 - High-level Coastal Deposits at Sheung Pak Lai, Lau Fau Shan (extracted from aerial photo no. Y12500)

Plate 6 - High-level Coastal Deposits at Tap Mun (extracted from aerial photo no. Y13113)

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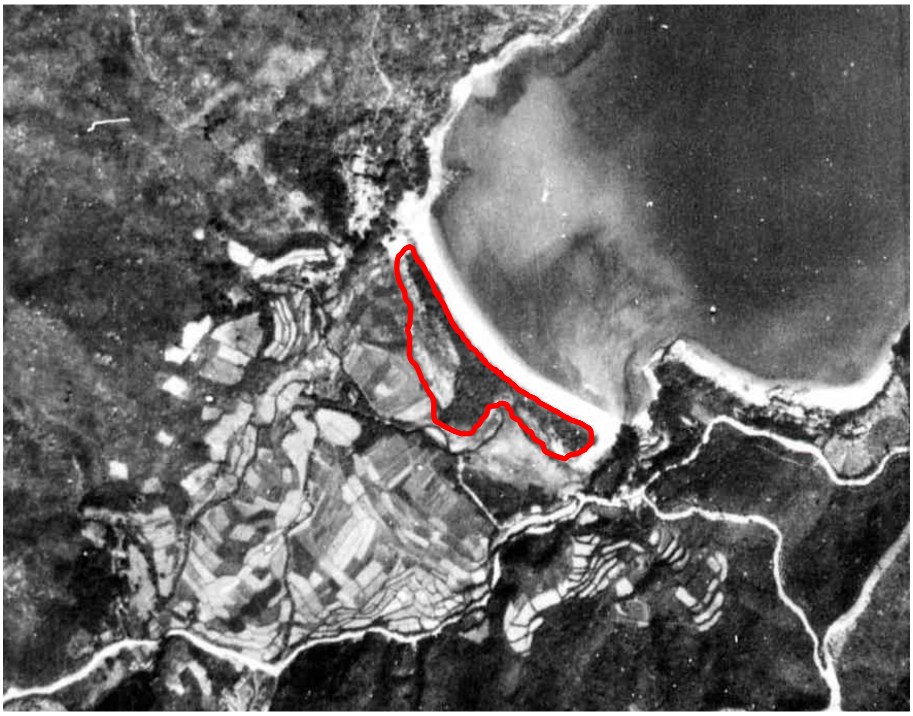

Plate 7 - High-level Coastal Deposits at Chi Ma Wan (extracted from aerial photo no. Y5727)

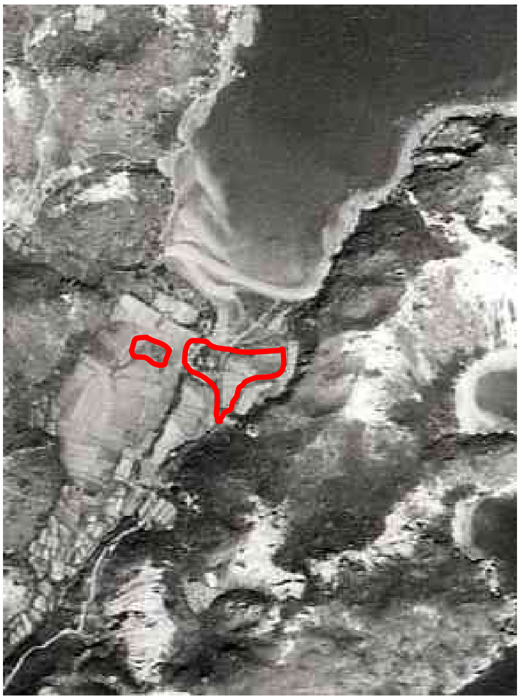

Plate 8 - High-level Coastal Deposits at Chek Lap Kok (extracted from aerial photo no. Y12888)

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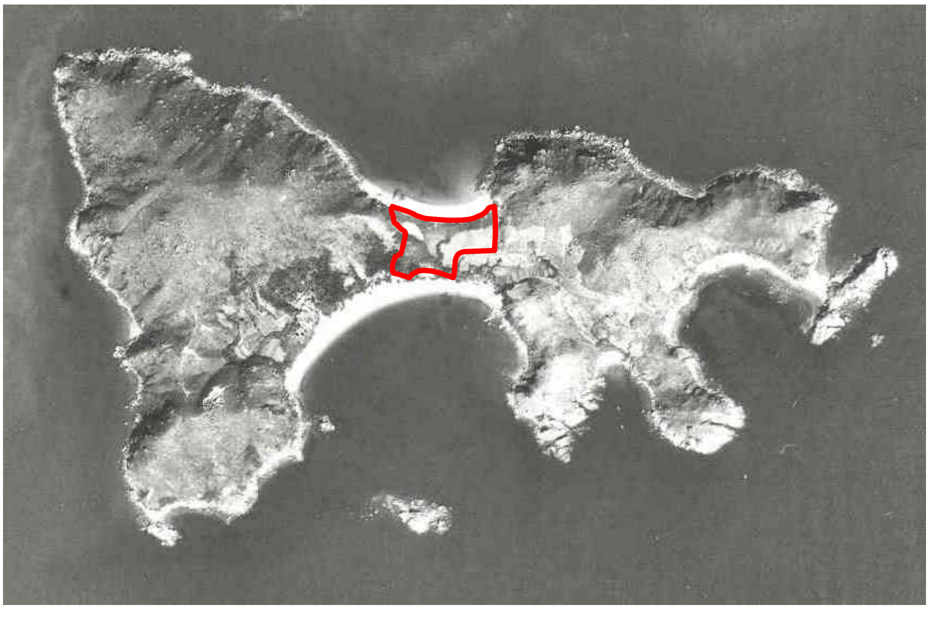

Plate 9 - High-level Coastal Deposits at Siu A Chau (extracted from aerial photo no. Y12724)

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APPENDIX I

GLOSSARY OF TERMS

Glossary of Terms

Alluvium: general term for unconsolidated detrital rock material deposited by a stream, or other body of running water, as a sorted or semi-sorted sediment; occurs in the bed of a stream, on a flood plain or delta, or as a cone or fan below gullies at the base of a mountain slope (after: Gary *et al*., 1972).

Back beach [Backbeach]: see **backshore**.

Backshore: (a) the upper or inner, usually dry, zone of the **shore** or **beach**, lying between the **high-water** line (**HWL**) of mean spring tides and the upper limit of shore-zone processes; it is acted upon by waves or covered by water only during exceptionally severe storms or unusually high tides. It is essentially horizontal or slopes gently landward, and is divided from the **foreshore** by the crest of the most seaward **berm** (after Bates & Jackson, 1987) (b) The area lying immediately at the base of a sea **cliff** (after Bates & Jackson, 1987). Synonym: **backbeach**

Bar *(coast)***:** a generic term for any of various elongate **offshore** ridges, banks, or mounds of sand, gravel, or other unconsolidated material, submerged at least at high tide, and built up by the action of waves or currents on the water bottom, especially at the mouth of a river or estuary, or at a slight distance from a **beach** (after Bates & Jackson, 1987).

Bathymetric: pertaining to measurement of the depth of the sea or ocean; commonly applied to maps portraying seabed morphology.

Beach: (a) the unconsolidated material that covers a gently sloping zone, typically with a concave profile, extending landward from the **low-water** line (**LWL**) to the place where there is a definite change in material or physiographical form (such as a **cliff**), or to the line of permanent vegetation (usually the effective limit of the highest storm waves); a **shore** of a body of water, formed and washed by waves or tides, usually covered by sand or gravel, and lacking a bare rocky surface (after Bates & Jackson, 1987). (b) the relatively thick and temporary accumulation of loose water-borne material (usually well-sorted sand and pebbles, accompanied by mud, cobbles, boulders, and smoothed rock and shell fragments) that is in active transit along, or deposited on, the **shore** zone between the limits of **low-water** and **high-water** (after Bates & Jackson, 1987).

Berm: a low, impermanent, nearly horizontal or landward-sloping bench, shelf, ledge, or narrow terrace on the **backshore** of a **beach**, formed of material thrown up and deposited by storm waves. Some beaches have no berms, others have one or several. Synonym: **backshore**; backshore terrace (after Bates & Jackson, 1987).

Breakers *(waves)***:** a sea-surface wave that has become so steep (wave steepness of 1/7) that the crest outraces the body of the wave and collapses into a turbulent mass on the **shore** or over a reef or rock. Breaking usually occurs when the water depth is less than 1.28 times the wave height (after Bates & Jackson, 1987).

Breaker zone: (a) a collective term for **breakers** (b) wave activity in the surf zone. Synonym: surf zone (after Bates & Jackson, 1987).

Cliff: any high, very steep to perpendicular or overhanging face of rock. A cliff is usually produced by erosion, less commonly by faulting (after Bates & Jackson, 1987).

Colluvium: a general term applied to loose, heterogeneous, and incoherent accumulations of soil material or rock fragments; deposited chiefly by mass wasting processes. Usually occurs as sheets on, or at the base of, a steep slope or **cliff** (after: Gary *et al*., 1972). A wide range of transport mechanisms are involved, from rain splash and continuous creep, to

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sliding and flowing (after: Macdonald, 1983). The chief characteristic of colluvial deposits is the absence of sorting, with grain size varying from the finest particles to huge boulders (after: Raeburn & Milner, 1927).

Coastline: see **shoreline**.

Dune: a low mound, ridge, bank, or hill of loose, wind-blown granular material (generally sand, sometimes volcanic ash), either bare or covered with vegetation, capable of movement from place to place in the direction of the prevailing wind, but always retaining its characteristic shape (after Bates & Jackson, 1987).

Foreshore: (a) the lower or outer, gradually seaward-sloping, zone of the **shore** or **beach**, lying between the crest of the most seaward **berm** on the **backshore** (or the upper limit of wave wash at high tide) and the ordinary **low-water** mark; the zone regularly covered and uncovered by the rise and fall of the tide, or the zone lying between the ordinary tide levels. Sometimes referred to as the **shore** (after Bates & Jackson, 1987).

High-water: water at the maximum level reached during a tidal cycle [the High-water Line, Mark or Level]. Synonym: high tide (after Bates & Jackson, 1987).

Inshore: situated close to the **shore** or indicating a shoreward position; specifically said of a zone of variable width extending from the **low-water shoreline** through the **breaker zone** (after Bates & Jackson, 1987).

Low-water: water at the minimum level reached during a tidal cycle [the Low-water Line, Mark or Level]. Synonym: low tide (after Bates & Jackson, 1987).

Nearshore: the zone extending seaward an indefinite, but generally short, distance from the **shoreline**; specifically said of the indefinite zone extending from the **low-water shoreline** well beyond the breaker zone, defining the area of **nearshore** currents, and including the **inshore** zone and part of the **offshore** zone. Depths are usually less than 10 m (after Bates & Jackson, 1987).

Offshore: (a) situated off, or at a distance from the **shore**; specifically said of the comparatively flat, always submerged zone of variable width extending from the **breaker zone** to the seaward edge of the continental shelf. The accepted minimal depth is 10 metres. The offshore zone is seaward of the **inshore** or **nearshore** zone, although it is often regarded as the zone extending seaward from the **low-water shoreline** (after Bates & Jackson, 1987).

Raised beach: an ancient **beach** occurring above the present **shoreline** and separated from the present **beach**, having been elevated above **high-water** mark, either by local crustal movements (uplift), or by a lowering of sea level, and commonly bounded by an inland **cliff** (after Bates & Jackson, 1987).

Shore [coast]: the narrow strip of land immediately bordering any body of water, especially a sea or a large lake; specifically, the zone over which the ground is alternately exposed and covered by tides or waves, or the zone between **high-water** and **low-water**. The shore is the most seaward part of the **coast**; its upper boundary is the landward limit of effective wave action at the base of the **cliff**, and its seaward limit is the **low-water** line. Subdivided into a **foreshore** and a **backshore** (after Bates & Jackson, 1987).

Shoreface: (a) the narrow, rather steeply sloping zone seaward from the **low-water shoreline**, permanently covered by water, over which **beach** sands and gravels actively oscillate with changing wave conditions. The zone lies between the seaward limit of the **shore**, and the more nearly horizontal surface of the **offshore** zone (after Bates & Jackson, 1987).

Shoreline: (a) the intersection of a specified plane of water with the **shore** or **beach**; it migrates with changes of the tide or of the water level. The term is commonly used in the sense of “**high-water shoreline**” or the

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intersection of the plane of mean **high-water** with the **shore** or **beach**, or the landward limit of the intermittently exposed **shore**. (b) the general configuration or outline of the **shore**. - The terms shoreline and coastline are often used synonymously, but there is a tendency to regard the "coastline" as a limit fixed in position for a relatively long time, and "shoreline" as a limit that is constantly moving across the **beach**. Synonym: **shore** (after Bates & Jackson, 1987).

Storm beach: a low, rounded ridge of coarse gravel, cobbles, and boulders, piled up by powerful storm waves behind or at the inner (landward) margin of a **beach**, above the level reached by normal high spring tides or by ordinary waves (after Bates & Jackson, 1987).

Surf zone: see **breaker zone**.

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APPENDIX II

TABULATED DATA RECORDING THE DISTRIBUTION OF MAPPED HIGH-LEVEL COASTAL DEPOSITS IN HONG KONG

Details of mapped High Level Coastal Deposits in Hong Kong

No.	Northings	Eastings	Map Sheet	Location	Length (m)	Width (m)	Range of Level (mPD)	Range of active beach (m)	Facing Direction	Setting	Landform	Photo No. (Year)
1	836150	816140	2	Hang Hau Tsuen, Lau Fau Shan	200	50	3.9	2.3	WNW	EC	RB	Y13083-4 (1964)
2	845750	845800	4	Ap Chau	180	30	3.3-4.1	no data	SW	EB	B	Y13075-6 (1964)
3	843710	845250	4	Kau Lo Tau	120	30	no data	no data	SE	EB	B	Y13075-6 (1964)
4	842890	845800	4	Chung Wan	140	30	no data	no data	N	EB	B	Y13075-6 (1964)
5	842800	846000	4	Chung Wan	100	30	no data	no data	N	EB	B	Y13075-6 (1964)
6	842820	846200	4	Chung Wan	140	30	no data	no data	N	EB	B	Y13075-6 (1964)
7	843200	846390	4	Chung Wan Tsui	40	30	4.9	no data	N	EB	T	Y13075-6 (1964)
8	843180	846960	4	Liu Ko Ngam	80	20	no data	no data	SE	EB	B	Y13075-6 (1964)
9	843800	847640	4	Pak Sha Tsui	100	25	5.2	no data	SE	EB	B	Y13075-6 (1964)
10	843700	847530	4	Pak Sha Tsui	40	20	4.3	no data	S	EC	S	Y13075-6 (1964)
11	845330	848360	4	Po Yue Pai, Kat O Chau	400	60	3-3.4	no data	SE	EB	B	Y13077-8 (1964)
12	845590	848010	4	Chung Kan O	300	60	3.3-4	no data	SW	EB	B	Y13077-8 (1964)
13	845480	849770	4	Chung Wan	90	30	no data	no data	SE	EB	B	Y13077-8 (1964)
14	845750	848190	4	Tung O Wan	120	70	4.9-6.4	no data	ENE	EB	B	Y13077-8 (1964)
15	845450	862300	4	Cheung Sha Wan, Ping Chau	370	25	5.3	no data	E	EB	B	10029-30 (1974)
16	845080	862450	4	Tai Tong Wan, Ping Chau	300	40	4.3	no data	NE	EB	B	10029-30 (1974)
17	844680	863030	4	A Ma Wan, Ping Chau	1000	20	4.3-5	no data	NE	EB	B	10029-30 (1974)
18	843250	850450	4	Wu Pai, Ngo Mei Chau	180	25	3.7	no data	N	EB	B	Y13123-4 (1964)
19	842820	850730	4	Lo Kei Wan, Ngo Mei Chau	100	20	no data	no data	S	EB	B	Y13123-4 (1964)
20	842150	850620	4	Tung Wan	300	40	no data	no data	E	EB	B+S	Y13123-4 (1964)
21	841070	849730	4	Wong Wan	280	20	no data	no data	SW	EB	B	Y13107-8 (1964)
22	840600	848750	4	Hung Shek Mun	140	20	4.3-4.9	no data	S	EB	B	Y13107-8 (1964)
23	840150	854750	4	Tai Wan, Chek Chau	100	5	no data	no data	NW	EB	B	Y13111-2 (1964)
24	837770	855470	4	Che Wan, Tap Mun Chau	580	20	7.3-7.6	no data	E	EB	B	Y13111-2 (1964)
25	836850	855500	4	Chung Wai, Tap Mun Chau	200	30	no data	no data	SE	EB	B	Y13111-2 (1964)
26	837100	855240	4	Ha Wai, Tap Mun Chau	260	40	no data	no data	SW	EB	B	Y13111-2 (1964)
27	837790	848400	4	Wong Wan Chai	80	40	2.7	no data	SSE	EB	B	Y13107-8 (1964)
28	838550	849520	4	Fung Wong Wat	180	30	2.7-4.0	no data	E	EB	B	Y13107-8 (1964)
29	840420	851000	4	Pak Kok Shan	60	20	no data	no data	NW	EB	B	Y13107-8 (1964)
30	840180	848920	4	Tong Pai Tau	80	20	no data	no data	NE	EB	B	Y13107-8 (1964)
31	830190	808710	5	Yung Long	120	40	no data	no data	NW	EB	B	Y12993-4 (1964)
32	830380	808890	5	Yung Long	420	20	no data	no data	NW	EB	B	Y12993-4 (1964)
33	830950	810050	5	Tsang Tsui	100	100	2.9-3.6	no data	N	AP	B	Y12994-5 (1964)
34	831070	810210	5	Tsang Tsui	200	20	4.0	3.5	N	EB	B	Y12994-5 (1964)
35	831180	810600	5	Tsang Kok	180	30	no data	no data	N	EB	B	Y12994-5 (1964)
36	831110	811160	5	Nim Wan	90	120	no data	no data	N	AP	B	Y13047-8 (1964)
37	831310	811400	5	Nim Wan	440	60	no data	no data	NW	EB	B	Y13047-8 (1964)
38	831580	812080	5	Nim Wan Road	300	25	5.5	no data	NW	AP	B	Y13047-8 (1964)
39	831970	812220	5	Ha Pak Nai	540	240	3.6-5.2	no data	N	AP	RB	Y13047-8 (1964)
40	833130	812650	5	North of Ha Pak Nai	340	130	3.1-3.7	no data	W	EC	RB	Y13047-8 (1964)
41	833440	812780	5	North of Ha Pak Nai	200	30	3.1-3.3	no data	NW	EC	RB	Y13047-8 (1964)
42	833820	813500	5	Sheung Pak Nai	100	90	4.5-4.7	no data	NW	AP	RB	Y13047-8 (1964)
43	833950	813440	5	Sheung Pak Nai	700	80	3.2-3.4	no data	NW	AP	RB	Y13047-8 (1964)
44	833980	813700	5	Sheung Pak Nai	280	40	4.4-5.1	no data	NW	AP	RB	Y13047-8 (1964)
45	834080	813640	5	Sheung Pak Nai	220	60	3.7	no data	NW	AP	RB	Y13047-8 (1964)
46	834310	813640	5	Sheung Pak Nai	320	60	3-3.1	no data	N	AP	RB	Y13047-8 (1964)
47	834400	813620	5	Sheung Pak Nai	180	30	2.8	no data	N	AP	RB	Y13047-8 (1964)
48	834460	813900	5	Sheung Pak Nai	320	40	2.8-4.7	no data	N	EB	RB	Y13047-8 (1964)
49	834430	814170	5	Deep Bay Road	440	40	4.9-5.1	no data	NNW	AP	B	Y13047-8 (1964)
50	834610	814280	5	Deep Bay Road	160	20	4.3-4.7	no data	NW	AP	RB	Y13047-8 (1964)
51	834580	814650	5	Ngau Hom Sha	240	80	4.3-5.4	no data	N	AP	RB	Y13047-8 (1964)
52	834740	814620	5	Deep Bay Road	360	40	4.7-5.4	no data	N	AP	RB	Y13047-8 (1964)
53	834700	814900	5	Ngau Hom Sha	220	130	4-4.5	no data	N	AP	RB	Y13047-8 (1964)
54	834880	814950	5	Deep Bay Road	340	40	4.5	no data	N	AP	RB	Y13047-8 (1964)
55	829550	808940	5	Lung Kwu Sheung Tan	100	20	3.2-4.1	sand 2.7-3.3/ rubble 4.5-4.8	SW	EB	B	Y12993-4 (1964)

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No.	Northings	Eastings	Map Sheet	Location	Length (m)	Width (m)	Range of Level (mPD)	Range of active beach (m)	Facing Direction	Setting	Landform	Photo No. (Year)
56	829400	809200	5	Lung Kwu Sheung Tan	460	100	5.4-6.1	3.3-3.8	SW	EB	B	Y12993-4 (1964)
57	829200	809300	5	Lung Kwu Sheung Tan	220	20	4.2-4.7	3.3-3.6	SW	EB	B	Y12993-4 (1964)
58	827750	810000	5	Sha Po Kong	830	80	6.7-7.5	4-5.9	W	EB	B	Y12960-1 (1964)
59	826530	809700	5	Tap Shek Kok	170	20	no data	no data	SW	EB	B	Y12960-1 (1964)
60	825400	811910	5	Mong Hau Shek	240	15	4.0-6.0	no data	SW	EB	B	Y12960-1 (1964)
61	825700	813100	5	West of Wu Tip Wan	280	40	no data	no data	S	EC	B	Y12961-2 (1964)
62	826150	813730	5	Wu Tip Wan	1400	200	no data	no data	SE	EC	B	Y12961-2 (1964)
63	826900	814350	5	Lung Mun Road	320	80	no data	no data	E	EB	B	Y12961-2 (1964)
64	819550	811480	9	the then Sham Wan Tsuen, Chek Lap Kok	50	40	no data	no data	N	AP	RB	Y12888-9 (1964)
65	819500	811580	9	the then Sham Wan Tsuen, Chek Lap Kok	80	30	no data	no data	N	AP	RB	Y12888-9 (1964)
66	819100	819900	10	Sam Pak Wan	140	20	4.1-4.3	no data	SE	EB	RB	Y12893-4 (1964)
67	818350	819530	10	Yi Pak Wan	250	20	4.5	2.7-3.2	E	EB	B	Y12893-4 (1964)
68	823800	824530	10	Tung Wan Tsai	200	20	4-6.5	3.9	E	EB	B	Y12921-2 (1964)
69	823450	824380	10	Tung Wan	180	20	4.1	no data	E	EB	B	Y12921-2 (1964)
70	814710	817910	10	Wang Tong, Silver Mine Bay	400	80	4.8-5.9	no data	SE	EB	RB	Y12861-2 (1964)
71	814350	817800	10	Chung Hau, Silver Mine Bay	180	150	5.9	4.9-5.1	E	EB	RB	Y12861-2 (1964)
72	812290	818130	10	Ngau Kwu Wan	80	40	5.4-6.8	4.4-4.8	SE	EB	RB	Y12861-2 (1964)
73	814780	820050	10	Kau Shat Wan	120	20	2.7	no data	E	EB	RB	Y12861-2 (1964)
74	817580	819500	10	Discovery Bay	300	40	no data	no data	ENE	EB	B	Y12893-4 (1964)
75	807250	802510	13	Fan Lau Sai Wan	240	30	4.6-6.1	no data	W	EB	RB	Y12739-40 (1964)
76	807080	802480	13	Fan Lau Tsuen	100	50	5.2	no data	W	EB	RB	Y12739-40 (1964)
77	807050	802850	13	Fan Lau Tung Wan	320	80	4-11.9	no data	SE	EB	RB	Y12739-40 (1964)
78	809040	809630	13	Shui Hau Wan	330	30	6.6	no data	E	EB	RB	Y12745-6 (1964)
79	810550	812630	13	Cheung Sha Beach	140	50	8.7-9.1	no data	S	EB	B	Y12746-7 (1964)
80	810620	812960	13	Cheung Sha Beach	460	60	6.5-6.7	no data	S	EB	B	Y12746-7 (1964)
81	810600	813600	13	Cheung Sha Ha Tsuen	160	60	4.3-5.6	no data	SW	EB	B	Y12746-7 (1964)
82	810500	813690	13	Cheung Sha Ha Tsuen	60	20	no data	no data	W	EB	B	Y12746-7 (1964)
83	804900	809050	13	Siu A Chau	160	90	5.6-6	no data	N	EB	T	Y12723-4 (1964)
84	803050	808950	13	Tung Wan, Soko Islands	40	120	no data	no data	W	EB	B	Y12722-3 (1964)
85	811230	815730	14	Pui O Wan	920	40	4.1-4.6	no data	SSW	EB	RB	Y12748-9 (1964)
86	811400	815750	14	Pui O Wan	360	50	7.1	no data	SSW	AP	RB	Y12748-9 (1964)
87	810860	816170	14	Pui O Wan	100	20	4.2	no data	WSW	EB	RB	Y12748-9 (1964)
88	811250	815960	14	Pui O Wan	60	15	no data	no data	AW	AP	RB	Y12748-9 (1964)
89	811350	817350	14	Chi Ma Wan	260	60	3.4-3.7	no data	ENE	EB	RB	Y12748-9 (1964)
90	808900	817700	14	Tai Long Wan, Chi Ma Wan Peninsula	440	40	9.1-9.2	no data	S	EB	RB	Y12748-9 (1964)
91	808800	820780	14	Tai Kwai Wan, Cheung Chau	140	50	6.4	no data	W	EB	B	Y12751-2 (1964)
92	808250	820510	14	Cheung Kwai Estate, Cheung Chau	100	20	no data	no data	NW	EB	B	Y12751-2 (1964)
93	806890	820090	14	Sai Wan, Cheung Chau	40	50	3.5	no data	E	EB	B	Y12751-2 (1964)
94	807950	821050	14	Tung Wan, Cheung Chau	700	120	6.2-6.8	East 4.3-4.8/ West 3.7-4	W	EB	T	Y12751-2 (1964)
95	807400	820960	14	Tai Tsoi Yuen Kui, Cheung Chau	120	80	no data	no data	NW	EB	B	Y12751-2 (1964)

Remark:

EB	Embayment
EC	Exposed Coast
AP	Alluvial Plain
B	Berm
RB	Raised Bar
S	Spit
T	Tombolo

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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.

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土木工程拓展署
土力工程處
規劃部總土力工程師
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MAJOR GEOTECHNICAL ENGINEERING OFFICE PUBLICATIONS
土力工程處之主要刊物

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.

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.

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

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