Geotechnical Area Studies Programme

GASP Report VII

Clear Water Bay

Geotechnical Control Office
Civil Engineering Services Department
Hong Kong

First published, August 1988

This Report was prepared in the Planning Division of the Geotechnical Control Office by A. Hansen, R. J. Purser and K. A. Styles.

Address:

Geotechnical Control Office
Empire Centre, 6th Floor
Tsim Sha Tsui East, Kowloon
Hong Kong.

This publication is available from:

Government Publications Sales Centre
General Post Office Building, Ground Floor
Connaught Place
Hong Kong.

Overseas orders should be placed with:

Publications (Sales) Office
Information Services Department
Beaconsfield House, 4th Floor
Queen's Road Central
Hong Kong.

Price in Hong Kong: HK$150.

Price overseas: US$25 (including surface postage)

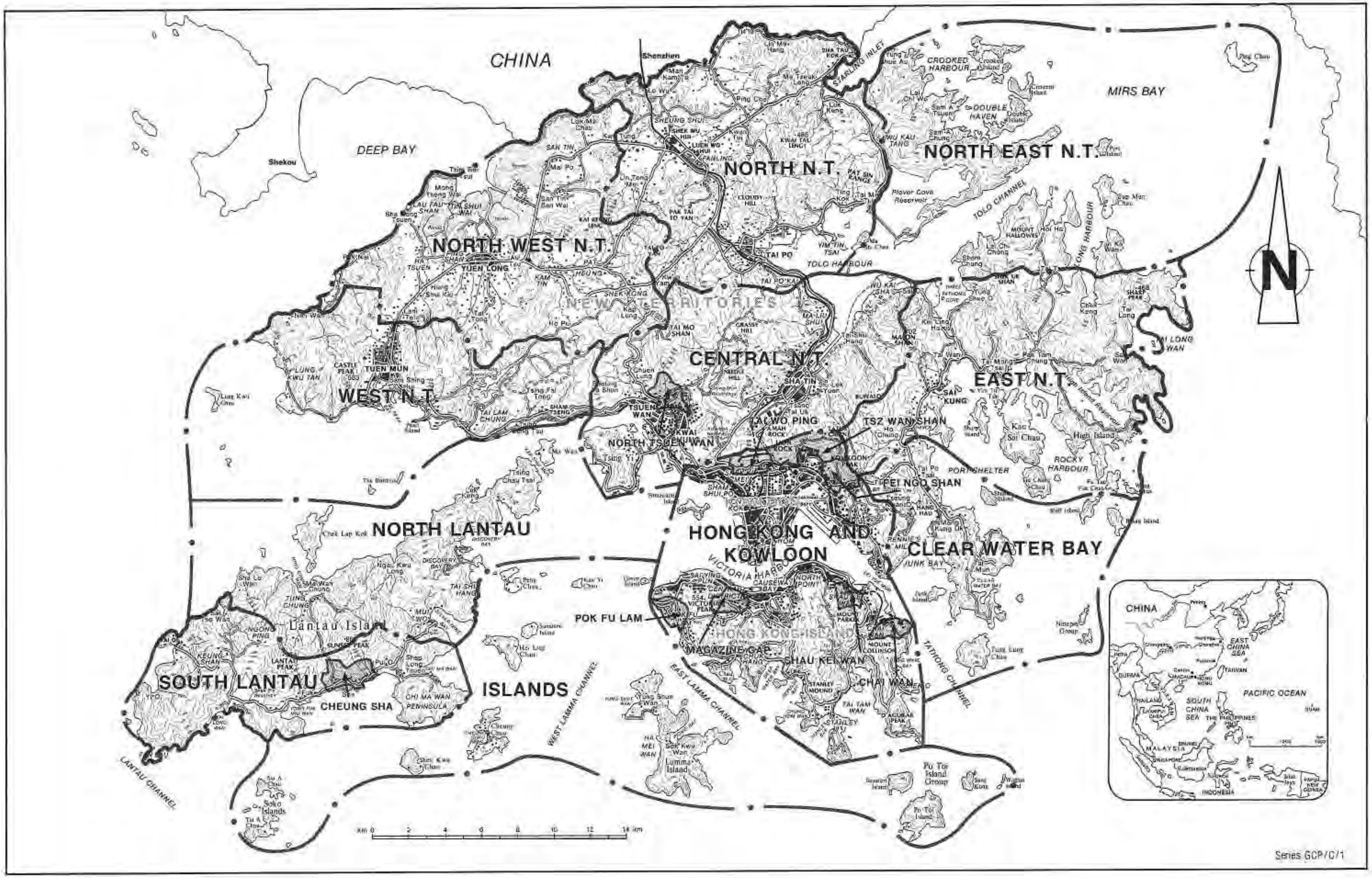
Cover Photograph: Junk Bay and Environs.

Geotechnical Area Studies Programme

GASP Report VII

Clear Water Bay

Geotechnical Control Office
Civil Engineering Services Department
Hong Kong
August 1988



Map of the Territory of Hong Kong Showing the Locations of the Geotechnical Area Studies.
(Boundaries of the Regional Studies are shown by dashed lines and locations of District Studies are indicated by dark screens)

FOREWORD

This Report aims to provide an adequate geotechnical basis for the planning and land use management of the Clear Water Bay area, mainly by way of information presented on a series of maps at a scale of 1:20 000. It is the seventh of twelve reports to be published as a result of the Territory-wide Geotechnical Area Studies Programme (GASP) carried out by the Geotechnical Control Office between 1979 and 1985.

GASP is based largely on terrain classification techniques using aerial photographs, together with field reconnaissance and the evaluation of a large number of existing site investigation records. It employs a unique system of terrain evaluation developed especially for Hong Kong conditions for the analysis and interpretation of the available data.

The GASP Reports were originally conceived as providing information almost solely for territorial land use planning, for which purpose the mapping scale of 1:20 000 is considered to be suitable. However, the information they contain also provides a good basis for engineering feasibility studies of large sites. The overall geotechnical assessment of a study area is presented on a series of seven user-oriented maps. Four of these are supplied with this published Report—the Engineering Geology Map (EGM), Geotechnical Land Use Map (GLUM), Physical Constraints Map (PCM), and Generalised Limitations and Engineering Appraisal Map (GLEAM). The GLUM classifies the terrain into four classes according to the level of geotechnical limitations, the PCM presents the major physical constraints that are likely to influence development, and the GLEAM delineates broad areas with potential for development from the geotechnical and planning points of view. In addition to the four maps accompanying this Report, the Terrain Classification Map, Landform Map and Erosion Map can be consulted in the Geotechnical Information Unit of the Geotechnical Control Office.

Users of GASP Reports should make reference to the new 1:20 000 scale Hong Kong Geological Survey Maps and Memoirs which are being prepared by the Geotechnical Control Office. These provide more up to date geological information than is available in this Report. The new Geological Map which covers the Clear Water Bay area, together with the accompanying Memoir, will be published in 1989.

This Report was originally produced in August 1985, for use within the Hong Kong Government on the basis of information assembled during the period July 1983 to October 1984. This fact should be borne in mind by users, who should also note that the contents of the Report have for the most part not been updated. Further, although every effort has been made to ensure the accuracy of the information contained in the Report, this cannot be guaranteed. The Geotechnical Control Office cannot therefore accept any liability for errors in the data or for misinterpretations made during the study.

It must be emphasised that this document was prepared for general planning and resource evaluation purposes. As a general rule, 1:20 000 scale maps, particularly the GLUM, should not be used to evaluate parcels of land smaller than 3 hectares in size, and should never be interpreted, reproduced or enlarged to a scale greater than 1:20 000. Failure to heed this warning could result in serious misinterpretation of the information they contain.

The GASP study was undertaken by a team of specialist Geotechnical Engineers in the Planning & Terrain Evaluation Section of the Planning Division of the GCO, which included Messrs A. Hansen, R. J. Purser and K. A. Styles. The Planning & Terrain Evaluation Section is led by Mr K. A. Styles, and the Planning Division is under the direction of Dr A. D. Burnett.

Acknowledgements are due to the Survey & Mapping Office, Buildings & Lands Department of the Hong Kong Government, who provided most of the aerial photographs used in the study.

E. W. Brand
Principal Government Geotechnical Engineer
August 1988

CONTENTS

List of Figures

List of Maps

List of Plates

List of Tables

1. INTRODUCTION

1.1 The Clear Water Bay Geotechnical Area Study

This Report presents the results of a 1:20 000 scale Regional Geotechnical Area Study of the Junk Bay, Silverstrand and Joss House Bay area, which was carried out in the Geotechnical Control Office between July 1983 and October 1984. The area covered by the study, which is designated as GASP VII, is shown in Figures 1 to 3.

The study is based primarily on:

(*a*) Terrain classification using aerial photograph interpretation (API).

(*b*) Examination of geotechnical data collected from existing site investigation records and available literature.

(*c*) Field reconnaissance.

Subsurface investigations were not carried out specifically for this study.

This Geotechnical Area Study was based on the bedrock geology given on the 1:50 000 scale geological map produced by Allen & Stephens (1971). The mapping of the superficial deposits was carried out independently during the study.

It should be noted that the Geotechnical Control Office is at present remapping the whole Territory geologically to produce a new series of maps at a scale of 1:20 000, together with accompanying Memoirs. These will supersede both the bedrock geology and the mapping of superficial deposits presented in this Report. The new map which covers much of the area dealt with in this GASP Report and the accompanying Memoir will be available in 1989.

1.2 The Geotechnical Area Studies Programme

The Geotechnical Area Studies Programme (GASP) was initiated by the Geotechnical Control Office in September 1979 with the aim of providing systematic geotechnical input for land management and development planning of the Territory of Hong Kong. The Programme encompasses the entire land area of the Territory at a scale of 1:20 000 and a number of selected areas at 1:2 500.

The GASP areas were selected so that the results of each Study can be used for the planning and engineering feasibility of future development. For this purpose, the study results are summarised on a series of maps.

The Geotechnical Area Studies were planned to be carried out in the following three phases:

(*a*) *Regional Study*—Initial geotechnical assessment (at a scale of 1:20 000) based entirely upon aerial photograph interpretation, site reconnaissance and existing geotechnical information.

(*b*) *District Study: Stage 1*—Initial geotechnical assessment (at a scale of 1:2 500), based entirely upon aerial photograph interpretation, site reconnaissance and existing geotechnical information, to provide a more detailed assessment of specific areas identified in the Regional Studies.

(*c*) *District Study: Stage 2*—Expanded geotechnical assessment, based upon the results of a Stage 1 Study together with data obtained from a planned programme of site investigation.

Twelve Regional Studies have been completed, which cover the Territory of Hong Kong. This is the seventh of the Reports to be published; five others will follow in due course. A number of District Studies: Stage 1 have been carried out. Whilst these District Study: Stage 1 Reports are only for use within Government, some information in map form is available on request (see Section 1.7).

1.3 Aims of the Geotechnical Area Studies Programme

The Geotechnical Area Studies Programme (GASP) Reports produced for regional appraisal are designed for development planning and engineering feasibility at a scale of 1:20 000. They provide relatively specific physical resource information for the assessment of geotechnical limitations and the engineering geological characteristics of the terrain for outline and strategic planning purposes.

Nine terrain-related land resource factors are assessed in this study: slope angle, geological materials, terrain component, erosion and instability, slope aspect, relief, vegetation, existing land use and rainfall. All these factors are important for assessing the nature, degree and intensity of geotechnical constraint associated with the terrain. They are discussed in detail in Appendices A and C.

In this Report, the maps are presented in both a technical and a non-technical format to make the geotechnical information they contain usable by a wide readership. The non-technical aspects are designed for planners, landscape architects, estate surveyors and land agents, while the more technical discussion is designed for civil and geotechnical engineers and engineering geologists.

It should be noted that the need for appropriate site investigation is not obviated by the results of a Geotechnical Area Study.

1.4 Organisation of the Report

The main text, contained in Sections 1 to 4, provides a summary of the study and its findings. The figures are located after the references.

Section 2 describes the topography, geology, geomorphology, hydrology, vegetation, erosion and land use of the Clear Water Bay area. A detailed description of the Allen & Stephens (1971) geological units is provided in Appendix C.

Section 3 provides an assessment of the material characteristics and summarises the technical findings of the study. Section 4 provides a geotechnical assessment for development planning and discusses the suitability for development of various parts of the study area from an engineering point of view.

The conclusions are presented in Section 5, and Section 6 contains the cited references.

The figures are designed to explain and demonstrate the system used for compiling the maps from the data. Figure 13 illustrates the system, and Figures 14 to 20 are extracts from the set of maps. The full size originals of these maps are held by the Geotechnical Control Office.

A selection of maps, plans, stereopairs and photographs follow the example figures, and these are presented as Plates 1 to 16. These plates, together with Figure 2, provide a visual impression of the study area.

Appendix A provides details of the techniques used in the terrain evaluation system. Appendix B tabulates the terrain-related data from the study. Appendix C contains supplementary information on geology along with information on site investigations, aerial photographs and rainfall relevant to the study area. Appendix D discusses landform evolution and its relationship to engineering. A glossary of terms used in the Programme is presented in Appendix E.

A copy of the Geotechnical Land Use Map (GLUM), the Physical Constraints Map (PCM), the Engineering Geology Map (EGM) and the Generalised Limitations and Engineering Appraisal Map (GLEAM) of the study area are contained in the accompanying Map Folder. Information relating to the preparation and limitations of these maps is presented in Section 1.5 and in Appendix A.

1.5 Maps Produced within the Regional Study

1.5.1 *General*

Maps are available in two forms for a Regional GASP Report. They are prepared in conventional line form, and the information they contain is also summarised within a computer data bank for the production of computer-generated plots.

The conventional line maps are produced by standard cartographic processes, whereas the computer plots are totally machine generated. The conventional line maps are either completely or partially derived from the information stored on the Terrain Classification Map. Figure A1 in Appendix A shows the relationship between map type and the method of production.

The computer-generated plots are referenced to the Hong Kong Metric Grid, and information is stored within a grid cell framework. Computer-generated plots can be produced at various scales from 1:20 000 to 1:100 000.

Currently, there are seven conventional line maps produced at a scale of 1:20 000 for each regional study area. The broad characteristics and purpose of each map is listed below. There are a number of general rules for the use of these maps, and these are discussed at Appendix A.10.

1.5.2 *Terrain Classification Map (TCM)*

This map records the general nature of the geological material (insitu, colluvial, alluvial, etc), slope angle, terrain component, erosion and instability. It forms the basis of the mapping system and is not designed for general distribution. The map is produced by aerial photograph interpretation and field work. An example is provided in Figure 14b.

1.5.3 *Landform Map (LM)*

This map is totally derived from the Terrain Classification Map, and it summarises the broad terrain pattern; slope angle and terrain component are delineated at a scale of 1:20 000. It is designed for the use of technical and non-technical users who require general landform data for planning purposes. An example is presented in Figure 19a.

1.5.4 *Erosion Map (EM)*

This map is totally derived from the Terrain Classification Map, and it delineates the broad pattern of erosion and instability at a scale of 1:20 000. It is designed for technical or non-technical users who require information regarding the general nature, degree and intensity of erosion and instability for planning and/or engineering purposes. An example is presented in Figure 20a.

1.5.5 *Geotechnical Land Use Map (GLUM)*

This map is totally derived from the Terrain Classification Map, and it delineates the general level of geotechnical limitation associated with the terrain at a scale of 1:20 000. It is designed for non-technical users who require general information relating to geotechnical difficulty of the terrain for development planning. A copy of the GLUM Classification System is presented at Table 1.1, and a detailed discussion is provided in Appendix A.7. An example of the map is provided in Figure 15a, and a copy of the map sheet is located in the Map Folder.

Table 1.1 GLUM Classification System

Characteristics of GLUM Classes	Class I	Class II	Subclass IIS	Class III	Class IV
Geotechnical Limitations	Low	Moderate		High	Extreme
Suitability for Development	High	Moderate	Moderate – Low	Low	Probably Unsuitable
Engineering Costs for Development	Low	Normal	Normal – High	High	Very High
Intensity of Site Investigation Required	Normal	Normal		Intensive	Very Intensive
Typical Terrain Characteristics (Some, but not necessarily all of the stated characteristics will occur in the respective Class)	Gentle slopes and insitu soils. Minor erosion on flatter slopes. Undisturbed terrain (minor cut and fill only).	Flat to moderate slopes. Colluvial soils showing evidence of minor erosion. Insitu soils which may be eroded. Reclamation. Rock outcrops. Poor drainage. Cut and fill slopes of low height.	Floodplain subject to periodic flooding and inundation.	Steep slopes. Colluvial and insitu soils showing evidence of severe erosion. Poor drainage. Cut and fill slopes of moderate height.	Combination of characteristics such as steep to very steep slopes, general instability on colluvium, severe erosion, poor drainage, high cut and fill slopes.

Note: This classification system is intended as a guide to planners and is not to be used for a detailed geotechnical appraisal of individual sites.

1.5.6 *Physical Constraints Map (PCM)*

This map is totally derived from the Terrain Classification Map, and it presents the major physical land resource constraints at a scale of 1:20 000. It is designed for technical or non-technical users who require information relating to the types of physical constraints which affect the terrain. It should be used in conjunction with the GLUM but is designed to stand alone as an assessment of the physical resources for general planning and engineering purposes. An example of this map is presented in Figure 16a and is discussed in detail in Appendix A.6. A copy of the map sheet is located in the Map Folder.

1.5.7 *Engineering Geology Map (EGM)*

Some of the information in this map is derived from the Terrain Classification Map, and some is compiled from other geological sources (Allen & Stephens, 1971). This map displays the broad pattern of geological materials at a scale of 1:20 000. It is designed for technical users who require engineering geological information for strategic planning and engineering purposes. An example is presented in Figure 17a and is discussed in detail in Appendix A.8. A copy of the map is located in the Map Folder.

1.5.8 *Generalised Limitations and Engineering Appraisal Map (GLEAM)*

This map is prepared by an assessment of the terrain information recorded in the Terrain Classification Map, GLUM, PCM, EGM and current land management. This map evaluates the engineering-related factors which influence the potential of the terrain for future development. Areas with potential are identified at a scale of 1:20 000. The GLEAM is designed for technical and non-technical users who require information relating to the engineering suitability of the terrain for development. An example of the map is presented in Figure 18a, and a detailed discussion is provided in Section 4.2 and in Appendix A.9. A copy of the map is located in the Map Folder.

1.5.9 *Computer-generated Maps*

Information from the Terrain Classification Map and other sources is summarised within the Geotechnical Terrain Classification System (GEOTECS). Land resource information is stored in a data bank management system which is referenced to the Hong Kong Metric Grid.

GEOTECS enables the rapid production of computer-generated plots which assist in the correlation of terrain attributes and other data on a Territory-wide basis. GEOTECS enables the interaction between land resources to be investigated, and permits the development of planning and engineering strategies. Computer-generated plots or tables can be based on any attribute or combination of attributes stored within the system. GEOTECS records data on a two-hectare grid cell basis and is recommended for use at a scale of approximately 1:50 000 for strategic planning and resource inventory purposes.

A number of computer-generated plots are presented which demonstrate the flexibility and multifunctional application of GEOTECS as a tool for resource evaluation.

1.6 Suitability of the Maps for Technical and Non-technical Use

The maps accompanying this Report are designed for a range of users with quite different professional backgrounds. In Table 1.2, each map is assessed in relation to its expected value to a variety of potential users. A number of professional groups which require geotechnical information (technical or non-technical) are highlighted. The list of five disciplines given in the table is by no means exhaustive, but it illustrates the potential of the maps for different requirements. A three-class user recommendation (Fundamental, Useful and Background) indicates the relative value of each map to users.

Table 1.2 Value of the Maps Produced in a Regional GASP Report

Type of Map	Value of the Maps Produced at 1:20 000 Scale for Regional Assessment (of sites generally greater than 10 ha in size)				
	—Strategic Planner —Town Planner	—Landscape Architect	—Estate Surveyor —Land Agent	—Civil Engineer	—Geotechnical Engineer —Engineering Geologist
GLUM*	Fundamental	Fundamental	Fundamental	Fundamental	Useful
PCM*	Fundamental	Fundamental	Background	Fundamental	Fundamental
EGM*	Background	Background	Background	Fundamental	Fundamental
GLEAM*	Fundamental	Fundamental	Fundamental	Fundamental	Fundamental
LM	Useful	Useful	Background	Background	Background
EM	Useful	Useful	Background	Useful	Useful
TCM	Background	Background	Background	Background	Background
GEOTECS	Fundamental	Useful	Fundamental	Useful	Fundamental

* Located in the Map Folder accompanying this Report.

1.7 Access to GASP Data

Much of the data used in preparation of this Report, and the maps not included in the accompanying Folder, are available through the Geotechnical Information Unit (GIU) of the Geotechnical Control Office.

A number of large scale (1:2 500) maps produced within the GASP District Study: Stage 1 Programme are available for areas within the Territory. No District Studies: Stage 1 have been completed within the Clear Water Bay study area.

2. DESCRIPTION OF THE CLEAR WATER BAY STUDY AREA

2.1 Geographical Location

The study area occupies approximately 3 735 ha in the southeastern portion of the New Territories, as shown in Figures 1 to 3, and includes the Junk Bay New Town Development. Common boundaries are shared with the Hong Kong and Kowloon Geotechnical Area Study (GASP I) to the west and the East New Territories Geotechnical Area Study (GASP IX) to the north.

The western boundary follows the ridgeline from Lei Yue Mun Point north to Devil's Peak, Chiu Keng Wan Shan, Black Hill, Tai Sheung Tok and turns east at Pak Kung Au. The northwest boundary follows the ridgeline that includes Hebe Hill, Kwai Au Shan and Hebe Knoll, crossing the coast at Heung Chung.

Also included are a number of islands, of which the Largest is Tung Lung. Others include Junk Island, Steep Island, Shelter Island, Bluff Island, Basalt Island and the islands of the Ninepin Group.

2.2 Topography

The topography of the mainland portion of the study area is dominated by the ridgelines which partially surround the drowned valley of Junk Bay. To the west, the boundary of the study area follows a major ridge that includes Black Hill with an elevation of 280 m and Tai Sheung Tok at 419 m.

The ridgeline forming the western boundary falls away to a 'saddle' at Pak Kung Au but continues as a ridge containing Kwai Au Shan (312 m). Along the southern end of the western ridge, the slopes are steep to very steep (Plate 1), but in the north they tend to flatten. The valley to the east is fairly open.

A smaller, north trending ridge occurs in the northwest of the study area and includes Razor Hill (432 m). East of this ridgeline and south of Tai Po Tsai is a broad, flat valley. Coastal slopes are generally steep with cliffs resulting from undercutting by wave action (Plate 1).

Within the Clear Water Bay Peninsula, a steep north to south trending ridgeline is the dominant feature. This ridgeline runs from Nam Tau Sha to High Junk Peak, the highest point in the area at an elevation of 606 m (Plate 3). To the west of this major ridgeline, a moderately broad colluvium-filled valley drains to the south and is bounded by a low ridgeline east of Pak Shin Kok. A wide band of undulating low hills and northeast draining valleys extends from Ngam Tau Sha to Mau Po to the east of the main ridgeline.

In the eastern sector of the Clear Water Bay Country Park, east to west trending ridgelines predominate but they coalesce into a north trending plateau of about 240 m elevation. Coastal slopes are also steep in this area, with the steepest facing south.

In the southern part of the peninsula, a short northeast trending ridgeline containing Tin Ha Shan (273 m), is surrounded by steep, unstable slopes. The low north to south trending ridgeline at the tip of the peninsula has been extensively modified by site formation activities.

The largest of the islands is Tung Lung, which is formed by moderately steep slopes with a major ridgeline trending northwest. The highest point has an elevation of 232 m and is approximately in the centre of the island (Plates 5 & 6).

The other islands generally consist of moderately-steep to steep inland slopes, with very steep coastal cliffs. Shelter Island has a northwest trending ridge, whilst that on Junk Island trends northeast. The highest points on these two islands are 117 m and 99 m respectively.

The distributions of slope gradient and aspect are presented at Appendix B in Tables B1 and B3 respectively.

2.3 Geology

2.3.1 *General*

The regional geology of the study area consists of a thick sequence of volcanic and volcaniclastic rocks. These rocks have been intruded by younger igneous rocks. These are partially overlain by a variety of superficial deposits.

The distribution of the various geological materials are presented on the Engineering Geology Map located in the Map Folder accompanying this Report.

The geological boundaries for the bedrock geology are based on those mapped by Allen & Stephens (1971). The boundaries for the superficial deposits are drawn from aerial photograph interpretation, fieldwork and a review of borehole information carried out for this study (Styles, 1983).

The Geotechnical Control Office is currently preparing a new series of geological maps at a scale of 1:20 000 which will result in a more precise definition of the distribution of the geological units within the Territory. The map and accompanying Memoir for the area will be published in 1989.

As a precursor to the geological remapping programme, Bennett (1984 a, b, c) reviewed the superficial deposits, weathering, stratigraphy, tectonic history and metamorphism in the Territory. Further general geological information is presented by Atherton & Burnett (1986) and Brand (1988). From an historical viewpoint, Davis (1952) is still of considerable interest.

On the basis of this GASP study, the relative proportions of the geological materials are graphically illustrated in Figure 4, and the percentages are presented in tabulated form in Table B6 in Appendix B.

The bedrock materials have generally been subjected to severe weathering. The depth of decomposition is determined by the relative resistance of the individual lithological units and groundwater regimes in association with the local geological structure.

The nature of the individual rock types is summarised below, their distribution is presented in Appendix B and further geological descriptions are given in Appendix C. Their general engineering behaviour and planning significance are discussed in Section 3.1 and summarised in Table 3.1. The general distribution of the major rock types is illustrated in the pie chart at Figure 4 and in the GEOTECS Plot at Figure 6.

2.3.2 *Volcanic and Volcaniclastic Units*

The Repulse Bay Formation outcrops over some 2 950 ha (80%) of the study area and is subdivided into major lithotypes by Allen & Stephens (1971). These are:

(i) *Sedimentary Rocks and Water-Laid Volcaniclastic Rocks (RBs)*

These rocks occupy 6 ha or 0.2% of the study area. They only outcrop in one location just south of Nim Wai. This outcrop consists of thin bands of chert and sandstone.

(ii) *Mainly Acid Lavas (RBv)*

This class outcrops on the islands of the Ninepins Group, Basalt Island, Bluff Island, on the mainland north of High Junk Peak and in the eastern part of the Clear Water Bay Country Park. The main rock type is a hard, resistant, uniform rhyolite which generally possesses a thin weathering profile. These rocks occupy 485 ha or 13% of the area.

(iii) *Mainly Banded Acid Lavas, Some Welded Tuffs (RBvb)*

These rock types outcrop over a large part of the central and southern Clear Water Bay Peninsula. The principal rock type is a banded rhyolite. This rock type occupies 700 ha or 18.7% of the study area.

(iv) *Agglomerate (RBag)*

Only a very small outcrop of this lithological unit occurs within the study area on the eastern side of Junk Bay. It consists of tuff breccia which is deeply weathered. This rock type occupies 4 ha or 0.1% of the study area.

(v) *Pyroclastic Rocks with Some Lavas (RBp)*

This rock unit forms a large part of the western and northern portions of the mainland and also outcrops on Tin Ha Shan. Tung Lung Island consists entirely of this unit. Lapilli welded tuff is the main rock type on Tung Lung and the adjacent mainland but the area around Junk Bay contains predominantly coarse tuffs. These rocks comprise 1 762 ha or 47.2% of the study area.

2.3.3 *Intrusive Igneous Units*

The igneous rocks which intrude the volcanics are subdivided by Allen & Stephens (1971) on the basis of lithology, age and intrusive relationship as follows:

(i) *Granophyric Microgranite (Mc)*

This rock type occurs on Junk Island and on the mainland. It is a fine grained pinkish granitic rock that is more closely jointed and also tends to have a thinner weathering profile than the more common coarser grained granites. This rock type occupies 18 ha or 0.5% of the area.

(ii) *Hong Kong Granite (HK)*

Outcrops of this rock type are confined to the western margin of the study area. The rock is a medium to coarse grained porphyritic granite that is usually subject to deep weathering. Hong Kong Granite occupies 78 ha or 2.1% of the area.

(iii) *Quartz Monzonite (Mo)*

This outcrops as an elongate dyke-like structure south of Tin Ha Shan. The rock is a grey to pinkish-grey, medium to coarse grained igneous rock that is subject to fairly deep weathering. Quartz Monzonite occupies 8 ha or 0.2% of the area.

In total, the intrusive igneous rocks outcrop across some 100 ha and cover about 3% of the area.

Many members of the intrusive igneous rock suite have similar physical properties and, from a general engineering point of view, appear to behave in a similar manner.

2.3.4 *Superficial Units*

In addition to the solid geology, both natural and man-made superficial deposits constitute some 16% (610 ha) of the land surface. These superficial deposits are classified as follows:

(i) *Colluvium*

The colluvial materials occur over 428 ha or 12.9% of the study area. These deposits are formed by gravity transport of rock and soil debris down slope, and occur as recent or relict deposits. They are very heterogeneous in their physical properties and, in this Report, are subdivided only on the basis of the parent rock type (Table B6 in Appendix B). Colluvium may be highly permeable and contain 'pipes' or voids that may act as conduits for subsurface flows of groundwater. Some older deposits may be weathered and consolidated but most recent ones are in a loose state. The material can vary from clayey silty sand to coarse cobbles and boulders. The mechanical behaviour is primarily controlled by the matrix.

(ii) *Alluvium*

The principal surface occurrence of this material is in small coastal flats such as at Shek Miu Wan, illustrated in Plate 3. These deposits probably consist of poorly sorted sands and gravels which are derived from, and may interdigitate with, colluvial lobes. Approximately 45 ha of these materials are present above sea level, occupying 1.2% of the area. There are extensive older alluvial deposits beneath the marine sediments in Junk Bay and east of the Clear Water Bay Peninsula.

(iii) *Marine Deposits*

These materials are not present on the land surface of the study area but are extensive beneath reclamation and on the sea floor. They range from fine clayey silts to coarse shelly sands. Marine sands have been extracted from the sea floor in the channel between Tung Lung Island and the mainland.

(iv) *Littoral Deposits*

Around the extensive coastline of the study area, there are numerous small coves with isolated beaches consisting of coarse, well sorted sands. Approximately 35 ha of littoral deposits are mapped in the area.

(v) *Reclamation*

At the time of preparation of this Report, the extent of reclamation was limited to about 53 ha. These occur principally around the inner part of Junk Bay (Plates 8–12, 15 & 16). Included in this class is a large tip which contains domestic and industrial waste (Plates 11 & 15). The remainder of the reclamation consists of a mixture of weathered rock and crushed material and construction wastes. The Junk Bay New Town will involve the creation of some 320 ha of new reclamation composed mainly of crushed rock.

(vi) *Fill*

During site formation, platforms and slopes are created that may partly consist of fill. This material forms approximately 49 ha (1.3%) of the area with the largest extent associated with the Shaw Studios adjacent to the Clear Water Bay Road. The material's composition depends on its source (usually local) and the engineering behaviour is largely dependant on the degree and method of compaction.

2.3.5 *Structural Geology*

Volcanic rocks of the Repulse Bay Formation outcrop over most of the study area. Granites outcrop along parts of the western boundary, with the contact dipping eastwards below the volcanics.

There are two main structural trends present which comprise:

(i) north-northwest to south-southeast trending faults and folds, and

(ii) east to west trending set of faults and folds which may be associated with the igneous intrusions.

These structural elements combine to produce an interlocking system of faults, resulting in discrete fault blocks and a general dissection of the terrain.

Numerous lineaments are evident on aerial photographs, some of which have been identified as faults by Allen & Stephens (1971). Most of the lineaments are probably normal faults, although some may be the result of tear faulting.

Major jointing may also produce some of the lineaments especially in the Acid Lavas of the Repulse Bay Formation. The distribution of photolineaments and faults is shown on the Engineering Geology Map (EGM) which is located in the Map Folder accompanying this Report.

2.4 Geomorphology

2.4.1 *General*

The geomorphology of the terrain within the Territory reflects a complex Quaternary history of erosional and depositional responses to climatic change and eustatic (sea level) fluctuations superimposed on the distribution of the major geological units. Individual landforms are continually evolving, as determined by the local balance between rapid weathering rates and denudation from intense seasonal rainfall. A description of the mechanics of the weathering process and its engineering significance are contained in Appendix D.

The landforms reflect the pattern of prominent ridges separated by well-developed valleys which have been drowned since their formation, during periods of low sea-level. Sea-level is now probably at a 'midslope' level with respect to the overall relief. Consequently, many of the coastal slopes continue below sea-level and are subject to high rates of erosion as a result of wave action.

Tables B5 and B10 in Appendix B present data on the distribution of the major landform units. The distribution of slope gradients is illustrated in the GEOTECS Plot at Figure 5.

The characteristics of the terrain are described in relation to geological materials. The volcanic terrain which covers most of the area is subdivided by relief into areas of mountainous and undulating terrain.

2.4.2 *Granitic Terrain*

The area which is underlain by intrusive igneous rocks is very small, being restricted to the western boundary ridgeline and some small intrusions in the southern portion of the Clear Water Bay Peninsula. Slope angles are generally moderately steep as these areas have been subjected to active stream incision and marine erosion. The resulting slope profiles characteristically contain long, straight or gently convex sideslopes with small basal concavities and narrow ridge convexities.

The ridgecrest which forms the western boundary is generally rounded and affected by minor to moderate sheet and gully erosion. Weathering in the granites often results in residual corestones in areas where the joint spacing is relatively wide. These may be exhumed by erosion of the surrounding soil matrix to produce surface boulders.

2.4.3 *Mountainous Volcanic Terrain*

The dominant terrain type in the study area consists of moderate to steep, slightly concave sideslopes with narrow ridge convexities, on volcanic bedrock. Generally, soils are thin, overlying a shallow zone of weathered bedrock.

Evidence of both recent and relict landslip activity occurs on many slopes. Soil creep and slope wash also contribute to erosion, particularly where the slopes are steeper.

The terrain is typically irregular in shape, with large rock exposures on ridgelines such as High Junk Peak and on the extensive wave-cut coastline. The surface may be covered by a thin veneer of boulder scree deposits and clayey soil with a high percentage of rock fragments. Large boulders may be scattered over the upper slopes.

Most of the islands have steep coastal cliffs where the slopes are undercut by wave action. Inland, the slopes are usually of moderate gradient and the soils are thin.

2.4.4 *Undulating Volcanic Terrain*

In areas where the relative relief between local hillcrests and valley floors is generally less than 70 m, soils and weathering depths on the volcanic rocks are generally deeper than on the steeper slopes, erosion rates are much lower and there is considerably less instability. These areas are of significance because they may be potential areas for development. This type of undulating topography may be found around Tseng Lan Shue, along a $\frac{1}{2}$ km wide band from Chuk Kok to the Shaw Film Studios, around Mang Kung Uk to Siu Chik Sha, from Ng Fai Tin to Mau Po and around Tai Hang Tun. The Clear Water Bay Golf Course occupies similar terrain.

2.4.5 *Colluvial Terrain*

Colluvial deposits exist over approximately 13% of the terrain in the study area. Deposits are delineated if they are of significance to engineering at a scale of 1:20 000 (Styles, 1983). The mapped distribution is shown on the Physical Constraints Map and the Engineering Geology Map, and is summarised on the GEOTECS Plot in Figure 6. A breakdown of the 480 ha of colluvial terrain according to slope angle is also summarised in Table B5 in Appendix B. Approximately 319 ha is less than 15° in slope angle and 26 ha is steeper than 30°. There is 135 ha within the 15 to 30° slope range. Almost 75% of the deposits which occur within the latter slope range are located on terrain which is subject to possible groundwater flow.

Although some of the colluvium that infills valleys may be very thick, as at Tai Po Tsai, most of the deposits are thin veneers of landslip debris. Fan-like deposits mainly occur on lower slopes as a result of the accumulation of debris from a number of landslip events. On upper slopes, inverted-triangular-shaped deposits are present, infilling local concavities.

Many drainage plains are formed by colluvium. Streams have frequently incised into these deposits, with the depth of incision being controlled by the local gradient and the upstream catchment area of the drainage system.

Streams which exist in bedrock areas may disappear underground upon reaching colluvial deposits. Large natural 'tunnels' or 'pipes' may occur as voids in the colluvium (Nash & Dale, 1983). The build-up of pore water pressures within colluvium during periods of rainfall is an important factor in the stability of the material.

Some areas of colluvium display a hummocky, irregular surface which may reflect potential or previous instability. These areas are identified on the Physical Constraints Map and Engineering Geology Map.

2.4.6 *Alluvial Terrain*

The alluvial terrain is usually flat or gently sloping. There is a complex interrelationship between colluvium and alluvium and lobes of colluvium frequently interdigitate within the alluvial plain. This type of terrain is restricted to small coastal flats on the edge of Junk Bay near Shek Miu Wan, Tai Chik Sha, Hang Hau Town and Tseung Kwan O.

Some alluvium is obscured by disturbed terrain, and this is reflected separately in the area calculations (Table B5 in Appendix B). The terrain in these areas is usually flat or gently sloping but may also have a veneer of fill. Colluvial lenses or more extensive detrital bodies may also exist within the alluvial sequence, and both deposits may extend below the marine deposits.

The alluvial and colluvial deposits started to infill the major valleys following the cessation of downward incision produced by the lowering of sea level during the Pleistocene. Because the sea level was lowered by up to 80 m, it is probable that the alluvium or colluvium could extend below present sea level to a depth up to this figure. The actual depth is dependent on how far sea level fell and on how much incision occurred before the onset of rising sea level.

Sea level has also been slightly higher than at present, leaving small raised beach and raised alluvial terrace features in various parts of the lowland terrain. Although no such landform has been positively recognised during this study, there is evidence on Lantau and in the northwest New Territories. This possibility should be considered during the interpretation phase of any site investigation.

2.5 Hydrology

2.5.1 *Surface Hydrology*

The Clear Water Bay study area contains one large fourth order catchment in the north. The limits of this catchment are formed by the western and northern boundary ridges. The numerous low order catchments around Junk Bay are all former contributors to the central drowned valley. The largest of these is a fourth order catchment that includes the village of Tseng Lan Shue and drains into the sea at Tseung Kwan O. Stream directions are structurally controlled with dominant north to south and east to west trends. South of this catchment is a smaller third order catchment centred on Rennies Mill (Tiu Keng Leng). The stream pattern in this catchment is more dendritic which may be a reflection of the underlying granitic geology. From this catchment south to Lei Yue Mun Point, only small irregular drainage basins are present which have short steep streams that drain directly to the sea.

The majority of streams and associated catchments on the Clear Water Bay Peninsula are small with direct drainage to the sea. There are two third order catchments at Tai Chik Sha and Tai Hang Tuk. These exhibit some structural control with east to west and northeast to southwest directions dominant at Tai Chik Sha and northwest trending streams at Tai Hang Tuk.

As the islands are small and do not contain any significant catchments, all the streams are short, steep and drain directly to the sea.

2.5.2 *Groundwater Hydrology*

For the purposes of water supply, the soils and rocks within the Clear Water Bay study area cannot generally be regarded as constituting type aquifer units.

Groundwater flow through the majority of lithotypes within the area is normally via some form of sheeting or conduit flow. The permeability characteristics of most of the rock or soil masses are probably a function of jointing, fissuring or piping rather than intergranular flow. Consequently, zones of groundwater flow and velocities are difficult to predict. Flow in the bedrock is almost certainly centred on zones where joints and fissures are concentrated.

In the superficial materials, groundwater movement is probably intergranular or conduit flow which develops as a result of tunnel erosion (Nash & Dale, 1983). The type and velocity of flow and aquifer permeability will depend largely on the grain size of the deposit. Boulder fields are the most permeable, with overconsolidated colluvial clay the least permeable. Within the alluvial deposits, groundwater may flow along old buried stream courses or as intergranular flow. These alluvial deposits probably have a high groundwater table. Within the study area, there are approximately 488 ha of footslope colluvial terrain which may be affected by piping as conduit flow.

2.6 Vegetation

The vegetation of the study area is considerably affected by human activities, and the present pattern represents significiant variation from the natural regime. In this Report, a nine class classification system is used to distinguish broad categories of vegetation type. The spatial distribution of these groups is illustrated in the GEOTECS Plot in Figure 7, whilst Figure 4 shows their relative proportions. About 16.7% (632 ha) of the study area is devoid of vegetation due to man's disturbance. Denudation within the study area is generally the result of site formation and, to a lesser extent, man-induced soil erosion. The data is presented in Table B7 at Appendix B.

The vegetation classes are as follows:

(i) *Grassland*

This class generally consists of indigenous or introduced grass species which occur naturally or after the clearing of shrubland or woodland. Grassland occupies 1 039 ha (27.8%) of the study area and occurs as scattered patches, normally on terrain with fairly high relief.

(ii) *Cultivation*

This occupies 190 ha (5.1%) of the study area. Most of the agricultural activity has now ceased but some horticulture occurs in the Lower Ho Chung Valley and around Tseng Lan Shue.

(iii) *Mixed Broadleaf Woodland*

This group occupies 579 ha (15.5%) of the study area, and extensive tracts occur on Razor Hill and near Tai Wan Tau. Other large areas are found around Tseng Lan Shue. This type of vegetation is probably the indigenous vegetation of this part of the South China coast.

(iv) *Shrubland (Less than 50% Ground Cover)*

Shrubland occurs as regrowth on areas of disturbed terrain or on grassland unaffected by hillfires. This group occupies 331 ha (8.8%) of the study area and is most common within the Clear Water Bay Country Park.

(v) *Shrubland (Greater than 50% Ground Cover)*

Similar to (iv) but with denser cover, indicating greater maturity and a longer period of colonisation. This class occupies 673 ha (18.0%) of the study area and is scattered throughout the undeveloped land.

(vi) *No Vegetation on Natural Terrain*

This group is normally associated with erosion in undeveloped areas and consequently occupies only 69 ha (1.9%) of the study area.

(vii) *No Vegetation due to Man's Disturbance*

Some 632 ha (16.7%) of the study area is devoid of vegetation due to man's disturbance. This is generally the result of construction site formation and, to a lesser extent, man-induced soil erosion.

(viii) *Rock Outcrop*

Areas of rock outcrop may contain sparse intermittent grass and shrubland vegetation, but the and is predominantly rock with little soil. Rock outcrops occur over some 222 ha (6.0%) of the study area and is restricted to hills such as High Junk Peak and coastal cliffs.

(ix) *Waterbodies*

Approximately 10 ha of the study area are occupied by ponds.

Vegetation cover influences the intensity of denudational processes, both by its effect on hillslope hydrology and by exerting a degree of control on the shear strength of the soil mantle. A well developed vegetation cover acts to trap precipitation on both the plants and in the soil litter, thus reducing both volume and velocity of surface runoff. This protects the soil from erosion but promotes infiltration, which may have a detrimental effect on stability. Evapotranspiration rates are also improved by a healthy vegetation cover. Root systems act to bind the soil together, thus increasing the shear strength of the soil mantle and reducing the hazard of shallow slope failures (Carson & Kirkby, 1972). One significant effect of a substantial vegetation cover is that it reduces the degree of erosion on undisturbed natural terrain. Most of the erosion observed on the natural terrain is associated either with minor disturbance by man (footpaths triggering gullying) or with minor gullying associated with the headward extension of drainage lines.

The variation in the vegetation pattern across the area is a product of the relationship between the soils, the microclimate (aspect, exposure and elevation) and human influence. Hill fires have reduced woodland vegetation to shrubland or grassland over much of the terrain. Even the low broadleaf woodland which does exist often has a high density of thin young trees, with a dense shrub ground cover associated with regrowth rather than the more open woodland associated with native stands.

Vegetation in Hong Kong is characterised by a wide range of species; approximately 2 350 species occur in the Territory, according to Thrower (1970). In fact, there are representatives of some 50% of the world's 441 plant families. This may have implications for the use of vegetation as a means of controlling erosion and surface instability because it indicates that growing conditions, at least for part of the year, are suitable for an extremely large number of species. Many of the strains used successfully to control erosion in other countries may be suitable for use within the Territory.

2.7 Erosion and Instability

2.7.1 *General*

The surface condition of the terrain is classified on the basis of the major forms of erosion. The presence of slope failures or instability is also recorded within this attribute.

Areas subject to erosion are classified as affected by 'sheet', 'rill' or 'gully' erosion. Each of these classes is subdivided into three subclasses: minor, moderate or severe. Instability is subdivided into the basic classes of 'well-defined landslips', 'coastal instability' and 'general instability'. A final category of 'no appreciable erosion' is used for those areas that show no evidence of either instability or erosion.

The areas affected by the severe forms of erosion and slope instability are shown on the Physical Constraints Map and the latter on the Engineering Geology Map. A summary of the distribution of erosion and instability is given in Table 2.1, Table B2 at Appendix B, the pie charts in Figure 4 and is illustrated in the GEOTECS Plot in Figure 8.

Erosion and instability affect 29.5% (1 101 ha) of the study area. However, approximately 14.6% (547 ha) of the study area is currently developed, within which erosion is restricted to unprotected platforms and slopes. In addition to this, approximately 389 ha of the terrain is subject to erosion.

Table 2.1 Erosion and Instability

Erosion		% of Total Area	Area (ha)
Instability			
—well-defined landslips		<0.2	6
—coastal instability		2.6	98
—general instability		16.3	608
Appreciable Erosion	Sheet erosion	4.7	177
	Rill erosion	0.0	0
	Gully erosion	5.7	212
No Appreciable Erosion*		70.5	2 634
		100.0	3 735

* Includes 10 ha of ponds

2.7.2 *Erosion*

(i) *Sheet Erosion*

This form of erosion produces extensive areas of bare ground devoid of vegetation. Within the study area, extensive areas of sheet erosion occur on south facing slopes and ridgelines especially on the acid lavas of the Repulse Bay Formation (Plate 11). Sheet erosion is often encouraged by the development of footpaths which concentrate runoff. Sheet erosion occupies 177 ha (4.7%) of the study area.

(ii) *Rill Erosion*

This form of erosion is usually associated with cut and fill batters but may also occur on natural terrain. It is characterised by numerous subparallel drainage rivulets, which produce a striated appearance and result in significant soil loss. Within the study area, rill erosion has not been mapped, although it does occur on relatively small slopes.

(iii) *Gully Erosion*

This form of erosion produces incision into the land surface with consequent disruption of drainage lines and may result in tunnel erosion, soil piping and precipitate instability. Gully erosion affects 212 ha (5.7%) of the study area.

When all the forms of erosion are considered together, they account for a significant level of soil loss. These erosional forms do not in themselves constitute slope instability, but they indicate areas that may become unstable if adequate consideration is not given to drainage and other geotechnical factors during development and redevelopment.

2.7.3 *Instability*

The term 'instability' is used in this Report to refer to 'well-defined landslips' and terrain over which there is 'general instability'. It provides an indication of the inherent weakness of the terrain and/or the occurrence of unfavourable groundwater conditions. Expensive slope stabilisation works may be required to permit development of natural unstable areas.

The term 'well-defined landslip' refers to the scar and debris associated with a slope failure. Only landslips larger than 1 ha are delineated at the mapping scale of 1:20 000. It is difficult to define very small features and individual landslip scars within a terrain classification system designed for use at 1:20 000 scale, because often, these features are too small in comparison to the size of the basic mapping unit. Therefore, where large numbers of small Landslips or other evidence of instability occur on insitu or colluvial terrain, the landform is classified as being subject to 'general instability'.

Slope instability of some form or other is relatively common within the study area. Approximately 712 ha of the terrain displays some form of instability, and this represents 19.1% of the study area.

(i) *Well-defined Landslips*

Within the study area, 'well-defined landslips' occupy only 6 ha (<0.2%) of the land surface. The largest landslip is north of Hang Hau Town and two smaller ones occur north of Sam Long and northeast of Pik Uk Au.

(ii) *Coastal Instability*

This form of instability is usually associated with marine erosion and undercutting of coastal slopes. The more exposed, southeast facing coastal slopes are most susceptible, especially in their steeper sections. Coastal instability occupies 98 ha (2.6%) of the study area. Some large individual landslips are included in this class such as those on Tung Lung Island and Bluff Island.

(iii) *General Instability—Recent*

This form of instability relates to colluvial and insitu terrain where many small landslips and other evidence of instability occurs but it is not possible to show them as discrete units on a 1:20 000 scale map due to their small size. This is the major class of instability and occupies 484 ha (13.0%) of the study area. It occurs over much of the steep terrain especially in areas around streams and often occurs as the headward extension of drainage lines.

(iv) *General Instability—Relict*

This form of instability occupies 124 ha (3.3%) of the study area and occurs in the similar situations as *'General Instability—Recent'.* The two classes are closely related. This class of instability is no less important in terms of development constraints than recent instability. Areas of relict instability may be reactivated by construction, site formation, or changes to the drainage or hydraulic regime of an area.

The general relationships between geology, erosion and instability are discussed in Section 3.1.

2.8 Land Use

2.8.1 *Existing Development*

At the time of the study, the existing development in the Clear Water Bay area is of relatively low intensity. The GEOTECS Plot at Figure 9 shows the general distribution of the major land uses in the study area. Extensive new development is proposed and is discussed in Section 2.8.3.

As part of the GEOTECS Computer databank inventory, current land use has been mapped using aerial photographic techniques in combination with other sources. Long thin features such as roads, railways and streams tend to be under represented in the terrain inventory because they rarely occupy the majority of any one grid cell. The GEOTECS Plot in Figure 9 shows the general distribution of land use groups within the study area. The distribution of existing land use and GLUM classes is discussed in Section 2.8.2, and the relative proportions are presented in Figure 4 and in Table B13 in Appendix B.

At the time of preparation of this Report, only preliminary work had commenced on the Junk Bay New Town Development and, as a result, only a small proportion of the study area has been mapped as residential development. Existing residential development consists mainly of two storey village structures centred on Silverstrand, Tai Po Tsai and adjacent to the Clear Water Bay Road. Small fishing villages are scattered along the coastline of the peninsula, but the islands have few permanent residents.

Squatters are principally concentrated around Tiu Keng Leng (Rennies Mill) and east of Devil's Peak. These villages have relatively easy access to the existing industrial developments in Kwun Tong and Yau Tong.

Within the study area, industrial development is limited to inner Junk Bay where a foundry and a number of small shipyards are located. Movie studios are located adjacent to the Clear Water Bay Road. In total, only 37 ha (1.0%) of the area contains industrial development.

The largest recreational facility within the study area is a private golf course on the tip of the Clear Water Bay Peninsula occupying 102 ha (2.7%) of the area.

The Clear Water Bay Country Park occupies about 651 ha (17.4%) and is split into two parts. The western portion follows a north to south trending ridgeline that includes High Junk Peak and Tin Ha Shan. The eastern sector includes an area that was formerly used as a naval firing range.

Agriculture is of only limited extent. Many former areas are evident but these are now abandoned, and only the lower Ho Chung valley on the northern boundary is still productive. Some 190 ha (5.1%) are used for horticulture or other forms of agriculture.

The largest land use category in the area is 'undisturbed (undeveloped)'. This covers 2 056 ha (55.1%) and the islands, along with large parts of the mainland.

2.8.2 *GLUM Class and Existing Land Use*

The distribution of GLUM classes is shown in the Geotechnical Land Use Map contained in the Map Folder. The general distribution of the four classes is shown in the pie chart in Figure 4. The relationship between existing land use and GLUM class is tabulated in Table B13 in Appendix B. The following is a summary of the geotechnical characteristics of the terrain associated with the current principal land uses.

(i) *Natural and Undeveloped Areas*

Some 3 189 ha (85.4%) of the area is undeveloped, and of this some 31.6% is subject to high geotechnical limitations (GLUM Class III), 24.4% is affected by extreme geotechnical limitations (GLUM Class IV), 28% is influenced by moderate geotechnical limitations (GLUM Class II) and 14% has low geotechnical limitations (GLUM Class I). The balance of 2.0% is unclassified within the GLUM system.

(ii) *Squatters*

Squatters appear to be located on 182 ha and this represents only 4.9% of the study area. Approximately 47.8% of this terrain is classified as having high to extreme geotechnical limitations. The distribution of squatters within the Clear Water Bay study area is illustrated in the GEOTECS Plot in Figure 9.

(iii) *Residential*

Approximately 175 ha (4.7%) of the study area is occupied by exclusively residential development. This figure excludes squatters and single storey development. The GLUM class distribution is as follows: 33.3% in GLUM Class I, 36.8% in GLUM Class II, 23.1% in GLUM Class III and 6.8% in GLUM Class IV.

(iv) *Commercial and Industrial*

Within this study area, there is only 55 ha (1.6%) of land used for commercial or industrial purposes. The GLUM class distribution is as follows: 7.3% in GLUM Class I, 81.8% GLUM Class II, 3.6% GLUM Class III and 3.6% in GLUM Class IV.

(v) *Recreational*

Sporting facilities and urban recreational areas occupy 103 ha. These areas are concentrated on undulating terrain excavated from steep natural terrain on the Clear Water Bay peninsula. This is the reason for the high proportion of GLUM Class III terrain associated with this land use. The GLUM class distribution is as follows: 21.4% GLUM Class I, 17.4% GLUM Class II, 53.4% GLUM Class III and 7.8% GLUM Class IV.

(vi) *Institutional and Community*

Institutional and community facilities such as temples, schools and hospitals occupy only 1.0% (35 ha). The GLUM class distribution is: 51.4% GLUM Class I, 24.3% GLUM Class II and 24.3 GLUM Class III terrain.

(vii) *Cemeteries*

Only 4 ha is classified as cemeteries. There are equal proportions of GLUM Classes II and III with 50.0% in each.

(viii) *Transportation*

Roads occupy a significant proportion of the developed areas but, as they usually occupy only a small proportion of the 2 ha grid cell, they are rarely mapped as discrete units. A total of only 42.8 ha is mapped as being used for transportation services. The GLUM class distribution is: 23.8% GLUM Class I, 23.8% GLUM Class II, 42.9% GLUM Class III, 9.5% GLUM Class IV.

(ix) *Incomplete Development*

Construction zones, areas of unused reclamation and temporary uses occupy approximately 116 ha (3.1%) of the area. The GLUM class distribution is: 21.1% in GLUM Class I, 22.8% in GLUM Class II, 38.6% in GLUM Class III, 3.5% in GLUM Class IV, with the balance unclassified.

2.8.3 *Future Development*

Development principles for the Clear Water Bay area are presented within the 'Hong Kong Planning Standards and Guidelines' (HKPSG). The future development of natural terrain and the upgrading of existing development are expected to achieve these standards, in as much as available land, suitability of terrain and local requirements allow.

The statutory requirements for the type of development, current and proposed, are set out in Outline Zoning Plans (OZP), where they exist, and more detailed intentions are defined in Outline Development Plans (ODP).

Statutory restrictions on development, as in Country Parks and designated 'green belt' areas, together with the natural constraints of the terrain, result in limiting the availability of land for development.

The Junk Bay New Town is planned to accommodate 328 000, together with the provision of industrial and community facilities over a ten year period. Some 460 ha will be required for the New Town, of which 320 ha will consist of new reclamation requiring an estimation 45 million cubic metres of fill.

As well as the Junk Bay New Town, additional development is proposed in Sheung Sz Wan, Silverstrand, Tai Po Tsai, Tseng Lan Shue and the lower Ho Chung Valley. These developments would involve the construction of low density residential accommodation similar to that already existing in these areas.

3. ASSESSMENT OF MATERIAL CHARACTERISTICS

3.1 Description and Evaluation of Natural Materials

3.1.1 *General*

Planning and engineering are influenced by the distribution and nature of geological materials. A wide variety of geological materials are present in the study area, and the nature and extent of their influence varies accordingly. The general properties of the rocks occurring in the study area are summarised in Table 3.1. They are described in engineering geological terms and are broadly assessed from an engineering view point. The various geological materials (columns 1 to 4) are described by their lithology (column 5) and their typical topography and weathering pattern (columns 6 and 7). Each material is also evaluated in terms of its engineering properties (column 8) and engineering performance (column 9). The suitability for borrow and possible uses of the material are given in column 10.

Particular attention should be paid to the following points. Firstly, the lithology of the material (column 5) is given for an unweathered sample. Secondly, the topographic form (column 6) with which the material is often associated, may provide a clue for its recognition and may provide an initial indication of the type of material underlying a particular site. Thirdly, the weathering potential of the material (column 7) may assist in estimation of cut and fill volumes, erodibility and vegetation regrowth potential. It should be noted that the depth of weathering may be related to the form of the local terrain. Finally, the quantitative information on engineering properties included in column 8 should be used for preliminary guidance and information only and should not be used for design purposes.

Each rock type has its own range of material characteristics, but many of these overlap. Similar engineering behaviour may occur in dissimilar rock types. The material characteristics which effect the way in which they can be used are:

(i) *Weathering*

Within the regional context, it is important to appreciate the influence of local features on determining the actual depth of weathering at a particular location. The descriptions given in column 7 of Table 3.1 are for general guidance only. For example, volcanic rocks normally weather to depths of about 10 m but rock outcrops such as High Junk Peak or the coastal cliffs are devoid of weathered material. Investigations for Kohima Barracks revealed up to 20 m of highly to completely weathered material in the valley floors.

For any given rock type, the depth of weathering is largely controlled by the joint spacing, lithology and rate of erosion. The volume of fresh rock remaining after a weathering front has penetrated a given distance into a joint bounded block will depend on the original spacing of the joints. A larger volume of fresh rock usually remains in a widely jointed rock mass than in one which is narrowly jointed after being weathered for the same length of time.

Another factor that may be important in the weathering process is the presence of hydrothermally altered material. Chemical changes in the rock caused by the infiltration of hot fluids at depth increase the susceptibility to weathering. In some cases, the products of the alteration closely resemble those of weathering.

Erosion removes the soft products of weathering and reduces the actual thickness of the weathered profile. Major stream courses, if not filled with colluvium or alluvium, generally have fresh rock exposed in their beds due to incision of the weathered profile. In areas of active coastal erosion, the weathering profile is usually absent but may be developed beneath the marine and/or offshore terrestrial deposits related to a previous sea level.

In the Territory, weathering is largely a chemical process that transforms hard rock to soft soil, and thus the engineering character of a particular site is affected by its local weathering. On a larger, planning scale, the average depth of weathering influences the availability of soft borrow materials, the ease of site formation, the general cost of foundations and the stability of slopes.

An idealised weathering profile is presented in Table A3 in Appendix A.

(ii) *Erosion, Instability and Geology*

The different geological materials are subject to various degrees of erosion and instability (Randall & Taylor, 1982; Rodin et al, 1982; Richards & Cowland, 1986). This is reflected in the relative proportions of the various geological materials present in eroded or unstable areas and, conversely, the proportions of erosion and instability occurring within each geological class. These factors are illustrated in Figure 4 and tabulated in Appendix B, Table B11. The Area Instability Index presented in the table indicates the percentage of each rock type affected by instability.

Before interpreting these results, it must be remembered that factors other than geology influence erosion and instability. In the study area, the activities of man have modified the susceptibility of the terrain to erosion and instability. In addition, the proximity to the sea, slope angle, aspect, geology, vegetation and microclimatic variations all contribute to the degree of erosion. There is a wide difference in the extent of the rock units, and consequently, the sample size of some material types is too small for generalisation.

(iii) *Material Resources*
The geological materials, found in such great variety in the study area, all have some potential for use in engineering activities. The geological suitability of these materials is summarised in column 10 of Table 3.1, but other factors also have to be considered when making any recommendation regarding suitability for use. These factors are: suitability of terrain and how it affects adjacent areas (e.g. instability), volume of material available, ratio of hard and soft materials, environmental considerations, accessibility potential for development or reinstatement, and finally, possible effect on water catchments.

A broad division can be based on whether the material is 'soft' or 'hard', and this relates to the mode of extraction. Soft material can be economically extracted in volume by machine methods. Hard material requires blasting prior to extraction. In Section 4.2.4 of this Report, a method of identifying potential quarry sites is given in the GEOTECS Plot in Figure 12.

Table 3.1 presents, in summarised form, the general characteristics of the various geological materials and how they influence engineering and planning activities. The characteristics of each material are affected by local conditions, and the comments presented in the table are intended for general guidance only.

In terms of general engineering behaviour, the geological materials of the study area are broadly classified into five groups:

(*a*) Man-made deposits—fill and reclamation.

(*b*) Recent deposits—alluvium, littoral and marine deposits.

(*c*) Colluvium.

(*d*) Intrusive igneous rocks.

(*e*) Volcanic and volcaniclastic rocks.

3.1.2 *Characteristics of Fill and Reclamation*

The materials in this group have been placed by man and are therefore the youngest of all the materials in the study area. Their nature is controlled not only by their source, but also by the method of placement and compaction.

The engineering standards applied to these materials have varied over the years, and the older fill deposits may be inadequately compacted and contain voids and or large blocks of masonry. The material for land-based fill has usually been obtained from nearby site formation works, such as at the Shaw Studios, and may consist in part, of the weathered local rock type together with construction debris. Areas of older reclamation may incorporate materials obtained from further afield. In the older areas of reclamation, lateral and vertical variability in material behaviour should be anticipated. The presence of old structures, such as foundations or old sea walls, should be checked by consulting archival data.

Reclamation materials, in a loose, permeable and saturated state may have water related problems, and grouting or dewatering may be necessary in deep foundations. It should also be noted that dewatering may induce settlement in adjacent structures. Where water problems occur, basements may require 'tanking' or other water-resistant designs.

Within this study area, a large reclamation consists of sanitary landfill. This material, mixed with layers of natural borrow, may be subject to large and unpredictable settlements.

Fill is a natural material that provides site formation above the general level of the terrain. The general location of fill is shown on the Engineering Geology Map contained in the Map Folder accompanying this Report. Common problems with old fill slopes are due to the practice of 'end-tipping'. Fill material was simply tipped down slope and allowed to accumulate at its angle of repose, in much the same way as natural colluvium. The resultant poor compaction and loose structure resulting from this practice has made old fill slopes susceptible to liquefaction through rainwater infiltration, blockage of pre-existing natural drainage channels, or from fracture of water mains.

When carrying out site investigations in areas of fill, it is often advisable to consult old aerial photographs in order to determine the age and extent of the deposit. Standard Penetration Tests may give a guide to material density, but undisturbed samples are required in order to test the shear strength parameters. Special note should be taken of the relative density of the material. Fill and reclamation are also discussed in Appendix D.3.3.

3.1.3 *Characteristics of Alluvium, Littoral and Marine Deposits*

In the study area, these natural materials occur as thin, flat-lying recent deposits that have poorly developed or no weathering profile. They form complex coastal and submarine stratigraphies due to the fluctuations in sea level during the last 10 000 years. In geological terms they are immature.

There is a wide range in the particle size distribution in this group.

The alluvial material is predominantly a cobbly sand with poor stratification and is usually in a loose condition. The littoral deposits consist of well-sorted coarse sands that are usually well-compacted due to wave action, but are subject to marine erosion. Marine deposits in the study area are variable with some areas of sand that have been commercially extracted, and other areas of highly compressible marine mud. Many of the marine deposits have plasticity indices that plot above the 'A' line with values in excess of 50% and are, therefore, highly plastic. No incidence of erosion was evident on the terrestrial deposits, but alluvium is erodible if hydrological conditions are adversely altered by construction activity.

All steep-sided excavations require strutting as these superficial materials have little cohesion. There is little natural instability in these materials due mainly to their intrinsically low slope angle. These various deposits exhibit a wide range of shear strengths; the lowest values correspond to the marine muds and the highest values to alluvial horizons. Consolidation is rapid in the alluvium and littoral deposits, but may be very slow and of a high magnitude in the marine deposits. The absolute magnitude of settlement is largely dependent on the imposed load, local groundwater conditions and the local stratigraphy. Investigations carried out for the Junk Bay New Town indicated that up to 5 m of vertical settlement is likely in areas of reclamation. Undisturbed samples are required for laboratory tests to determine the material strength characteristics applicable to individual sites. Site investigations in alluvium may be enhanced by the application of geophysical techniques such as resistivity or shallow seismic refraction. Offshore, marine seismic techniques are useful in obtaining profiles of marine sediments.

None of the materials in this group have high bearing capacities and all large loads need to be transferred to underlying bedrock. Low to moderate loads can be accommodated by raft foundations, but problems of differential settlement may be experienced. The appropriate piling technique used to transfer high loads will be dependent on the overall stratigraphy but nearly all members of this group are amenable to driven piles. The materials in this group are easily excavated by machine methods. Marine deposits of sand, such as those in Tai Mui Wan are limited and the marine silts and clays are generally unsuitable as hydraulic fill. The siting of villages and associated agriculture on areas of alluvium generally precludes the use of these areas as sources of fill.

From a planning point of view, this group of materials, although not free of problems, is generally suitable for development. The littoral deposits, however, are subject to marine erosion.

3.1.4 *Characteristics of Colluvium*

Colluvium is a complex heterogeneous material which is highly variable in its engineering character. The distribution is described in Sections 2.3 and 2.4 and in Appendix C.1.4.

As well as being derived from a range of rock types, colluvium is generally deposited intermittently over a period of time. This intermittent deposition results in considerable variation in the degree of weathering of its constituent boulders and detrital fragments. Within this area, the dominant source of colluvium is the volcanic suite of rocks.

Relict colluvium may be considerably weathered, but recent colluvial deposits, especially those occurring in the beds of fast flowing streams, may contain very little weathered material.

From an examination of Tables B10 and B11, it appears that colluvium has a higher incidence of erosion compared with insitu materials. This may reflect the mode of origin of these materials and the fact that colluvial deposits frequently occur in drainage lines, where they are subject to erosion by streams and are generally subject to a high water table.

Erosion in colluvium may sometimes result in the undercutting of contained boulders which subsequently move down slope. Internal erosion may also take place within the deposits, and voids may pose a hazard to earthworks and engineering design. These voids may occur as tunnels which act as major subsurface conduits for water movement (Nash & Dale, 1983).

One of the engineering problems associated with colluvium in Hong Kong is instability. Because this material consists mainly of the debris of past landslips, it accumulates at its angle of repose. Although these deposits may settle and become more dense with time, they are liable to subsequent movement if disturbed, whether by stream undercutting or by man.

Slope failures in colluvium are often characterised by narrow landslip scars (less than 15 m in width) with extensive debris trails. Length to width ratios are generally 4 to 6:1 for colluvium. From the GEOTECS data presented in Table B11 and in Figure 4, volcanic colluvium appears to have a higher proportion of instability compared to the granitic colluvium. This is possibly a result of the steeper slope angles associated with both the parent rock type and the volcanic colluvial terrain.

Table 3.1 Description and Evaluation of Geological Materials

MATERIAL DESCRIPTION							EVALUATION OF MATERIAL		
Type	Age	Symbol	Map Unit	General Lithological Description	Topographic Form	Weathering and Soil Development	Material Properties	Engineering Comment (Stability, Foundation, Hydrogeology)	Material Uses and Excavation Characteristics
SUPERFICIAL DEPOSITS	QUATERNARY – RECENT	R	RECLAMATION/FILL	Generally local or imported borrow of colluvium, decomposed volcanics or plutonics. Often a mixture of silt, sand, gravel and cobbles. Some building waste or sanitary fill also included.	Extensive planar deposits adjacent to coast (reclamation) or as platforms and adjacent slopes (fill) in otherwise undulating terrain.	These materials placed by man have no soil (pedogenic) or weathering profile but may contain weathered rocks or be underlain by natural superficial deposits and/or a pre-existing weathered profile.	These materials are highly variable dependent on the source of fill. Generally, they can be described as low fines, low plasticity, granular cobbly soils. Relative density is dependent on method and degree of compactive effort. $\emptyset \cong$ 25–35°. Properties for sanitary landfill cannot be quantified.	Few problems if properly compacted. Old fill slopes may be poorly compacted and subject to failure. Steep excavations require support. High groundwater requires special drainage. Low bearing pressures can be accepted directly, high loads need raft, spread or piled foundations. Settlement problems minor except in sanitary landfill, which may have associated leachate and gas problems.	These areas, when properly formed, provide platforms with high development potential. Care should be taken in excavation of sanitary landfill when biodegradation is incomplete.
SUPERFICIAL DEPOSITS	QUATERNARY – RECENT	L	LITTORAL DEPOSITS	Essentially beach and dune sand with occasional gravel horizons.	Deposits are very local in nature and generally confined to the intertidal zone, forming beaches and sandbars. Occasionally raised beaches may occur.	Nil	Generally sand-sized granular material, often uniformly graded and well rounded.	Materials are usually saturated and saline. Raised beaches may be leached by rainwater but may remain saline at depth. Groundwater extraction may induce incursion of saline water. Poor grading characteristics—low fines. Low bearing pressures can be accepted directly, moderate and high loads need raft, spread or piled foundations.	Main development potential is as beaches for recreational purposes. Excavation of these materials is usually prohibited.
SUPERFICIAL DEPOSITS	QUATERNARY – PLEISTOCENE?	A	ALLUVIAL DEPOSITS	Generally brownish-grey silty sand with subangular gravel. Occasionally contains cobble and boulder horizons.	Material forms broad floodplains with local fan deposits upslope. May be present more continuously as horizons interdigitated with marine muds or forming channel infill deposits.	In subaerial locations very minor development of soil horizon. Relict deposits may be more weathered. Very old deposits may contain completely weathered boulders.	Very variable soil type which is often sandy and gravelly at its base and clayey towards its top. Clay fraction varies from 5–40% and silt 15–55%. SPT's range from 5 to 15 as depth and granular content increase. Material varies from medium to non-plastic. $c' \cong C - 10$ kPa, $\emptyset' \cong$ 20–25°.	Locally low-lying terrain may be subject to flooding. Materials are usually saturated and of a low density – clay layers are normally consolidated. Buried channels may pose local problems of high water flows into tunnels or excavations. Steep excavations require support. Groundwater may be saline if adjacent to coast. Incursion of saline groundwater following abstraction of fresh groundwater may occur. Low bearing pressures can be accepted directly, moderate and high loads need raft, spread or piled foundations.	Land deposits easily excavated. Marine deposits often form reasonable hydraulic fill. Excavation by cutter, suction or bucket dredger.
SUPERFICIAL DEPOSITS	QUATERNARY – PLEISTOCENE?	M	MARINE SEDIMENTS	Usually dark grey silty sand or clay with traces of shell fragments, and some sand horizons, especially near shore. A mixed succession with alluvium and/or colluvium may be present.	Seabed sediments of variable thickness (0–10's of metres) below low tide mark.	Nil	Usually a soft to very soft normally consolidated soil with a high moisture content and high plasticity (LL > 50%), clay content ranges from 20–35%, silt content from 50–70%. Cu < 10 kPa, $c' \cong$ 0–5 kPa, $\emptyset' \cong$ 25°. SPT < 10, but increases with depth.	Material is poor to unsatisfactory for hydraulic fill. It is also poor as a foundation because of settlement and bearing capacity problems. Will probably be susceptible to mud wave if fill is end-tipped onto it. Consolidation may be aided by wick drains and/or surcharge loading.	Easily excavated using bucket or possibly suction dredger where necessary. Sandy deposits may be used in construction but silt and clay may pose problems of disposal.
SUPERFICIAL DEPOSITS	QUATERNARY – PLEISTOCENE?	C	COLLUVIUM: VOLCANIC DERIVED; GRANITIC DERIVED; MIXED	Composed of a range of materials which vary from boulder colluvium, to gravelly colluvium with clay and sand, to finer textured gravelly sands and clay slopewash. The boulder colluvium with sand and gravel occurs on the higher sideslopes, while the gravelly sands and sandy silts with clays are to be found on the middle to lower sideslopes and footslopes. Coarse boulder colluvium exists in many stream channels.	Mainly occupies the lower sideslope and footslope terrain and may underlie much of the alluvial floodplain. Generally gently to moderately steep, broad, low, rounded dissected outwash-fans and interfluves with undulating and hummocky surfaces; elsewhere irregular planar-to-shallow concave colluvial footslopes, leading upslope to gentle to moderately steep outwash slopes.	Colluvium can occur as independent deposits of a unique age such that one deposit overlies another. The older deposits may be subject to severe weathering and may be completely decomposed to a mottled, coloured sandy silt or clayey silt similar to the insitu residual deposits of their parent materials. The depth of such weathering may be in the order of 10 m or more.	Only very general guidelines can be given for the matrix or finer components of this variable material. MC's average 20–30%, DD varies from 1 300 to 1 700 kg/m³. Grading ranges from 2–40% clay, 10–60% silt, 40–80% sand and medium gravel. Plasticity varies from PL 22–28%, LL 28–40%. Typical shear strength values are $c' \cong$ 0–5 kPa, $\emptyset' \cong$ 29–42°. Standard compaction values: OMC $\cong$ 17–20%, MDD $\cong$ 1 630–1 750 kg/m³. CBR $\cong$ 3–8%.	This material has moved in its geologic past and is prone to reactivation if not carefully treated by such measures as low batter angles, drainage, and surface protection, especially when saturated. Has low to moderate bearing capacity characteristics but should always be carefully drained because it may be susceptible to failure when wet. Voids may cause settlement of roads, services and buildings. Tunnelling probably difficult. Site investigation likely to be difficult and expensive.	May be used for borrow due to its ease of excavation by machine, broad grading characteristics and relative ease of access on hillsides. Some stream fill bouldery deposits will be of limited use. Large boulders may require blasting or splitting.
BEDROCK	UPPER JURASSIC	Mc	INTRUSIVE IGNEOUS ROCK (PLUTONIC): GRANOPHYRIC MICROGRANITE	Pink to grey fine-grained non-porphyritic rock. Pink and white feldspars and quartz with granophyric texture. Jointing similar to other granitic rocks.	Forms local areas of moderate relief with broad convex hillcrests.	Weathers to produce a clayey silty sand with corestones. Depth of weathering similar to other granites. Fresh rock outcrops in stream beds on occasions.	Few test results available. Grading of weathered material has given clay $\cong$ 10%, silt $\cong$ 30% and sand $\cong$ 60%.	Weathered material may be unstable if undercut. Joints control stability in any rock cutting.	Weathered material could be machine excavated for use as fill. Fresh rock will require blasting.

Table 3.1 Description and Evaluation of Geological Materials *(Continued)*

Type	Age	Symbol	Map Unit	General Lithological Description	Topographic Form	Weathering and Soil Development	Material Properties	Engineering Comment (Stability, Foundation, Hydrogeology)	Material Uses and Excavation Characteristics
MATERIAL DESCRIPTION							EVALUATION OF MATERIAL		
BEDROCK	UPPER JURASSIC	HK	INTRUSIVE IGNEOUS ROCKS (PLUTONIC): HONG KONG GRANITE	Pink to grey medium-grained equigranular, non-porphyritic rock. Minerals include quartz, potassium feldspar, plagioclase, biotite and muscovite. Rough sheeting joints and widely spaced tectonic joints present.	Forms extensive areas of moderate to steep concave-convex slopes. High-level infilled valleys are common. Drainage pattern is often dendritic in nature and is commonly dislocated by major tectonic discontinuities. These units are characterised by moderate to severe gully and sheet erosion associated with hillcrest and upper sideslope terrain.	Shallow to deep residual soils over weathered granites. Local development of less weathered outcrop in stream beds and occasional cliff faces. Residual core boulders common on surface of sideslopes and gullys. Weathering depths in excess of 20 m occur.	As with all Hong Kong rock types but particularly the granitic varieties, material properties vary with depth within the weathering profile. For completely weathered granite (Grade V), typical values are: Ø′ ≅ 31–43°, c′ ≅ 0–25 kPa, permeability ≅ 10^{-5} – 10^{-8} m/s, DD ≅ 1 500 kg/m³, MC ≅ 15% near surface, ≅ 30% at depth. Fresh rock has an unconfined compressive strength in the range 125–175 MPa. Rock mass strength essentially dependent on joint characteristics, roughness angles for tectonic joints 5–10°, for sheet joints 10–15°. Basic friction angle ≅ 39°.	Weathered mantle is subject to sheet and gully erosion and even to landslides in steep slopes or if severely undercut. Perched water tables conform with highly permeable upper weathered zones. Rock is prone to discontinuity-controlled failures in fresh to moderately weathered state (Grades I–III). Stream and drainage lines tend to align with geological weaknesses. Large structures may require deep foundations. Cut slope design may be governed by large depths of weathered material.	Extensively quarried and used as concrete aggregate. Weathered material widely used as fill as it is easily excavated with machines. Core boulders can cause problems during excavation.
		Mo	QUARTZ MONZONITE	Grey to pinkish-grey, fine to-medium-grained, porphyritic, strong acid plutonic igneous rock. Phenocrysts are plagioclase. Generally wide rough joints.	Dissected essentially planar-concave terrain forming strong relief.	Shallow to deep residual soil over moderately weathered rock. Corestones extensive.	Coarser-grained fresh rock has an unconfined compressive strength of 100–150 MPa and a DD of 2 600–2 750 kg/m³. Point Load Is(50) ≅ 5 – 8 MPa.	Relatively unknown rock type—comments as for granites but more care required with weathered materials because likely to be slightly more clayey. Several troublesome case histories noted.	Material can be scraped for borrow when weathered. Fresh rock must be blasted. Not often used for aggregate but after testing to establish characteristics should be satisfactory. Should have good asphalt adhesion characteristics.
	LOWER TO MIDDLE JURASSIC	RBs	SEDIMENTARY, VOLCANICLASTIC AND EXTRUSIVE IGNEOUS ROCKS; REPULSE BAY FORMATION: SEDIMENTARY AND WATER-LAID VOLCANICLASTIC ROCKS	Generally a hard, thinly banded black and grey siltstone and black shale, interbedded with volcanic sandstones and tuffs, sometimes cherty. Very closely spaced joints in some units.	Forms areas of moderate to low relief.	Shallow to moderately deep, reddish to brown, fine, sandy to silty clay, i.e. residual soil sometimes with ferruginous gravel and weathered rock fragments, overlying completely to highly weathered rock which grades into less weathered strongly jointed volcanic rock at depths from 5–20 m.	No test data available but likely to be variable, dependent on individual stratigraphic unit.	The sediments are bedded and fissile and weather relatively rapidly to a grey silt when exposed. Some stability problems may arise. Groundwater regime may be controlled by the bedded character of the rock.	Can be scraped and ripped when weathered. Fresh rock will need pneumatic machines or blasting. Due to highly variable properties and presence of chert bands, this material would not make a good source of aggregate but is well suited for filling.
		RBv	ACID LAVAS	Dark green or bluish grey, fine-grained with light phenocrysts, banded, strong rhyolite. The rock often displays closely spaced smooth joints.	Forms steep narrow ridges with deep structurally controlled valleys. Rock outcrops common.	Rock usually develops a thin (< 1 m) soil horizon and a thin (< 10 m) weathered zone before passing rapidly into moderately to slightly weathered bedrock.	No laboratory results available but should be similar to other volcanics as below.	Stability of weathered material and also of highly jointed rock masses may be suspect, especially during or immediately after prolonged heavy rainfall. Failures are quite common, especially in over-steepened slopes. Rapid surface runoff is common. Stability of rock slopes controlled by relatively closely spaced discontinuities in moderately weathered to fresh rock mass. —Few opportunities for creation of platforms; usable sites may be small and fragmented, —Access route selection hampered by terrain, —Tunnelling probably easier than in granitoids. Deep weathering and close jointing should be anticipated near structural geological lineaments.	Very hard and abrasive when fresh, will require blasting which may result in brittle fracture. Inadvisable for aggregate unless tested for silica/cement reaction.
		RBvb	MAINLY BANDED ACID LAVAS, SOME WELDED TUFFS	Amygdaloidal banded rhyolite, banded trachyandesite, spherulitic rhyolite and ignimbrite. Displays closely spaced smooth joints.	Massive volcanic peaks with deeply dissected slopes forming a system of subparallel ridges and spurs. Crests are narrow and sharply convex with steep to very steep valley slopes. Rock outcrops are common on the upper slopes.	Rock usually produces a thin (< 1 m) soil horizon, followed downwards, especially on lower slopes, by yellowish brown sandy completely weathered material overlying less weathered, locally strongly jointed rock below an average depth of 11 m. On steep, high slopes considerable rock exposure occurs, with thin soil or weathering cover.	The near surface completely decomposed material has a DD ≅ 1:500 kg/m³ and a saturation greater than 70%. Gradings are variable but 20–40% silt, 10–20% clay and 40–60% fine sand is common. Plasticity varies from PL 22–32%, LL 35–60%. Typical shear strength values are: c′ ≅ 0–10 kPa, Ø′ ≅ 30–35° Fresh rock properties are approximately as follows: unconfined compressive strength ≅ 150–250 MPa. Joint strength parameters are c′ ≅ 0 kPa, Ø′ ≅ 30°, roughness angles 5–10°. DD ≅ 2 500–2 700 kg/m³. Point Load Is(50) ≅ 6–12 MPa. Tangent modulus ≅ 30 000–60 000 MPa.		Material can be used for fill if it is weathered locally. It is possible to quarry, although very hard and not generally favoured. Coarse crystal tuff horizons may provide good aggregate.
		RBag	AGGLOMERATE	Tuff breccia, lapilli breccia and blocks of sediments in a coarse lapilli matrix. Volcanic bombs over 600 mm can be found. Jointing is closely spaced and smooth.					
		RBp	DOMINANTLY PYROCLASTIC ROCKS SOME	The principal rock type is grey to dark grey fine-grained rhyodacitic tuff but welded tuffs, coarse tuffs, lavas and sedimentary rocks may be also be found in this unit. Jointing is usually smooth and closely spaced.					

* The property values presented are only approximate and are given without prejudice for general information. These properties should not be taken as design values. The latter should be determined where necessary by separate careful site investigation and laboratory analysis.

Abbreviations

c′ —effective cohesion—kPa—kilopascal
Ø′ —effective angle of internal friction—°—degree
Cu —undrained shear strength—kPa—kilopascal
OMC —optimum moisture content—kg/m³—kilograms per cubic metre
MDD —maximum dry density—kg/m³—kilograms per cubic metre
DD —dry density—kg/m³—kilograms per cubic metre
CBR —California Bearing Ratio—%—percent
Is (50) —point load strength index—MPa—megapascal
LL —liquid limit—%—percent
PL —plastic limit—%—percent
MC —moisture content—%—percent
SPT —standard penetration test value
≅ —about equal to

In general, colluvium is unsuitable as a founding material for large structures, and it is normal for caissons to be excavated through to the underlying rock. The presence of large boulders in the colluvium can make this a difficult process. Some boulders within colluvial deposits may be in excess of 5 m in diameter and need to be identified as detrital and not as bedrock.

Colluvium is often highly permeable, especially in 'bouldery' colluvial streambeds. Older weathered deposits may be less permeable, but the presence of internal erosion tunnels may give rise to complex groundwater patterns. Streams which exist over bedrock frequently disappear beneath areas of colluvium.

The presence of tunnels or 'pipes' may severely disrupt the groundwater, and site investigations that involve the installation of piezometers in colluvium need to be carefully interpreted to avoid generating an inappropriate groundwater model.

An aid to anticipating the presence of these pipes is to observe the behaviour of streams that intercept the colluvial mass. If these streams disappear underground, then there is a reasonable chance that subterranean pipes are present.

Boreholes and trial pits are used to obtain samples and exposures for the classification of colluvial deposits. Care should be taken, however, to use drilling methods that will not result in a loss of matrix material. Trial pits often provide more reliable information when dealing with colluvium, but these are practical only in shallow deposits. Where the matrix percentage is high, appropriate laboratory tests may be carried out on undisturbed samples to provide strength and compressibility data for design. Where the boulder percentage is high, however, it may be necessary to rely on more empirical relationships for stability assessment.

Colluvium is often up to 30 m thick and is essentially unconsolidated; therefore it has some potential for use as a soft borrow material. These deposits usually occur at the base of steep slopes and are the result of the accumulation of landslip debris; any excavation for borrow may destabilise the adjacent terrain. Older colluvial deposits may have suitable grading characteristics for use as fill, but the younger streambed deposits, generally lacking in matrix, are probably unsuitable. Excavation by machine methods could be difficult if large boulders are encountered.

On a regional scale, the presence of large areas of colluvium acts as a major constraint on the overall layout of a project. Problems can be minimised by avoiding designs that require large cut slopes in this material.

3.1.5 *Characteristics of the Intrusive Igneous Rocks*

The intrusive igneous rocks underlie only a very small proportion of the study area. They are of similar origin and consequently have similar engineering characteristics. A large amount of site investigation and laboratory information is available for the intrusive rocks, and these materials are generally quite well understood (Lumb 1962 a & b, 1965, 1983).

Only three intrusive igneous rock types are present in this study area. These are the Hong Kong Granite, Granophyric Microgranite and Quartz Monzonite. The Hong Kong Granite is part of a large batholith that extends to the west, and the other two rock types are present as dykes and stocks in the southern part of the Clear Water Bay Peninsula and on Junk Island.

The various granite intrusions tend to have similar jointing patterns. Joints in these rocks generally range from medium to very widely spaced but tend to be widely spaced overall. Two distinct joint groups are present: sheeting joints and tectonic joints. The sheeting joints tend to be rough and wavy, orientated subparallel to the topography and spaced at about 1 to 3 m intervals. They are best developed near the surface. Tectonic joints are generally orientated normal to the sheeting joints, smooth to moderately rough and spaced in the order of 1 m apart. On weathering, both joint groups are often preserved as relict features with coatings of limonite, manganese dioxide or thin layers of clay.

The weathering of the Hong Kong Granite may be deep and up to 30 m of soft material has been recorded. The jointing patterns consist of the older, smooth tectonic joint sets and younger, rough sheeting joints resulting from stress relief by erosion. The sheeting joints tend to be subparallel to the topography and are commonly spaced at 1 to 3 m intervals. The effective roughness may be reduced by weathering along these joints. The resultant weathered profile consists of an upper layer of silty clayey sand that may contain residual corestones due to the generally wide joint spacing. The soil is usually highly erodible, and the terrain is characterised by extensive bare areas due to sheet and gully erosion.

As with the volcanic rocks, the frequency of tectonic joints increases markedly in the vicinity of photolineaments. Joints are probably the major conduits of groundwater flow below the weathered mantle due to the impermeability of the fresh rock.

Despite the wider joint spacing compared to the volcanics, the intrusive igneous rocks of this study area tend to weather to a greater extent and depth. This is primarily due to the higher porosity and rock permeability of the granitic rocks. Weathering in these rocks has been the subject of recent study in Hong Kong (Hencher & Martin, 1982); consequently, only a summary is presented here.

As stated in Section 3.1.1, an extremely wide range of depths of weathering of intrusive igneous rocks occurs within the study area. In general, for similar locations in the terrain, these rocks are weathered to approximately twice the depth of volcanic rocks.

The intrusive igneous rocks normally weather inwards away from discontinuities, and quite thick weathering zones may occur along joints even in Zone C rock. Within the profile, large boulders are developed due to the wide joint spacing, and these may be concentrated on the surface by the erosion and removal of the soft completely decomposed material. As a result of weathering, joints lose their effective roughness which, combined with the concentration of clay minerals, leads to a reduction in shear strength. The intact rock becomes weaker and more porous.

In general, instability in these rocks is not as extensive as in colluvium or volcanic materials. Landslips do not appear to have the same impact on the terrain and tend to form small rotational or joint-controlled failures associated with natural terrain or cut slopes. Length to width ratios are generally 1 to 2:1.

Permeability in these materials varies with weathering. Completely decomposed rock that has been eluviated (clay content washed out) may be highly permeable. A transition from porous flow to joint-controlled flow occurs from weathered to unweathered rock. These materials may be subject to tunnel erosion (piping), especially in the residual soils or newly exposed completely weathered material (Nash & Dale, 1983).

The bearing capacity of the highly weathered granite will probably be satisfactory for low to moderate loading, but on occasions an open porous structure may result in low insitu densities, resulting in settlement problems for surface footings. Artificial lowering of groundwater during construction can also adversely affect steep cuttings and predicted settlements. A further problem for the construction of deep foundations or trench excavations below the groundwater table is the potential for piping within the coarse-grained, loose or medium dense decomposed granite. This may lead to problems with bored piles and other foundation problems.

Site investigations in the granite should identify weathering grades as well as the nature and orientation of joints. Standard Penetration Tests (SPT) can give useful information in those materials, which can be difficult to sample and test, and which collapse on loading or wetting. Block sampling and air-foam drilling may be of particular value in these circumstances. (Brand & Phillipson, 1984; Phillipson & Chipp, 1981, 1982). Where deep foundations are envisaged, boreholes should be drilled to well below the proposed bearing level, as weathering can be irregular with zones of completely weathered soil underlying less weathered material.

For the construction of slopes in Zone D or Zone C granite, which has high intact rock strength and relatively lower discontinuity strength, direct shear tests should be carried out to determine shear strengths of discontinuities. In Zone A or B, the strength and compressibility of the intact decomposed materials are more important, and these should be investigated by appropriate laboratory tests.

This group of rocks is extensively used for construction materials within the Territory. The deeply weathered material is easily extracted by machine methods for use as soft borrow, and the underlying rock is highly favoured for the production of crushed aggregate.

Granitic rocks are generally favoured for aggregate production due to the relative ease of crushing and shape characteristics (Brand et al, 1984). Problems, however, have been experienced with poor asphalt adhesion when these materials are used for road pavement. This is primarily due to the high free quartz content. Rock types such as monzonite, which have a significantly lower quartz content and similar crushing characteristics, may be more suitable for this purpose and should be considered for quarrying.

From a planning point of view, granitic rocks are generally favoured. They require more site formation works compared with the flat superficial deposits, but the moderate slope angles, ease of excavation, high yield of fill and general stability of slopes is reflected in the extensive development which already exists on these rocks.

3.1.6 *Characteristics of the Volcanic Rocks*

The location and type of volcanic and volcaniclastic rocks found in the study area are discussed in Section 2.3.2 and in Appendix C.1.2. Excluding the minor sedimentary member, these rocks tend to have similar material characteristics.

The engineering behaviour of the rock mass is controlled by a combination of factors. The major factors are: the frequency, orientation and roughness of joints and other discontinuities; the degree and extent of weathering; cleft water pressures and permeability characteristics.

The volcanic rocks of the Repulse Bay Formation are generally well jointed. Joint spacing (Geological Society of London, 1977) commonly ranges from 'moderately narrow' (20 to 60 mm) to 'wide' (200 to 600 mm) or, more rarely, 'very widely' spaced (600 to 2 000 mm). Small outcrops that have a joint spacing of greater than 2 m tend to stand out on hillsides and ridges such as High Junk Peak. Locally, the joint spacing is very variable, often ranging from wide to narrow over distances of less than 10 m. Most exposures contain several sets of joints, each set exhibiting a range of orientations. This range is generally related to the persistence of the joints, with less persistent joints being the most variable in orientation. Joints can sometimes be seen to curve in larger exposures. Persistent joints which exist in well-defined sets tend to be fairly smooth, although they are occasionally striated. Smaller, discontinuous joints are often irregular and stepped and are of less engineering significance. Many of the joints are steeply inclined and may result in 'unfavourable' orientations in relation to construction. Site investigations for projects involving rock cut slopes should be designed to identify and define the dominant joint sets prior to engineering design.

In these rocks, weathering tends to be relatively shallow, with average depths in the order of 8 to 10 m. The volcaniclastic rocks are generally more deeply weathered, and up to 20 m of weathered material is common. As discussed in Section 3.1.1, the depth of weathering is largely dependent on the joint spacing. Along photolineaments (shown on the Engineering Geology Map), very close jointing may be encountered which locally depresses the weathering profile. This effect increases the erodibility of the material by streams. These streams tend to preferentially follow such lines of weakness and can be seen on aerial photographs as lineaments. Another factor influencing the weathering depth is the rate of erosion. On some of the isolated, exposed islands, there is very little vegetation and the high rates of soil erosion produce many areas of bare rock. On weathering, the volcanic rocks tend to produce a clayey silt with minor sand and a fairly uniform profile. The coarse tuffs, if widely jointed, may produce corestones and boulders in a similar manner to granitic rocks.

The higher clay contents of the weathered materials tend to reduce the incidence of erosion in these rocks even though they occur on steep slopes. The GEOTECS data in Tables B10 and B11 and Figure 4 indicate that the Repulse Bay Formation rocks show a general trend of relatively low incidence of erosion. This is probably a good reflection of the erodibility of these materials, due to the large statistical sample and the relative lack of major urban development on these rocks. The morphological forms associated with slope failure in volcanics are similar to those in colluvium, in that they are characterised by small landslip scars with extensive debris deposits. That is, they are characterised by large length to width ratios (4 or 5:1).

When fresh, these rocks generally have a high strength, but the presence of joints substantially reduces the effective mass strength. These rocks are difficult to crush and are not currently used for aggregate production due to their fine grain and relatively high strength. The narrow joint spacing in many of the volcanic rocks may produce fragments unsuitable for aggregate when crushed. The weathered mantle may be suitable for soft borrow, but the shallow weathering depths will limit the potential yield from most sites.

The steep terrain and thin weathered mantle may make many areas of volcanic rock unsuitable for intensive development. Large volumes of excavation, much of it requiring blasting, would be necessary for site formation, and the resulting slopes may be subject to joint-controlled instability. However, where these rocks occur on flat to gently sloping terrain, such as the north of Tung Lung Island or Shelter Island their foundation depths may be fairly shallow.

Site investigations in the volcanic rocks should be designed to determine the depth and degree of weathering, the frequency and orientation of jointing and the position and seasonal fluctuations of the water table. The Standard Penetration Test can be a useful indicator of the depth of successive zones of decomposition of the rock mass. Direct shear tests on the discontinuities of Zone C/D rocks, and direct shear and triaxial tests on Zone A/B rocks, can be used to determine the shear strengths of joints and soil matrix. It should be noted that, because most failures of insitu material are shallow, the overburden pressure on a failure plane is probably quite low. Representative shear strength parameters should therefore be obtained from laboratory triaxial tests carried out at appropriately low confining pressures.

4. GEOTECHNICAL ASSESSMENT FOR PLANNING PURPOSES

4.1 Geotechnical Limitations and Suitability for Development

4.1.1 *Introduction*

The Geotechnical Land Use Map (GLUM) indicates the general levels of geotechnical limitation associated with the terrain. These in turn reflect the basic suitability of the land for development from a geotechnical point of view. A copy of the Geotechnical Land Use Map is described in detail in Appendix A7 and is enclosed in the Map Folder which accompanies this Report.

The distribution of the four GLUM classes is summarised in the pie diagram presented in Figure 4 and at Tables B8, B9 and B13 in Appendix B. The GEOTECS Plot at Figure 10 illustrates the general extent of the various GLUM classes.

The Generalised Limitations and Engineering Appraisal Map (GLEAM) identifies parcels of land with potential for development from a geotechnical point of view. The geotechnical limitations and other planning constraints, such as provision of access, presence of Country Parks and designated Green Belt, are highlighted.

4.1.2 *Land with Low to Moderate Geotechnical Limitations*

Within the study area, there exists a relatively small area (583 ha) with low geotechnical limitations and approximately 1 075 ha with moderate geotechnical limitations. Terrain with low to moderate limitations (GLUM Classes I & II) forms 44.4% of the study area. Some 320 ha of the GLUM Class I & II terrain is developed, and 1 340 ha of the GLUM Classes I & II terrain is substantially undeveloped.

Land with a low degree of geotechnical limitations is expected to require only normal geotechnical investigation, with the costs of site formation, foundation and drainage work being relatively low. This terrain consists typically of gently sloping untransported (insitu) rock or residual soil. Development of land with moderate geotechnical limitations probably requires a normal site investigation but, in certain situations, foundation conditions could be more complex than for GLUM Class I, nevertheless costs of site formation, foundation and drainage works should not be high. GLUM Class II terrain includes those areas where instability or erosion are not problems: insitu terrain of moderate steepness or flat or gently sloping alluvial terrain. Areas of reclamation are also included in GLUM Class II.

The major areas of GLUM Classes I & II terrain outside of the developed parts of the Clear Water Bay study area are discussed in the description of potential development areas in Section 4.2. There are extensive areas of these classes north on Tung Lung Island, Shelter Island, in the eastern portion of the Clear Water Bay Country Park and in the north and northeast of the study area.

4.1.3 *Land with High Geotechnical Limitations*

Approximately 32% (1 202 ha) of the study area has a high level of geotechnical limitation (GLUM Class III) and, of this, some 16% (192 ha) is currently developed.

GLUM Class III terrain is expected to require intensive geotechnical investigation, and the costs associated with site investigation, site formation, foundation and drainage work will probably be high. Typical GLUM Class III land is steeper than 30° on insitu terrain without evidence of instability, and at gentler gradients where instability or colluvium are present. GLUM Class III terrain is likely to exhibit subsurface variations in material profile and drainage regime which need to be determined during site investigation.

Small areas of GLUM Class III terrain may be included within the Potential Development Areas (PDA) shown on the GLEAM if they are unlikely to adversely affect the overall development opportunities of the area.

4.1.4 *Land with Extreme Geotechnical Limitations*

Approximately 22% (812 ha) of the area is classified as GLUM Class IV. This terrain should not be developed if alternatives exist. Only 4% (32.5 ha) of this class occurs within areas of existing development.

Intensive site investigation would be required at the planning stage and prior to detailed design to minimise the hazard of slope failure. Although investigation costs are expected to be very high, they would probably be relatively minor in comparison to the costs of site formation, foundation and drainage works and the costs associated with maintenance and remedial treatment.

Terrain attributes which contribute to the designation of GLUM Class IV include steep insitu and colluvial terrain and areas with evidence of instability. In most cases, it will be obvious from the topography alone that GLUM Class IV terrain would present extreme geotechnical difficulties.

Extensive areas of this land are present on the coasts of Basalt and Bluff Islands, in the eastern and central parts of the Clear Water Bay Country Park and to the west of Rennie's Mill.

Isolated GLUM Class IV terrain within the developed area is usually associated with locally steep slopes produced during site formation or road construction.

Other areas of GLUM Class IV are due to natural drainage lines crossing colluvium or the presence of instability. These features are highlighted on the Physical Constraints Map (PCM).

4.2 Potential Development Areas

4.2.1 *General Planning Considerations*

Land utilisation is governed by development requirements, which are based on demand, potential and constraint. Many of the fundamentals which influence planning decisions are not directly influenced by geotechnical considerations. However, geotechnical considerations are implicit in efficient and secure engineering. Section 4.1 has briefly discussed some of the constraints associated with the terrain within the study area which cause geotechnical problems for engineering works. Some of these problems are initiated during development. For this reason, the interaction between engineering and the terrain should be an important consideration during the planning process, since not only is efficient construction important, but long term serviceability and safety should also be fundamental aims.

From a geotechnical viewpoint, land with potential for development should generally be free of constraints. Engineering design, should ideally be unhindered by geotechnical limitations. Within the study area, there are many natural areas with potential for development, but a significant proportion occur within the bounds of designated Country Park, Green Belt and Water Supply Catchment. These artificial constraints are noted but are not used to exclude areas that have potential from a geotechnical point of view based on their natural terrain attributes.

In dealing with land which is as yet undeveloped, the Generalised Limitations and Engineering Appraisal Map (GLEAM) is valuable at two levels. At the planning stage, it identifies broad areas in which an integrated approach to large-scale development could be adopted. Subsequently, at the engineering feasibility stage, it enables possible problems to be anticipated for the design of site investigations, preliminary layout and other more detailed aspects of design. The importance of the GLEAM as a tool for integrated planning and engineering feasibility in the study area is outlined in Section 4.2.2.

The Geotechnical Land Use Map, Physical Constraints Map and Engineering Geology Map enable the extent and nature of local engineering problems to be incorporated in the planning process for the whole of the study area. These maps are introduced in Section 1.5, and their background, derivation and use is described in detail in Appendix A.

4.2.2 *Generalised Limitations and Engineering Appraisal Map (GLEAM) and Development Potential*

The GLEAM identifies 16 areas within the study area which have potential for development from a geotechnical point of view. This represents approximately 1 300 ha or 35% of the total area. The areas range in size from about 15 ha up to 250 ha. They occur on different types of terrain, which are not necessarily suitable for the same type of development.

The areas of potential are identified from the interpretation of the terrain and geological features, and the various levels of geotechnical engineering difficulty which they present.

Where individual features or constraints are of local significance to the planning and engineering feasibility of a 'potential' area, they are indicated on the GLEAM. These are referred to as Potential Development Areas (PDA). The Generalised Limitations and Engineering Appraisal Map is enclosed in the Map Folder. A description of the derivation of the map is presented in Appendix A.9.

In addition to the geotechnical constraints, the potential of a site for development is governed by other factors, such as existing land use (Green Belt or Country Park), proposed development intensity, proximity to services, access routes and intrusion on the natural landscape. Economic factors are a major consideration. Some of these factors may ultimately rule out development of a particular area but, unless the overall practicalities of development render a site unfeasible (i.e. a small site on a remote hilltop), they are shown on the GLEAM. Each area with potential for development is numbered and presented on the GLEAM.

The comments for each area reflect the general strategic considerations which influence planning and engineering feasibility. In the main, they relate to the suitability of the areas for intensive development. Reference should be made to the Geotechnical Land Use Map, Engineering Geology Map and Physical Constraints Map (PCM) for identification of factors influencing development opportunities. In particular, the PCM shows the nature of any constraint. If a constraint is identified on the PCM, and the constraint occurs within a potential development area, then the area of constraint is also shown on the GLEAM.

4.2.3 *Development Opportunities*

There are 16 areas within the study area which have potential for development from a geotechnical point of view. These areas constitute approximately 1 300 ha of land and are shown on the 1:20 000 scale GLEAM.

Area 1 *Tung Lung Island* (180 ha approx.) A large proportion of the Island is suitable for development from a geotechnical point of view. It is entirely underlain by volcanic rocks (RBp) of the Repulse Bay Formation, and the slope angles are generally moderately steep. About 5% of this PDA has slopes between 0 and 5°, 25% is between 5 and 15°, with the balance in the 15 to 30° range.

The coastal areas exhibit very little insitu weathered material but, on ridgecrests or in areas affected by geological structural discontinuities, up to 10 m in thickness of weathered material may occur. There appears to be only small drainage plain deposits of colluvium, and instability is confined to coastal regions. Coastal instability may, however, threaten adjacent land by progressive undercutting, and development should consider this potential hazard.

The channel at Fat Tong Mun is some 300 m wide and could be traversed with either a bridge or a causeway. The marine deposits in this area are predominantly sandy, and settlement may not be severe. The relatively large areas of suitable land may make development of this island viable.

The island is currently undeveloped, and there is little evidence of permanent residents. A fort at the north of the island is of archaeological significance. The only other structure on the island is the lighthouse at Tathong Point.

The northern and southwestern regions appear to be the most promising, and large platforms could be developed without excessive excavations.

Area 2 *Tin Ha Wan* (75 ha approx.) A large area on the southwest tip of the Clear Water Bay Peninsula shows potential for development from a geotechnical point of view.

The majority of the underlying rock is volcanic, but a 100 m wide dyke of quartz monzonite passes through the southern part of the area. In the north, the site is partly covered by alluvium at Tin Ha Wan, and a small area of colluvium is present in the south. Approximately 90% of the area is classified as either GLUM Class I or II. Slope angles are generally low, with over 50% of the area being less than 15° in gradient.

The area is currently unused but a large portion falls within the Clear Water Bay Country Park. Access should not be too difficult since the road that serves the golf course is of a high standard. Platforms conformable with the general trend of the terrain could be constructed. Large platforms may require excavations in hard rock due to the anticipated shallow weathering profile.

Area 3 *Tin Ha Shan* (30 ha approx.) The crest and sideslopes of Tin Ha Shan and the area around Tei Tong Tsui consist of land with only minor geotechnical limitations. Slope angles are generally moderate. The site is underlain by volcanic rocks and an extension of the quartz monzonite encountered in Area 2. The area includes a small colluvium-filled eastward draining valley.

There is extensive instability on the southwestern slopes of Tin Ha Shan. The area with potential for development is not affected because it is above and to the east of the instability. No erosion is evident.

Most of this site is currently within the Clear Water Bay Country Park but is otherwise undeveloped. Access could be from the golf course road, but the higher parts of the site may require expensive and difficult, access formation work. Access from the southwest is constrained by instability. The eastern extension at Tai Wong Kung could be developed with a minimum of site formation and access work and is also outside the bounds of the Country Park.

The higher ground could be utilised by the construction of narrow platforms conformable to the terrain in order to minimise the amount of hard rock excavation due to the anticipated shallow weathering depths. Fill in excess of local requirements may be produced.

Area 4 *Junk Island* (20 ha approx.) About half of this island has terrain that is geotechnically suitable for development. The underlying rock type is mainly volcanic, and no colluvium or other superficial deposits are evident. An outcrop of fine grained granite occurs on the north of the island near a small village. Slope angles are moderately steep; over 40% of the designated portion of the island has slope angles in the 0 to 5° range, 40% is in the 5 to 15° range and only 20% is in the 15 to 30° range. No erosion or instability are apparent in this PDA, and about 70% is designated as GLUM Class I.

As with Tung Lung Island, the major problem is access. The terrain is highly suitable for development, and the only use at present is a small village on the northern coast. The channel is approximately 250 m wide and could be bridged by a causeway, but the relatively small area of land gained for development (20 ha) may not make this viable.

Area 5 *Ngam Ha Tong* (15 ha approx.) This small area along a ridgeline to the west of So Shi Tau has some potential because the slopes are generally of a low angle. About 30% has angles in the 0 to 5° range, 30% is in the 5 to 15° range and the remainder is in the 15 to 30° range.

The underlying geology is volcanic, and no colluvium or other superficial deposits are present. The adjacent steep terrain shows signs of instability, and this may inhibit development and access. This proposed site is adjacent to a beach used for recreation and may be suitable for the development of additional recreational facilities. It is, however, partly located within the bounds of the Clear Water Bay Country Park.

Area 6 *Eastern Clear Water Bay Country Park and Sheung Sz Wan* (250 ha approx.) This very large stretch of land has areas of high potential for development from a geotechnical point of view. The site is entirely underlain by volcanic rocks, with three lithological units of the Repulse Bay Formation. These are: Dominantly Pyroclastic Rock with Some Lavas (RBp), Acid Lavas (RBv), and Mainly Banded Acid Lavas—Some Welded Tuffs (RBvb). Of these, the tuffs of the RBp unit probably have a deeper weathering profile compared with the lavas of the RBv and RBvb units. Approximately 10% of the area is covered by colluvium, which is mainly concentrated in the drainage lines.

The flattest slopes occur in the northern sector around Sheung Yeung, where there is some existing residential development. Colluvium, at an angle of about 5 to 15°, is present at Leung Fai Tin, and some problems with high groundwater tables are possible.

In the south around Tai Wan Tau, the terrain is dissected by incised drainage lines, and this would probably require the provision of entrainment, if developed. Overall, there is very little erosion of any form, but some peripheral areas in the east may be affected by instability on adjacent steep terrain.

Some large structural geological discontinuities traverse the area, and these may indicate zones of deep weathering or unusual groundwater conditions. The weathering profile should not be very deep, with about 5 to 10 m of soft material.

In the eastern portion of the Clear Water Bay Country Park, the terrain is in the form in an irregular upland plateau with a maximum elevation of 263 m. Slope angles are steeper than other parts of the PDA, and there may be additional hazards associated with the naval firing range. Access to this part of the study area would have to be developed along the east trending ridgelines in the south to connect with the Clear Water Bay Road.

Area 7 *Ng Fai Tin* (40 ha approx.) To the north of Area 6, separated by some steep unstable terrain, two parcels of geotechnically suitable land occur near Ng Fai Tin and Mang Kung Uk. These areas are underlain by volcanic rocks, with about 20% covered by colluvium and 5% by alluvium. Slope angles are 15% in the 0 to 5° class, 40% in the 5 to 15° class and the remainder in the 15 to 30° class.

About 20% of the terrain is classified as GLUM Class III, with 45% in GLUM Class II and 35% in GLUM Class I. The areas of high GLUM classes correspond to deposits of colluvium, which may have unusual groundwater conditions. These colluvial areas are adjacent to existing village development, and access could be easily gained from the Clear Water Bay Road and Ngam Tau Road. The land is currently unused and ranges in elevation from sea-level up to 180 m. The only identifiable erosion is confined to stream channels, and instability is not evident.

Area 8 *Shelter Island* (40 ha approx.) The majority of this island is suitable for development unconstrained by geotechnical limitations. The underlying geology is entirely volcanic, and only a small deposit of colluvium is apparent. Denudation is restricted to minor gully erosion in stream channels, and there is only limited occurrence of coastal instability on the northern coastline of the island.

Despite its favourable landforms, the development of the island is likely to be constrained by access. The island is probably too far from the mainland for causeway construction. There is no existing development, and the area does not occur within a Country Park.

Area 9 *Silverstrand to Pak Shek Kok* (150 ha approx.) This large area on the western side of the Clear Water Bay Peninsula includes a long narrow ridgecrest trending north to south in the Clear Water Bay Country Park.

Included in this area is a large deposit of colluvium in a valley which drains to the sea at Siu Chik Sha. The valley is flanked by slopes mainly in the range of 15 to 30°. Overall, the distribution of slope angles is 30% in the 0 to 5° class, 40% in the 5 to 15° class and 30% in the 15 to 30° class. The distribution of GLUM classes is as follows: 20% GLUM Class I, 50% GLUM Class II and 30% GLUM Class III. The elevation of the site ranges from sea-level up to 160 m. The underlying geology is entirely volcanic rocks, and the weathering depths are likely to be in the range of 5 to 15 m.

As part of the Junk Bay New Town Development, it is proposed that a large platform at +70 m be excavated in the northeastern portion of this site. This would subsequently be developed for high density housing. The adjacent parts of Area 9 are proposed for use as an urban fringe park. It appears that further intensive development is geotechnically feasible.

Although the site is apparently free of instability, the eastern side of the valley is overlooked by steep, potentially unstable slopes. Minor debris flows from landslips could possibly affect developments along the valley floor. Some minor to moderate sheet erosion is present on the ridgecrests, but this is considered to be of no major consequence to construction.

In the southwestern sector of the area, a large cut platform has been excavated to provide fill for the adjacent controlled tip. Access has already been developed for the controlled tip, and extension into Area 9 should not be difficult. Access to other parts of this area could be constructed from the Clear Water Bay Road, but access to the central ridgecrest may require extensive construction work.

Area 10 *Nam Wai to Yau Yue Wan* (150 ha approx.) This area, adjacent to Junk Bay and extending north to the study boundary at Nam Wai, is entirely underlain by volcanic rocks. It contains a large area of colluvium around Tai Po Tsai, and about 10% of the site is covered by colluvial material. The weathering depths in the volcanic rocks are probably in the range of 5 to 15 m.

The slope angles are distributed as follows: 10% in the 0 to 5° range, 15% in the 5 to 15° range and 75% in the 15 to 30° range. The GLUM classes are present in the following proportions: 15% GLUM Class I, 75% GLUM Class II and 10% GLUM Class III.

There is no evidence of instability within the site. However, some fill slopes in the area may exhibit evidence of instability and severe erosion.

This Potential Development Area is currently unused but is adjacent to village development to which there is existing access. It is geotechnically feasible for more intensive development in the form of large platform construction in this area.

Area 11 *Tseng Lan Shue* (130 ha approx.) This area contains a number of wide valleys that are filled with colluvium and some alluvium at Pak Shek Wo. The underlying geology is mainly volcanic rock, but about 10% of the site is underlain by granite. The weathering depths in the granitic area can be expected to be of the order of 15 to 30 m, compared with the volcanic areas which will have about 5 to 15 m of soft material. The granite areas may have some potential for use as soft borrow sites for fill or reclamation.

The slope angle classes are distributed as follows: 10% in the range of 0 to 5°, 25% in the range of 5 to 15° and 65% in the range of 15 to 30°. GLUM classes are present in the following proportions; 15% GLUM Class I, 45% GLUM Class II and 40% GLUM Class III. The high proportion of GLUM Class III terrain is due to the extensive deposits of colluvium associated with drainage plains which may have high groundwater levels. There is some adjacent instability caused principally by stream undercutting. Some minor gully erosion is also associated with the colluvial deposits.

The area is partly used for agriculture, especially around Tai Ngau Wu. There are some adjacent small village sites to which access already exists.

Area 12 *Mok Tse Che* (75 ha approx.) This site is completely underlain by volcanic rocks. It is bounded in the north by the study area boundary and is a continuation of the Ho Chung Valley PDA, which is considered in the East New Territories Report (GASP IX).

Slope angles are moderately steep, with 75% of the area with slopes in the 15 to 30° class, 20% in the 5 to 15° class and only 5% in the 0 to 5° class. Distribution of GLUM classes is as follows: 15% is in GLUM Class I, 80% in GLUM Class II and 5% in GLUM Class III. Only 5% of the site is covered by colluvium. In the centre, however, there is an extensive colluvium-filled valley that has been excluded from the PDA due to the presence of instability.

Around Hebe Knoll, there is still some agricultural activity, but otherwise the PDA is unused. Access is currently available from the Clear Water Bay Road.

Area 13 *Tseung Kwan O* (70 ha approx.) To the south of PDA 11 and to the west of Mau Wu Shan, three parcels of land have been grouped as Area 13. Volcanic rocks underlie each of them and weathering depths are probably in the order of 5 to 15 m.

About 10% of the designated area is covered with colluvium, some of which is subject to minor gully erosion. Overall, the sites have slopes of fairly low angles, with 5% in the 0 to 5° class, 65% in the 5 to 15° class and 30% in the 15 to 30° class. This is reflected in the GLUM class distribution, where about 60% is in GLUM Class I, 30% in GLUM Class II and only 10% in GLUM Class III.

A large platform at +85 m is proposed as part of the Junk Bay New Town development to provide fill for reclamation, and this, along with adjacent areas, will be used for intensive residential development. The southern portion of this area is proposed for use as a rural protection area. There is some unstable terrain within this PDA which should be considered at the planning stage.

Area 14 *Tiu Keng Wan* (35 ha approx.) This area actually consists of 12 separate small parcels of land that extend from Tiu Keng Wan to Lei Yue Mun Point. These areas in themselves may be geotechnically suitable for development, but there are problems of access. The intervening land is steep and, in places, unstable. The areas may have some potential for use for low intensity residential development.

There are no deposits of colluvium identified on these sites, but about 33% is underlain by granitic rocks, with the remainder having volcanic bedrock. Slope angles within the designated areas are distributed as follows: 20% in the 5 to 15° class and 80% in the 15 to 30° class. GLUM classes are similarly distributed, with about 20% GLUM Class II and the balance as GLUM Class III.

Area 15 *Ninepin Group* (25 ha approx.) This group of remote islands has only a small proportion of land free of geotechnical constraint that could be developed. Remote location and steep unstable coastal regions make their development difficult. They could be used for government institutional purposes which require remote or isolated sites.

The islands are formed by volcanic rocks, and the weathering profile is probably very shallow due to the lack of significant vegetation and the consequent rapid soil erosion. The slope angles are distributed as follows: 10% in the 0 to 5° range, 30% in the 5 to 15° range and 60% in the 15 to 30° range. There are no major colluvial deposits in this area.

Area 16 *Bluff and Basalt Islands* (30 ha approx.) The situation with these islands is similar to that for the Ninepin Group, in that their remote location severely inhibits any potential for development. Of the two islands, Bluff Island has the greater potential. It does, however, have steep unstable coastal slopes, especially on the southwestern shore. Within the designated areas, which are all underlain by volcanic rocks, the slope angles are: 20% in the 5 to 15° range, with the balance in the 15 to 30° range. There are some areas of colluvium and one small deposit of alluvium on Basalt Island.

An additional constraint arises from the use of Basalt Island as a firing range.

The GLUM classes are: 10% GLUM Class I, 80% GLUM Class II and 10% GLUM Class III. Weathering depths are expected to be shallow due to rapid erosion, except near the structural geological discontinuities that transect the islands. Any development would have to take into account the severe coastal instability.

4.2.4 *Assessment of Planning Strategies Using GEOTECS*

Any search for areas suitable for a proposed land use requires an initial shortlisting of potential sites. Where the initial assessment of suitability can be defined in terms of the existing terrain and the existing land use, GEOTECS may be used to prepare computer-generated plots which indicate areas fulfilling any given strategy (Styles et al, 1986). Computer-generated plots are used to illustrate various aspects of this Report. GEOTECS is discussed in Section 1.5.9 and described in detail in Appendix A.11.

The following considerations are important for the satisfactory use of the system:

(*a*) The highlighting of areas using GEOTECS provides only an initial assessment of potential or suitability. The results do not necessarily reveal all the options available.

(*b*) Factors other than those included in GEOTECS will influence any planning decision.

(*c*) The applicability of any such assessment depends on the selection of relevant GEOTECS attributes for the strategy.

(*d*) Each two-hectare grid cell in the GEOTECS system is independent of adjacent cells.

(*e*) The land information stored within GEOTECS is designed for geotechnical, geological and engineering applications. It should be used to gauge the general distribution of specific attributes and/or combinations of attributes.

One of the advantages of the GEOTECS approach is that it enables a set of primary options to be derived regardless of individual local knowledge or preference. It assesses the terrain in a systematic manner according to the criteria selected from the various terrain-related attributes. Two examples are provided to illustrate the application of GEOTECS for planning and engineering purposes.

(i) *Development Potential in Squatter Areas*

An initial assessment of the suitability of the terrain for development is used as the basis for the GLEAM (see Appendix A.9). Using the GLEAM criteria to determine 'potential' terrain and relating it to the presence of squatters, the GEOTECS Plot in Figure 11 has been produced. The squatter areas which could be cleared to provide land suitable for development are shown.

Squatters occur on approximately 182 ha within the study area. Some 94 ha of this terrain has potential for development from a geotechnical point of view. The GEOTECS symbol (+) also shows the general location of some 126 ha of land with development potential on natural terrain. Squatters occur on approximately 88 ha of geotechnically difficult terrain (GLUM Classes III & IV).

A number of options could be derived for squatter management using GEOTECS. Highlighted in this example are opportunities for new development of terrain adjacent to existing squatter areas and squatter areas with potential for redevelopment.

(ii) *Potential Quarry Sites*

The GEOTECS Plot in Figure 12 indicates areas which exhibit quarry potential on the basis of several terrain attributes. The main selection criterion for areas without intensive existing land use is that of a convex, straight or cliff slope less than 40° in gradient. As a secondary criterion, areas are also selected on the basis of slope angle alone. These selection criteria enable quarry potential to be maximised between the existing ground surface and the final quarry face. Thus, groups of several units with optimum potential or with occasional secondary potential may make suitable sites. Bedrock geology is not used in the initial assessment presented in the GEOTECS Plot in Figure 12, although it must be incorporated for advanced planning. Once potential rock types are selected, they can be added to the GEOTECS strategy for the production of a further plot. Hence, the refinement of alternative quarry sites is possible.

Approximately 2 097 ha of undesignated natural terrain has potential for quarry sites. A further 808 ha with potential for quarrying occur within existing Country Parks or are under cultivation. These figures indicate that many options exist, but these options would be severely reduced when rock type is specified.

5. CONCLUSIONS

The findings reached during the Clear Water Bay study are presented on a series of physical resource, planning and engineering maps produced at a scale of 1:20 000. The major maps are: the Geotechnical Land Use Map (GLUM), the Physical Constraints Map (PCM), the Engineering Geology Map (EGM), and the Generalised Limitations and Engineering Appraisal Map (GLEAM).

The major conclusions fall very broadly into two categories which relate, firstly, to materials and land resource distribution, and secondly, to land management associated with planning and engineering feasibility.

5.1 Materials and Land Resource Distribution

(*a*) Slope instability of some form or other is relatively common within the study area. Approximately 712 ha of the terrain (19.1%) is associated with or affected by instability. Instability is associated with most of the geological materials, but is most prevalent in this area on the volcanics. Slope failures in the colluvium and volcanics are generally characterised by small landslip scars with extensive debris trails. In the case of volcanic rocks, this is probably due to the relatively steep slopes on which failure occurs. Landslips on the intrusive igneous rocks are also common but tend to be relatively small rotational or joint controlled failures, often associated with cut slopes. Slope failures in intrusive igneous rocks usually cause less impact on the terrain than failures in volcanic rock or colluvium.

(*b*) The geology of the area is relatively complex, and several aspects require careful investigation. Weathering depths are variable, with very deep weathering occurring in some granitic areas. The competition from alternative land uses restricts the future excavation of borrow and rock materials. There are numerous photolineaments present, some of which are likely to be faults, shear zones, major joint zones or dykes.

(*c*) Approximately 480 ha of the footslope terrain is covered by extensive colluvial deposits; 8.5% of the colluvium is affected by instability. Significant geotechnical limitations should be anticipated on zones of runoff and surface drainage across the colluvium, which occupy some 51% (245 ha) of the generally low angle (<15°) colluvial footslope terrain.

(*d*) The granitic terrain has a slightly lower proportion of GLUM Classes I & II (31.4%) than the volcanics (50.5%). Of the 477 ha of colluvial terrain which occurs within the study area, some 93.6% is subject to high to extreme geotechnical constraints (GLUM Classes III & IV).

(*e*) Approximately 33.3% of the study area is characterised by slopes which have gradients between 0 and 15°. A further 60.6% of the terrain has slope gradients between 15 and 40°, and 6.1% is steeper than 40°.

(*f*) There was approximately 63 ha of reclamation within the study area in February 1984, and a further 320 ha were proposed as part of the New Town development. The siting of development on extensive reclamation that is underlain by thick compressible marine sediments may give rise to foundation problems and settlement of services. This aspect will require careful design and control during construction.

(*g*) Approximately 14.6% of the study area is currently developed in some form or other. Squatters occupy 4.9% of the area, and 17.4% is allocated to Country Park. The remaining 63.1% consists of undeveloped natural terrain.

5.2 Land Management Associated with Planning and Engineering Feasibility

(*a*) During the last 20 years a number of large landslips within the Territory, have resulted in considerable loss of life and very substantial property damage (So, 1971; Lumb, 1975; Brand, 1984). Landslips have occurred in developed areas, squatter villages and natural terrain (Government of Hong Kong, 1972 a & b, 1977). Slope instability not only poses a threat to life and property but also diminishes the viability for development of the natural terrain which remains undeveloped. In the Clear Water Bay study area, the geotechnical constraints associated with the terrain are important factors for land management purposes and engineering feasibility.

(*b*) Opportunities do exist for urban expansion in the study area, although it is unrealistic to envisage that future development can avoid areas with geotechnical limitations. The Generalised Limitations and Engineering Appraisal Map (GLEAM) recognises this fact and delineates 16 areas which have overall potential for development from a geotechnical point of view. These represent a total of 1 300 ha or 35% of the terrain. Some areas of GLUM Class III, and possibly Class IV, terrain occur within these areas, but an integrated approach to planning and engineering design should minimize the hazard of slope failure.

(*c*) If areas are selected for intensive development on GLUM Classes III & IV terrain, they should be subject to terrain classification at a scale of 1:2 500 (District Study, Stage 1) or a comparable level of investigation.

(*d*) This study indicates that there is 2 246 ha of currently undisturbed natural terrain, which does not include Country Park. Of this figure, GLUM Classes I & II occur on some 42% (936 ha) of the terrain, and 1 310 ha is associated with high to extreme geotechnical limitations (GLUM Classes III & IV). There is approximately 651 ha of land within the Clear Water Bay Country Park and, of this figure, 253 ha is classified as either having low or moderate geotechnical limitation (GLUM Classes I & II).

(*e*) Physical land resources are considered basic input for planning and land use management. The other constraints on the suitability of an area for development should be assessed in sympathy with the physical land resource information.

6. REFERENCES

Allen, P. M. & Stephens E. A. (1971). *Report on the Geological Survey of Hong Kong.* Hong Kong Government Press, 116 p. (& 2 maps).

Atherton, J. M. & Burnett, A. D. (1986). *Hong Kong Rocks.* Urban Council, Hong Kong, 151 p.

Bennett, J. D. (1984a). *Review of Superficial Deposits and Weathering in Hong Kong.* Geotechnical Control Office, Hong Kong, 51 p. (GCO Publication no. 4/84).

Bennett, J. D. (1984b). *Review of Hong Kong Stratigraphy.* Geotechnical Control Office, Hong Kong, 62 p. (GCO Publication no. 5/84).

Bennett, J. D. (1984c). *Review of Tectonic History, Structure and Metamorphism of Hong Kong.* Geotechnical Control Office, Hong Kong, 63 p. (GCO Publication no. 6/84).

Brand, E. W. (1984). Landslides in Southeast Asia: a state-of-the-art report. *Proceedings of the Fourth International Symposium on Landslides,* Toronto, vol. 1, pp 17–59. (Addendum, vol. 3, pp 105–106).

Brand, E. W. (1988). *Bibliography on the Geology and Geotechnical Engineering of Hong Kong to December 1987.* Geotechnical Control Office, Hong Kong, 147 p. (GCO Publication no. 1/88).

Brand, E. W., Burnett, A. D. & Styles, K. A. (1982a). The Geotechnical Area Studies Programme in Hong Kong. *Proceedings of the Seventh Southeast Asian Geotechnical Conference,* Hong Kong, vol. 1, pp 107–123.

Brand, E. W., Maunder, C. A. & Massey, J. B. (1984). Aggregates in Hong Kong. *Proceedings of the International Symposium on Aggregates,* Nice, France. (Published in *Bulletin of the International Association of Engineering Geology,* no. 29, pp 11–16).

Brand, E. W. & Phillipson, H. B. (1984). Site investigation and geotechnical engineering practice in Hong Kong. *Geotechnical Engineering,* vol. 15, pp 97–153.

Brand, E. W., Styles, K. A. & Burnett, A. D. (1982b). Geotechnical land use maps for planning in Hong Kong. *Proceedings of the Fourth Congress of the International Association of Engineering Geology,* New Delhi, vol. 1, pp 145–153.

Burnett, A. D. Brand, E. W. & Styles, K. A. (1985). Terrain evaluation mapping for a landslide inventory in Hong Kong. *Proceedings of the Fourth International Conference and Field Workshop on Landslides,* Tokyo, pp 63–68.

Burnett, A. D. & Styles, K. A. (1982). An approach to urban engineering geological mapping as used in Hong Kong. *Proceedings of the Fourth Congress of the International Association of Engineering Geology,* New Delhi, vol. 1, pp 167–176.

Carson, M. A. & Kirkby, M. J. (1972). *Hillslope Form and Process.* Cambridge University Press, London, 475 p.

Davis, S. G. (1952). *The Geology of Hong Kong.* Government Printer, Hong Kong, 231 p.

Geological Society of Hong Kong (1984). *Abstracts of the Conference on Geological Aspects of Site Investigation,* Hong Kong, edited by W. W. S. Yim & I. McFeat-Smith. Geological Society of Hong Kong, Abstracts no. 2, 50 p.

Geological Society of London (1977). The description of rock masses for engineering purposes. (Geol. Soc. Working Party Report). *Quarterly Journal of Engineering Geology,* vol. 10, pp 355–388.

Geotechnical Control Office (1984). *Geotechnical Manual for Slopes.* (Second edition). Geotechnical Control Office, Hong Kong, 295 p.

Government of Hong Kong (1972a). *Interim Report of the Commission of Inquiry into the Rainstorm Disasters, 1972.* Hong Kong Government Printer, 22 p.

Government of Hong Kong (1972b). *Final Report of the Commission of Inquiry into Rainstorm Disasters, 1972.* Hong Kong Government Printer, 94 p.

Government of Hong Kong (1977). *Report on the Slope Failures at Sau Mau Ping, August 1976.* Hong Kong Government Printer, 105 p. (& 8 drgs).

Hansen, A. (1984a). Landslide hazard analysis. *Slope Instability,* edited by D. Brunsden & D. B. Prior, pp 523–602. John Wiley & Sons, Chichester, UK.

Hansen, A. (1984b). Engineering geomorphology: the application of an evolutionary model of Hong Kong's terrain. *Zeitschrift für Geomorphologie,* supplementary vol. 51, pp 39–50.

Hansen, A. & Nash, J. M. (1984). A brief review of soil erosion in Hong Kong—causes, effects and remedial measures. *Proceedings of the Conference on Geological Aspects of Site Investigation*, Hong Kong, pp 139–150. (Published as *Geological Society of Hong Kong, Bulletin* no. 2)

Hencher, S. R. & Martin, R. P. (1982). The description and classification of weathered rocks in Hong Kong for engineering purposes. *Proceedings of the Seventh Southeast Asian Geotechnical Conference,* Hong Kong, vol. 1, pp 125–142. (Discussion, vol. 2, pp 167–168).

Holt, J. K. (1962). The soils of Hong Kong's coastal waters. *Proceedings of the Symposium on Hong Kong Soils,* Hong Kong, pp 33–51.

Howard, A. D. (1967), Drainage analysis in geologic interpretation: a summation. *Bulletin of the American Association of Petroleum Geology,* vol. 51, no. 11, pp 2246–2259.

Leach, B. (1982). The development of a groundwater recharge model for Hong Kong. *Journal of Hydrological Sciences*, vol. 4, pp 469–491.

Leach, B. & Herbert, R. (1982). The genesis of a numerical model for the study of the hydrogeology of a steep hillside in Hong Kong. *Quarterly Journal of Engineering Geology*, vol. 15, pp 243–259.

Lumb, P. (1962a). General nature of the soils of Hong Kong. *Proceedings of the Symposium on Hong Kong Soils*, Hong Kong, pp 19–32 (& 1 drg).

Lumb, P. (1962b). The properties of decomposed granite. *Géotechnique*, vol. 12, pp 226–243.

Lumb, P. (1964). *Report on the Settlement of Buildings in the Mong Kok District of Kowloon, Hong Kong.* Hong Kong Government Printer, 22 p. (& 8 drgs).

Lumb, P. (1965). The residual soils of Hong Kong. *Géotechnique*, vol. 15, pp 180–194. (Discussion, vol. 16, 1966, pp 78–81 & 359–360).

Lumb, P. (1972). Building settlements in Hong Kong. *Proceedings of the Third Southeast Asian Conference on Soil Engineering*, Hong Kong, pp 115–121. (Discussion, pp 394–396).

Lumb, P. (1975). Slope failures in Hong Kong. *Quarterly Journal of Engineering Geology*, vol. 8, pp 31–65.

Lumb, P. (1983). Engineering properties of fresh and decomposed igneous rocks from Hong Kong. *Engineering Geology*, vol. 19, pp 81–94.

Moye, D. G. (1955). Engineering geology for the Snowy Mountain Scheme. *Journal of the Institution of Engineers Australia,* vol. 27, pp 281–299.

Nash, J. M. & Dale, M. J. (1983). Geology and hydrogeology of natural tunnel erosion in superficial deposits in Hong Kong. *Proceedings of the Meeting on the Geology of Surficial Deposits in Hong Kong*, Hong Kong, pp 61–72. (Published as *Geological Society of Hong Kong, Bulletin* no. 1)

Phillipson, H. B. & Chipp, P. N. (1981). High quality core sampling—recent developments in Hong Kong. *Hong Kong Engineer*, vol. 9, no. 4, pp 9–15.

Phillipson, H. B. & Chipp, P. N. (1982). Airfoam sampling of residual soils in Hong Kong. *Proceedings of the ASCE Speciality Conference on Engineering and Construction in Tropical and Residual Soils*, Honolulu, Hawaii, pp 339–356.

Randall, P. A. & Taylor, B. W. (1982). Engineering geology in the Mid-levels Study, Hong Kong. *Proceedings of the Seventh Southeast Asian Geotechnical Conference*, Hong Kong, vol. 1, pp 189–204.

Richards, L. R. & Cowland, J. W. (1986). Stability evaluation of some urban rock slopes in a transient groundwater regime. *Rock Engineering and Excavation in an Urban Environment*, proceedings of a conference held in Hong Kong. Institution of Mining and Metallurgy, London, pp. 357–363.

Rodin, S., Henkel, D. J. & Brown, R. L. (1982). Geotechnical study of a large hillside area in Hong Kong. *Hong Kong Engineer*, vol. 10, no. 5, pp 37–45.

Ruxton, B. P. (1960). The geology of Hong Kong. *Quarterly Journal of the Geological Society of London,* vol. 115, pp 233–260.

Ruxton, B. P. & Berry, L. (1957). Weathering of granite and associated erosional features in Hong Kong. *Bulletin of the Geological Society of America,* vol. 68, pp 1263–1291.

So, C. L. (1971). Mass movements associated with the rainstorm of June 1966 in Hong Kong. *Transactions of the Institute of British Geographers*, no. 53, pp 55–65.

Strahler, A. N. (1952). Dynamic basis of geomorphology. *Bulletin of the Geological Society of America,* vol. 63, pp 923–938.

Styles, K. A. (1982). Aerial photograph interpretation—terrain classification. *Proceedings of the Seventh Southeast Asian Geotechnical Conference,* Hong Kong, vol. 2, pp 149–158.

Styles, K. A. (1983). Delineation of colluvial deposits in Hong Kong using the technique of terrain classification. *Proceedings of the Meeting on the Geology of Surficial Deposits in Hong Kong*, Hong Kong, pp 103–113. (Published as *Geological Society of Hong Kong, Bulletin* no. 1)

Styles, K. A. & Burnett, A. D. (1983). The assessment of hydrogeological features using the technique of terrain classification. *Proceedings of the ESCAP-RMRDC Workshop on Hydrogeological Mapping in Asia and the pacific Region*, Bandung, Indonesia, vol. 7, pp 121–144.

Styles, K. A. & Burnett, A. D. (1985). Geotechnical Area Studies Programme and land planning in Hong Kong. *Planning and Development*, vol. 1, no. 2, pp 13–23.

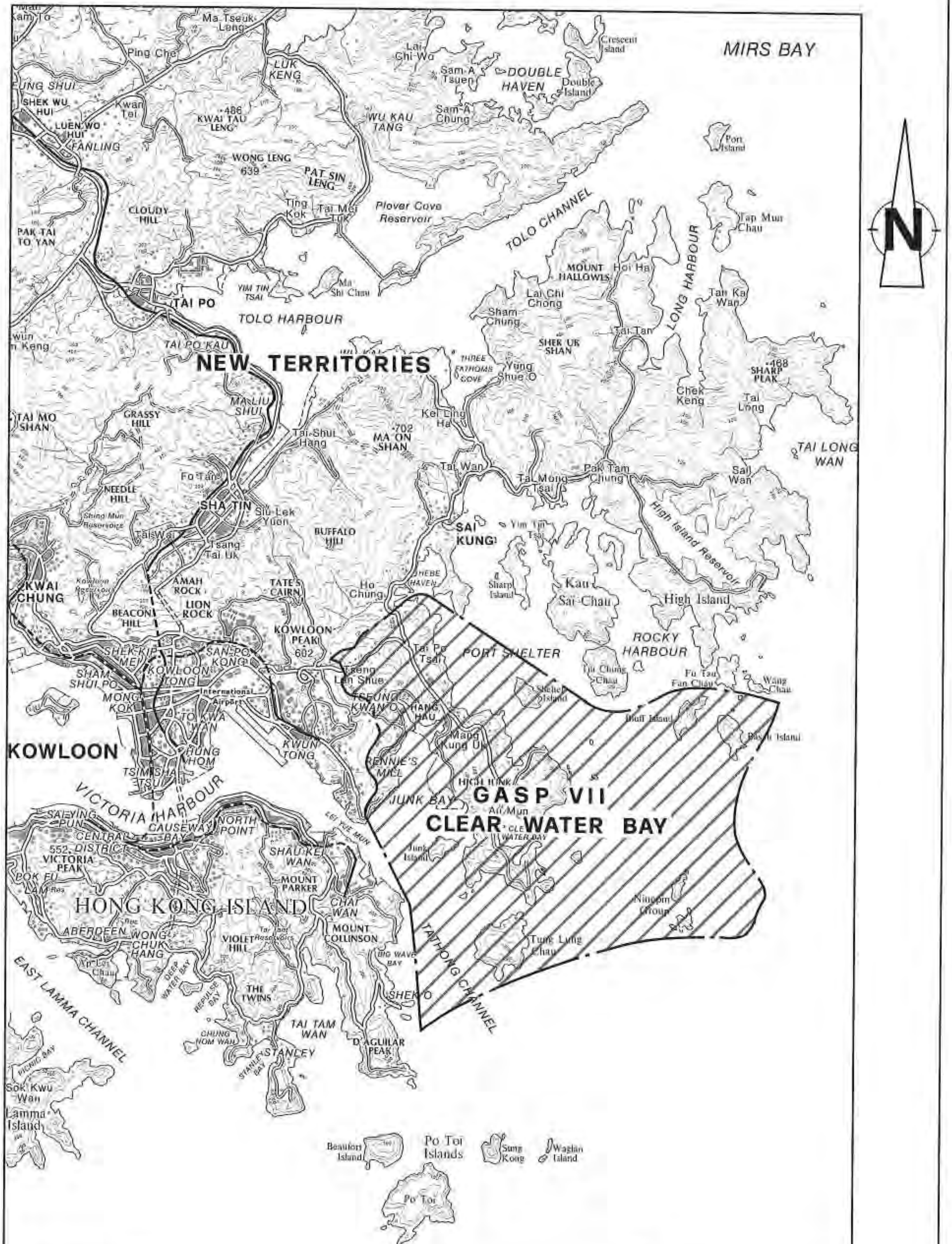
Styles, K. A., Burnett, A. D. & Cox, D. C. (1982). Geotechnical assessment of the terrain for land management and planning purposes in Hong Kong. *Proceedings of the First International Symposium on Soil, Geology and Landforms: Impact on Land Use Planning in Developing Countries (Landplan),* Bangkok, pp F16.1–F16.9.

Styles, K. A., Hansen, A. & Burnett, A. D. (1986). Use of a computer-based land inventory for delineation of terrain which is geotechnically suitable for development. *Proceedings of the Fifth International Congress of the International Association of Engineering Geology*, Buenos Aires, vol. 6, pp 1841–1848.

Styles, K. A., Hansen, A., Dale, M. J. & Burnett, A. D. (1984). Terrain classification methods for development planning and geotechnical appraisal: a Hong Kong case. *Proceedings of the Fourth International Symposium on Landslides,* Toronto, vol. 2, pp 561–568.

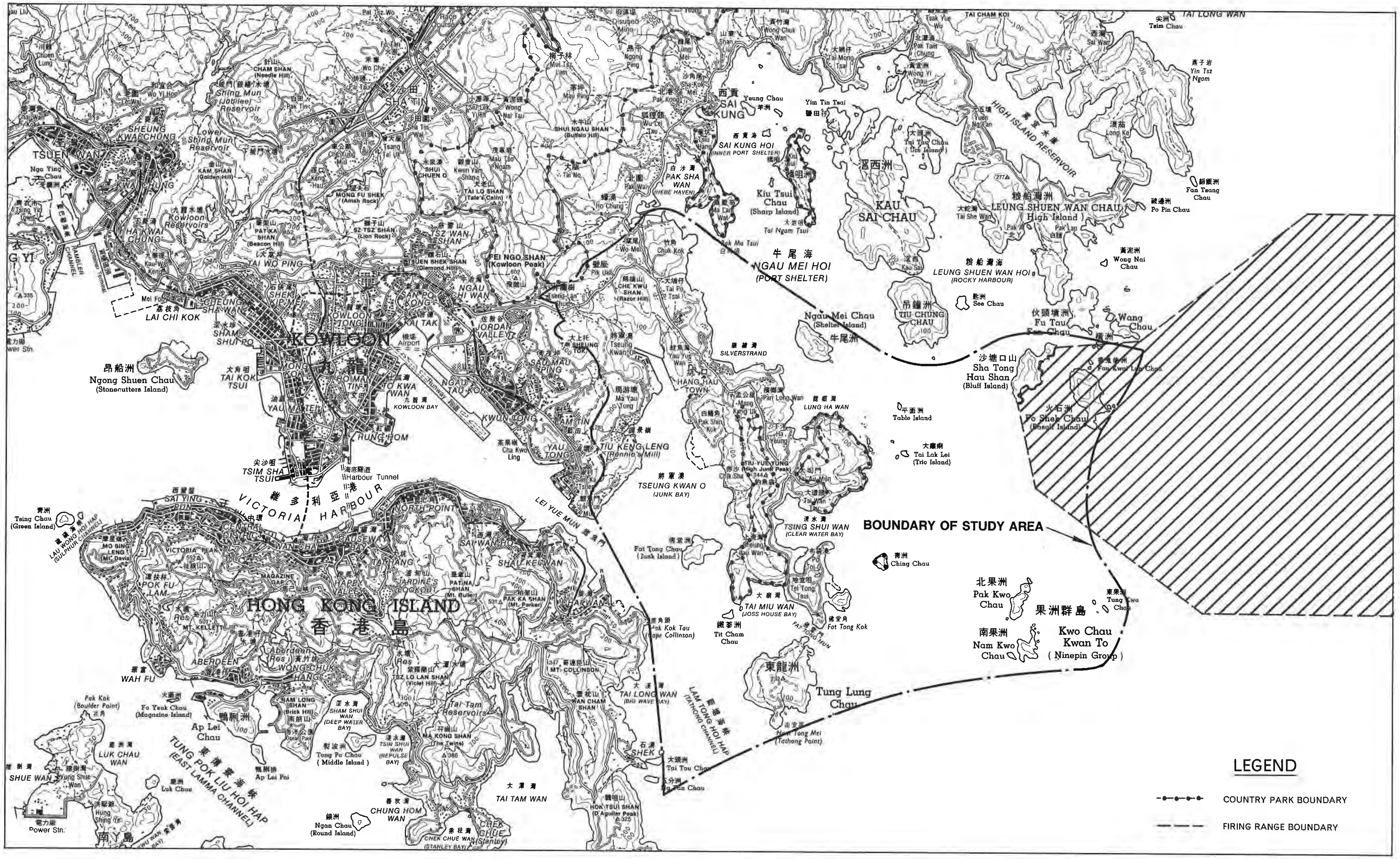
Thrower, L. B. (1970). The vegetation of Hong Kong. *Proceedings of the Royal Asiatic Society,* vol. 10, pp 21–43.

Vail, A. J. & Beattie, A. A. (1985). Earthworks in Hong Kong—their failure and stabilisation. *Proceedings of the International Symposium on Failures in Earthworks,* London, pp 15–28.

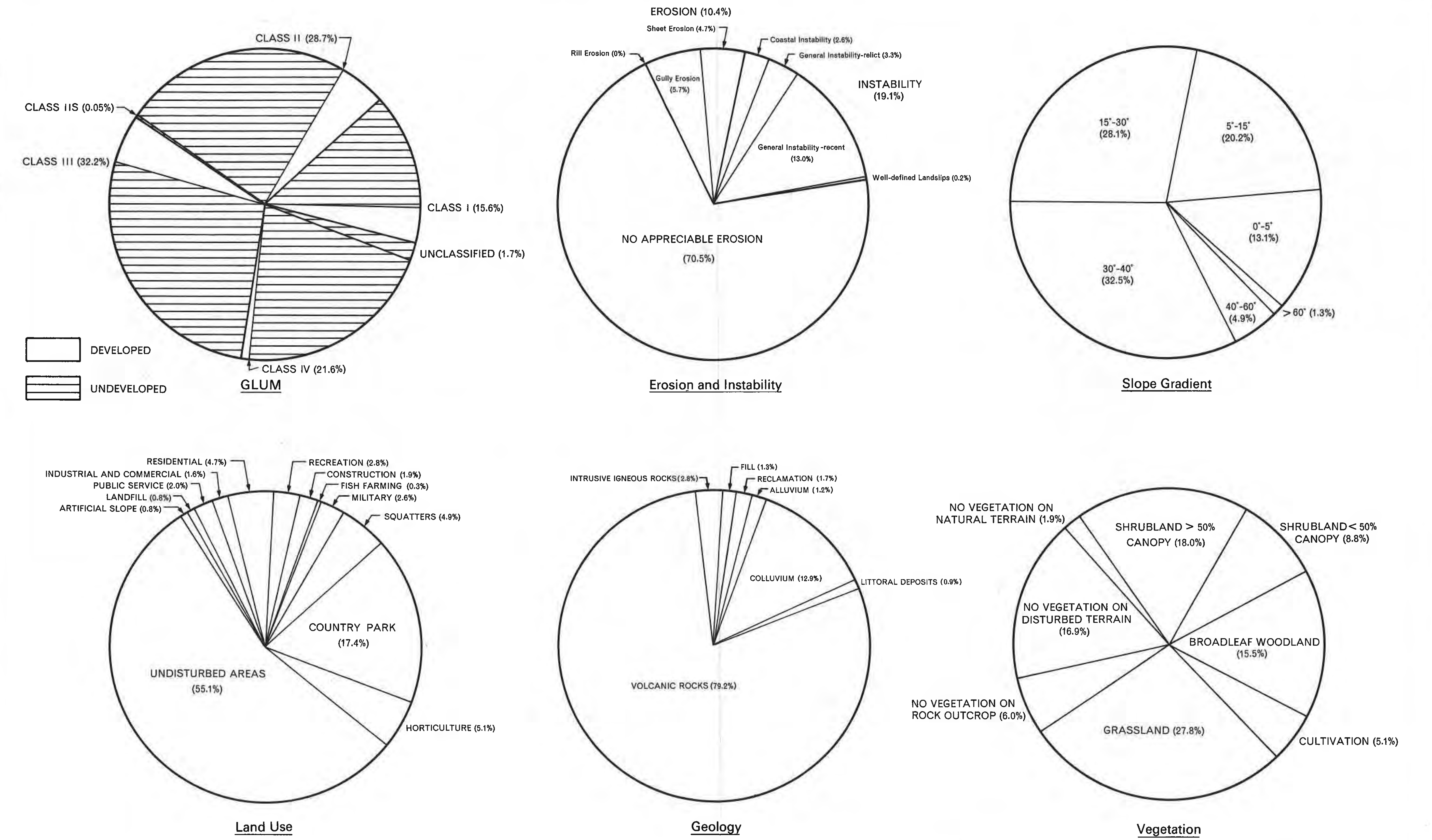


Scale 1:200 000	Location Map of the Clear Water Bay Study Area	Fig. 1

Scale 1:93 000	Aerial Photomosaic of the Clear Water Bay Study Area	Fig. 2

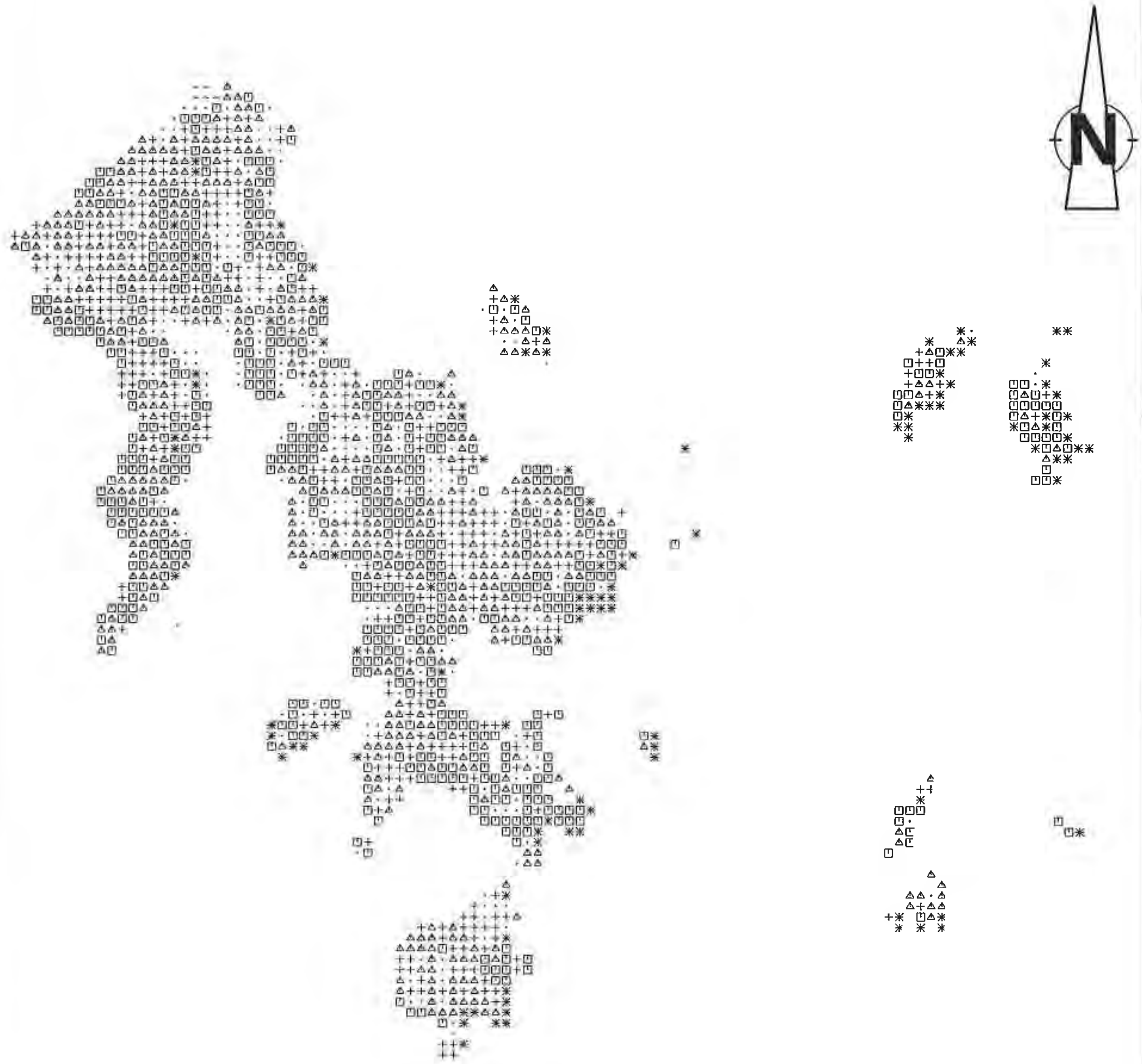


Scale 1:100 000	Clear Water Bay Study Area	Fig. 3



Pie Charts of Selected Attributes of the Clear Water Bay Area

Fig. 4



SYMBOL	MEANING	% TOTAL
·	0-5° SLOPE GRADIENT	12.8
+	5-15° SLOPE GRADIENT	20.2
△	15-30° SLOPE GRADIENT	28.1
⊡	30-40° SLOPE GRADIENT	32.5
✳	> 40° SLOPE GRADIENT	6.1
~	ARTIFICIAL CHANNEL, RESERVOIR OR POND	0.3

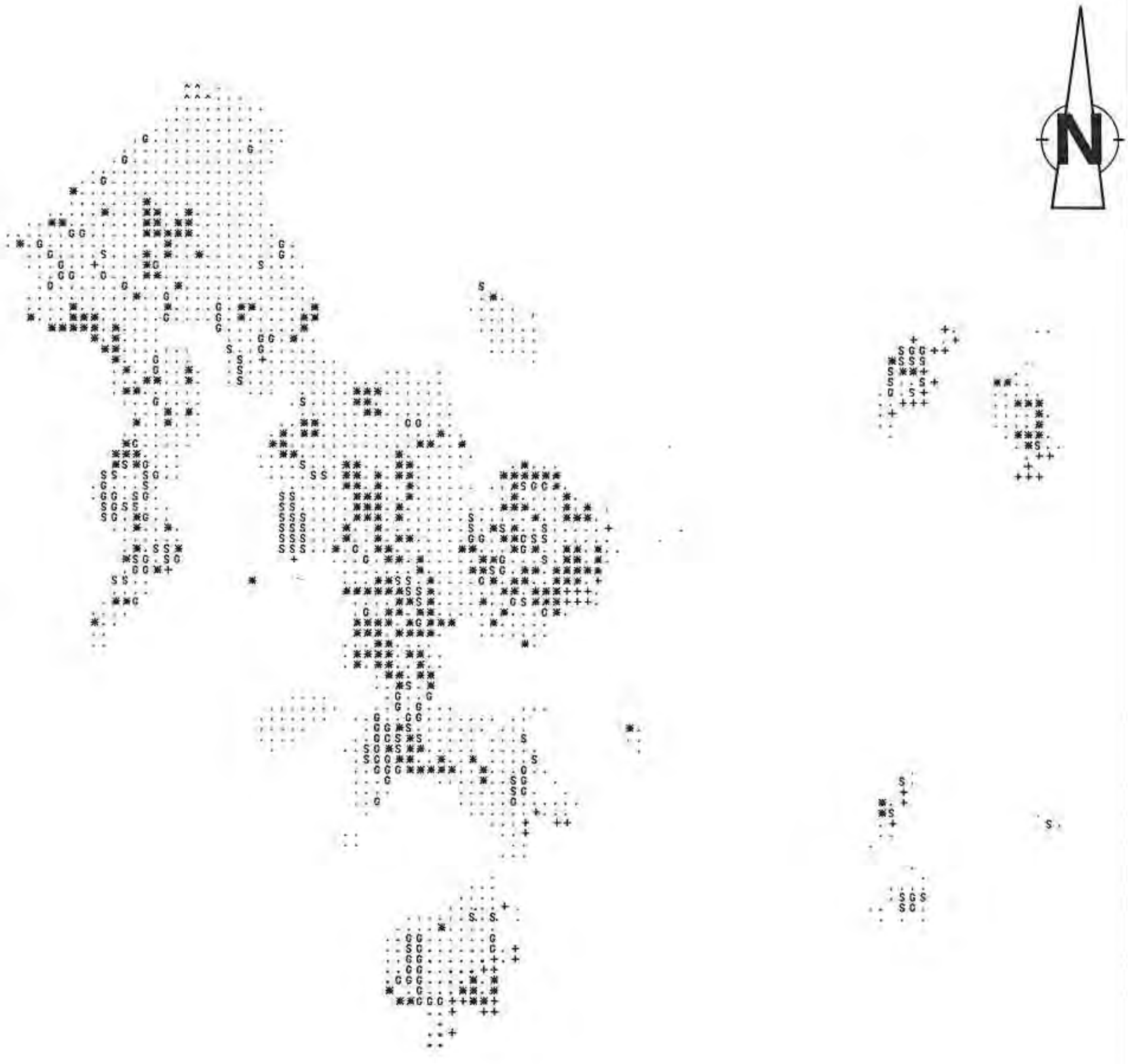
Scale 1:95 000	GEOTECS Plot - Slope Gradient	Fig. 5

SYMBOL	MEANING	% TOTAL
F	FILL	1.3
R	RECLAMATION	1.7
A	ALLUVIUM	0.9
⚠	COLLUVIUM	12.9
L	LITTORAL DEPOSITS	0.9
v	VOLCANIC ROCK (REPULSE BAY FORMATION)	79.2
+	INTRUSIVE IGNEOUS ROCKS	2.8
∽	RESERVOIR OR POND	0.3

Scale 1:95 000	GEOTECS Plot - Geology	Fig. 6

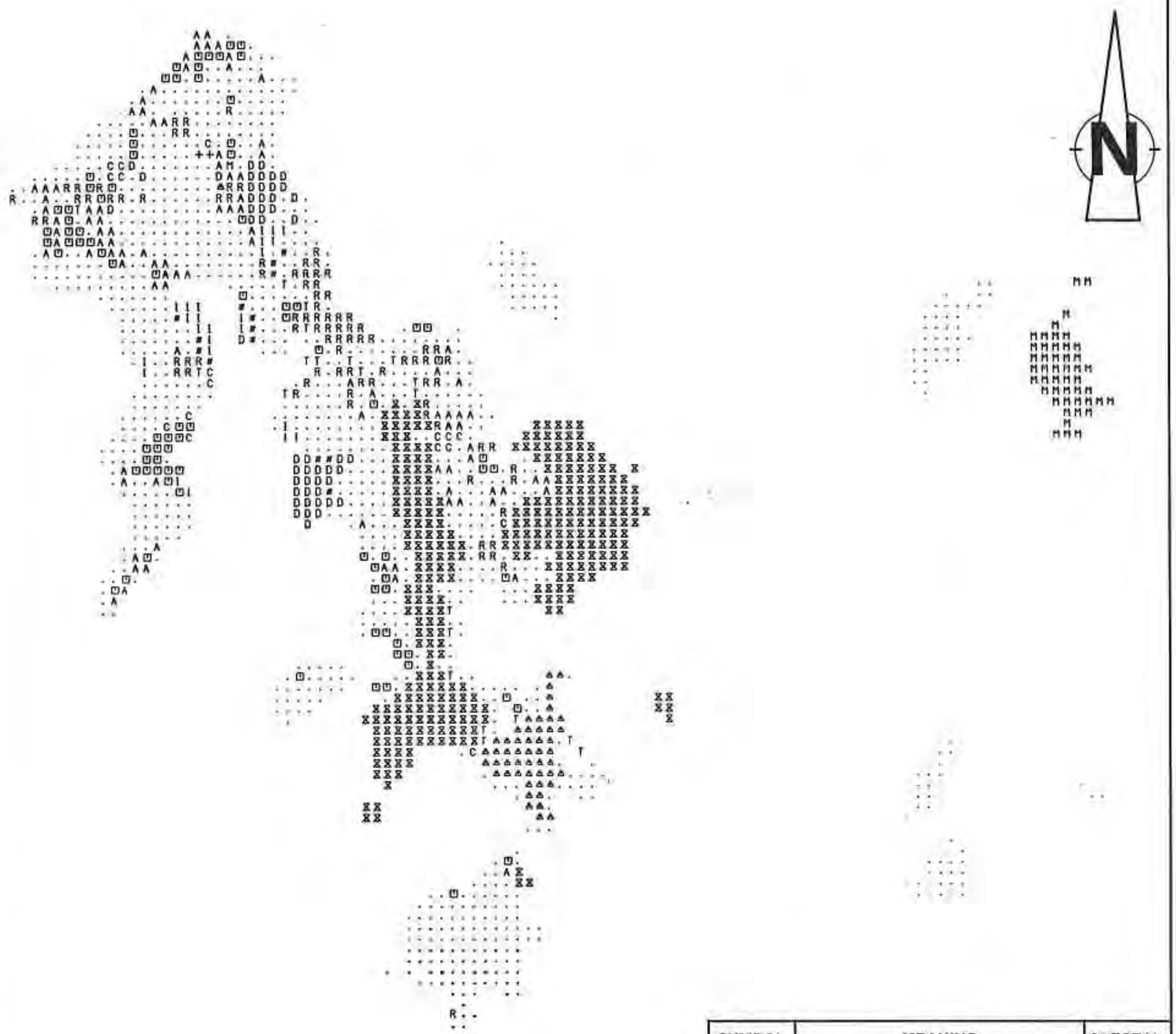
SYMBOL	MEANING	% TOTAL
+	GRASSLAND	27.8
C	CULTIVATION	5.1
◫	SHRUBLAND <50% CANOPY COVER	8.8
△	SHRUBLAND >50% CANOPY COVER	18.0
↑	WOODLAND	15.5
✳	ROCK OUTCROP	6.0
•	NO VEGETATION	18.5
^	RESERVOIR OR POND	0.3

Scale 1:95 000	GEOTECS Plot - Vegetation	Fig. 7



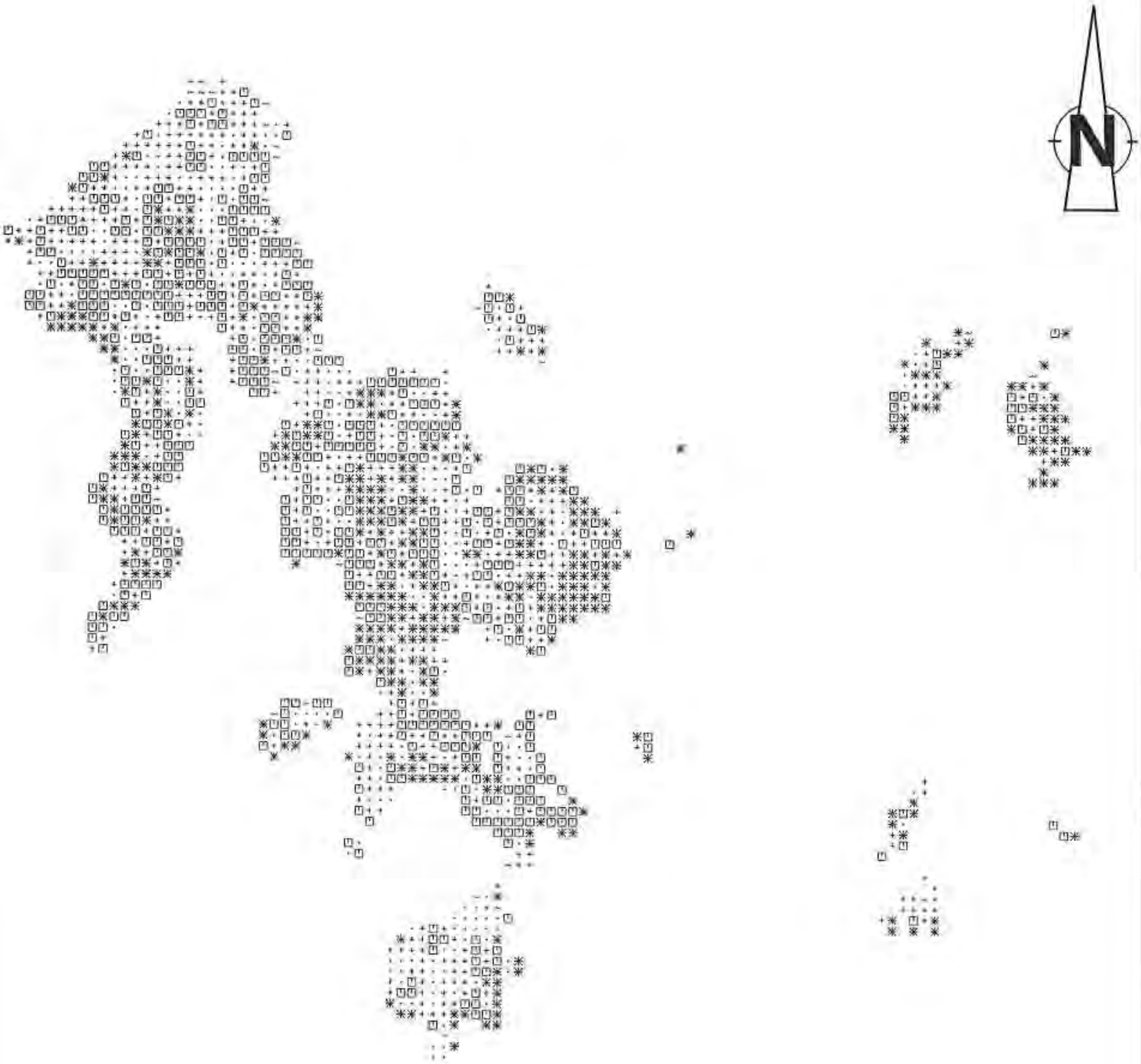
SYMBOL	MEANING	%TOTAL
·	NO APPRECIABLE EROSION	70.2
S	SHEET EROSION	4.7
G	GULLY EROSION	5.7
+	LANDSLIPS AND COASTAL INSTABILITY	2.8
✳	GENERAL EVIDENCE OF INSTABILITY	16.3
^	RESERVOIR OR POND	0.3

Scale 1:95 000	GEOTECS Plot - Erosion and Instability	Fig. 8



SYMBOL	MEANING	% TOTAL
⊡	SQUATTERS	4.9
△	RECREATIONAL	2.8
+	CEMETERIES	0.1
⧖	NATURAL AREAS (COUNTRY PARK)	17.4
#	ARTIFICIAL SLOPE	0.8
·	NATURAL AREAS (NOT IN COUNTRY PARK)	55.1
A	AGRICULTURAL	5.4
C	COMMUNITY AND INSTITUTIONAL	0.9
D	INCOMPLETE DEVELOPMENT	2.7
I	COMMERCIAL AND INDUSTRIAL	1.3
M	MILITARY	2.6
R	RESIDENTIAL (INCLUDING MIXED)	4.9
T	TRANSPORTATION	1.1

Scale 1:95 000	GEOTECS Plot - Land Use	Fig. 9

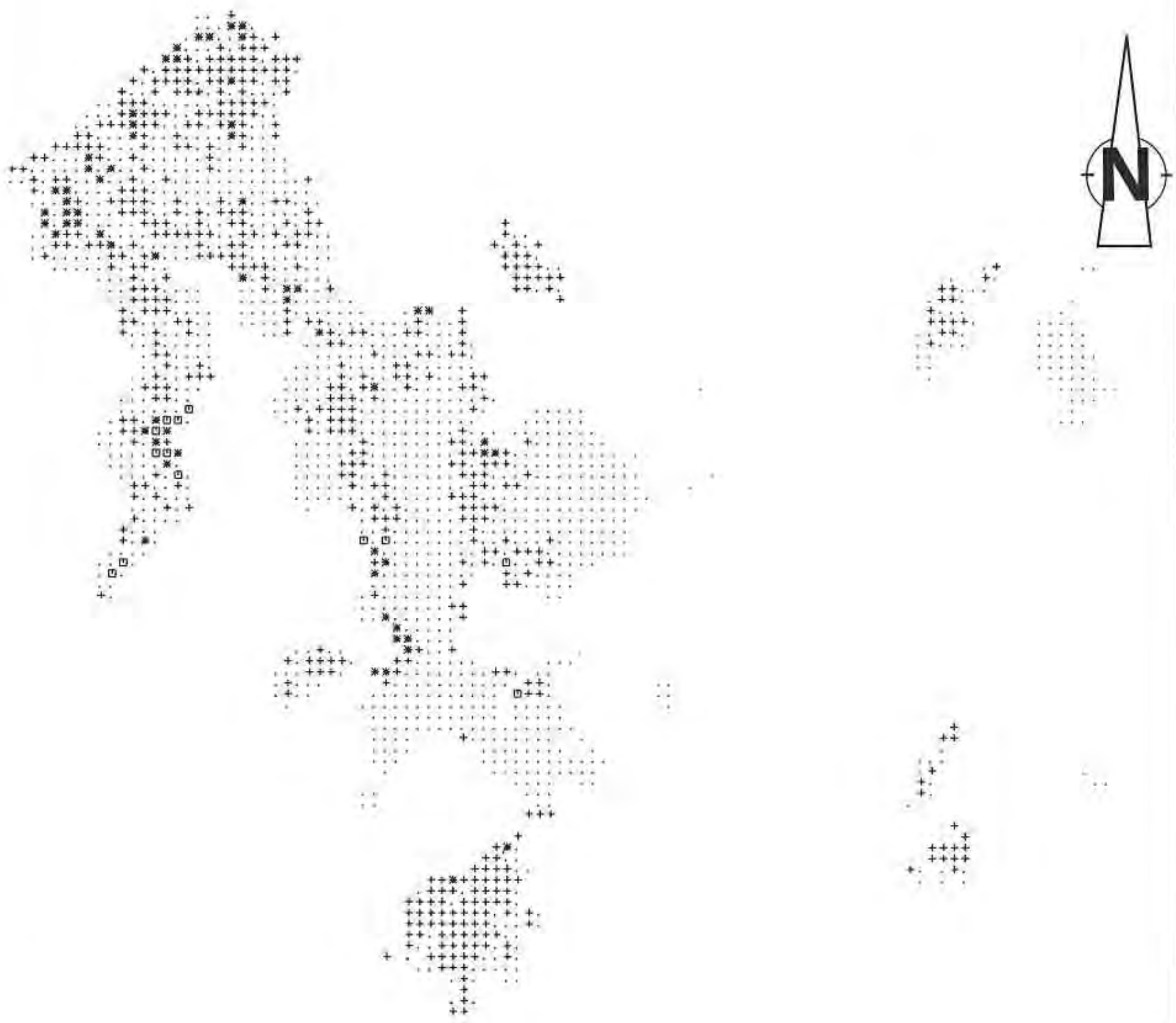


SYMBOL	MEANING	% TOTAL
·	GLUM CLASS I	15.6
+	GLUM CLASS II	28.7
△	GLUM CLASS IIS	0.1
⊡	GLUM CLASS III	32.2
✳	GLUM CLASS IV	21.7
~	UNCLASSIFIED	1.7

Scale 1:95 000

GEOTECS Plot - Geotechnical Land Use Map

Fig. 10



SYMBOL	MEANING	%TOTAL
⊡	DEVELOPMENT CONSTRAINT IN SQUATTER AREA	0.7
+	DEVELOPMENT POTENTIAL IN UNDISTURBED AREA	28.6
✳	DEVELOPMENT POTENTIAL IN SQUATTER AREA	3.4
·	NOT APPLICABLE	67.3

Scale 1:95 000	GEOTECS Plot - Squatters on Land with Potential for Development	Fig. 11

SYMBOL	MEANING	%TOTAL
⧖	POTENTIAL (SLOPE) COUNTRY PARK OR CULTIVATION	9.9
✳	POTENTIAL (TERRAIN) (NO CURRENT USAGE)	34.5
⧗	POTENTIAL (SLOPE) (NO CURRENT USAGE)	21.6
✡	POTENTIAL (TERRAIN) COUNTRY PARK OR CULTIVATION	11.7
•	EXISTING USAGE	17.3
C	COUNTRY PARK OR CULTIVATION	1.1
ϕ	UNDESIGNATED (MAY HAVE POTENTIAL)	3.8

Scale 1:95 000	GEOTECS Plot - Potential Quarry Sites	Fig. 12

Fig. 1	Location Map of the Clear Water Bay Area 1:200 000
Fig. 2	**Aerial Photomosaic of the Clear Water Bay Area 1:93 000**
Fig. 3	**Reduced Scale Base Map of the Clear Water Bay Area 1:100 000**

Fig. 14 to 20 show A4 size inset examples of a typical set of GASP Maps (1:20 000)

Fig. 14a	Base Map
Fig. 14b	**Terrain Classification Map (TCM)**

Fig. 14b → Fig. 15 to Fig. 20:

Fig.	15a	Geotechnical Land Use Map (GLUM)
	15b	Terrain Classification Map Superimposed on the GLUM
Fig.	16a	Physical Constraints Map (PCM)
	16b	Terrain Classification Map Superimposed on the PCM
Fig.	17a	Engineering Geology Map (EGM)
	17b	Terrain Classification Map Superimposed on the EGM
Fig.	18a	Generalised Limitations and Engineering Appraisal Map (GLEAM)
	18b	Terrain Classification Map Superimposed on the GLEAM
Fig.	19a	Landform Map (LM)
	19b	Terrain Classification Map Superimposed on the LM
Fig.	20a	Erosion Map (EM)
	20b	Terrain Classification Map Superimposed on the EM

Full size Clear Water Bay map sheets in the Map Folder (1:20 000):

Geotechnical Land Use Map (GLUM)	Physical Constraints Map (PCM)	Engineering Geology Map (EGM)	Generalised Limitations and Engineering Appraisal Map
(GASP/20/VII/1)	(GASP/20/VII/6)	(GASP/20/VII/2)	(GASP/20/VII/15)

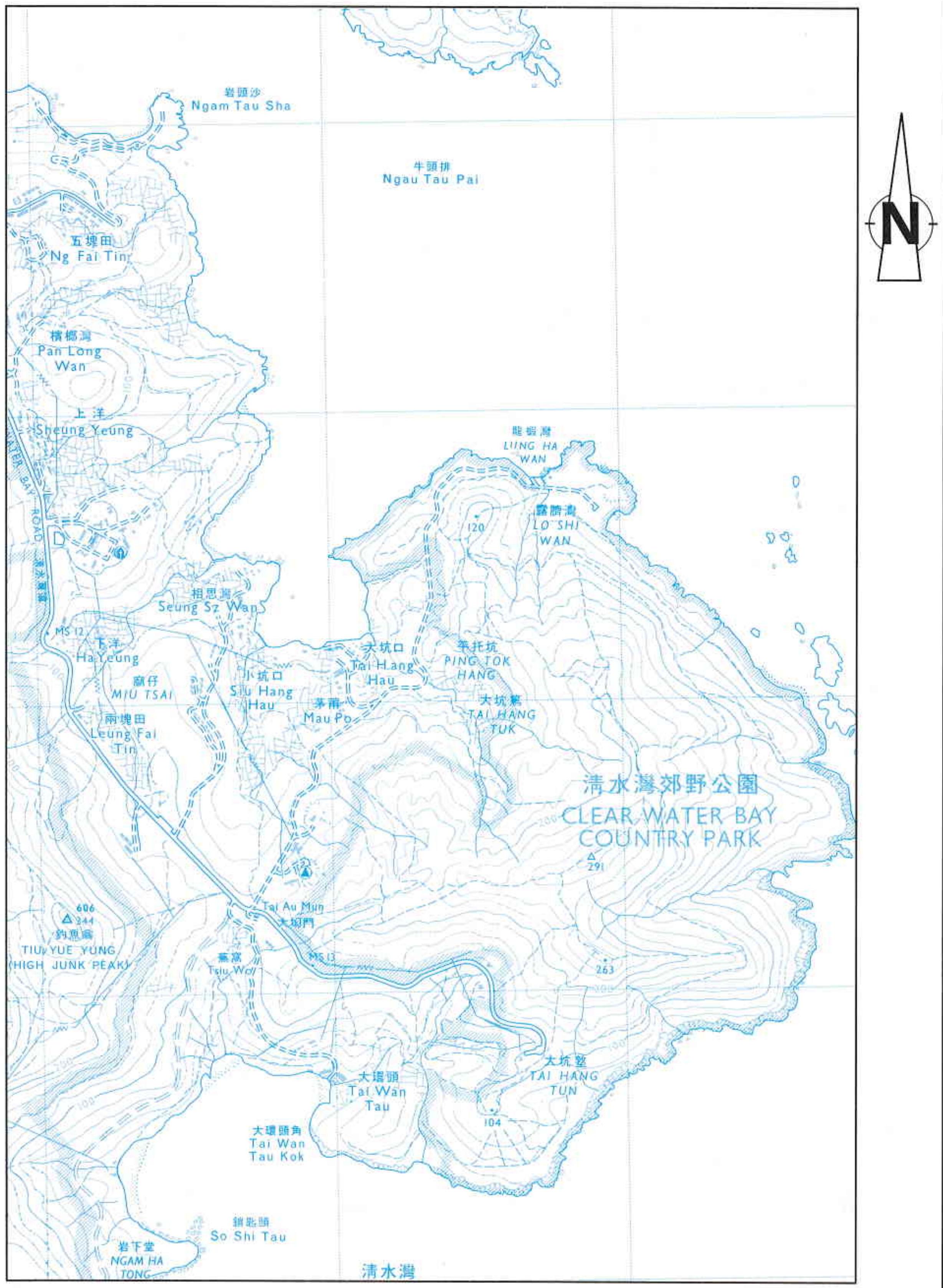
Presentation of Maps — Fig. 13

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. 14b)

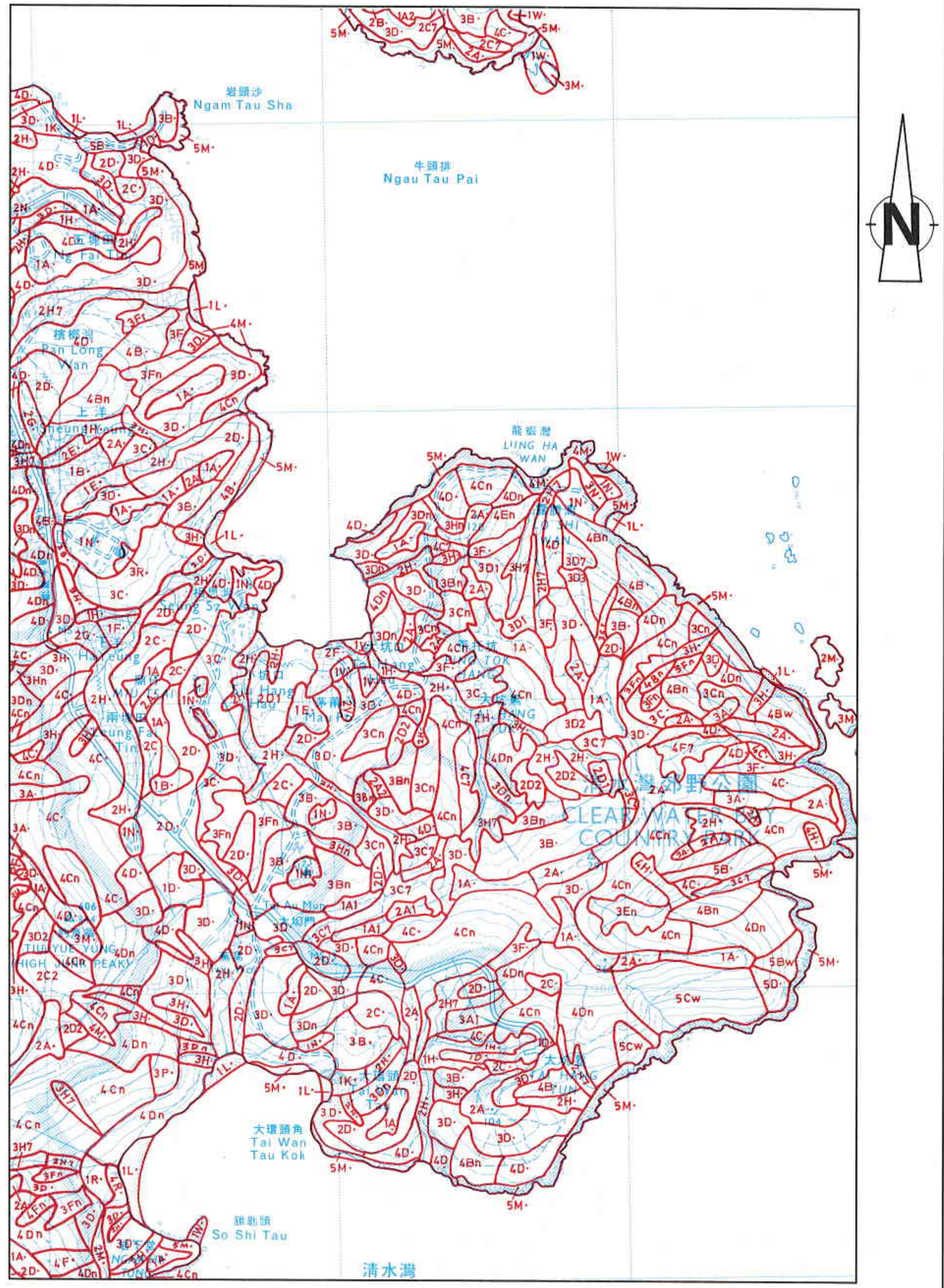
SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

TERRAIN COMPONENT	CODE
Crest or ridge	A
Sideslope-straight	B
-concave	C
-convex	D
Footslope-straight	E
-concave	F
-convex	G
Drainage plain	H
Floodplain	I
Coastal plain	K
Littoral zone	L
Rock outcrop	M
Cut - straight	N
- concave	O
- convex	P
Fill-straight	R
-concave	S
-convex	T
General disturbed terrain	V
Wave cut platform	W
Alluvial plain	X
Reclamation	Z
Waterbodies - Natural stream	1
- Man-made channel	2
- Water storage dam	3
- Fish pond	4

EROSION	CODE
No appreciable erosion	.
Sheet erosion-minor	1
-moderate	2
-severe	3
Rill erosion - minor	4
- moderate	5
- severe	6
Gully erosion-minor	7
-moderate	8
-severe	9
Well-defined landslip > 1ha in size	a
General) recent	n
instability) relict	r
Coastal instability	w



Scale 1:20 000	Example of the Base Map	Fig. 14a



Scale 1:20 000	Example of the Terrain Classification Map (TCM)	Fig. 14b

LEGEND FOR GEOTECHNICAL LAND USE MAP (Fig. 15a)

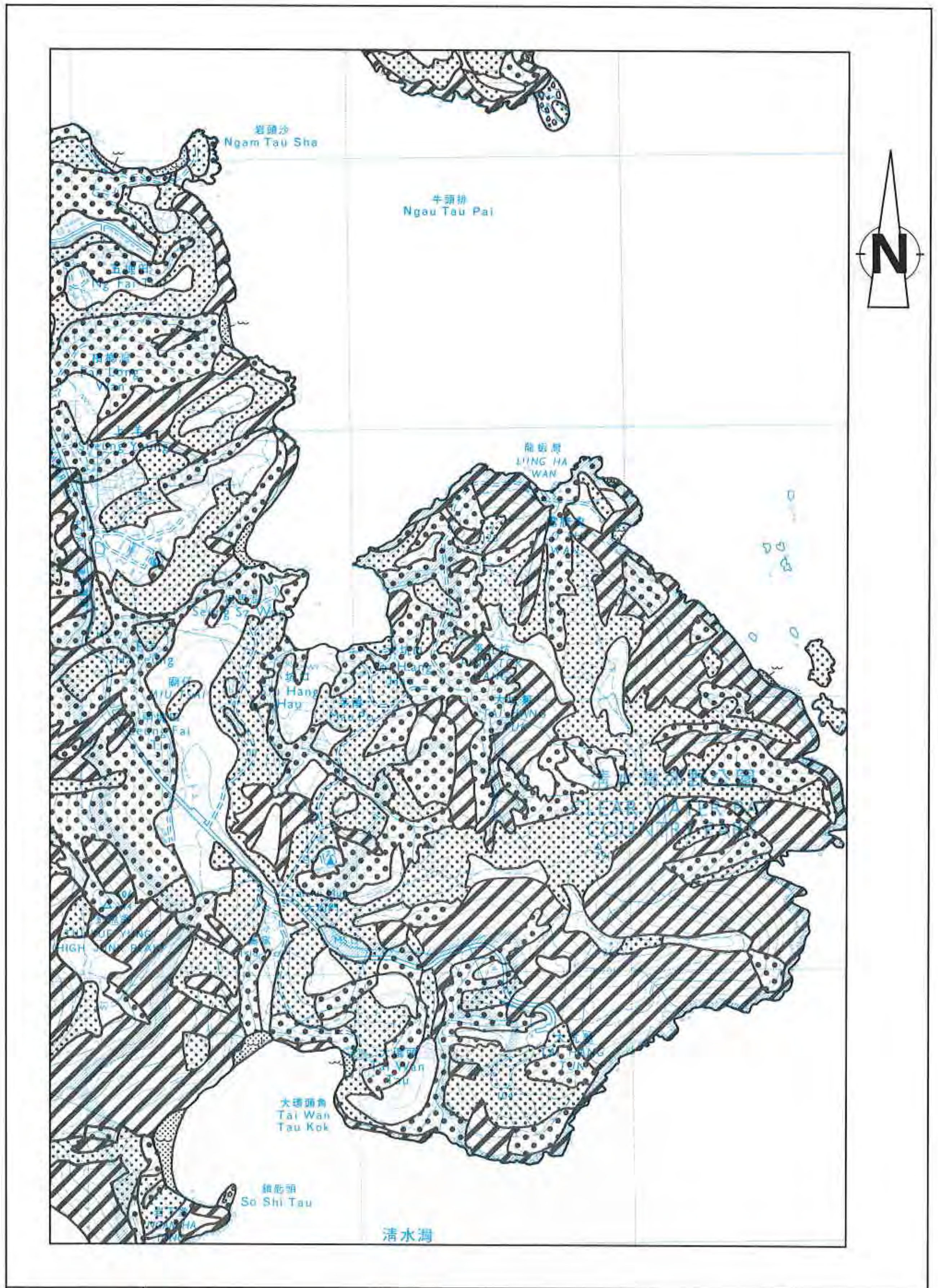
Class I - Low Geotechnical Limitations	
Class II - Moderate Geotechnical Limitations	
Class IIS - Moderate Geotechnical Limitations (including flooding)	
Class III - High Geotechnical Limitations	
Class IV - Extreme Geotechnical Limitations	
Waterbodies (streams, man-made channels, storage dams)	Unclassified
Ponds	Unclassified
Littoral zone (generally subject to tidal action)	Unclassified
Wave cut platform	Unclassified

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig.15b)

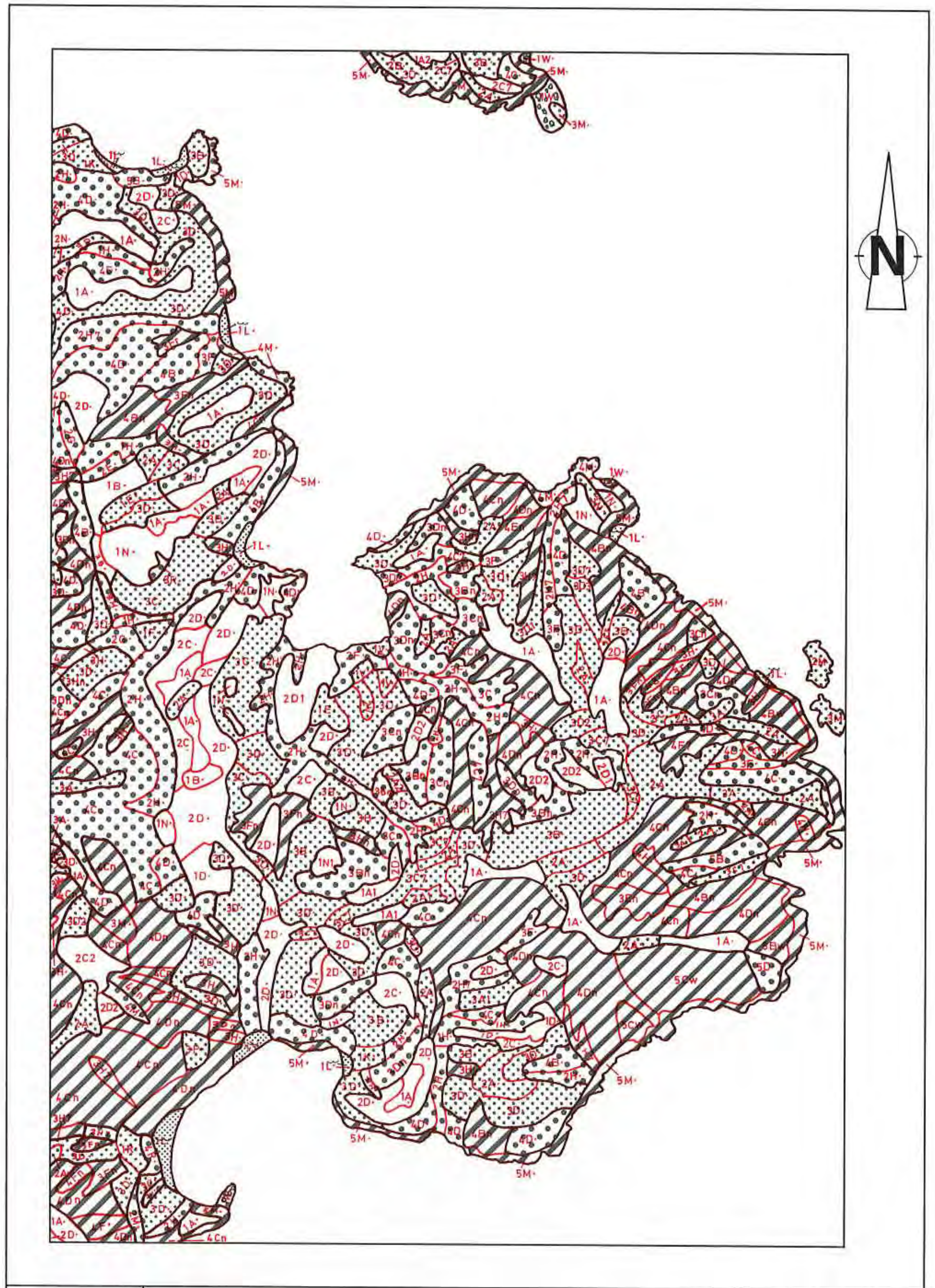
SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

TERRAIN COMPONENT	CODE
Crest or ridge	A
Sideslope-straight	B
-concave	C
-convex	D
Footslope-straight	E
-concave	F
-convex	G
Drainage plain	H
Floodplain	I
Coastal plain	K
Littoral zone	L
Rock outcrop	M
Cut - straight	N
- concave	O
- convex	P
Fill-straight	R
-concave	S
-convex	T
General disturbed terrain	V
Wave cut platform	W
Alluvial plain	X
Reclamation	Z
Waterbodies - Natural stream	1
- Man-made channel	2
- Water storage dam	3
- Fish pond	4

EROSION	CODE
No appreciable erosion	.
Sheet erosion-minor	1
-moderate	2
-severe	3
Rill erosion - minor	4
- moderate	5
- severe	6
Gully erosion-minor	7
-moderate	8
-severe	9
Well-defined landslip > 1ha in size	a
General instability) recent	n
General instability) relict	r
Coastal instability	w



Scale 1:20 000	Example of the Geotechnical Land Use Map (GLUM)	Fig. 15a



Scale 1:20 000	Example of the Terrain Classification Map Superimposed on the GLUM	Fig. 15b

LEGEND FOR PHYSICAL CONSTRAINTS MAP (Fig. 16a)

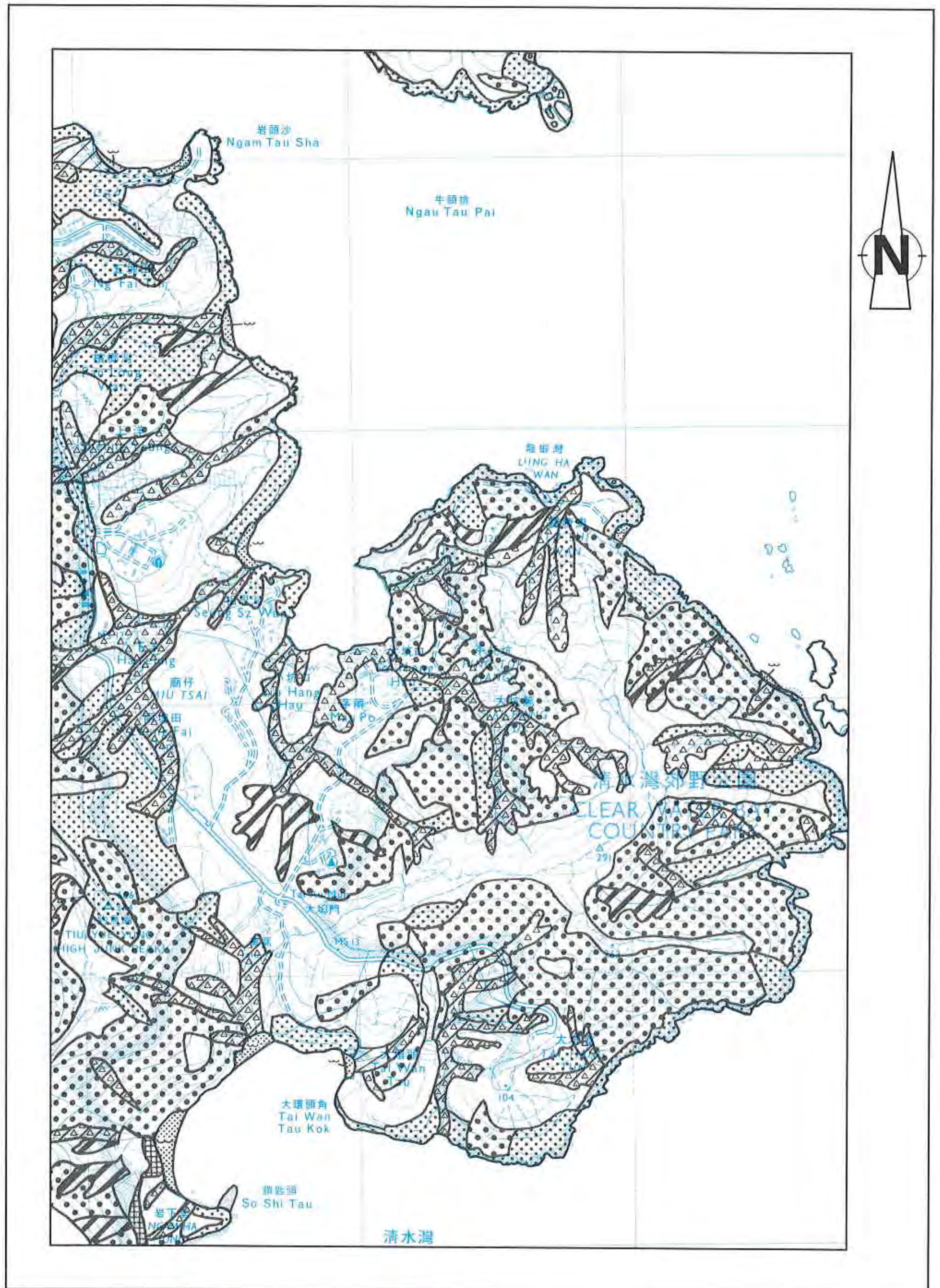
- Colluvium
- Zones of colluvium which are subject to overland flow and periodic inundation. Evidence of unusual groundwater regime (delineated as drainage plain on Landform Map)
- Floodplain - subject to overland flow and regular inundation. Evidence of unusual groundwater regime (delineated as floodplain on Landform Map)
- Zones of general instability associated with predominantly colluvial terrain
- Zones of general instability associated with predominantly insitu terrain
- Slopes on insitu terrain which are generally steeper than 30° (other than those delineated as colluvial or unstable)
- Disturbed terrain - extensive cut and fill batters which generally exceed 30°
- Instability on disturbed terrain
- Waterbodies (streams, man-made channels, storage dams)
- Ponds
- Moderate or severe gully erosion (may be superimposed upon other constraints)
- Littoral zone (generally subject to tidal action)
- Wave cut platform

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig 16b)

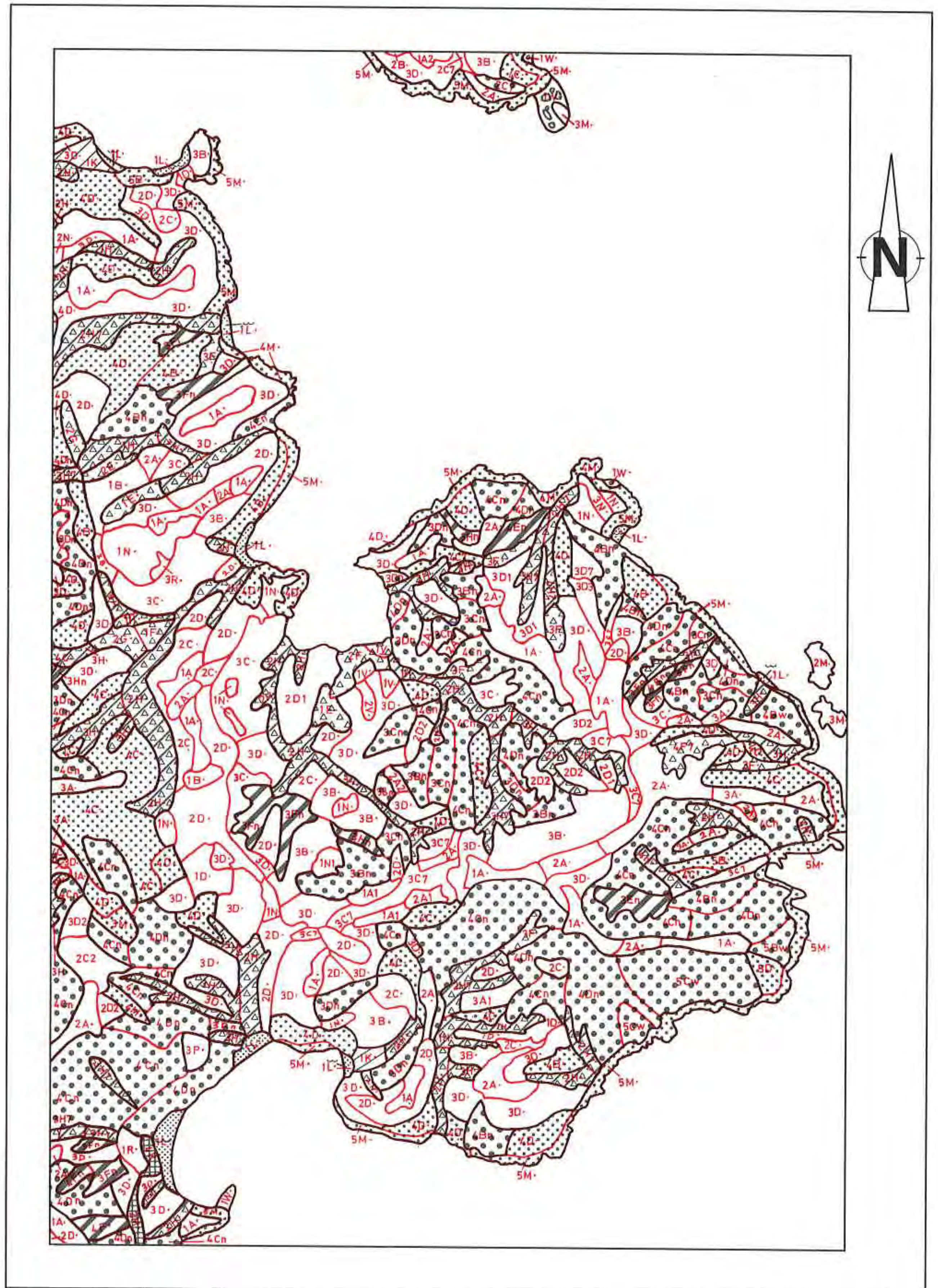
SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

TERRAIN COMPONENT	CODE
Crest or ridge	A
Sideslope-straight	B
-concave	C
-convex	D
Footslope-straight	E
-concave	F
-convex	G
Drainage plain	H
Floodplain	I
Coastal plain	K
Littoral zone	L
Rock outcrop	M
Cut - straight	N
- concave	O
- convex	P
Fill-straight	R
-concave	S
-convex	T
General disturbed terrain	V
Wave cut platform	W
Alluvial plain	X
Reclamation	Z
Waterbodies - Natural stream	1
- Man-made channel	2
- Water storage dam	3
- Fish pond	4

EROSION	CODE
No appreciable erosion	.
Sheet erosion-minor	1
-moderate	2
-severe	3
Rill erosion - minor	4
- moderate	5
- severe	6
Gully erosion-minor	7
-moderate	8
-severe	9
Well-defined landslip > 1ha in size	a
General instability) recent	n
General instability) relict	r
Coastal instability	w



Scale 1:20 000	Example of the Physical Constraints Map (PCM)	Fig. 16a



Scale 1:20 000	Example of the Terrain Classification Map Superimposed on the PCM	Fig. 16b

LEGEND FOR ENGINEERING GEOLOGY MAP (Fig. 17a)

- Fill
- Reclamation
- Littoral deposits
- Alluvium (undifferentiated)
- Colluvium (undifferentiated)
- Sedimentary rocks and water-laid volcaniclastic rocks) Repulse Bay Formation
- Acid lavas) Repulse Bay Formation
- Mainly banded acid lavas some welded tuffs) Repulse Bay Formation
- Agglomerate) Repulse Bay Formation
- Dominantly pyroclastic rocks with some lavas) Repulse Bay Formation
- Granophyric microgranite
- Hong Kong Granite
- Quartz monzonite and porphyritic adamellite

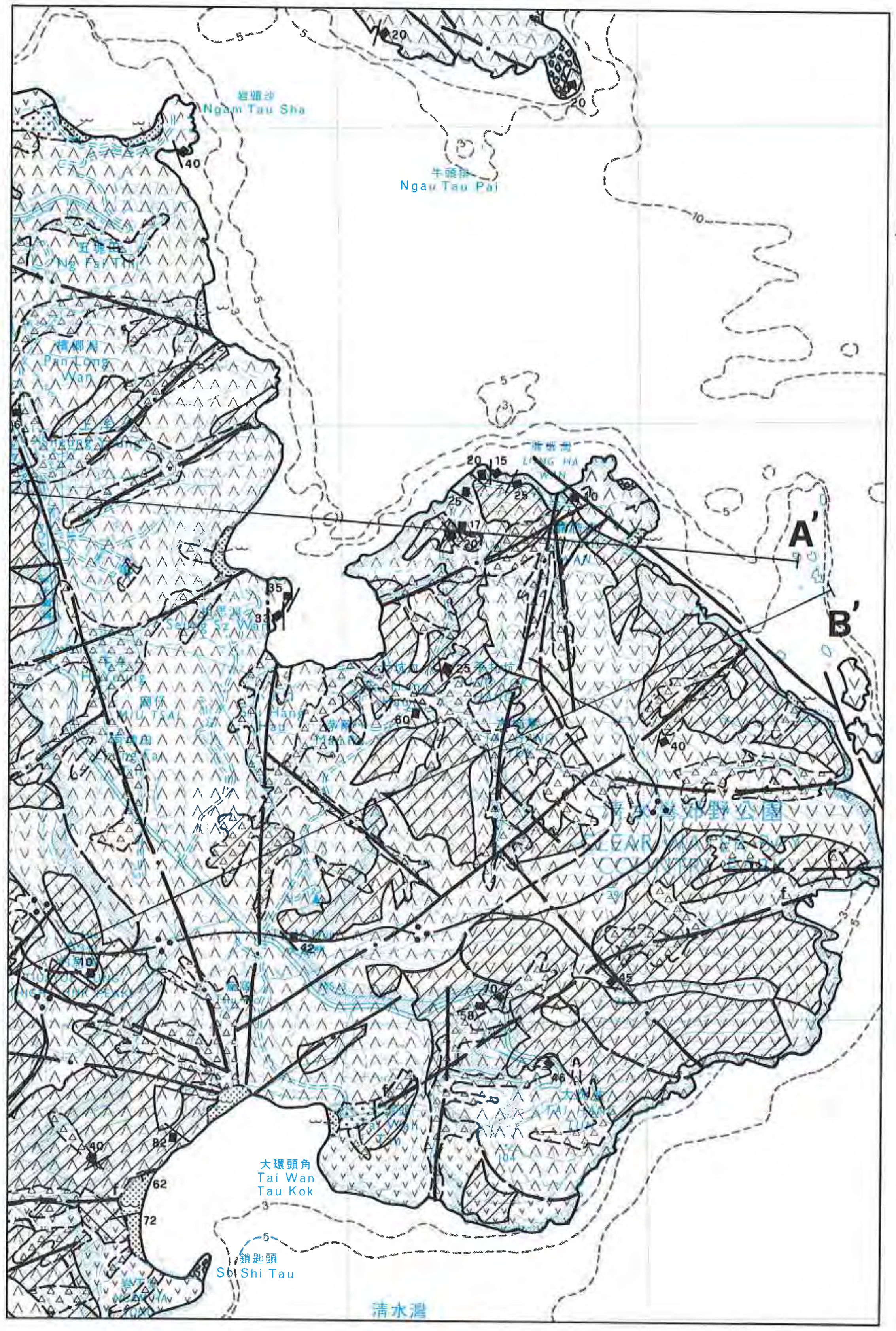
- Strike and dip of bed
- Vertical bedding
- Horizontal bedding
- Strike and dip of flow-banding in lavas
- Vertical flow-banding in lavas
- Quartz monzonite and porphyritic adamellite dyke (Mo)
- Geological boundary (solid)
- Geological boundary (superficial)
- Geological photolineament
- Faults
- Catchment boundary (order indicated by number of dots)
- Geological cross-section line (A–B)
- Depth in fathoms
- General instability
- Wave cut platform

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig.17b)

SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

TERRAIN COMPONENT	CODE
Crest or ridge	A
Sideslope-straight	B
-concave	C
-convex	D
Footslope-straight	E
-concave	F
-convex	G
Drainage plain	H
Floodplain	I
Coastal plain	K
Littoral zone	L
Rock outcrop	M
Cut - straight	N
- concave	O
- convex	P
Fill-straight	R
-concave	S
-convex	T
General disturbed terrain	V
Wave cut platform	W
Alluvial plain	X
Reclamation	Z
Waterbodies - Natural stream	1
- Man-made channel	2
- Water storage dam	3
- Fish pond	4

EROSION	CODE
No appreciable erosion	.
Sheet erosion-minor	1
-moderate	2
-severe	3
Rill erosion - minor	4
- moderate	5
- severe	6
Gully erosion-minor	7
-moderate	8
-severe	9
Well-defined landslip > 1ha in size	a
General instability) recent	n
General instability) relict	r
Coastal instability	w



Scale 1:20 000	Example of the Engineering Geology Map (EGM)	Fig. 17a

Scale 1:20 000	Example of the Terrain Classification Map Superimposed on the EGM	Fig. 17b

LEGEND FOR GENERALISED LIMITATIONS AND ENGINEERING APPRAISAL MAP (Fig. 18a)

DEVELOPMENT PLANNING ZONES :

- Zone of potential for development (assessed in geotechnical terms)
- Zone of local geotechnical constraints (identified on PCM) within general PDA
- Zone of constraints for development (assessed principally in geotechnical terms)
- Zone of existing development, (based on principal use of GEOTECS 2 hectares unit)
- Country Park boundary
- (C) Catchwater
- Firing Range boundary
- NOTE — Numerals on map refer to relevant general planning/engineering notes

FEATURES OF ENGINEERING SIGNIFICANCE :

- Geological photolineament
- (R) Ridgeline
- (D, Di) Drainage, incised drainage
- Coll. — Colluvium (also in 'zone of local constraint', and PCM)
- Str. — Structure/Structural
- W. — Weathering
- B. — Boulders
- Instability influencing area
- Steeper slopes influencing area (orientation of symbols indicates downslope direction)
- Potential for borrow or extensive cut and fill : opportunity to create site formation in 'constrained' area or larger site formation in 'potential' area.
- (f) Fault

NOTE

i) Features are generally indicated only where of significance to identified potential areas

ii) For explanation of significance of identified features, see Report Appendix A, Table A5, and Section 4.2.

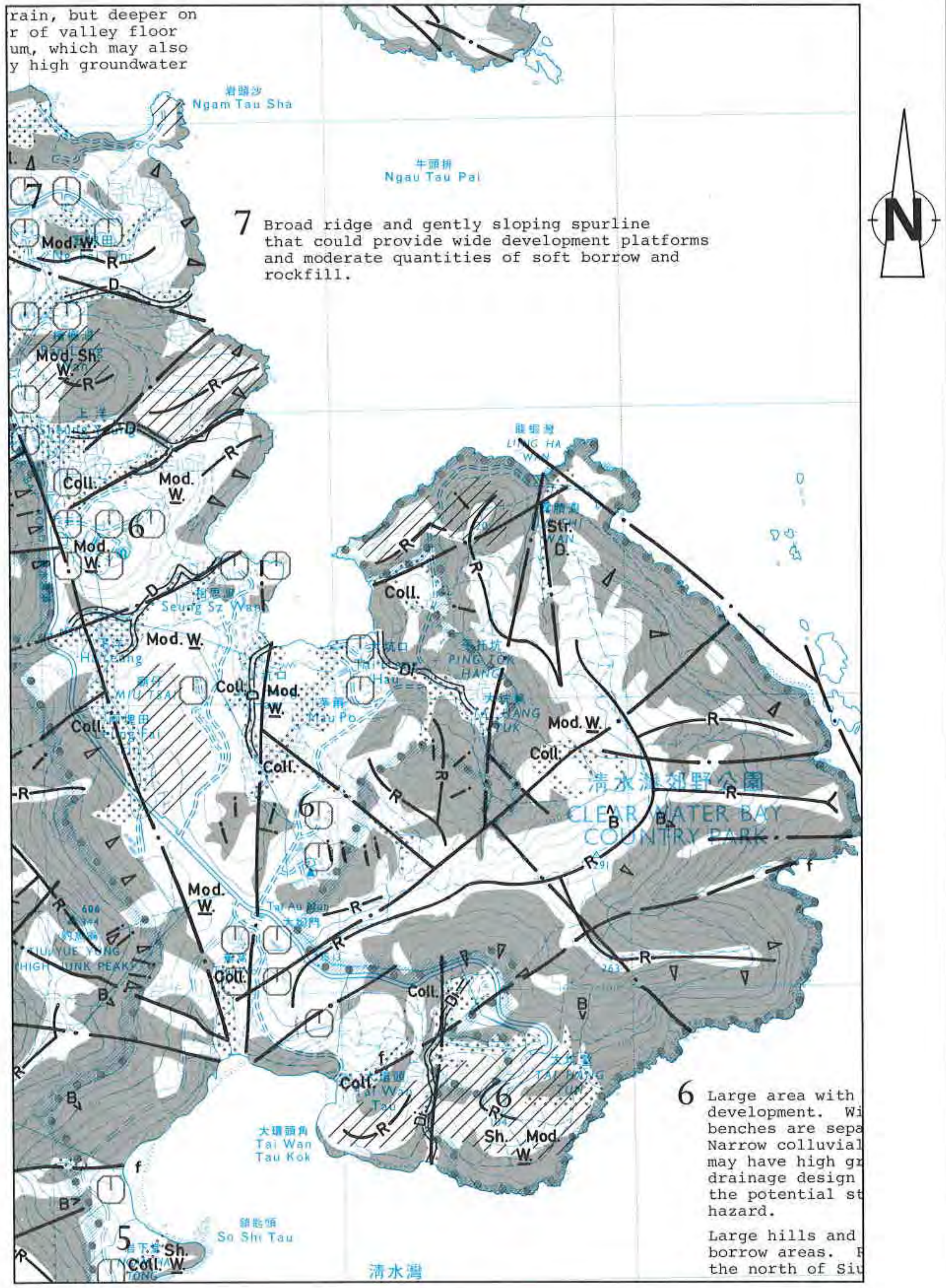
iii) Geological boundaries and photolineaments are shown in full on the EGM. Those lineaments indicated represent the surface expression of obvious structural discontinuities which affect the PDA's.

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. 18b)

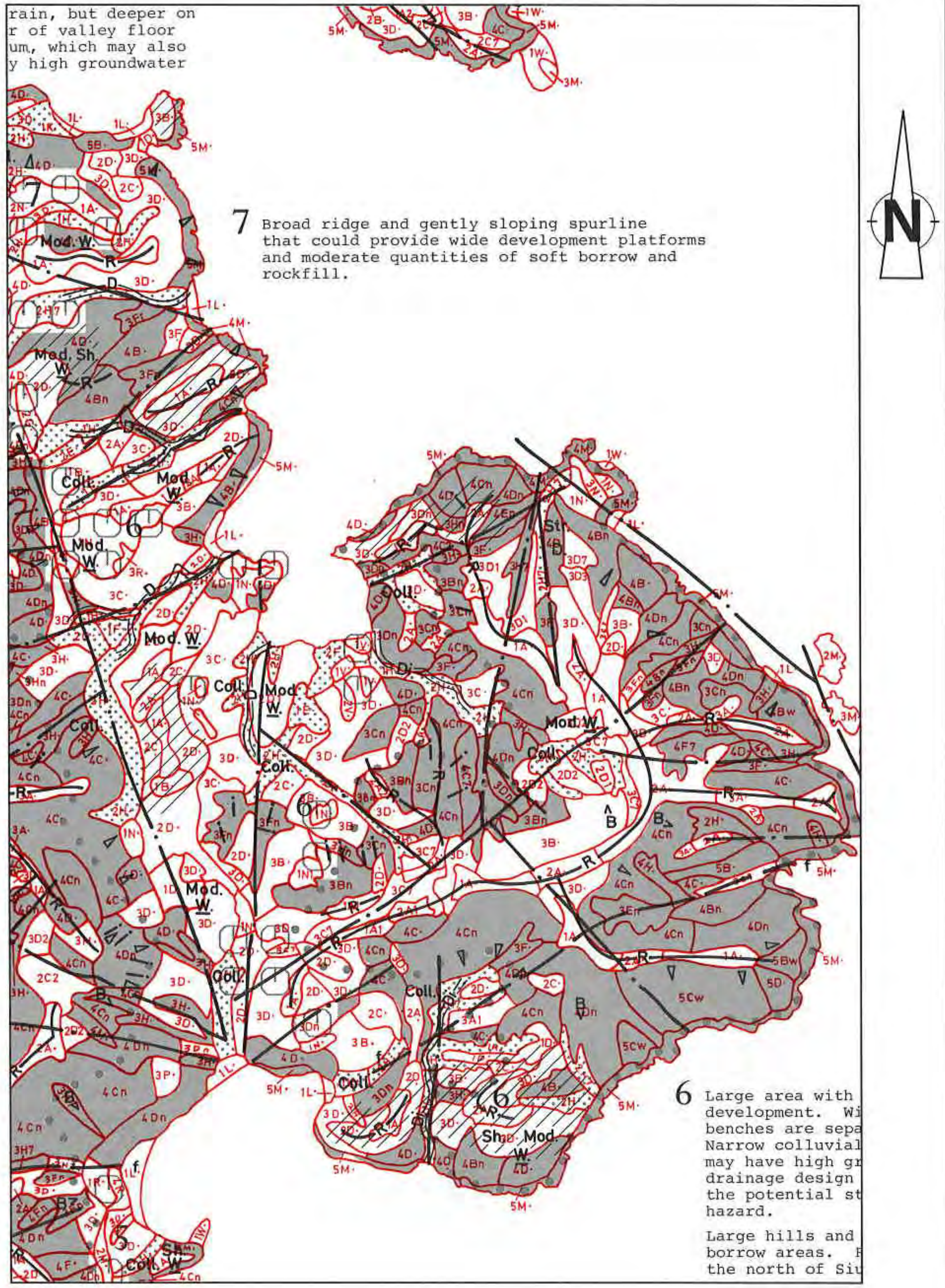
SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

TERRAIN COMPONENT	CODE
Crest or ridge	A
Sideslope-straight	B
-concave	C
-convex	D
Footslope-straight	E
-concave	F
-convex	G
Drainage plain	H
Floodplain	I
Coastal plain	K
Littoral zone	L
Rock outcrop	M
Cut - straight	N
- concave	O
- convex	P
Fill-straight	R
-concave	S
-convex	T
General disturbed terrain	V
Wave cut platform	W
Alluvial plain	X
Reclamation	Z
Waterbodies - Natural stream	1
- Man-made channel	2
- Water storage dam	3
- Fish pond	4

EROSION	CODE
No appreciable erosion	-
Sheet erosion-minor	1
-moderate	2
-severe	3
Rill erosion - minor	4
- moderate	5
- severe	6
Gully erosion-minor	7
-moderate	8
-severe	9
Well-defined landslip > 1ha in size	a
General instability) recent	n
General instability) relict	r
Coastal instability	w



Scale 1:20 000	Example of the Generalised Limitations and Engineering Appraisal Map (GLEAM)	Fig. 18a



Scale 1:20 000	Example of the Terrain Classification Map Superimposed on the GLEAM	Fig. 18b

LEGEND FOR LANDFORM MAP (Fig. 19a)

SLOPE GRADIENT	CODE
0 - 5° (gently sloping)	1
5 - 15° (gently-moderately sloping)	2
15 - 30° (moderately sloping)	3
30 - 40° (steep)	4
40 - 60° (mountainous)	5
> 60° (precipitous)	6

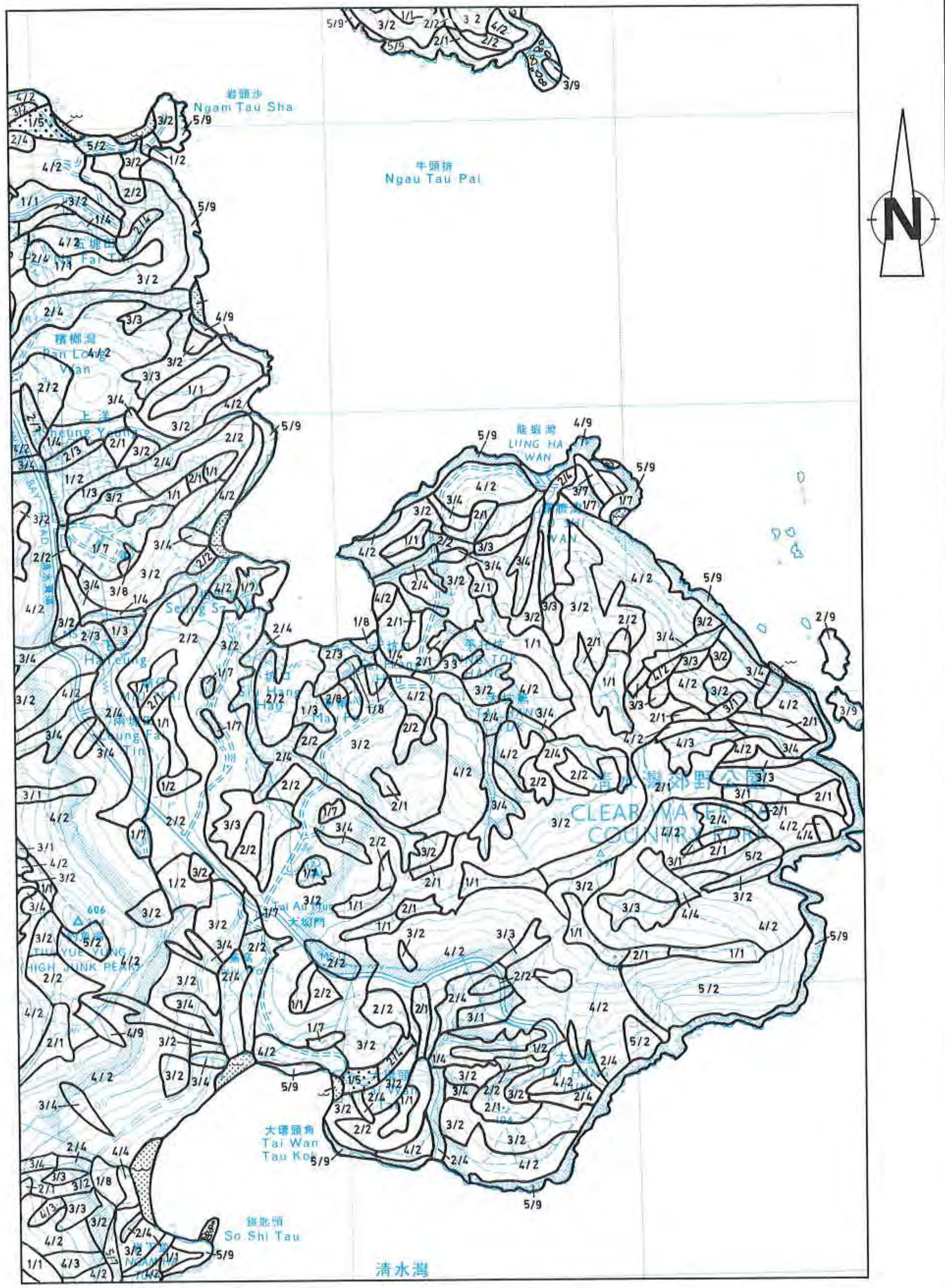
DESCRIPTION	CODE
Crest or ridge	1
Sideslope - insitu	2
Footslope - colluvium	3
Drainage plain - colluvium subject to overland flow and regular inundation. Unusual groundwater regime.	4
Alluvial plain - includes raised terraces.	5
Flood plain - portion of alluvial plain subject to overland flow and regular inundation. Unusual groundwater regime.	6
Disturbed terrain - cut	7
Disturbed terrain - fill	8
Cliff and rock outcrop	9
Reclamation	
Waterbodies (Streams, man-made channels, storage dams)	
Ponds	
Littoral zone (generally subject to tidal action)	
Wave cut platform	

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. 19b)

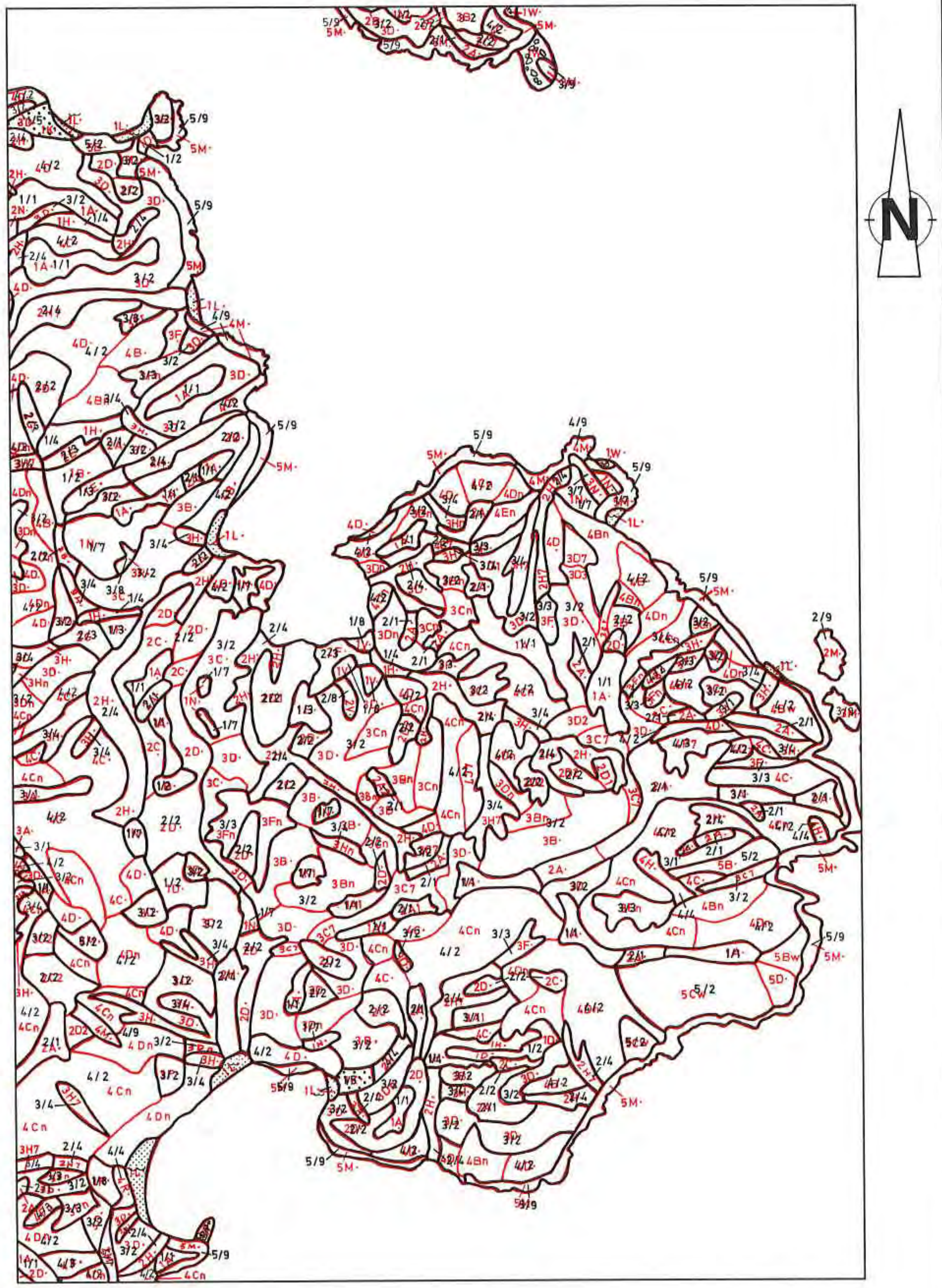
SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

TERRAIN COMPONENT	CODE
Crest or ridge	A
Sideslope-straight	B
-concave	C
-convex	D
Footslope-straight	E
-concave	F
-convex	G
Drainage plain	H
Floodplain	I
Coastal plain	K
Littoral zone	L
Rock outcrop	M
Cut - straight	N
- concave	O
- convex	P
Fill-straight	R
-concave	S
-convex	T
General disturbed terrain	V
Wave cut platform	W
Alluvial plain	X
Reclamation	Z
Waterbodies - Natural stream	1
- Man-made channel	2
- Water storage dam	3
- Fish pond	4

EROSION	CODE
No appreciable erosion	.
Sheet erosion-minor	1
-moderate	2
-severe	3
Rill erosion - minor	4
- moderate	5
- severe	6
Gully erosion-minor	7
-moderate	8
-severe	9
Well-defined landslip > 1ha in size	a
General instability) recent	n
) relict	r
Coastal instability	w



Scale 1:20 000	Example of the Landform Map (LM)	Fig. 19a



Scale 1:20 000	Example of the Terrain Classification Map Superimposed on the LM	Fig. 19b

LEGEND FOR EROSION MAP (Fig. 20a)

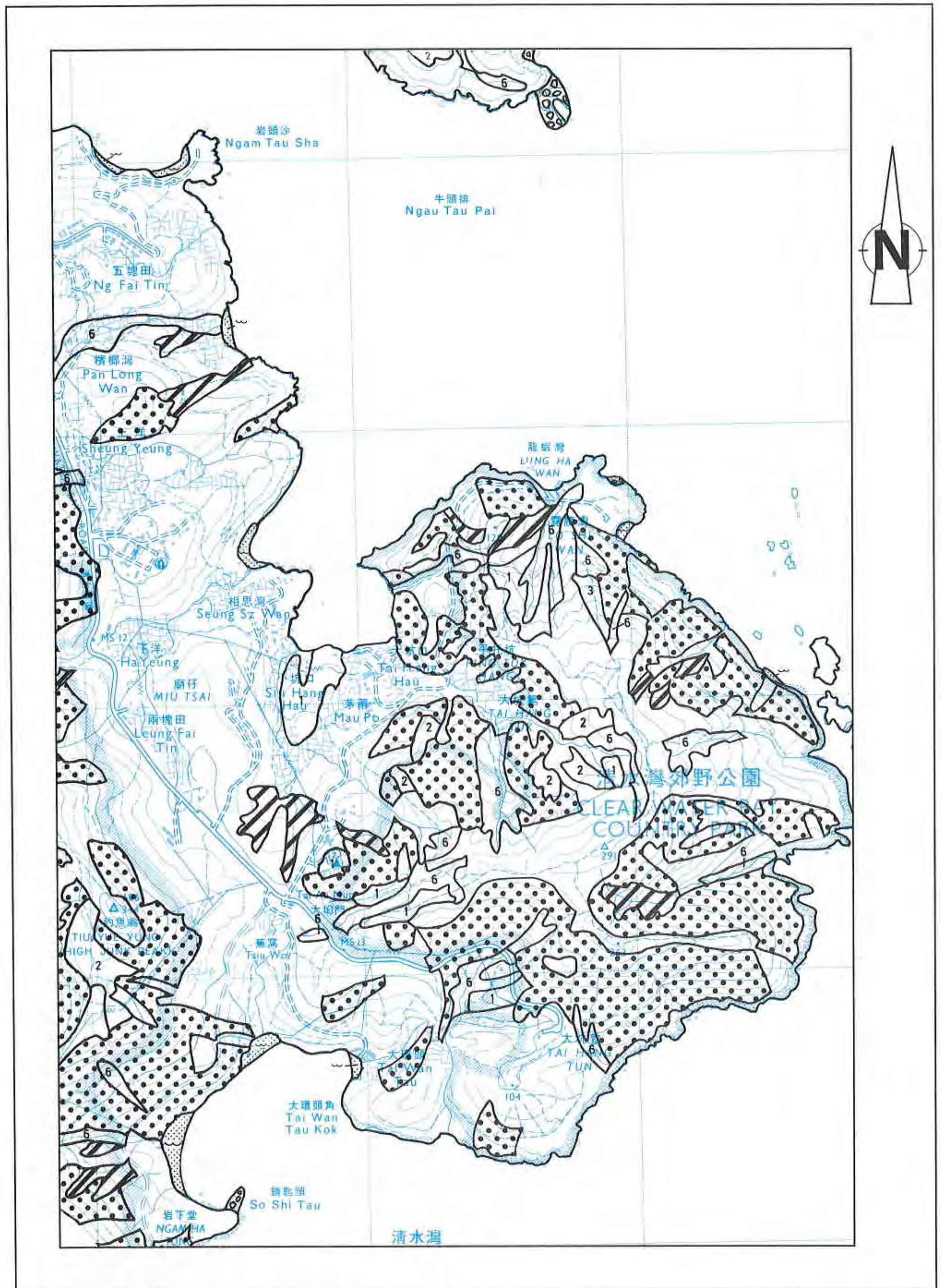
	No appreciable erosion
1	Minor sheet erosion
2	Moderate sheet erosion
3	Severe sheet erosion
4	Minor rill erosion
5	Moderate to severe rill erosion
6	Minor gully erosion
7	Moderate to severe gully erosion
	Zones of general instability associated with predominantly insitu terrain
	Zones of general instability associated with predominantly colluvial terrain
	Waterbodies (streams, man-made channels, storage dams)
	Ponds
	Littoral zone (generally subject to tidal action)
	Wave cut platform

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. 20b)

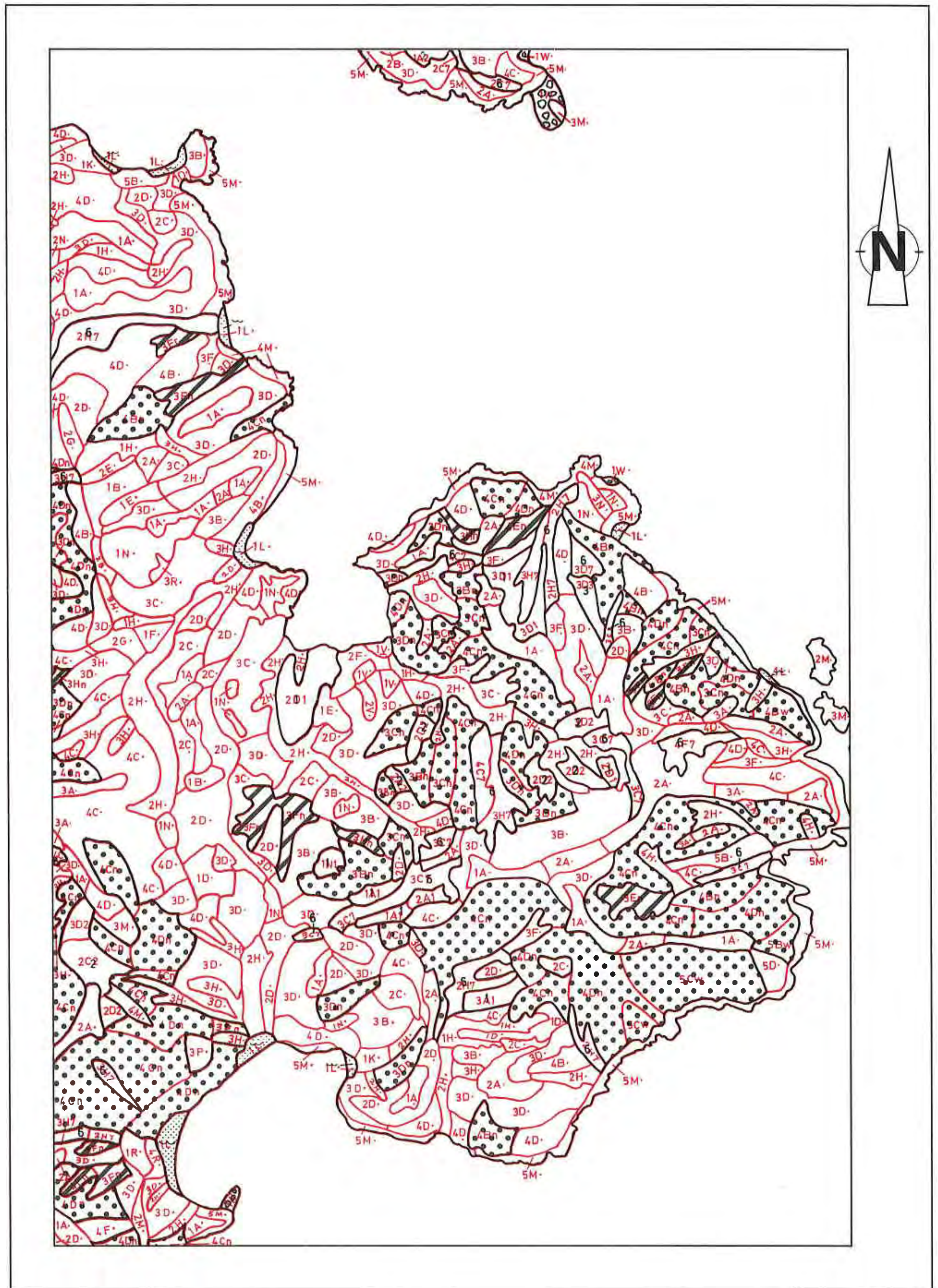
SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

TERRAIN COMPONENT	CODE
Crest or ridge	A
Sideslope-straight	B
-concave	C
-convex	D
Footslope-straight	E
-concave	F
-convex	G
Drainage plain	H
Floodplain	I
Coastal plain	K
Littoral zone	L
Rock outcrop	M
Cut - straight	N
- concave	O
- convex	P
Fill-straight	R
-concave	S
-convex	T
General disturbed terrain	V
Wave cut platform	W
Alluvial plain	X
Reclamation	Z
Waterbodies - Natural stream	1
- Man-made channel	2
- Water storage dam	3
- Fish pond	4

EROSION	CODE
No appreciable erosion	-
Sheet erosion-minor	1
-moderate	2
-severe	3
Rill erosion - minor	4
- moderate	5
- severe	6
Gully erosion-minor	7
-moderate	8
-severe	9
Well-defined landslip > 1ha in size	a
General instability) recent	n
) relict	r
Coastal instability	w



Scale 1:20 000	Example of the Erosion Map (EM)	Fig. 20a



Scale 1:20 000	Example of the Terrain Classification Map Superimposed on the EM	Fig. 20b

Plate 1. Aerial View of the West Coast of Junk Bay. Gently to moderately sloping midslope terrain may be suitable for development. Note the geological photolineament in the coastal cliffs passing inland along a colluvium-filled depression. The upper slopes show numerous perched boulders. (GCO/OAP 1984/10026).

Plate 2. Aerial View of Tai Chik Sha and the Surrounding Terrain. A broad alluvial deposit is being used for intensive agriculture. Boulders on the upper slopes and both recent and old landslip scars on the sideslopes are evident. (GCO/OAP 1984/10049).

Plate 3. Aerial View of Shek Miu Wan. High Junk Peak is to the right. Colluvial and alluvial valley infill deposits extend downslope to the beach. The foreground consists of pyroclastic rocks whilst the higher ground is composed of acid lavas of the Repulse Bay Formation. (GCO/OAP 1984/10050).

Plate 4. Aerial View of the Northern Side of Basalt Island. A colluvial valley passes into a shingle bar where wave action has removed the finer particles. (GCO/OAP 1984/10022).

Plate 5. Aerial View of the Southern Coast of Tung Lung Island. Moderately sloping sideslopes are being subjected to basal undercutting by wave action. The resulting cliffs are prone to rockfalls and landslip activity that may extend up the sideslopes. (GCO/OAP 1984/9993).

Plate 6. Aerial View of Tathong Point. (GCO/OAP 1984/9992).

Plate 7. Aerial View of the Southeastern Coast of Basalt Island. Note the columnar jointing. (GCO/OAP 1984/10020).

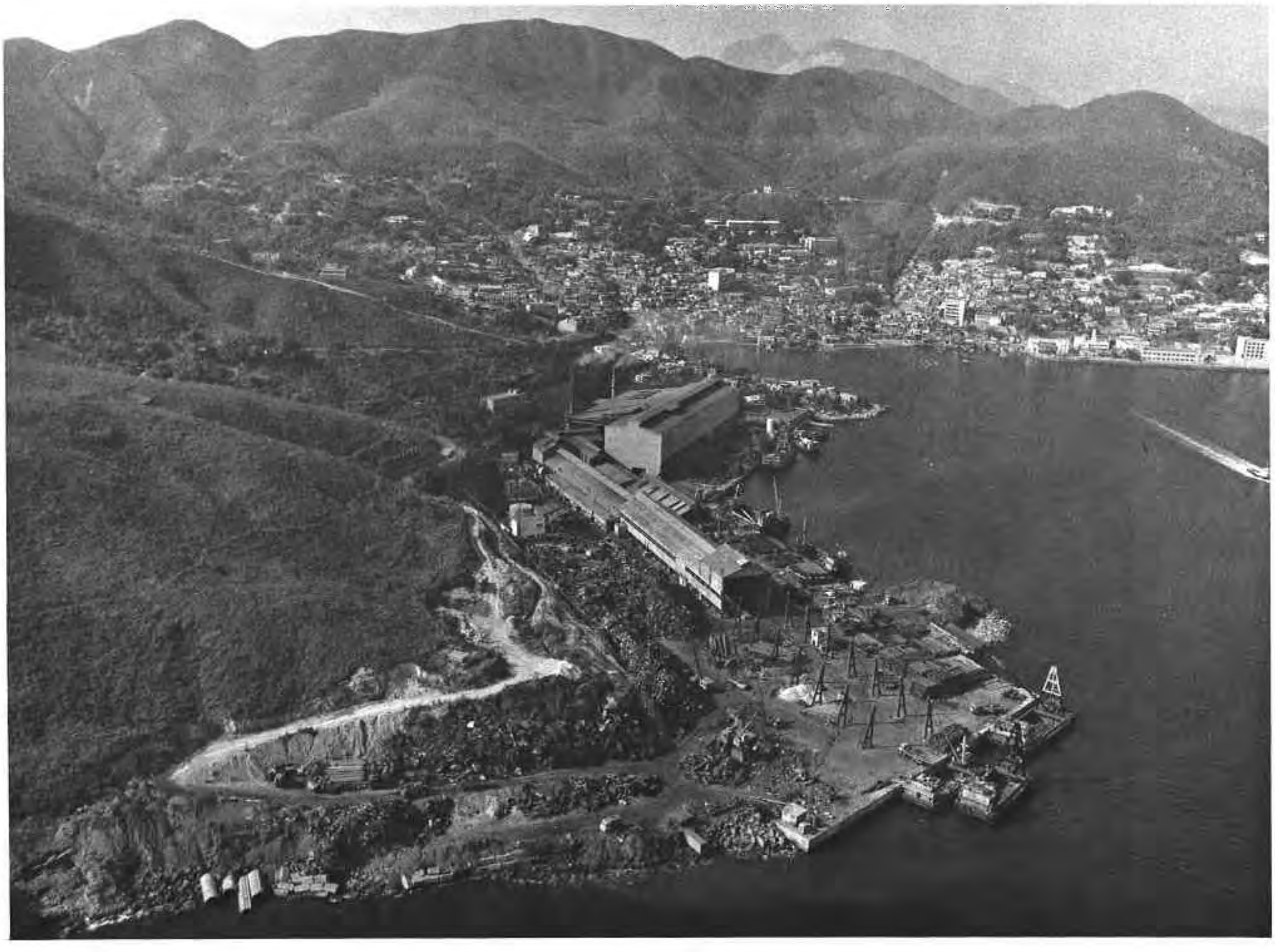


Plate 8. Rennie's Mill on the Eastern Side of Junk Bay. Industrial development including steel mills and shipyards are located partly on areas of reclamation. (GCO/OAP 1984/10029).

Plate 9. Aerial View of Junk Bay Around Hang Hau Village. This photograph was taken in January, 1984 and shows the coastline with only small areas of reclamation, much larger areas will be reclaimed as part of the Junk Bay New Town. The high cut slopes along the Clear Water Bay Road are evident in the background. (GCO/OAP 1984/10042).

Plate 10. Aerial View of the Southeastern Part of Hang Hau Village. (GCO/OAP 1984/10043).

Plate 11. Aerial View of the Cut Platforms East of the Junk Bay Controlled Tip. The material extracted during the formation of the cut platforms is used to surround the layers of waste in the controlled tip. (GCO/OAP 1984/10044).

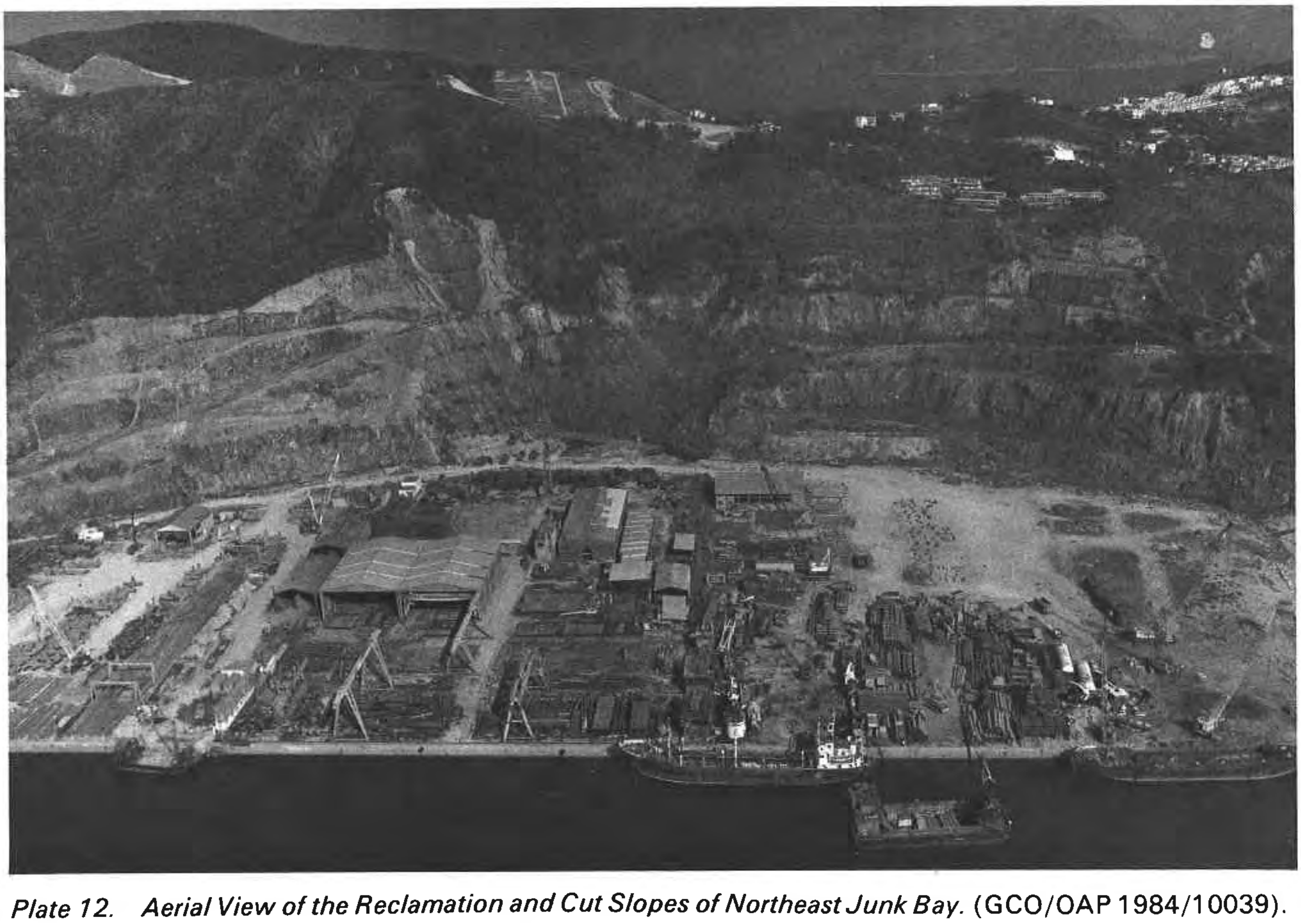


Plate 12. Aerial View of the Reclamation and Cut Slopes of Northeast Junk Bay. (GCO/OAP 1984/10039).

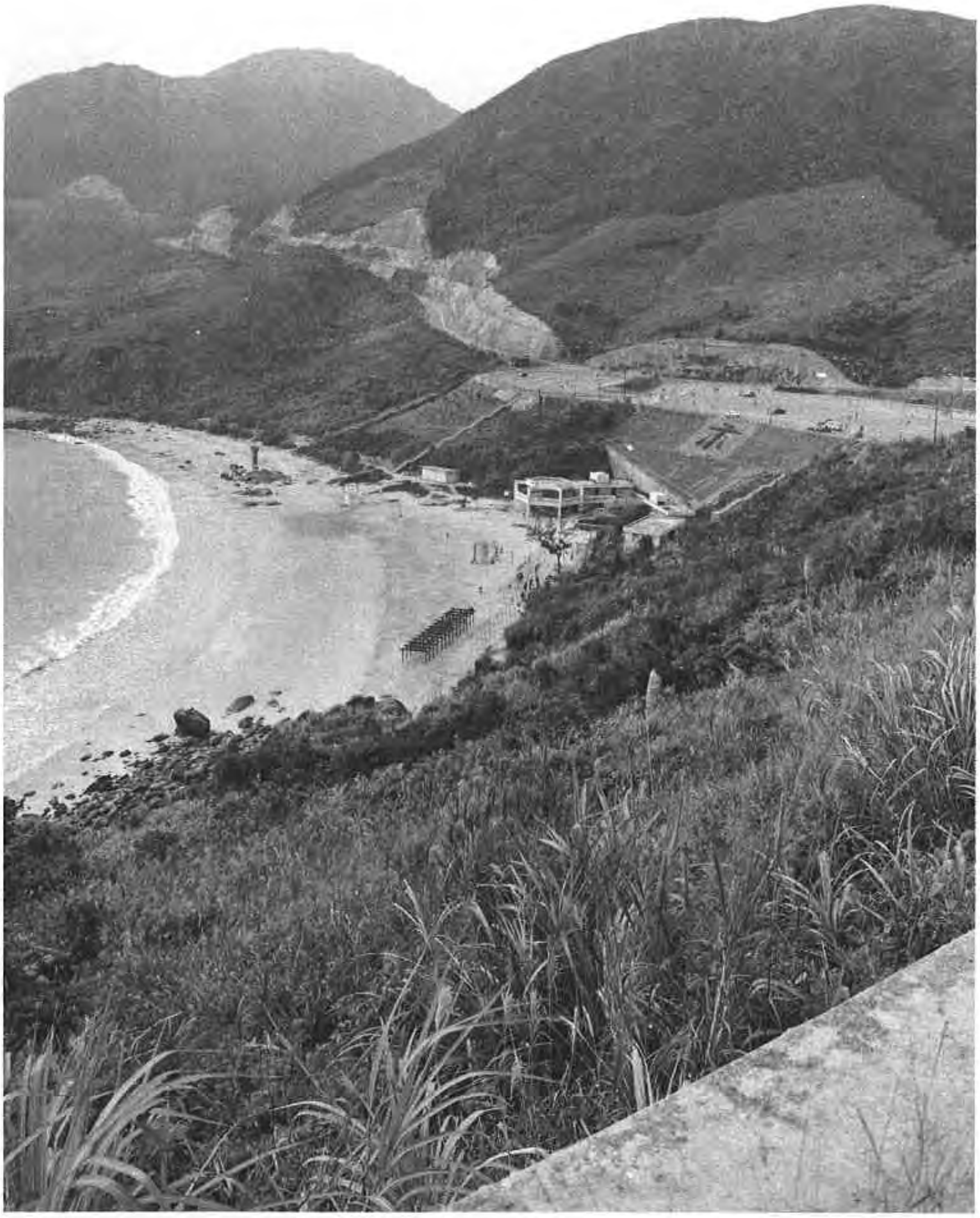


Plate 13. Clear Water Bay Main Beach. The littoral deposits consist of beach sands and boulders adjacent to wave cut rock platforms. The car park is on a fill platform.

Plate 14. Rock Cut Slope in Coarse Tuff of the Repulse Bay Formation. Completely weathered material is evident at the top of the cut face. Weathering is more strongly developed to the left of the drainage channel. Vertical, closely spaced jointing with subsidiary horizontal joints give the outcrop a blocky appearance.

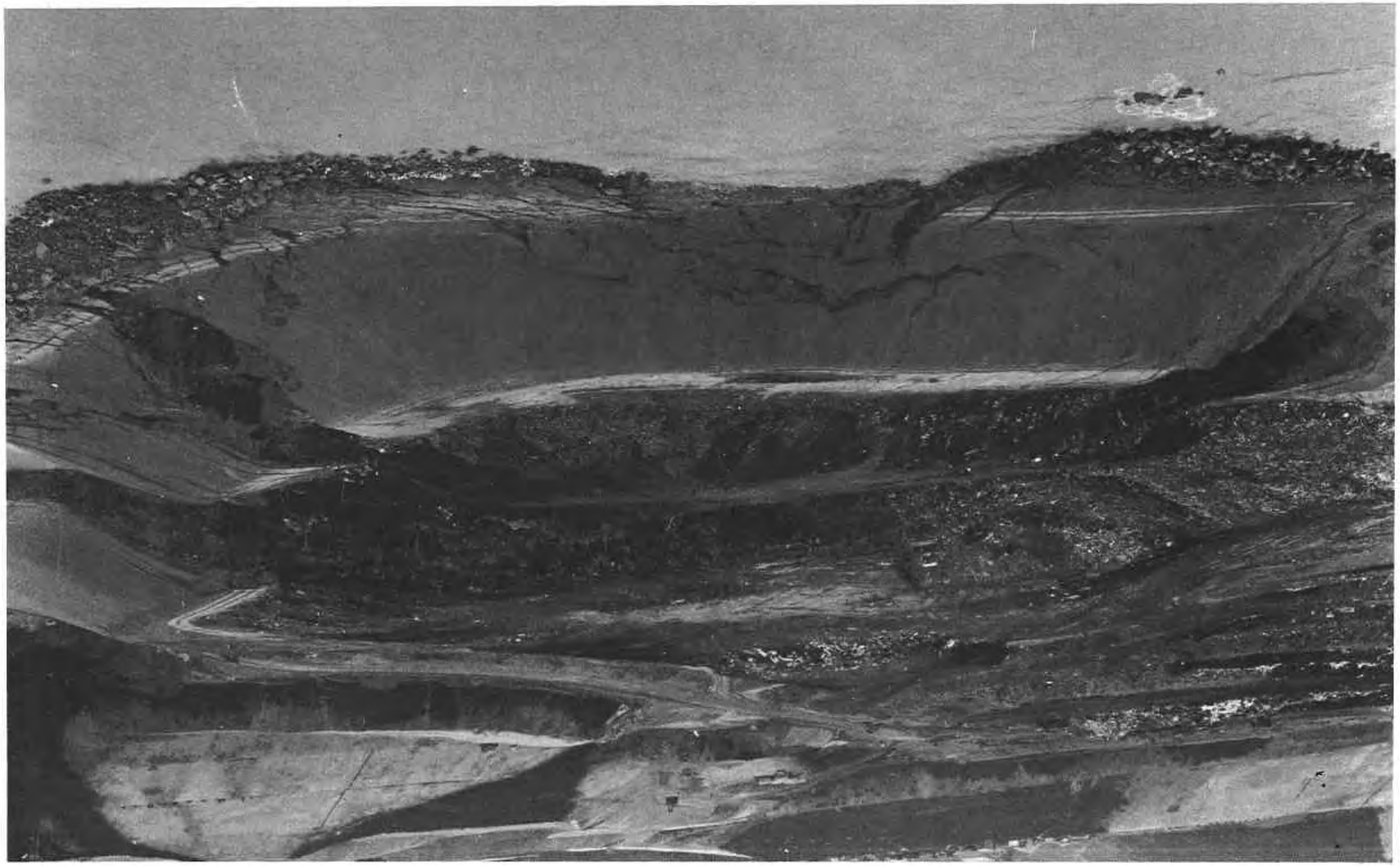


Plate 15. Failure of Landfill at the Junk Bay Controlled Tip. This Plate shows a failure of the southwestern corner of the Controlled Tip. Plant working on the site provide an indication of the scale of the failure.

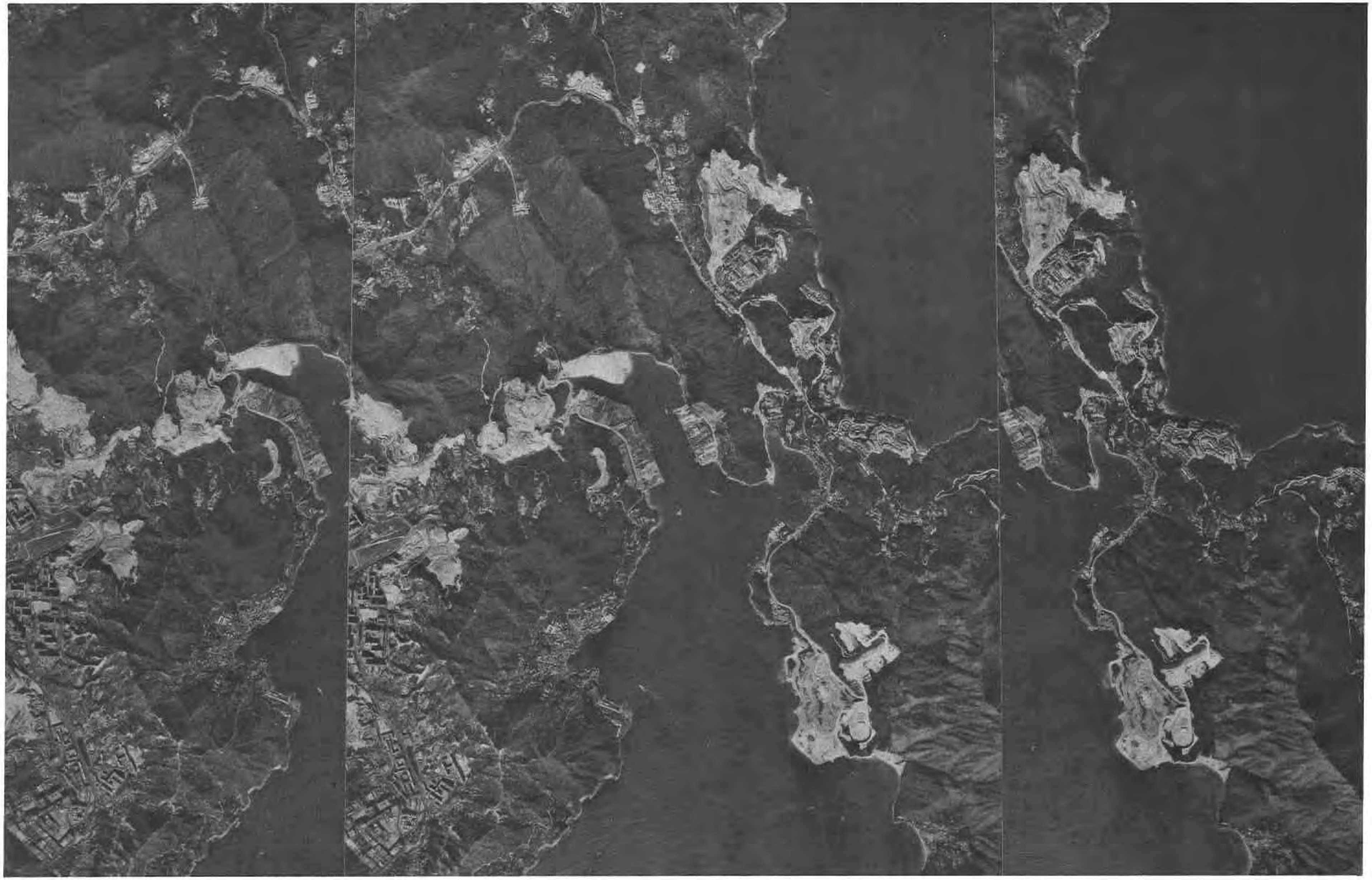


Plate 16. Stereo-triplet of Vertical Aerial Photographs of Junk Bay and the Surrounding Terrain. (1983/51672–51674).

APPENDIX A

SYSTEM OF TERRAIN EVALUATION AND ASSOCIATED TECHNIQUES

List of Figures

List of Tables

APPENDIX A

SYSTEM OF TERRAIN EVALUATION AND ASSOCIATED TECHNIQUES

A.1 Background

Terrain evaluation involves the identification of landform and terrain related features. This technique is used both to identify land use limitations and to assess in broad terms overall land use suitability. It is used as a planning tool and has a major application in the field of geotechnical engineering. In this Geotechnical Area Study, a systematic approach is used to collect, characterise and rationalise the natural variations which occur across the terrain. The structure and presentation of the terrain evaluation system used in this Report is illustrated in Figure 13.

The mechanism of producing a summary or inventory of physical land resources is known as *terrain classification.* This involves the systematic classification of the terrain to form a two-dimensional landform model. The Terrain Classification Map forms:

(*a*) The framework for the evaluation of the basic physical resource data designed specifically for geotechnical engineering purposes.

(*b*) The basis for the user-oriented derivative maps, particularly the Geotechnical Land Use Map (GLUM), the Physical Constraints Map (PCM) and the Generalised Limitations and Engineering Appraisal Map (GLEAM) are designed specifically for planning and land use management purposes and do not require specialist geotechnical interpretation.

A flow-chart depicting the basic technique of data acquisition and map production is shown in Figure A1. The GAS Programme is discussed by Styles & Burnett (1983, 1985), Styles et al (1982, 1984, 1986), Brand et al (1982 a & b), Burnett & Styles (1982) and Burnett et al (1985).

A.2 Technique of Terrain Classification

Terrain classification involves the systematic mapping and delineation of terrain characteristics. The major tool for the collection of these data is *aerial photograph interpretation* (API). This technique enables the stereoscopic examination of the terrain in a uniform and systematic manner. Aerial photograph interpretation greatly aids the collection of physical resource information, the types of data which can be derived from aerial photographs being many and varied. Any object or feature which can be recorded as a photographic image can be identified using API. The techniques are well established in the earth sciences for the delineation of resource data.

The main benefit of API lies in the significant reduction in the amount of field work, with consequent increased speed and uniformity of data acquisition (Styles, 1982). Access into, and evaluation of, difficult terrain can also be simplified using API.

In systematic mapping studies, the fundamental requirements for efficient API and terrain classification are thorough ground control and field reconnaissance.

In this study, three characteristics (attributes) are delineated on the 1:20 000 scale Terrain Classification Map, of which an example is given in Figure 14b. The three terrain attributes adopted for the analysis are:

(*a*) Slope gradient.

(*b*) Terrain component and morphology.

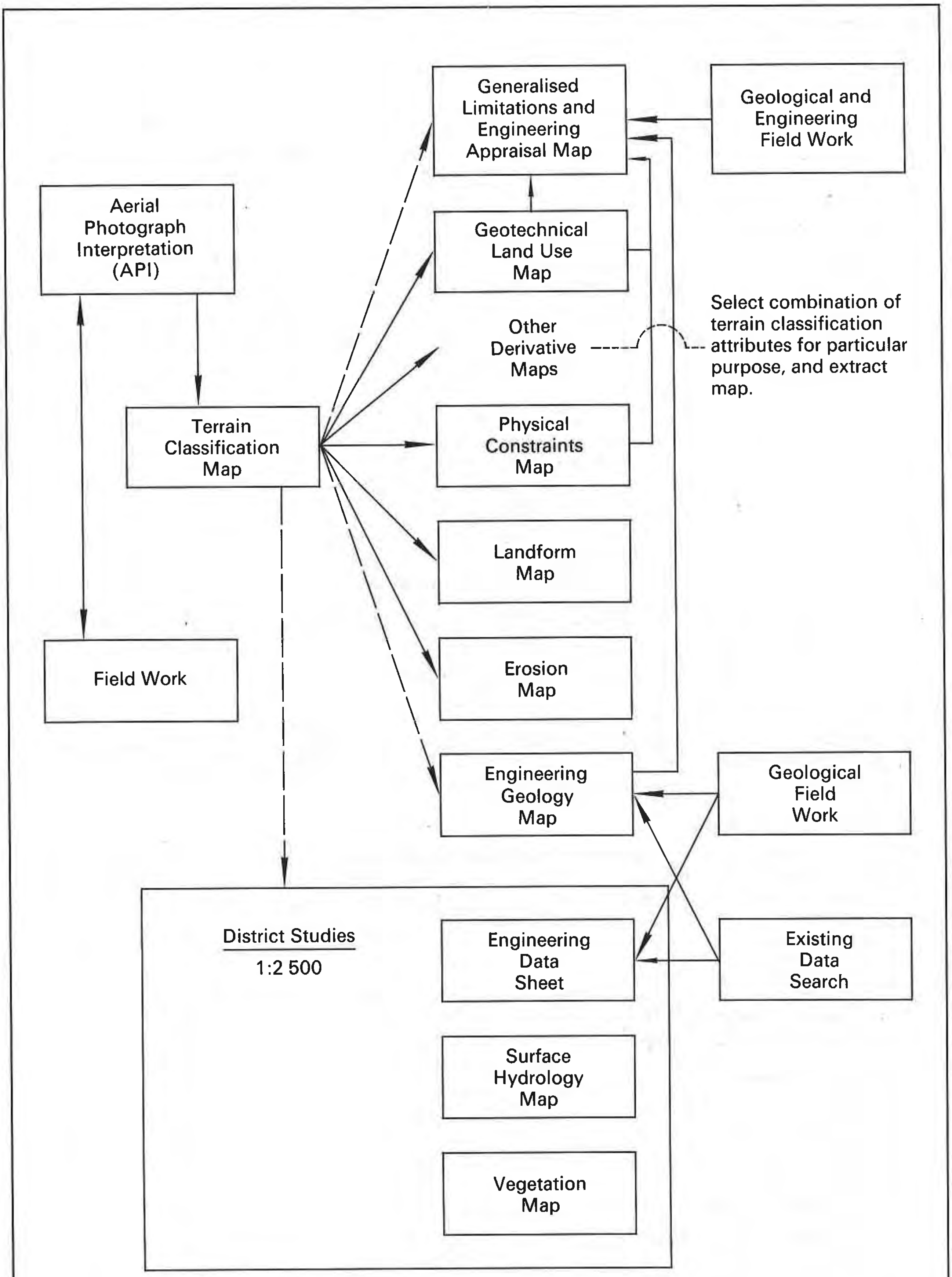
(*c*) Erosion and instability.

The complete terrain classification schedule is presented in Table A1. The information is presented in alphanumeric form, which enables the efficient delineation of multi-attribute map units. This method minimises the possibility of misinterpretation of map units by reducing the number of work sheets and by simplifying the production of derivative maps. As an example, a map unit designated as '2Ga' represents a convex slope, at an angle of 5–15°, composed of colluvium, in a footslope location, which contains a well-defined recent landslip.

The data collected in this study forms part of the Territory-wide programme of systematic terrain classification at a scale of 1:20 000. The physical resource information is integrated into a data bank management system known as the Geotechnical Terrain Classification System (GEOTECS). GEOTECS is discussed briefly in Sections 1.5.9 and A.11.

A.3 Terrain Classification Map

A brief description is given below of the three terrain attributes which are included in the terrain classification (refer to Table A1). The Terrain Classification Map is a work sheet and data base for the collection of land resource data and is not intended for use outside the GCO.



Technique of Data Acquisition and Derivation of Maps

Fig. A1

Table A1 Terrain Classification Attributes

Slope Gradient	*Code*	*Terrain Component*	*Code*	*Erosion and Instability*	*Code*
0– 5°	1	Hillcrest or ridge	A	No appreciable erosion	.
5–15°	2	Sideslope —straight	B	Sheet erosion —minor	1
15–30°	3	—concave	C	—moderate	2
30–40°	4	—convex	D	—severe	3
40–60°	5	Footslope —straight	E	Rill erosion —minor	4
>60°	6	—concave	F	—moderate	5
		—convex	G	—severe	6
		Drainage plain	H	Gully erosion —minor	7
		Floodplain	I	—moderate	8
		Coastal plain	K	—severe	9
		Littoral zone	L	Well-defined recent landslip, >1 ha in size	a
		Rock outcrop	M	Development of general instability —recent	n
		Cut —straight	N	—relict	r
		—concave	O	Coastal instability	w
		—convex	P		
		Fill —straight	R		
		—concave	S		
		—convex	T		
		General disturbed terrain	V		
		Alluvial plain	X		
		Reclamation	Z		
		Wave cut platform	W		
		Waterbodies:			
		Natural stream	1		
		Man-made channel	2		
		Water storage	3		
		Fish pond	4		

Notes: 1. In this classification, all footslope and drainage plain terrain corresponds to colluvium (terrain components E, F, G, H).
2. Disturbed colluvial terrain is indicated by underlining the landform code (terrain components N, O, P, R, S, T, V).
3. Disturbed alluvial terrain is indicated by double underlining the landform code (terrain components N, O, P, R, S, T, V).

A.3.1 *Slope Gradient*

Slope gradient is classified in degrees and is divided into six groups according to the schedule defined in Table A1. The slope angle of each terrain unit is measured along the direction of greatest declivity. This direction, which is normal to the contour, enables the identification of the most limiting slope angle.

A.3.2 *Terrain Component and Morphology*

The terrain component attribute describes the physical appearance of the slope. The terms used are essentially morphological descriptions and do not necessarily infer the geomorphological processes which are occurring on a slope. The terrain definitions adopted in this study are presented in the Glossary of Terms in Appendix E.

There are 14 major terrain component classes:

(*a*) Hillcrest (Code A).

(*b*) Sideslope (Codes B, C, D).

(*c*) Footslope (Codes E, F, G).

(*d*) Drainage plain (Code H).

(*e*) Alluvial plain (Code X).

(*f*) Floodplain (Code I).

(*g*) Coastal plain (Code K).

(*h*) Littoral zone (Code L).

(*i*) Cliff or rock outcrop (Code M).

(*j*) Cut slope (Codes N, O, P).

(*k*) Fill slope (Codes R, S, T).

(*l*) General disturbed terrain (Code V).

(*m*) Wave cut platform (Code W).

(*n*) Reclamation (Code Z).

In this study, all the footslope and drainage plain terrain consists of colluvium, and all the flood and alluvial plains consist of alluvium, whereas all the sideslope terrain consists of insitu geological materials. Other colluvial and alluvial subclasses occur in the cut slope, fill slope and general disturbed terrain components (Table A1).

The terrain component classes also indicate the general shape of the slope profile. The basic morphological classes are straight, concave and convex.

A.3.3 *Erosion and Instability*

These attributes describe the surface condition of the terrain on the basis of the major forms of terrain denudation. Slope failure and slope instability are indicated under this attribute. The five major erosion classes are:

(*a*) No appreciable erosion (Code .).

(*b*) Sheet erosion (Codes 1, 2, 3) is divided into three subclasses. Where vegetation is absent, the soil surface is subject to sheet erosion. Minor to severe sheet erosion appears as varying tones in aerial photographs. Severe sheeting appears as a highly reflectant white tone, which indicates the absence of almost all ground cover. Sheet erosion is classified in terms of the approximate proportion of bare ground. This type of erosion usually precedes rill and gully erosion.

(*c*) Rill erosion (Codes 4, 5, 6) is a form of denudation which occurs typically on exposed cut and fill slope batters. It is characterised by subparallel drainage rivulets which produce a typically striated appearance and result in significant soil loss.

(*d*) Gully erosion (Codes 7, 8, 9) often results in severe disruption of the terrain surface. Gully erosion produces significant hydrological problems due to infiltration and concentration of water flow, and may lead to slope failure. This class is divided into the three subclasses: minor, moderate and severe.

(*e*) Instability (Codes a, n, r, w) is divided into subclasses which relate to well-defined landslips and zones of general instability. The latter term relates to colluvial and insitu terrain where many failures and other evidence of instability occur, but due to their small size, it is not possible to delineate small landslips as discrete map units on a 1:20 000 scale map.

A.4 Landform Map

The Landform Map provides a simple model of the broad geomorphological classes and delineates the extent and distribution of the major terrain units within the study area. The Landform Map (example in Figure 19a) extracts from the Terrain Classification Map the significant terrain component and slope gradient classes. This information is presented as a separate map. In this form, it is easier to appreciate, understand and interpret the pattern of landform distribution.

The Landform Map uses a numeric code to classify the study area into parcels or zones of particular landform character. The broad terrain features are:

(*a*) Hillcrest or ridge.

(*b*) Sideslope (by definition consisting of insitu materials).

(*c*) Footslope (by definition consisting of colluvial materials).

(*d*) Drainage plains (colluvial areas subject to overland flow and regular inundation often associated with unusual groundwater regimes).

(*e*) Alluvial plain (including raised terraces).

(*f*) Floodplain (those portions of the alluvial plains which are subject to overland flow and regular inundation and possibly unusual groundwater regimes).

(*g*) Disturbed cut terrain (by definition man-made cuts, e.g. construction sites, quarries, borrow areas, utility corridors).

(*h*) Disturbed fill terrain (by definition man-made fills, e.g. construction sites, fill platforms).

(*i*) Cliff and rock outcrop.

(*j*) Wave cut platforms.

It should be noted that areas of alluvium are indicated with a light stipple on the map. Floodplain within the alluvium is shown with a diagonal hatch.

In addition to these broad landform units, the map also shows slope gradient information. This is incorporated into the landform classes so that it is possible to establish the average slope angle of the terrain.

Finally, the Landform Map shows by means of various symbols: reclamation, waterbodies (i.e. streams, channels and reservoirs), ponds and the littoral zone.

A.5 Erosion Map

The Erosion Map is derived from the Terrain Classification Map and delineates the major forms of erosion within the study area. The pattern of erosion can be related to the weathering characteristics of the geological units and to land use (Hansen & Nash, 1984). An example of this type of map is given in Figure 20a.

The map is important because it presents the general pattern of instability associated with the colluvial and insitu terrain. The following features are also shown:

(*a*) No appreciable erosion (Code .).

(*b*) Minor sheet erosion (Code 1).

(*c*) Moderate sheet erosion (Code 2).

(*d*) Severe sheet erosion (Code 3).

(*e*) Minor rill erosion (Code 4).

(*f*) Moderate to severe rill erosion (Code 5).

(*g*) Minor gully erosion (Code 6).

(*h*) Moderate to severe gully erosion (Code 7).

(*i*) General instability associated with insitu terrain (Codes a, n, r, w).

(*j*) General instability associated with colluvial terrain (Codes a, n. r, w).

(*k*) Wave cut platforms.

In common with all the other maps in the series, the areas of waterbody, pond and littoral zone are also shown.

The Erosion Map provides a simple reference, not only to those areas showing general instability in the form of landslips, but also to the other forms of denudation.

A.6 Physical Constraints Map

The Physical Constraints Map (PCM) presents the major physical constraints which will influence development in the area. It is extracted from the Terrain Classification Map and is designed specifically to supplement the GLUM. An example is presented in Figure 16a.

This is an interpretative map which synthesizes the natural physical constraints for land use management, planning and engineering purposes. The GLUM is a basic assessment of the geotechnical limitations associated with the terrain, whereas the Physical Constraints Map delineates the type of constraint. Obviously, areas that remain unclassified (blank) on the PCM are most suitable for development from a geotechnical point of view. These areas correspond to Class I and Class II in the GLUM system.

The major constraints which are shown on the map are:

(*a*) Zones of general instability associated with predominantly colluvial terrain.

(*b*) Zones of general instability associated with predominantly insitu terrain.

(*c*) Colluvium.

(*d*) Zones of colluvium which are subject to overland flow and periodic inundation (delineated as drainage plain on the Landform Map).

(*e*) Slopes on insitu terrain which are generally steeper than 30° (other than those delineated as colluvium or unstable).

(*f*) Floodplain (subject to overland flow and regular inundation and delineated as floodplain on the Landform Map).

(*g*) Disturbed terrain (extensive cut and fill batters which generally exceed 30°).

(*h*) Major waterbodies.

(*i*) Moderate and severe gully erosion.

(*j*) Instability on disturbed terrain.

A.7 Geotechnical Land Use Map

The Geotechnical Land Use Map (GLUM) represents a systematic method of interpreting and synthesizing terrain classification and geotechnical data into a format suitable for land management purposes (Table A2). The GLUM is therefore suitable *only for planning purposes.* Further limitations on the use of the GLUM are presented later in this section and must not be overlooked.

Table A2 GLUM Classification System

Characteristics of GLUM Classes	Class I	Class II	Subclass IIS	Class III	Class IV
Geotechnical Limitations	Low	Moderate		High	Extreme
Suitability for Development	High	Moderate	Moderate – Low	Low	Probably Unsuitable
Engineering Costs for Development	Low	Normal	Normal – High	High	Very High
Intensity of Site Investigation Required	Normal	Normal		Intensive	Very Intensive
Typical terrain characteristics (Some, but not necessarily all of the stated characteristics will occur in the respective Class)	Gentle slopes and insitu soils. Minor erosion on flatter slopes. Undisturbed terrain (minor cut & fill only).	Flat to moderate slopes. Colluvial soils showing evidence of minor erosion. Insitu soils which may be eroded. Reclamation. Rock outcrops. Poor drainage. Cut & fill slopes of low height.	Floodplain subject to periodic flooding and inundation.	Steep slopes. Colluvial & insitu soils showing evidence of severe erosion. Poor drainage. Cut & fill slopes of moderate height.	Combination of characteristics such as steep to very steep slopes, general instability on colluvium, severe erosion, poor drainage, high cut & fill slopes.

Note: This classification system is intended as a guide to planners and is not to be used for a detailed geotechnical appraisal of individual sites.

The GLUM is derived from the Terrain Classification Map. The slope, terrain component and erosion attributes described in Table A1 are considered in evaluating the general level of geotechnical limitation. A GLUM class is assigned to each combination of attributes to represent the limitation which is likely to be imposed on development. An appropriate GLUM class can therefore be allocated to each landform unit identified during the terrain classification of the study area. These are represented on the GLUM, an example of which is presented in Figure 15a. There are four GLUM Classes.

(i) *Class I—Low Geotechnical Limitations*

These areas are characterised by a low level of geotechnical limitation, and consequently have the highest suitability for development. Costs of site formation, foundation works and drainage works are expected to be low. Only normal geotechnical investigations will probably be required and investigation costs are expected to be low.

(ii) *Class II—Moderate Geotechnical Limitations*

These areas are characterised by moderate geotechnical limitations, and consequently are of moderate suitability for development, although the terrain conditions are more complex than in Class I. Costs of site formation, foundation works and drainage works will not be high. It is probable that normal geotechnical investigations only will be required, and investigation costs are not expected to be high.

Class IIS is a subclass defined specifically for the 1:20 000 scale studies. These areas are likely to be affected by periodic inundation and flooding. Although this factor alone will not significantly affect the geotechnical constraints associated with this flat, low-lying terrain, the general suitability for development can be considered moderate to low.

(iii) *Class III—High Geotechnical Limitations*

These areas are characterised by high geotechnical limitations, and consequently are of low suitability for development. Costs of site formation, foundation works and drainage works can be expected to be high. Intensive geotechnical investigations will be necessary, and investigation costs will be high.

(iv) *Class IV—Extreme Geotechnical Limitations*

These areas are characterised by extreme geotechnical limitations, and consequently development should be avoided if possible. In normal circumstances these areas would not be considered for development. If development of these areas is unavoidable, the costs of site formation, foundation works and drainage works will be very high. It is unlikely that the threat to development from natural hazards can be completely eliminated. Very intensive geotechnical investigations will be necessary both at the planning stage and prior to detailed design, and investigation costs will be extremely high.

The above descriptions are summarized in Table A2. Typical terrain characteristics which may be expected in each class are also given in the table, but it should be noted that not all of these characteristics need necessarily be present in any one map unit.

The following *important aspects* of the GLUM must be noted:

(*a*) The GLUM contains geotechnical information adequate *only for planning purposes.*

(*b*) The descriptions of the four GLUM classes should be taken *only as a guide* to the general level of geotechnical limitations associated with the terrain and consequent suitability for development.

(*c*) The GLUM class system assists in the assessment of the suitability of land for development from a geotechnical point of view. 'Development' is taken to mean high density residential, industrial, institutional and community uses. Further assistance in identifying larger areas with development potential is available within the GLEAM.

(*d*) The GLUM should not be used for engineering judgement of individual sites, nor does it obviate the need for adequate site investigation prior to the development of a particular parcel of land. When used in conjunction with the Engineering Geology Map and Physical Constraints Map, however, the GLUM will help to identify the major constraints which are present or are likely to occur on a particular parcel of land. The GLEAM will assist in evaluating the impact of local geotechnical constraints on those areas with development potential.

(*e*) The GLUM classes provide *only an indication* of the extent and relative costs of the geotechnical investigations required for the development of a parcel of land. The particular local ground conditions, the nature of the intended development and existing knowledge of the site and its surroundings will govern the final extent and cost of investigation.

(*f*) A GLUM class is assigned to a parcel of land directly from the terrain classification. In assigning the GLUM class, *no consideration is given to the nature of adjoining parcels of land.* In using the GLUM, therefore, it must be remembered that a parcel of land will be affected by the classes of land along its boundaries. Again, reference to the PCM and EGM will assist in determining more general conditions.

(*g*) The GLUM system is based essentially on the classification of the terrain by its *surface* features. Therefore, the GLUM does not provide reliable information about the deep subsurface geology or the subsurface hydrology, and detailed site investigation at a particular location might reveal subsurface conditions not predicted by the GLUM.

(*h*) Conservative GLUM classes are assigned to fill areas.

(*i*) In this Report, the GLUM is designed as a broadscale planning tool for use at a scale of 1:20 000. It should only be used to assess the *general level* of geotechnical limitations associated with a relatively large parcel of land rather than with an individual site. As a general rule, it should not be used to evaluate parcels of land smaller than 3 ha in size. An area designated a particular class at 1:20 000 scale (Regional Study) may consist, in part, of very small areas of other classes if examined at 1:2 500 scale (District Study). This is due to the size of the terrain classification map units at 1:20 000 scale as opposed to 1:2 500. At the latter scale, the average area of each map unit is approximately 0.1 ha, whereas the average area of each map unit at 1:20 000 scale is approximately 2 ha. Therefore, *the GLUM presented in a Regional Study must never be interpreted, reproduced or enlarged to scales larger than 1:20 000.* Failure to heed this warning will result in serious misinterpretation of the GLUM.

In the derivation of GLUM class, the pre-existing slope angles of the terrain are inferred where the natural slope profile is destroyed by cut and fill operations. The pre-existing slopes are determined from aerial photography of the site (if available) taken before disturbance, or by extrapolation from undisturbed slopes above, below or adjacent to the disturbed area. However, where quarry or construction operations increase the gradient of the constructed slope, the new slope gradient is recorded. Modification of the natural terrain may increase the geotechnical limitations, with a resultant increase in the costs associated with its use.

A.8 Engineering Geology Map

A.8.1 *Background*

The compilation and assessment of data for the Engineering Geology Map is undertaken during and after the terrain classification phase of a Geotechnical Area Study.

The comments made in this Report with regard to the engineering geology of the Clear Water Bay area are intended for use at a planning level and are based on the following:

(*a*) Extraction of selected information from the API source data; this was supplemented by limited field reconnaissance.

(*b*) Records of a limited amount of reliable site investigation data; this assisted the establishment of a three-dimensional appreciation of the geology and hydrology of the study area.

A.8.2 *Production of the Engineering Geology Map*

The Engineering Geology Map was compiled from selected information from the Terrain Classification Map, to which was added various existing data (Appendix C) and information collected during the field reconnaissance. The Engineering Geology Map presents on one map the bedrock and superficial geology of the area and indicates the general geomorphology and material properties of the lithological units.

The Engineering Geology Map for the study area is contained in the Map Folder accompanying this Report and an example is located at Figure 17a. Note that this map will be superseded during the remapping of the geology of the Territory (See Section 1.1).

The data selected for inclusion on the Engineering Geology Map in this Report are:

(*a*) Boundaries of major lithologies and superficial deposits.

(*b*) Major photolineaments.

(*c*) Major topographic features.

(*d*) Isopachs of submarine superficial deposits.

(*e*) Boundaries of major catchments.

(*f*) Zones of general instability.

(*g*) Zones of reclamation.

The catchment boundaries are indicated on the Engineering Geology Map according to the method suggested by Strahler (1952). By this system, all streams without tributaries are designated 'first order' streams. When two first order streams join, the resulting stream rises to second order status, and two second order streams, on joining, produce a third order stream. Thus, a unit increase in order takes place downstream of the junction of two streams with the same order. A stream of higher order has a larger number of tributaries, a higher discharge, and usually a broader valley than a stream of lower order.

A.8.3 *Colluvium Classification System*

A simple classification system is used to aid in the delineation and the description of colluvial deposits. This classification system is a simplified form of the system which was originally used in the colluvium mapping project undertaken on a Territory-wide basis by the GCO in 1979. The system is based on the origin of the major (usually the cobble and boulder) component of the colluvium and is divided into materials which are:

(*a*) Essentially volcanic derived.

(*b*) Essentially granite derived.

(*c*) Essentially metasediment derived.

(*d*) Mixed origin.

This classification is applied to the colluvial deposits on the basis of the parent geology. The classification is based on API and is not extensively field checked. These classes are not presented on the Engineering Geology Map but are included in the GEOTECS data bank.

A.8.4 *Data Collection*

The information presented on the Engineering Geology Map is a compilation of data gathered from a brief study of available Geotechnical Information Unit (GIU) site investigation reports, from field reconnaissance and from the extraction of the pertinent components of the terrain classification mapping and the Allen & Stephens (1971) geological mapping.

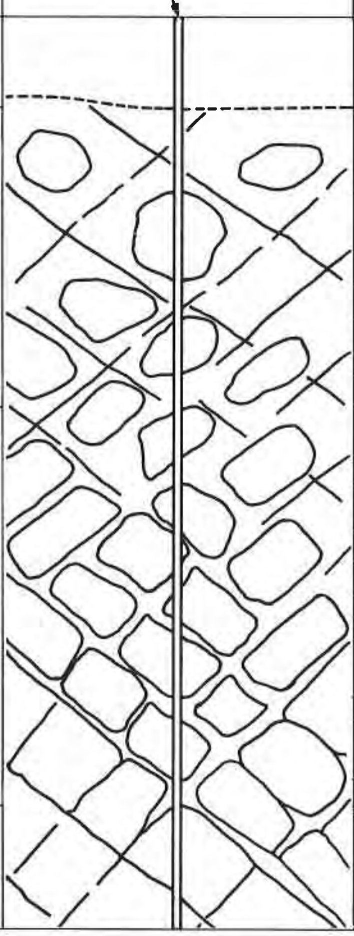
Details of the aerial photographs used for the terrain classification are given in Appendix C.3 and Table C.2.

A.9 Generalised Limitations and Engineering Appraisal Map

A.9.1 *Introduction*

Long-term strategic development planning requires an early and fundamental appreciation of areas suitable for extensive and/or intensive development. Development in the study area has been influenced by the geotechnical constraints associated with the terrain since the start of urban expansion in Hong Kong. With the obvious shortage of suitable terrain and the continuing pressure for expansion, it is essential that geotechnical influences are considered in detail at the start of any planning or engineering project. The maps produced within the GAS Programme are fundamental to this approach.

Table A3 Rock Weathering System

Zones of Decomposition Seen in Exposures (based on Ruxton & Berry, 1957)	Drillhole	Material Grade (see table below)	Probable Judgement of Zones Based on Drillcore Only
Zone A—Structureless sand, silt and clay. May have boulders concentrated at the surface.		VI	Zone A
Zone B—Predominantly grades IV or V material with core boulders of grades I, II or III material. The boulders constitute less than 50% of the mass and are rounded and not interlocked.		V III V III V	Zone B
Zone C—Predominantly core boulders of grades I, II and III material separated by seams of grades IV and V. The core boulders constitute more than 50% of the mass and are rectangular.		III V II III IV III IV II IV I IV II	Zone C
Zone D—Material of grades I or II constitutes more than 90% of the mass.		I	Zone D

Classification of Weathering Profile of Igneous Rock, as Seen in Exposures and Drillcores

Grade	Degree of Decomposition	Diagnostic Features in Samples and Cores
VI	Soil	No recognisable rock texture; surface layer contains humus and plant roots.
V	Completely decomposed	Rock completely decomposed by weathering in place, but texture still recognisable.
IV	Highly decomposed	Rock weakened so that fairly large pieces can be broken and crumbled in the hands.
III	Moderately decomposed	Large pieces (e.g. NX drill core) cannot be broken by hand.
II	Slightly decomposed	Strength approaching that of fresh rock – slight staining.
I	Fresh rock	

Classification of the Degree of Decomposition from Weathered Rock of Igneous Origin (after Moye, 1955).

The Generalised Limitations and Engineering Appraisal Map (GLEAM) is intended to extend the guidance on geotechnical problems given in the GLUM, the PCM and the EGM. It enables the planner or engineer to take a broader view of the opportunities for development in geotechnical terms. In addition, it highlights the features of the terrain which represent geotechnical constraints but are not considered detrimental to the overall development potential of the terrain.

The derivation of the GLEAM and its implications for planning and engineering are described below.

A.9.2 *Derivation of the GLEAM*

The GLEAM is derived from the Terrain Classification Map with further detailed aerial photograph interpretation and fieldwork. During its production, use is made of the GLUM, the PCM and the EGM. The general sequence is summarised in flowchart form in Figure A2.

The GLEAM identifies areas of potential for development. Continuous areas of already developed land are excluded from comment. 'Man-made' restrictions such as Country Parks, catchwaters and catchments are delineated, and principal access routes which would ease expansion are also shown.

An initial estimate of the boundary between geotechnical potential and constraint is made from the Terrain Classification Map. Potential areas are those generally less than 30° in insitu materials and 15° in fill and colluvium, where instability is not identified and erosion is limited. Slopes steeper than 30° would require extensive cuts or high retaining structures to provide useful platforms, and platforms constructed in fill or colluvial slopes would require long back slopes to achieve a suitable level of safety. Instability indicates that the natural slope is liable to present a hazard, and lines of excessive erosion would require entrainment of stream courses to avoid the risk of blockage, flooding and destabilising infiltration. The criteria used for initial assessment of the potential or constraint boundary are shown in Table A4.

To a certain extent, the constraints outlined above are similar to those identified in the Physical Constraints Map and in GLUM Classes III & IV, but their interpretation depends on the local situation and the nature of the engineering problem which is present.

In generalising the boundary between potential and constraint, small areas which have geotechnical constraint are included where they do not contradict the overall assessment of potential. In these cases, the nature of the constraint is reflected in the engineering notes, and the area is highlighted on the map as a stipple.

Further interpretation of the engineering geology and physical constraints is made using oblique and vertical aerial photographs. In this way, the boundaries are refined, and the basic engineering notes are prepared for the GLEAM.

The engineering notes are presented in the form of standard symbols which are described in the legend. They highlight local geotechnical constraints which would influence layout or the design details of a project. General constraints identified on the Physical Constraints Map are shown as a background to these notes. The features indicated on the GLEAM are described and discussed in note form in Table A5. The production of the GLEAM is supplemented by field checks of pertinent areas.

An appreciation of the non-geotechnical considerations of the potential development areas and of the implications of geotechnical suitability on planning considerations enables specific planning opportunities to be highlighted. These factors include the necessity for access across difficult terrain, visual intrusion or severe influence on natural environment resulting from construction works.

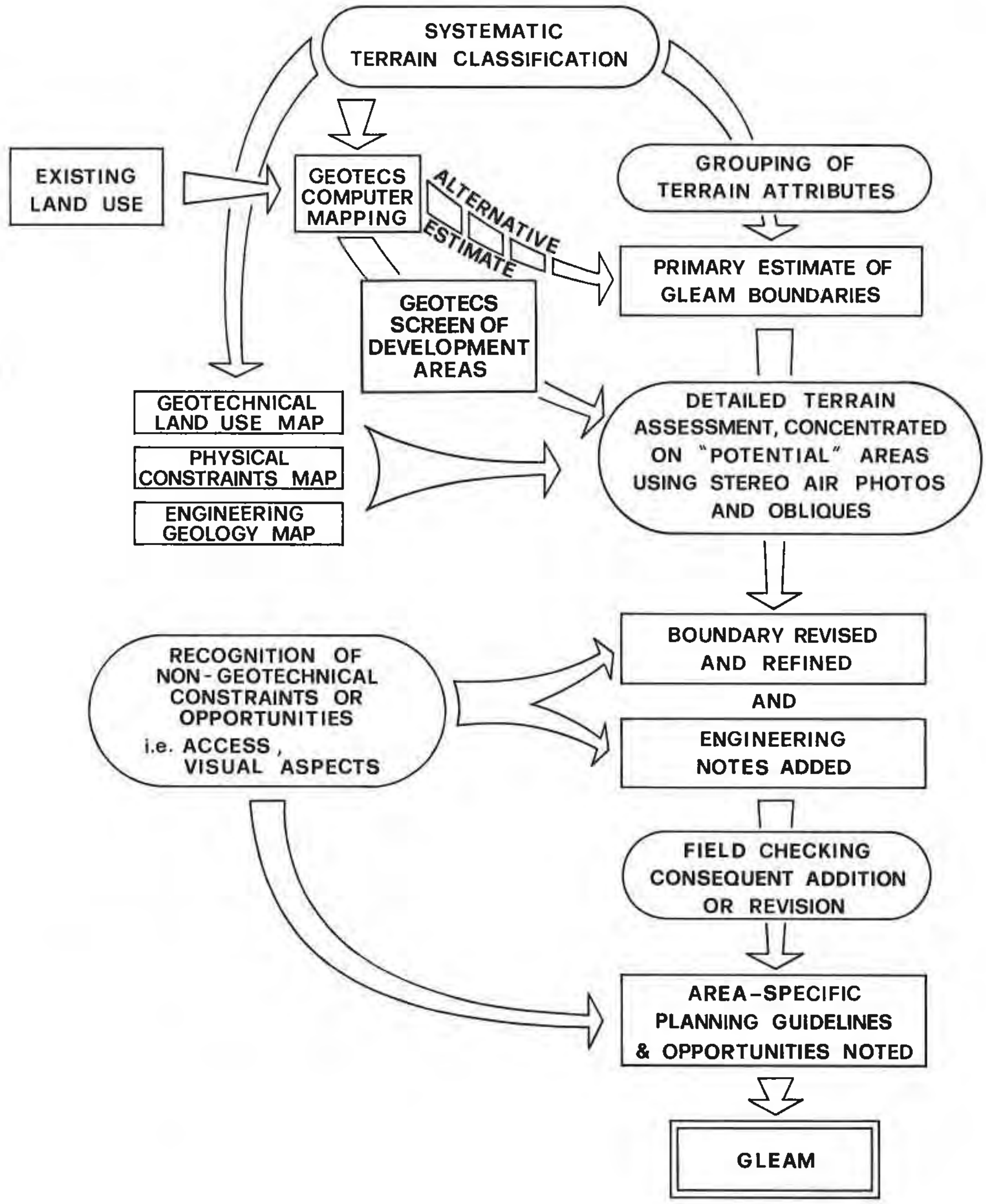
Hence, the GLEAM is a map that is designed to provide a broad indication of development opportunities assessed from a geotechnical point of view and to identify geotechnical considerations with local implications for planning and engineering.

A.9.3 *Application of the GLEAM in Strategic Planning*

The general boundaries between areas of 'Potential' and 'Constraint' should be used at a strategic planning stage to enable new development to be placed where it can most effectively use the opportunities provided by the terrain, and where it will be relatively unhindered by geotechnical difficulties. Where difficulties cannot be avoided, they are clearly indicated. Where large areas are suitable for development, the nature and scale of development should be planned to utilize all available opportunities.

Piecemeal development often results in considerable wastage of potential development land. Individual developers could be encouraged to conform to an outline site layout which maximises the use of the site resources.

Notes are incorporated on the GLEAM which assess in general, but in geotechnically based terms, the development opportunities of potential areas. These are prepared without detailed consideration of other planning constraints (political, socio-economic, aesthetic) which may influence the area but, nevertheless, the geotechnical constraints are of fundamental significance to the potential of an area for development.



Derivation of Generalised Limitations and Engineering Appraisal Map

Fig. A2

Table A4 Criteria for Initial Assessment of GLEAM Potential/Constraint Boundaries

Terrain Component*	Slope Gradient*	Erosion/Instability Classification		
		Erosion*		Instability*
		(., 1, 2, 3, 4, 5, 6, 7)	(8, 9)	(a, n, r, w)
A	1	Yes	Yes	No
	2, 3	Yes	No	No
B, C, D, M N, O, P	1, 2, 3	Yes	No	No
	4, 5, 6	No	No	No
E, F, G, H, I[Δ] K[Δ], R, S, T, X[Δ]	1, 2	Yes	No	No
	3, 4, 5, 6	No	No	No
N, O, P** R, R, S T, V, V	1, 2	Yes	No	No
	3	Subject to interpretation	No	No
	4, 5, 6	No	No	No
Z	1, 2	Yes	Yes	No

Yes = Potential development   No = Constraint†

Note: * See Table A1 for description of terrain classification codes.

Δ Terrain components I, K and X are only mapped at slope gradients of 1 and 2.

** The potential/constraint boundary is subject to interpretation. These terrain components are generally unlikely to occur outside developed or developing areas which are not considered in the GLEAM.

† All initially derived potential/constraint boundaries are subject to revision on assessment of the overall area, in particular erosion classifications 8 and 9. Instability is generally assessed as constraint.

A.9.4 *Application of the GLEAM in Engineering Feasibility and Detailed Planning*

After the identification of areas for development, planners, architects and engineers prepare the form, layout and design details of the scheme. At this stage, the GLEAM is also of value because it indicates the particular nature of local geotechnical difficulties which influence the design aspects of the project and which require consideration in preliminary layout and design. Details such as the limitations on site formation and the requirement for retaining structures, the optimum foundation type, special provisions for subsurface drainage and entrainment of natural drainage, the threat of boulders or rock instability, inconsistency in soil properties or local rock structures, are all important for planning and design. They must be considered in the initial stages of planning if the optimum development of sites is to be achieved. Often, designs reach an advanced stage before major geotechnical constraints are identified.

Table A5 incorporates notes on the engineering implications of local features highlighted on the GLEAM. Further discussion of the engineering aspects of terrain features and of the interaction between landforming processes of relevance to construction work are included in this Report.

Table A5 Notes on Features Indicated on the GLEAM

1. Colluvium
   - indicated where expected to be deep or irregular.
   - extent of colluvium is shown on PCM & EGM.
   - notes on colluvium are given in Sections 3.1.4 and Appendix D.3.5.
2. Drainage
   - indicated where expected to be subject to large flows,
   - masked drainage or hidden drainage indicated where ephemeral flows may cause problems or where original drainage pattern may still exist beneath surface disturbance.
   - may pose the risk of piping pressures or leaching of materials.
   - ephemeral flows together with smooth surface contours may indicate deeper weathering and may be associated with a structural weakness, thus forming a geological photolineament.
3. Incised drainage
   - may be associated with structural weakness.
   - in weathered material, may present local oversteepening.
4. Structure
   - local surface indication of jointing pattern, or localised resistance to weathering or movement, and therefore not necessarily a weakness.

   NOTE: When 'terrain associated with Drainage and Structure' or similar is noted – this is the surface result of drainage forming a 'pattern', recognisable from vertical aerial photographs, associated with a jointing or local faulting pattern.
5. Weathering
   - indicated where surface features, i.e. smoothness of terrain, or extensive gullying, show that deep weathering may be expected.
   - in general, deeper weathering is associated with granitic terrain, and occurs beneath ridge and spur lines.
6. 'Control'
   - terrain influenced by features as noted. i.e. D & S cont. = Drainage & Structure Control
7. Instability
   - indicated where the natural landform exhibits instability which poses a threat to development unless accommodated.
8. Steep slopes
   - indicated where the presence of a steeper slope would result in extensive cuts or high walls being necessary to produce a platform.
   - tends to restrict site formation possibilities.
9. Lineament
   - identified from aerial photography.
   - indicates a structural weakness or strength through an anomaly in the surface features.
   - lineaments (some) also shown on EGM.
   - further notes on lineaments in 2.

The information presented in the GLEAM, because it is interpretative in nature, cannot be conclusive in its application to a particular engineering project; nor from the nature and scale of the study can the comments be exhaustive. The GLEAM does indicate areas of potential for development whilst clearly defining the major geotechnical restrictions which are likely to influence planning and engineering feasibility.

A.9.5 *Production of the GLEAM and Evaluation of Planning Strategies*

Using the Geotechnical Terrain Classification System (GEOTECS) described in Section 1.5.9, it is possible to construct various strategies based on priorities of land utilisation in combination with the systematic data collected in the terrain classification process.

Particular types of existing land use can be isolated, and the engineering suitability or potential for an intended use can be evaluated. This can be achieved by the selection of appropriate terrain attributes. The attributes include: geology, slope angle, aspect, terrain component, erosion and instability, GLUM, relief, vegetation and land use.

Typical strategies and the computer maps are described in Section 4.2.4. The potential for development of squatter areas or possible quarry sites assessed in geotechnical terms are provided as examples.

The maps produced using GEOTECS are conceptual in nature, and further study of any potential development area is essential. Nevertheless, the mechanism of land resource appraisal afforded by the GEOTECS approach provides a powerful tool for land management purposes and engineering feasibility.

A.10 General Rules for the Use of the Maps and Associated Data

There are several basic rules regarding the use of the maps produced in the GAS Programme. Failure to heed these rules may result in the serious misinterpretation of the maps produced in this Report. The rules are:

(*a*) The maps are designed for use at a scale of 1:20 000. They should never be enlarged to scales larger than the published scale.

(*b*) The type of information shown on the map is designed for users who require data at 1:20 000 scale. The information presented on the 1:20 000 maps may not be valid at larger scales.

(*c*) The conventional line maps produced for use at a scale of 1:20 000 should not be used to evaluate parcels of land smaller than about 3 ha in size.

(*d*) The GEOTECS plots must never be used to evaluate specific small sites (less than 5 ha in size). They are designed for broad planning and engineering feasibility studies. GEOTECS plots should not be used at a scale larger than 1:20 000.

A.11 Measurement, Analysis and Storage of Data (GEOTECS)

A data bank has been established for each of the GASP areas. This facilitates the examination and analysis of the distribution of the physical resource attributes occurring in the area and their planning and engineering implications. It also provides a method of investigating the interrelationships among various attributes which occur within the areas.

The terrain classification for this study is part of the small-scale (1:20 000) systematic terrain classification which has been completed for the entire Territory of Hong Kong. The GASP VII data bank consists of 1 831 grid cells, each of which covers approximately 2.04 hectares (49 cells per grid kilometre square) and is referenced to the Hong Kong Metric Grid. This programme, which is known within the Geotechnical Control Office as the Geotechnical Terrain Classification System (GEOTECS), is discussed briefly in Section 1.5.9. Nine natural resource attributes are recorded for each grid cell. The attributes are: slope gradient, terrain component, erosion and instability, aspect, relief, superficial and bedrock geology, existing land use, and vegetation.

The area measurements are calculated on the number of grid cells which occur within the study area. The area occupied by a particular attribute is measured by recording the Terrain Classification Map unit which occupies the largest proportion of each cell.

The measurement of irregular shaped map units by a regular graticule inevitably results in some inaccuracies in area calculation. However, there is an overall 'averaging' effect which minimises the errors inherent in this method. Errors are limited to a few percent in total and, in comparison with inaccuracies prevalent in the area measurement of steeply sloping terrain, are considered insignificant.

On completion of the manual coding process, the data is stored for use in the computer. The attribute measurements are sorted, correlated and tabulated. The resulting tables can be broadly classified into three groups:

(*a*) Single attribute tables which present the total area of each attribute under consideration, e.g. slope gradient (Tables B1, B2, B3, B5, B6, B7, B9 and B12).

(*b*) Single attribute correlations which present the tabulated relationships between one single attribute and another, e.g. slope gradient versus aspect (Tables B4, B8, B11 and B13).

(*c*) Multiple attribute correlations which present the relationship between a combination of two or more attributes and an additional attribute, e.g. slope gradient, aspect geology versus erosion (Table B10). Within the framework of these tables, it is possible to define a multi-attribute unit based on any user-defined combination of attributes.

APPENDIX B

DATA TABLES FOR THE CLEAR WATER BAY GEOTECHNICAL AREA STUDY

Table B1 Slope Gradient

Slope Gradient	% of Total Area	Area (ha)
0– 5°*	13.0	487
5–15°	20.2	755
15–30°	28.1	1 051
30–40°	32.5	1 214
40–60°	4.9	181
>60°	1.3	47
	100.0	3 735

* Approximately 10 ha of ponds are included in the 0–5° Class.

Table B2 Erosion and Instability

Erosion		% of Total Area	Area (ha)
Instability			
—well-defined landslips		0.2	6
—general instability—recent		13.0	484
—general instability—relict		3.3	124
—coastal instability		2.6	98
Appreciable Erosion	Sheet erosion—minor	1.6	61
	—moderate to severe	3.1	116
	Rill erosion —minor	—	—
	—moderate to severe	—	—
	Gully erosion—minor	5.3	198
	—moderate to severe	0.4	14
No Appreciable Erosion*		70.5	2 634
		100.0	3 735

* Approximately 10 ha of ponds are included within No Appreciable Erosion.

Table B3 Aspect

Aspect	% of Total Area	Area (ha)
North	9.2	345
Northeast	13.5	504
East	17.5	653
Southeast	9.8	367
South	9.2	345
Southwest	9.5	353
West	10.0	373
Northwest	8.2	308
Flat/Unclassified*	13.1	487
	100.0	3 735

* Approximately 10 ha of ponds are included in the Flat/Unclassified category.

Table B4 Aspect and Slope Gradient

Aspect	Slope Gradient					Total Area (ha)
	5–15°	15–30°	30–40°	40–60°	>60°	
North	94	125	120	6	0	345
Northeast	96	147	214	35	12	504
East	176	153	253	60	12	653
Southeast	57	122	155	27	6	367
South	96	104	98	37	10	345
Southwest	69	133	147	2	2	353
West	73	157	131	8	4	373
Northwest	94	110	96	8	0	308
0–5° (Flat/Unclassified)*						488
						3 735

*Includes 10 ha of ponds.

Table B5 Landform

Terrain (Landform)	Slope Gradient	% of Total Area	Area (ha)
Hillcrest	0–30°	6.2	232
"	>30°	0.4	16
Sideslope	0– 5°	0.8	31
"	5–15°	10.4	388
"	15–30°	22.5	838
"	30–40°	29.3	1 093
"	>40°	1.7	65
Cliff/Rock outcrop	0–30°	0.4	16
"	>30°	5.6	208
Footslope (colluvium)	0– 5°	0.8	29
"	5–15°	1.1	43
"	15–30°	0.9	35
"	>30°	0.4	16
Drainage plain (colluvium)	0– 5°	2.5	92
"	5–15°	4.1	153
"	15–30°	2.7	100
"	>30°	0.3	10
Alluvial plain	0– 5°	0.8	31
"	>5°	0.1	2
Floodplain	0– 5°	0.1	2
Littoral zone	0–15°	0.9	35
Wave cut platform	—	0.5	18
Cut platforms : insitu	0– 5°	1.8	67
: colluvium	0– 5°	0	0
: alluvium	0– 5°	0	0
Cut slopes : insitu	>5°	2.3	88
: colluvium	>5°	0	0
: alluvium	>5°	0	0
Fill platforms : insitu	0– 5°	0.5	18
: colluvium	0– 5°	0.2	6
: alluvium	0– 5°	0	0
Fill slopes : insitu	>5°	0.5	18
: colluvium	>5°	0	0
: alluvium	>5°	0	0
Reclamation : platform	0– 5°	1.0	37
: slope	>5°	0.7	27
General disturbed terrain/platforms: insitu	0– 5°	0.1	2
General disturbed terrain/slope: insitu	>5°	0.1	2
: colluvium	>5°	0.1	2
: alluvium	>5°	0	0
Natural stream		0	0
Man-made channel		0	0
Water storage		0	0
Ponds		0.3	10
		100.0	3 735

Approximately 22 ha of reclamation and 22 ha of fill are included in the Man-made channel category.

Table B6 Geology

Geological Unit	% of Total Area	Area (ha)
Alluvium: undifferentiated	1.2	45
Colluvium: volcanic	11.4	426
: granitic	0.7	27
: sedimentary	0	0
: mixed	0.8	29
Littoral deposits	0.9	35
Marine deposits	0	0
Reclamation	1.7	63
Fill	1.3	49
Repulse Bay Formation: undifferentiated volcanics	0	0
: sedimentary rocks and waterlaid volcanics	0.2	6
: acid lavas	13.0	485
: mainly banded acid lavas, some welded tuffs	18.7	700
: coarse tuff	0	0
: agglomerate	0.1	4
: dominantly pyroclastics and some lavas	47.2	1 762
Needle Hill Granite (Fine grained phase)	0	716
Hong Kong Granite	2.1	78
Quartz Monzonite	0.2	8
Granophyric Microgranite	0.5	18
Feldspar Porphyry	0	0
Ma On Shan Granite	0	0
Cheung Chau Granite	0	0
Sung Kong Granite	0	0
Sung Kong Granite (Medium grained phase)	0	0
Tai Po Granodiorite	0	0
	100.0	3 735

Table B7 Vegetation

Vegetation	% of Total Area	Area (ha)
Grassland	27.8	1 039
Cultivation	5.1	190
Mixed broadleaf woodland	15.5	579
Shrubland (<50%)	8.8	331
Shrubland (>50%)	18.0	673
No vegetation on natural terrain	1.9	69
No vegetation due to disturbance of terrain by man*	16.9	632
No vegetation due to rock outcrop	6.0	222
Zoological and botanical gardens	0	0
	100.0	3 735

* Approximately 10 ha of ponds are included in this class.

Table B8 Geology and GLUM Class

Geological Unit	Area in GLUM Class (ha)				
	I	II	III	IV	Unclassified
Alluvium: undifferentiated	0	35	0	0	10
Colluvium: volcanic	0	27	279	120	0
: granitic	0	2	14	10	0
: sedimentary	0	0	0	0	0
: mixed	0	2	16	10	0
Littoral deposits	0	0	0	0	35
Marine deposits	0	0	0	0	0
Reclamation	0	37	24	2	0
Fill	0	30	0	18	0
Repulse Bay Formation: undifferentiated volcanics	0	0	0	0	0
: sedimentary rocks and waterlaid volcanics	0	6	0	0	0
: acid lavas	41	124	98	220	2
: mainly banded acid lavas, some welded tuffs	149	192	177	177	4
: coarse tuffs	0	0	0	0	0
: agglomerate	0	0	6	0	0
: dominantly pyroclastics and some lavas	379	602	512	257	12
Needle Hill Granite (Fine grained phase)	0	0	0	0	0
Hong Kong Granite	12	16	45	4	0
Quartz Monzonite	2	2	2	2	0
Granophyric Microgranite	0	0	10	8	0
Feldspar Porphyry	0	0	0	0	0
Ma On Shan Granite	0	0	0	0	0
Cheung Chau Granite	0	0	0	0	0
Sung Kong Granite	0	0	0	0	0
Sung Kong Granite (Medium grained phase)	0	0	0	0	0
Tai Po Granodiorite	0	0	0	0	0
	583	1 075	1 202	812	63

Table B9 GLUM Class

GLUM Class	Geotechnical Limitations	% of Total Area	Area (ha)
I	Low	15.6	583
II	Moderate	28.7	1 073
IIS	Moderate	0.1	2
III	High	32.2	1 202
IV	Extreme	21.7	812
Unclassified		1.7	63
		100.0	3 735

Table B10 Slope Gradient, Aspect, Geology, Erosion and Instability

Slope Gradient	Aspect	Surface Geology*	No Appreciable Erosion (ha)	Appreciable Erosion (ha)			Instability (ha)		Area (ha)	Area Instability Index
				Sheet	Rill	Gully	WDL*	GI*		
0–5°	Flat	V	214	8	0	0	0	0	222	0
		G	2	0	0	0	0	0	2	0
		S	0	0	0	0	0	0	0	0
		C	98	2	0	20	0	0	120	0
		A	43	0	0	0	0	0	43	0
		L	35	0	0	0	0	0	35	0
		F	53	12	0	0	0	0	65	0
5–15°	N	V	61	4	0	0	0	0	65	0
		G	0	0	0	0	0	0	0	0
		S	0	0	0	0	0	0	0	0
		C	24	0	0	4	0	0	28	0
		A	0	0	0	0	0	0	0	0
		F	0	0	0	0	0	0	0	0
	NE	V	63	4	0	2	0	0	69	0
		G	2	0	0	0	0	0	2	0
		S	0	0	0	0	0	0	0	0
		C	18	0	0	6	0	0	24	0
		A	0	0	0	0	0	0	0	0
		F	0	0	0	0	0	0	0	0
	E	V	106	6	0	2	0	0	114	0
		G	2	2	0	2	0	0	6	0
		S	0	0	0	0	0	0	0	0
		C	47	0	0	6	0	2	55	0.04
		A	0	0	0	0	0	0	0	0
		F	0	0	0	0	0	0	0	0
	SE	V	43	4	0	0	0	2	49	0.04
		G	2	0	0	0	0	0	2	0
		S	0	0	0	0	0	0	0	0
		C	0	0	0	6	0	0	6	0
		A	0	0	0	0	0	0	0	0
		F	0	0	0	0	0	0	0	0
	S	V	63	2	0	0	0	0	65	0
		G	4	0	0	0	0	0	4	0
		S	0	0	0	0	0	0	0	0
		C	20	0	0	4	0	0	24	0
		A	2	0	0	0	0	0	2	0
		F	0	0	0	0	0	0	0	0
	SW	V	33	12	0	0	0	2	47	0.04
		G	2	0	0	0	0	0	2	0
		S	0	0	0	0	0	0	0	0
		C	12	0	0	6	0	0	18	0
		A	0	0	0	0	0	0	0	0
		F	2	0	0	0	0	0	2	0
	W	V	39	10	0	4	0	0	53	0
		G	0	0	0	0	0	0	0	0
		S	0	0	0	0	0	0	0	0
		C	12	0	0	8	0	0	20	0
		A	0	0	0	0	0	0	0	0
		F	0	0	0	0	0	0	0	0
	NW	V	53	16	0	2	0	2	73	0.03
		G	0	0	0	0	0	0	0	0
		S	0	0	0	0	0	0	0	0
		C	14	0	0	6	0	0	20	0
		A	0	0	0	0	0	0	0	0
		F	0	0	0	0	0	0	0	0
15–30°	N	V	84	4	0	4	0	10	102	0.10
		G	0	0	0	0	0	0	0	0
		S	0	0	0	0	0	0	0	0
		C	10	0	0	10	0	2	22	0.09
		F	0	0	0	0	0	0	0	0
	NE	V	106	4	0	2	0	12	124	0.10
		G	0	0	0	0	0	4	4	1.00
		S	0	0	0	0	0	0	0	0
		C	10	0	0	6	0	2	18	0.11
		F	0	0	0	0	0	0	0	0
	E	V	102	2	0	4	0	6	108	0.06
		G	6	0	0	0	0	0	6	0
		S	0	0	0	0	0	0	0	0
		C	20	0	0	4	0	6	30	0.20
		F	2	0	0	0	0	0	2	0
	SE	V	75	4	0	4	4	4	91	0.09
		G	4	9	0	0	0	2	6	0.33
		S	0	0	0	0	0	0	0	0
		C	12	0	0	12	0	0	24	0
		F	0	0	0	0	0	0	0	0
	S	V	69	2	0	8	0	12	91	0.13
		G	2	0	0	0	0	0	2	0
		S	0	0	0	0	0	0	0	0
		C	0	0	0	8	0	2	10	0.20
		F	0	0	0	0	0	0	0	0
	SW	V	90	0	0	4	0	18	112	0.16
		G	2	0	0	0	0	0	2	0
		S	0	0	0	0	0	0	0	0
		C	4	0	0	0	0	2	6	0.33
		F	0	10	0	0	2	0	12	0
	W	V	90	6	0	18	0	18	132	0.14
		G	0	0	0	0	0	0	0	0
		S	0	0	0	0	0	0	0	0
		C	12	0	0	0	0	4	16	0.25
		F	0	8	0	0	0	0	8	0
	NW	V	71	2	0	8	0	14	95	0.15
		G	0	0	0	0	0	0	0	0
		S	0	0	0	0	0	0	0	0
		C	2	0	0	2	0	4	8	0.5
		F	4	2	0	0	0	0	6	0

* For legend see Table B10 (continued) on next page.

Table B10 Slope Gradient, Aspect, Geology, Erosion and Instability *(Continued)*

Slope Gradient	Aspect	Surface* Geology	No Appreciable Erosion (ha)	Appreciable Erosion (ha)			Instability (ha)		Area (ha)	Area Instability Index
				Sheet	Rill	Gully	WDL*	GI*		
30–40°	N	V	78	0	0	0	0	31	109	0.28
		G	8	0	0	0	0	0	8	0
		S	0	0	0	0	0	0	0	0
		C	0	0	0	0	0	2	2	1.00
		F	2	0	0	0	0	0	2	0
	NE	V	110	0	0	4	6	73	193	0.41
		G	6	0	0	0	0	0	6	0
		S	0	0	0	0	0	0	0	0
		C	4	0	0	0	0	4	8	0.50
		F	2	0	0	4	0	0	6	0
	E	V	116	14	0	10	12	84	236	0.41
		G	8	4	0	0	0	0	12	0
		S	0	0	0	0	0	0	0	0
		C	0	0	0	2	0	2	4	0.50
		F	0	4	0	0	0	0	4	0
	SE	V	67	6	0	2	2	55	132	0.43
		G	8	8	0	0	0	2	18	0.11
		S	0	0	0	0	0	0	0	0
		C	0	0	0	4	0	0	4	0
	S	V	41	0	0	0	0	45	86	0.52
		G	4	0	0	0	0	8	12	0.67
		S	0	0	0	0	0	0	0	0
		C	0	0	0	0	0	0	0	0
	SW	V	67	6	0	4	0	67	144	0.47
		G	0	0	0	0	0	0	0	0
		S	0	0	0	0	0	0	0	0
		C	0	0	0	0	0	2	2	1.00
	W	V	57	4	0	2	2	53	118	0.47
		G	8	0	0	0	0	0	8	0
		S	0	0	0	0	0	0	0	0
		C	0	0	0	0	0	0	0	0
		F	4	0	0	0	0	0	4	0
	NW	V	49	2	0	4	2	29	86	0.36
		G	0	0	0	0	0	2	2	1.00
		S	0	0	0	0	0	0	0	1.00
		C	0	0	0	0	0	6	0	1.00
>40°	N	V	2	0	0	0	4	0	6	0.67
		G	0	0	0	0	0	0	0	0
		S	0	0	0	0	0	0	0	0
	NE	V	41	0	0	0	4	2	47	0.13
		G	0	0	0	0	0	0	0	0
		S	0	0	0	0	0	0	0	0
	E	V	47	0	0	0	18	6	71	0.34
		G	0	0	0	0	0	0	0	0
		S	0	0	0	0	0	0	0	0
	SE	V	16	0	0	0	16	0	32	0.50
		G	0	0	0	0	0	0	0	0
		S	0	0	0	0	0	0	0	0
	S	V	24	0	0	0	22	0	46	0.48
		G	0	0	0	0	0	0	0	0
		S	0	0	0	0	0	0	0	0
	SW	V	0	0	0	0	4	0	4	1.00
		G	0	0	0	0	0	0	0	0
		S	0	0	0	0	0	0	0	0
	W	V	10	0	0	0	2	0	12	0.17
		G	0	0	0	0	0	0	0	0
		S	0	0	0	0	0	0	0	0
	NW	V	6	0	0	0	2	0	8	0.25
		G	0	0	0	0	0	0	0	0
		S	0	0	0	0	0	0	0	0

Note: V=volcanic rocks G=granitic rocks C=colluvium
A=alluvium L=littoral deposits F=fill and reclamation
WDL=well defined landslips and coastal instability
GI=general instability

Table B11 Geology, Erosion and Instability

Geological Unit	No Appreciable Erosion (ha)	Appreciable Erosion (ha)			Instability (ha)		Total Area (ha)	Area Instability Index
		Sheet	Rill	Gully	WDL	GI		
Reclamation	37	24	0	0	2	0	63	0.03
Fill	33	12	0	4	0	0	49	0
Alluvium:								
—undifferentiated	45	0	0	0	0	0	45	0
Littoral Zone	8	6	0	0	0	0	14	0
Colluvium:								
—volcanic	302	2	0	86	0	37	427	0.09
—granitic	8	0	0	18	0	0	26	0
—sedimentary	0	0	0	0	0	0	0	0
—mixed	12	10	0	12	0	4	24	0.14
Repulse Bay Formation:								
—undifferentiated volcanics	0	0	0	0	0	0	0	0
—sedimentary rocks and waterlaid volcanics	6	0	0	0	0	0	6	0
—acid lavas	271	34	0	14	59	106	484	0.34
—mainly banded acid lavas some welded tuffs	467	32	0	16	10	173	698	0.26
—coarse tuff	0	0	0	0	0	0	0	0
—agglomerate	2	2	0	0	0	0	4	0
—dominantly pyroclastics and some lavas	1 348	54	0	59	33	267	1 761	0.17
Needle Hill Granite (Fine grained phase)	0	0	0	0	0	0	0	0
Hong Kong Granite	53	14	0	0	0	10	77	0.13
Quartz Monzonite	4	0	0	2	0	2	8	0.25
Granophyric Microgranite	10	0	0	0	0	8	18	0.44
Feldspar Porphyry	0	0	0	0	0	0	0	0
Ma On Shan Granite	0	0	0	0	2	0	0	0
Cheung Chau Granite	0	0	0	0	4	0	0	0
Sung Kong Granite	0	0	0	0	0	0	0	0
Sung Kong Granite (Medium grained phase)	0	0	0	0	0	0	0	0
Tai Po Granodiorite	0	0	0	0	0	0	0	0

Table B12 Existing Land Use (From aerial photograph interpretation by the Geotechnical Control Office in 1984)

Existing Land Use	% of Total Area	Area (ha)
Developed	547	14.6
Undeveloped	2 248	60.2
Military	98	2.6
Country Park	651	17.4
Squatters	182	4.9
Ponds	10	0.3
Total	3 735	100.0

Table B13 Existing Land Use and GLUM Class

Existing Land Use	Area in GLUM Class (ha)				
	I	II	III	IV	Unclassified
Two storey residential	59	65	41	12	0
Intermixed	0	4	0	2	0
Industrial	0	33	2	2	0
Commercial	4	8	0	0	0
Park (open space)	0	2	0	0	0
Golf course	22	16	55	8	0
School	12	0	0	0	0
Hospital	4	0	0	0	0
Temples	2	0	4	0	0
Police/fire station	0	2	2	0	0
Wharves	0	6	0	0	0
Roads	10	4	18	4	0
Military	4	14	20	57	2
Cemetery	0	2	2	0	0
Prison	0	6	2	0	0
Horticulture	10	14	35	10	0
Fish farming	0	0	0	0	10
Undefined agriculture	29	33	53	6	0
Undisturbed areas (undeveloped)	304	583	683	437	49
Country park	73	180	141	255	2
Squatters—low intensity	18	35	49	6	0
Squatters—medium intensity	8	24	14	4	0
Squatters—high intensity	0	8	12	2	0
Construction	20	18	22	2	0
Reclamation (excluding other uses)	0	2	4	0	0
Landfill	0	12	16	2	0
Temporary land use	2	0	0	0	0
Artificial slopes	0	2	24	2	0
Total 3 735	583	1 073	1 202	812	63

APPENDIX C

SUPPLEMENTARY INFORMATION

List of Figures

List of Tables

APPENDIX C

SUPPLEMENTARY INFORMATION

C.1 Description of Geological Units

C.1.1 *Introduction*

The geological descriptions presented in this Appendix are drawn mainly from the Report on the Geological Survey of Hong Kong prepared by Allen & Stephens (1971). Supplementary information on superficial geology has been obtained from the Terrain Classification Map (TCM) and from the evaluation of records of site investigations carried out within the study area.

The geology of the Clear Water Bay portion of the New Territories is dominated by the volcanic rocks of the Repulse Bay Formation and the area contains only small outcrops of acid igneous rocks. It is probable that the granitic batholith extends beneath the volcanic rocks and therefore the Repulse Bay Formation occurs as a roof pendant.

C.1.2 *Volcanic and Volcaniclastic Units*

The Volcanic and Volcaniclastic Rocks of the Repulse Bay Formation consist of a succession of coarse tuffs, welded tuffs and lavas rich in quartz which were deposited during a period of volcanic activity in the mid-Jurassic period, approximately 160 million years ago. During periods of volcanic inactivity, thin sequences of sedimentary rocks were deposited in streams and lakes. These sedimentary rocks are now irregularly distributed throughout the Formation, having been enclosed by later eruptions. The Formation is sub-divided into a number of lithological units by Allen & Stephens (1971) and these are discussed below.

(i) *Sedimentary Rocks and Water-laid Volcaniclastic Rocks (RBs)*

This rock unit occupies only a small area in the north near Wo Mei. It consists of thin bands of chert and sandstone. The sandstone becomes coarser to the south until it grades into a coarse tuffaceous sediment. The boundaries appear to be tectonically disturbed and the stratigraphic relationships with the enclosing tuffs are unclear. The occurrence probably represents a small lake deposit.

(ii) *Acid Lavas (RBv)*

This rock unit outcrops on the islands of the Ninepin Group, Bluff Island, Basalt Island and on the mainland north of High Junk Peak and in the eastern part of the Clear Water Bay Country Park.

The unit forms a discrete flow of fairly uniform rhyolite containing abundant phenocrysts of pink feldspar, white feldspar and quartz. The feldspar grain size is relatively uniform and does not normally exceed 6 mm.

The rock is subject to prominent columnar jointing with columns varying in diameter from 200 mm up 2 m, with the mean being 800 mm. The attitude of most of the columns and the joint planes normal to their lengths indicate that the flow or sheet in which they are formed dips at low angles to the east.

Within the Clear Water Bay peninsula, the rhyolite overlies banded lavas of the RBvb unit but on the southeastern slopes of Tin Ha Shan it rests on welded tuff and, in one location, on a very thin sheet of spherulitic rhyolite. Boulders on hill-slopes northwest of Fat Tong Point exhibit columnar jointing.

(iii) *Mainly Banded Acid Lavas, Some Welded Tuffs (RBvb)*

This unit occurs extensively in the Clear Water Bay study area. Its principal component is amygdaloidal banded rhyolite, but there are, in addition, banded trachyandesite, spherulitic rhyolite and welded tuff. The unit is a specific stratigraphic horizon. In all locations it is overlain by columnar jointed rhyolite and it is underlain by an extensive sedimentary unit. The unit contains no explosively erupted tuffs or sedimentary rocks and contains only rocks which have originated from mobile fluids.

The exposure on the Clear Water Bay peninsula consists of a lower flow of spherulitic rhyolite and an upper flow, or flows, of trachyandesite.

The rhyolite is about 90 m thick immediately west of High Junk Peak where it forms a distinct topographic feature. It extends northwards, becoming thinner, for about 2 km and southwards to the sea on the north side of Clear Water Bay.

The rock is usually light green with phenocrysts of feldspar, usually less than 1 mm long, and small spherulites visible in hand specimen. It commonly contains small spots of limonite, and there are locations where the most distinctive feature of the rock is the streakiness caused by limonite-filled vugs.

The spherulitic rhyolite is succeeded by banded, porphyritic trachyandesite that is characterised by a lack of quartz phenocrysts. The visible feldspar phenocrysts are white and are usually less than 5 mm long. The colour of the groundmass is variable but is commonly dark bluish green. This rock is always broadly banded, the banding being generally contorted and folded. The hilltop immediately west of Clear Water Bay Beach consists of this rock it is also exposed extensively in the southern part of the peninsula where the blocky, flow banded and amygdaloidal top of the flow is exposed about 1 km north of Fat Tong Point. Veins of this lava cut spherulitic rhyolite on the hillside northwest of Clear Water Bay Beach.

Both spherulitic rhyolite and trachyandesite outcrop on Shelter Island. The spherulitic rock is, however, confined to the northwestern part. It weathers to a white colour, is thinly flow banded, and contains spherulites up to 5 mm in diameter. The trachyandesite is brecciated along narrow zones. It is extensively flow banded and occurs in the central and eastern parts of Shelter Island.

(iv) *Agglomerate (RBag)*

A small outcrop of agglomerate is exposed on the eastern side of Junk Bay south of Yau Yue Wan. It varies from tuff breccia to breccia and contains blocks of banded siltstone, coarse tuff, fine tuff, grey and purple chert, sandstone, pumice and lapilli tuff. It is enclosed within rocks of the RBp unit and is partly obscured by fill and reclamation. This unit tends to be deeply weathered and closely jointed.

(v) *Pyroclastic Rocks with Some Lavas (RBp)*

This rock unit consists mainly of fine grained tuffs, but there are numerous deposits of thinner units formed from incandescent ash flows.

Within the study area, the unit forms a large part of the western and northern portions of the mainland. Rocks of the unit also outcrop on Tin Ha Shan. Tung Lung Island consists entirely of this rock unit.

Welded lapilli tuff is predominant on Tung Lung Island and adjacent parts of the Clear Water Bay peninsula. On Tung Lung Island, the welded tuff is dark grey and has a eutaxitic texture. Angular and rounded blocks of pumiceous or vesicular rock are abundant and, in parts, attain a diameter of 200 mm or more. The surfaces of boulders and outcrops are invariably pitted; most holes are voids and may represent gas-filled cavities in the ash flow. Flow structures are either horizontal or have low dips, but the strike is not constant. The rock does not vary much in outcrop appearance anywhere on Tung Lung Island, which suggests that it is within a single ash flow more than 200 m thick.

White massive lapilli fine tuff, and some water-laid tuffs and siltstones, occur between two east to west trending faults on the large peninsula to the south of Tung Lung Island. A small area of massive tuff, also fault bounded, is exposed on the coast of Shek Chung Kok, while on the north coast of the island there is an outcrop of rhyodacite beneath the welded tuff.

Lapilli welded tuff is again the predominant rock on the mainland opposite Tung Lung Island, and it outcrops northwards along the coast of Clear Water Bay beneath banded lavas as far as Hang Hau Town. It is exposed along the coast of Port Shelter northeast of Hang Hau Town.

Massive lapilli coarse tuff is the dominant rock in the peninsula on the western side of Junk Bay from Lei Yue Mun Point northwards to Tate's Cairn. The rock is locally blocky and grades into an agglomerate on the northeastern side of Junk Bay. Northeast of this zone the lapilli tuff is welded and crops out in a belt trending north to northeast from Tai Sheung Tok, through Razor Hill to Nam Wai. Unwelded tuff occurs in the east of this zone. Most of the tuff in this area was formed by explosive volcanic action. The main rock type is lapilli tuff in which some of the lapilli and many bombs have the characteristic almond shape and rapidly cooled crust of ejectamenta formed by passage through the air during explosive eruptions.

C.1.3 *Intrusive Igneous Rocks*

Although the study area is probably completely underlain by an extensive granitic batholith, the surface outcrop of associated rocks is limited. This may be due to an eastwards dip of the roof of the batholith, as illustrated in the geological cross-section in Figure C1.

From evidence gathered in other parts of the Territory, the igneous intrusive rocks are considered by Allen & Stephens (1971) to have been emplaced in a succession of phases which began during the Upper Jurassic period (160 million years ago) and concluded at the start of the Cretaceous period (135 million years ago).

In general, five discrete phases of intrusion have been identified by Allen & Stephens (1971). These are summarised in Table C1. Representatives of only two of these phases occur in the Clear Water Bay study area.

Table C1 Intrusive Igneous Rock Types in Hong Kong (Allen & Stephens, 1971)

Phase	Igneous Rock Type	Present in Study Area
1	Tai Po Granodiorite	No
2	Fan Lau Porphyritic Granite Ma On Shan Granite Cheung Chau Granite Sung Kong Granite	No No No No
3	Quartz Monzonite Feldspar Porphyry Dyke Swarm	Yes No
4	Granophyric Microgranite Needle Hill Granite Hong Kong Granite	Yes No Yes
5	Dolerite	No

(i) *Quartz Monzonite (Mo)*

This rock type is present as an elongate dyke-like structure south of Tin Ha Shan. This body trends roughly east to west for about 1 500 m and is up to 100 m wide. The outcrop is covered by the sea in the west and is truncated in the east by a fault.

The rock is grey to pinkish grey, fine to medium grained and porphyritic. The coarse grained phenocrysts are composed of pink and white feldspar with occasional quartz. The rock is fairly uniform in appearance throughout its outcrop and has orientated feldspar crystals that are most apparent on the weathered surfaces.

Usually, the quartz monzonite has a chilled margin about 15 mm across at the contact, followed by a fine grained porphyritic phase of about 600 mm thickness. This phase becomes coarser towards the centre of the dyke. The country rock into which the quartz monzonite has been injected is usually undisturbed.

(ii) *Hong Kong Granite (HK)*

This rock unit occurs only on the western and northern margins of the study area, where it forms part of a large batholith that is extensively exposed in the adjacent Hong Kong and Kowloon (GASP 1) study area. It is part of a large circular intrusion incorporating the Kowloon Peninsula, Kwun Tong, and northern Hong Kong Island.

The dominant rock in the intrusion of Hong Kong Granite is medium grained, equigranular, non-porphyritic, pale pink or grey granite. The pink colour is partly the result of iron staining. The main constituents of the rock are potassium feldspar, quartz, plagioclase, biotite and muscovite. Accessory minerals usually include pyrite, calcite, apatite, epidote and orthite.

The contact with the volcanic rocks of the Repulse Bay Formation is well exposed in a quarry north of Lei Yue Mun Pass, where it dips at about 25° to the east.

The Hong Kong Granite is considered to be the youngest of the granitic intrusions, as evidence from elsewhere in the Territory indicates that it is not truncated by any other phases except for the post tectonic dolerite.

The Hong Kong Granite is subject to very deep weathering and decomposes to a silty sand. During decomposition, the action of percolating groundwater eluviates the fabric of the rock mass, leaving it with a high voids ratio and a low density.

(iii) *Granophyric Microgranite (Mc)*

Fine-grained porphyritic granite is exposed on the Clear Water Bay peninsula and north of Junk Island. The rock is a granophyric alkali granite.

In thin section, the phenocrysts are micro-perthite, often with crude cross-hatching, and quartz. A few small phenocrysts of albite have rim intergrowths of quartz. Chloritized biotite is not common, but when it occurs, it is usually associated with minor quantities of sericite, calcite and an opaque mineral. The groundmass is entirely granophyric.

The age of this rock is uncertain but probably represents the very last phase of igneous intrusion before the emplacement of the post-tectonic dolerites.

The coastal exposures have very little weathered material, and this rock tends to have a thinner weathering profile compared to the Hong Kong Granite due to its finer grain size.

C.1.4 *Superficial Units*

Within the study area, the superficial deposits form a complex inter-related sequence. The deposits may be subdivided on the basis of their age, genetic origin, geographic location and material characteristics. From an engineering point of view, the latter two are important but, in order to aid the prediction of these, the first two aspects should be considered.

All the superficial deposits are, geologically, very young, but they represent various important events in the recent geological history of this region. The level of the sea has changed with the cyclic advance and retreat of the ice caps. This changing sea level has had a marked effect on the deposition and erosion of superficial materials within the Territory.

On a genetic basis, these deposits can be subdivided as follows:

(i) *Colluvium*

This material has its origin through gravity sliding of soil and rock with water triggering but not transporting the unconsolidated mass. Surrounding Junk Bay and on the east coast of the study area are steep unstable hillslopes that have generated numerous lobes of colluvium. The largest deposits of these materials are at Tai Po Tsai and Tseung Kwan O. The large deposit at Tseung Kwan O extends beneath the sea and is overlain by more recent marine deposits of shelly silt and clay. In other parts of the Territory, colluvium may be of a variety of ages. The material deposited below sea level is at least 7 000 years old and probably corresponds to the last major fall and rise in sea level. The debris resulting from recent landslides, which is also classified as colluvium, may be quite young.

This range of ages results in a wide variety of material properties ascribed to the general class of colluvium.

The older deposits will have undergone a change in their particle size distribution as clay is produced in the weathering process. Consolidation also takes place with time, which will increase the material's insitu density. The younger deposits may also have a high clay content derived from the weathered mantle prior to failure, but this fraction will be rapidly removed if the material occurs within a drainage path. Fine material will be washed out, leaving a coarse bouldery deposit similar to those found on the slopes above Ngam Ha Tong on the Clear Water Bay Peninsula.

A further complicating factor is the nature of the parent rock type from which the deposit was derived. In this study, the geology is dominated by volcanic rocks of the Repulse Bay Formation. The particle size distributions of the colluvial materials are similar to those of the weathered profile of the volcanic rocks from which they were derived. In general, the colluvium consists of angular fresh rock fragments in a fine silty matrix. The limited deposits of granitic-derived colluvium in the west of the study area contains more coarse silty sand with weathered rock particles.

Colluvium frequently occurs within or adjacent to drainage channels and is commonly eroded and transported to be redeposited as alluvium. The transition from colluvium to alluvium is gradational, as illustrated by the interdigitation of colluvial lobes into the small alluvial plains at Tseung Kwan O, Tai Wan Tau, Tai Chik Sha and Sheung Lau Wan.

(ii) *Alluvium*

These deposits comprise all material deposited by flowing water and include colluvial debris reworked by streams. Alluvium can be classified on the basis of its age, depending on whether the deposit pre-dates or post-dates the Holocene marine transgression. The younger alluvium is not very extensive within this study area. The principal occurrences are at the distal parts of colluvial fans. The deposits are usually deltaic in form. Younger alluvium consists of varying proportions of cobbles, gravel, sand, silt and clay with only a crude stratification.

The older alluvium does not outcrop at the surface and occurs beneath the marine deposits in Junk Bay and off the eastern coast.

In the vicinity of Junk Bay, the older alluvium varies in thickness from about 3 m up to 16 m. Typically, it consists of layers of silty clay, clay and silty sand, sand, gravels and cobbles. The coarser lithic fragments are usually moderately weathered. Immediately above the contact with the underlying weathered insitu rock, the alluvium consists of cobbles and gravel. The older alluvium appears to be fluviatile in nature in this part of the Territory.

(iii) *Littoral Deposits*

These materials are formed by wave and tidal action with some aeolian transportation above the high tide level. Along the extensive coastline of this study area, littoral deposits of well sorted quartz sands have been deposited by wave and wind action. They are usually adjacent to small alluvial platforms or colluvial fans in sheltered areas such as Siu Chik Sha. The majority of the islands in the study area do not have extensive littoral deposits due to high current velocities and exposure to wave action; however the protected location of Junk Island has resulted in the deposition of littoral deposits on the north shoreline. The largest recreational beach in the study area is in the northwest of Clear Water Bay. Above the high tide level at this beach, wind blown (aeolian) sand has been deposited. These wind blown materials have a different particle size distribution and a lower density compared with the littoral deposits derived from wave action.

(iv) *Marine Deposits*

The marine deposits within the bounds of this study area have probably been laid down in the last 10 000 years and consist of grey shelly silts, clays and sands. The marine deposits are relatively unconsolidated, and the silt and clay layers are subject to large settlements when surcharged. In the areas near the head of Junk Bay, Hang Hau Town and Tiu Keng Wan, the sediments are mainly clayey silty sand with shell fragments. In the past, Joss House Bay has been dredged for sand.

The thickness of the marine deposits is variable with a maximum of 15 m recorded in the centre of Junk Bay. The marine deposits merge into a dark grey, clayey silty sand with shell fragments offshore of the alluvial deltaic deposits.

(v) *Man-Made Deposits*

This group includes all material deposited by man such as fill and reclamation. At the time of mapping, there were no extensive areas of this group of materials present due to the low intensity of existing development in the Clear Water Bay study area. When the Junk Bay New Town is completed there will be very large areas of man-made deposits.

The existing reclamation is mainly in the inner part of Junk Bay and was placed after the Second World War. The material is likely to contain a wide variety of materials that could include boulders, large fragments of masonry and other debris.

On the eastern side of Junk Bay, there is a large controlled tip. This contains soft compressible domestic and industrial waste interspersed with weathered volcanic material derived from a borrow area adjacent to the site. The character of the tip waste is likely to be highly variable, and it probably would be subject to very large and unpredictable settlements.

Some of the study area is affected by man-made structures. During construction, the natural terrain has been modified by cut and fill.

Fill for the preparation of most sites will probably have been derived from within the vicinity of the site. However, it is possible that some areas of fill may contain imported material that is geologically different to that which is found naturally on the site.

The method and degree of compaction of these deposits will vary, depending primarily on the date at which it was placed.

C.2 Site Investigation Data

The general intensity of the coverage by site investigations of the study area is illustrated in Figure C2. The listing of site investigations is not comprehensive, because it includes only investigations completed on behalf of the Hong Kong Government. Investigations carried out by private organisations and any investigations completed after June 1984 are not included.

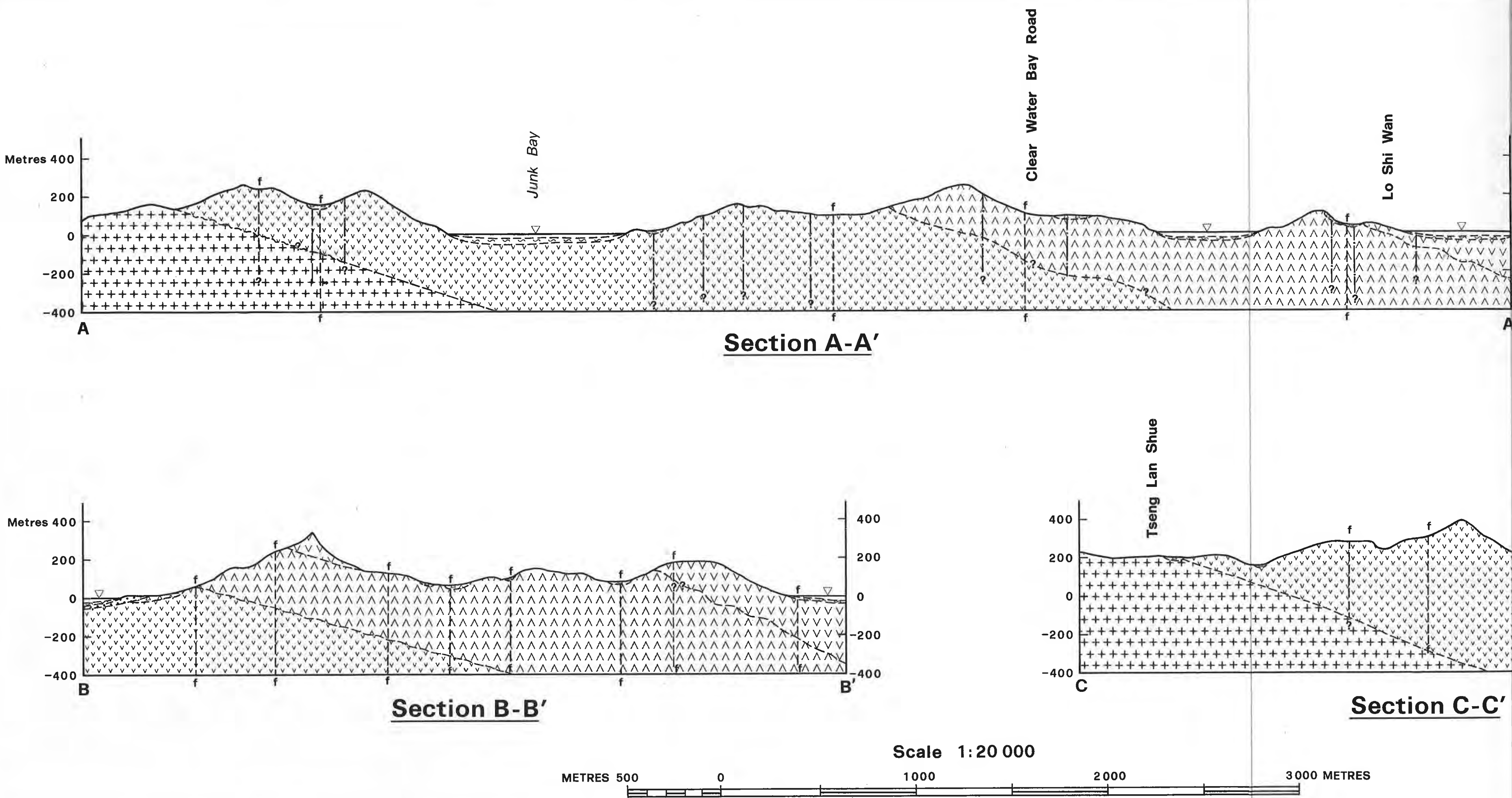
The Geotechnical Control Office GIU entry and retrieval system is based on a master grid marked on reference sheets. Each grid block is provided with an index card listing all the reports held within that individual grid block.

C.3 Aerial Photographs

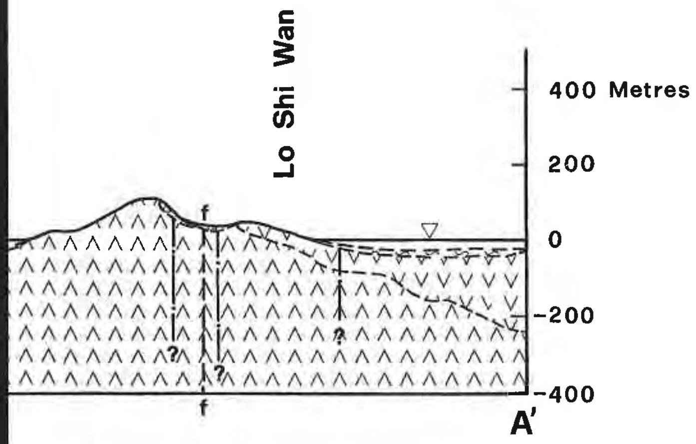
The Clear Water Bay study area has been extensively photographed from the air, and a very large number of vertical and oblique photographs are available from the Map Sales Office of the Survery & Mapping Office, Buildings & Lands Department. An abbreviated list of photographs is presented in Table C2.

C.4 Rainfall Data Relevant to the Clear Water Bay Study Area

A general appreciation of the annual and monthly rainfall distributions for the study area can be obtained from Figures C3 and C4. Figure C3 is a reproduction of the mean annual rainfall isohyets for the years 1952 to 1976, published by the Royal Observatory. Figure C4 is a histogram of monthly rainfall for three selected Royal Observatory rainfall stations. There are a total of six rainfall stations within the study area, the locations of which are indicated on Figure C5. Detailed monthly and annual rainfall information for these stations is available from the Royal Observatory.

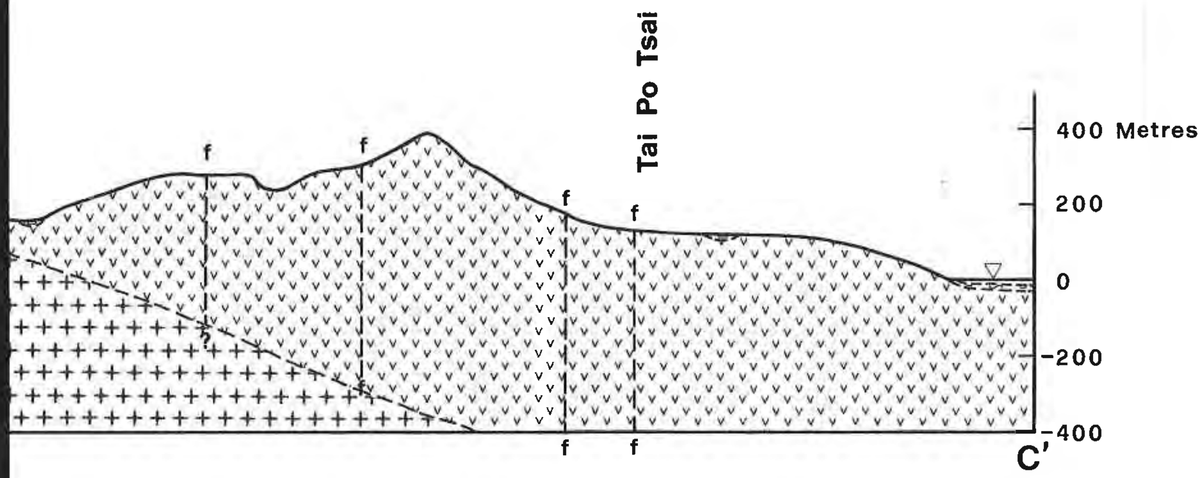


Geological Cross-sections – Clear Water Bay



ATTENTION: USERS

The bedrock geology shown on this sheet is that of Allen & Stephens (1971). Geological remapping of the Territory is currently underway and new geological maps at a scale of 1:20 000 and their accompanying memoirs should be consulted where available.



Section C-C'

3000 METRES

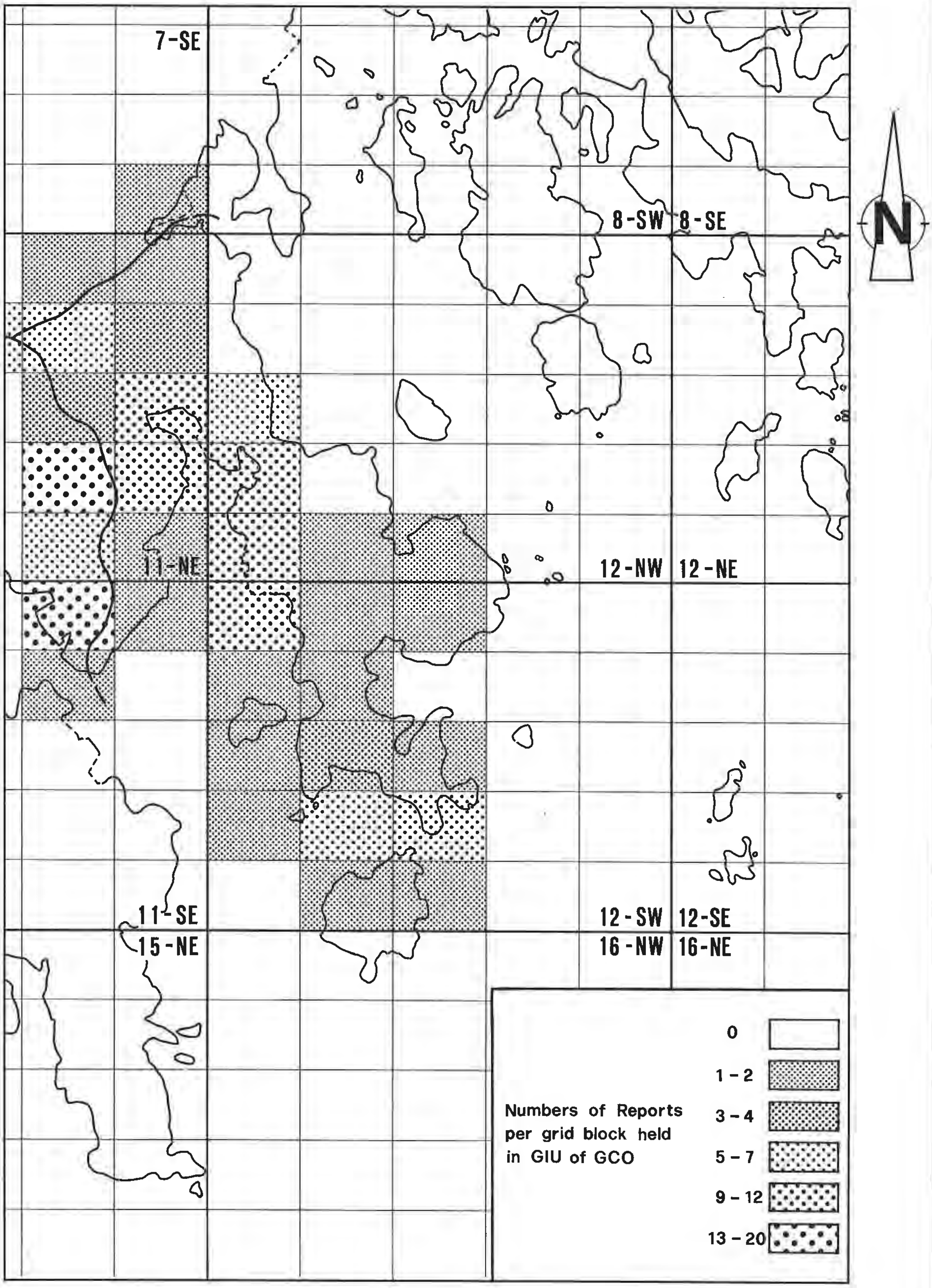
LEGEND

- Marine Deposit
- Hong Kong Granite
- Dominantly pyroclastic rocks with some lavas
- Acid lavas
- Mainly banded acid lavas
- Alluvium
- Colluvium
- – – – – – Geological Boundary
- —·—·— Geological photolineament
- f– – – –f Fault - plane shown diagramatically, actual dip and direction is unknown.

These cross-sections are scaled schematic diagrams only. The relationships illustrated in these sections are interpreted from selected site investigation data held in the Geotechnical Information Unit (GIU) of the GCO and from Allen and Stephens (1971).

All heights are in metres above Principal Datum which is approximately 1.20m below Mean Sea Level.

Compiled: A. Hansen	Drawn: C. P. Wan	Fig. C1
Scale: 1:20 000	Date: May, 1985	



Scale 1:100 000	Distribution of Site Investigation Reports Held in the Geotechnical Information Unit (GIU)	Fig. C2

Table C2 Selection of Aerial Photographs

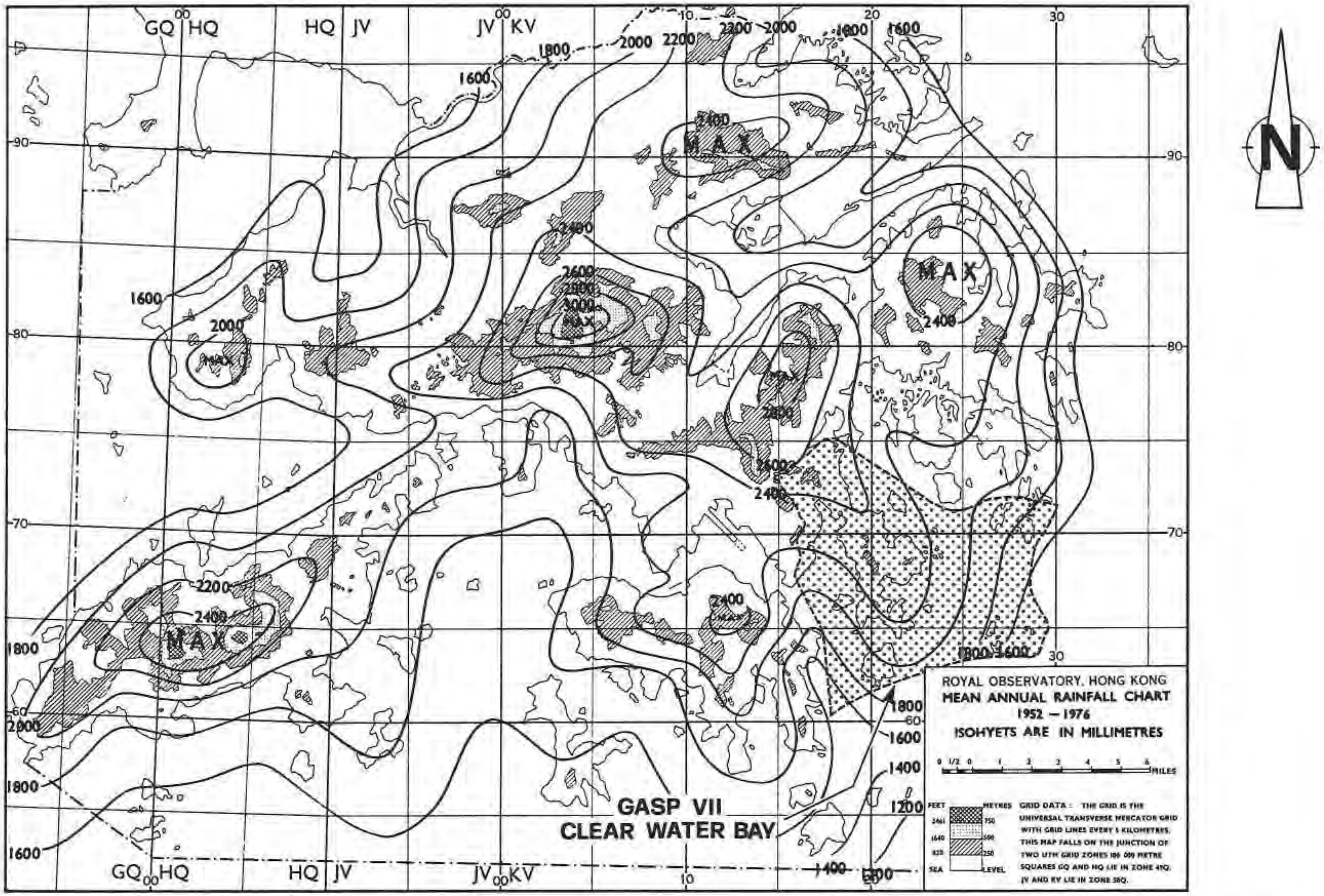
Year	Photograph Serial Number	Photograph Scale (Approx.)
1983	51732–51734	1:40 000
	51673–51688	1:40 000
	51383–51404	1:20 000
	51325–51334	1:20 000
	51261–51262	1:20 000
	50989–51049	1:8 000
	50225–50239	1:8 000
	50188–50192	1:8 000
	49988–49995	1:8 000
	49915–49933	1:8 000
	49853–49867	1:8 000
	49807–49817	1:8 000
	49591–49607	1:8 000
	59519–49533	1:8 000
	49331–49345	1:8 000
	48364–48374	1:9 000
	47711–47715	1:8 000
	47651–47657	1:8 000
	47599–47617	1:8 000
	47483–47506	1:8 000
	47440–47453	1:8 000
	47397–47404	1:8 000
	47189–47193	1:40 000
	47131–47140	1:40 000
	46822–46837	1:8 000
1982	46638–46651	1:8 000
	45642–45649	1:8 000
	45456–45462	1:8 000
	45382–45389	1:8 000
	45315–45323	1:8 000
	44602–44603	1:8 000
	44512–44529*	1:20 000
	44452–44466*	1:20 000
	44285–44306	1:8 000
	44237–44256	1:8 000
	44192–44198	1:8 000
	44084–44097	1:8 000
	43652–43661	1:8 000
	43314–43320	1:8 000
	43283–43289	1:8 000
	42408–42414	1:8 000
	41817–41821	1:8 000
	41466–41471	1:8 000
	40858–40864	1:8 000
	40682–40687	1:8 000
	40604–40624	1:8 000
1981	40534–40538	1:8 000
	39979–39981	1:8 000
	39945–39956	1:8 000
	39904–39914	1:8 000
	39857–39870	1:8 000
	39806–39817	1:8 000
	38649–38663	1:8 000
	38210–38223	1:8 000
	38178–38185	1:8 000
	37449–37453	1:8 000
	37384–37389	1:8 000
	37170–37180	1:8 000
	37085–37094	1:8 000
	36996–37020	1:8 000
1980	35414–35438	1:8 000
	32833–32834	1:8 000
	32778–32794	1:8 000
	32732–32740	1:8 000
	32681–32693	1:8 000
	32465–32478	1:8 000
	32395–32401	1:8 000
	32269–32278	1:8 000
	32189–32201	1:8 000
	32176–32182	1:8 000
	31498–31511	1:8 000
	31449–31451	1:8 000
	30871–30875	1:8 000
	30732–30738	1:8 000
	30084–30090	1:8 000
	30037–30044	1:8 000
	29849–29859	1:8 000

Note: Vertical and oblique aerial photographs are available from the Photographic Library, Survey & Mapping Office, Buildings & Lands Department, 14th Floor, Murray Bldg, Garden Road, Hong Kong.

Table C2 Selection of Aerial Photographs *(Continued)*

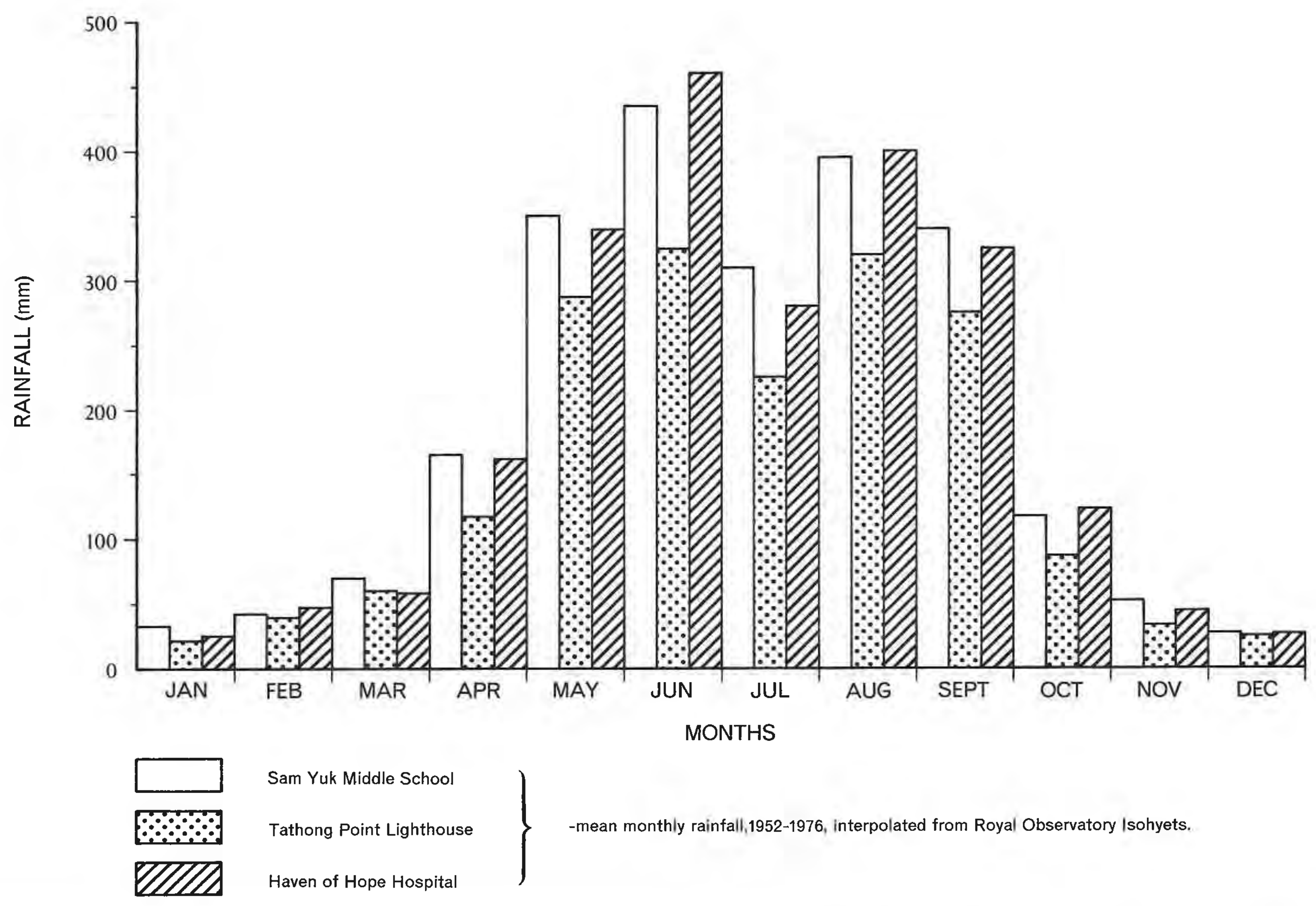
Year	Photograph Serial Number	Photograph Scale (Approx.)
1980	29781–29859	1:8 000
	29726–29756	1:8 000
	29498–29511	1:8 000
	28992–29020	1:8 000
	28956–27921	1:8 000
	28816–28819	1:8 000
1979	28078–28087	1:20 000
	28015–28031	1:20 000
	27947–27955	1:20 000
	27757–27765	1:20 000
	27293–27296	1:8 000
	27260–27261	1:8 000
	26629–26643	1:8 000
	26441–26445	1:8 000
	25961–25975	1:8 000
	25780–25790	1:8 000
	25740–25748	1:8 000
1978	24206–24211	1:8 000
	24168–24177	1:8 000
	24113–24115	1:8 000
	23911–23912	1:8 000
	22144–22146	1:8 000
	20805–20815	1:25 000
	20751–20753	1:25 000
1977	20391–20397	1:8 000
	20346–20362	1:8 000
	20295–20301	1:8 000
	19938–19959	1:8 000
	19315–19317	1:8 000
	18894–18913	1:8 000
	18719–18728	1:8 000
	18281–18297	1:8 000
1976	15355–15357	1:8 000
	15333–15336	1:8 000
	15316–15318	1:8 000
	14970–14977	1:10 000
	13028–13045	1:8 000
	12989–13005	1:8 000
	12961–12968	1:8 000
	12580–12581	1:8 000
1974	10437–10439	1:8 000
	10151–10153	1:8 000
	10127–10130	1:8 000
	9698–9711	1:25 000
	9290–9370	1:8 000
1973	8046–8050	1:25 000
	8035–8040	1:25 000
	8002–8006	1:25 000
	5476–5478	1:25 000
	5295–5297	1:10 000
	5290–5293	1:25 000
	5257–5262	1:10 000
1967	5665	1:25 000
	5620–5626	1:25 000
	5574–5590	1:25 000
	5521–5527	1:25 000
	5487–5491	1:25 000
1964	2831–2837*	1:25 000
	2600–2604*	1:25 000
	2532–2539*	1:25 000
	2498–2502*	1:25 000
	2453–2456*	1:25 000
1963	9359–9365*	1:7 800

Note: *indicates aerial photographs used during systematic terrain classification.



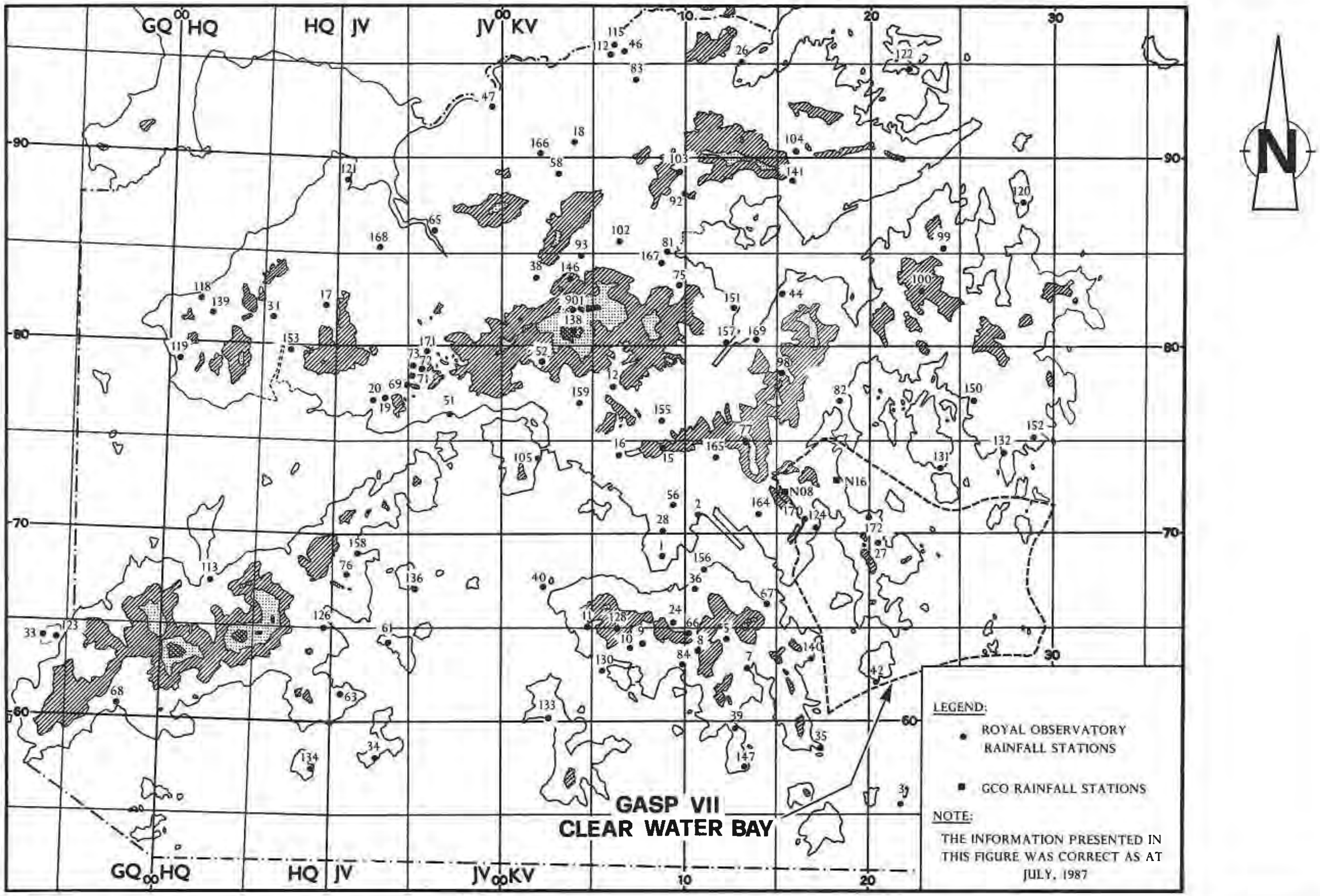
Mean Annual Rainfall Isohyets (1952–1976)

Fig. C3



Summary of Mean Monthly Rainfall Data

Fig. C4



Locations of Rainfall Stations

Fig. C5

APPENDIX D

INFLUENCE OF ROCK MASS AND TERRAIN CHARACTERISTICS ON PLANNING AND ENGINEERING IN HONG KONG

List of Figures

APPENDIX D

INFLUENCE OF ROCK MASS AND TERRAIN CHARACTERISTICS ON PLANNING AND ENGINEERING IN HONG KONG

D.1 Introduction

The descriptions of the material characteristics and properties which are contained in this Appendix are intended to give planners and engineers a background understanding of the components of the Territory's terrain and materials. These components are described in the context of natural landform evolution. Consideration of the significance of natural landform evolution will allow interpretation of the terrain as it relates to engineering properties and behaviour and their influence on development. The information contained in this Appendix is presented as background to Section 3.

D.2 Rock Mass Characteristics

These sections outline the principal reasons for the differing rock mass characteristics and their influence on the development and behaviour of weathered rock and soil, both in the evolution of natural terrain and in their relevance to engineering. In this context, they are relevant at the planning stage of a project as they are capable of influencing the engineering feasibility of a particular form of project through construction cost, ancillary works and long-term maintenance. Particular problems, if anticipated at the earliest stages, can be avoided or accommodated with the minimum disruption, delay or expense. The main discussion on the planning and engineering significance of geotechnical problems is given in Sections 3 and 4.

The portion of Figure D1 devoted to Rock Mass Characteristics, and reproduced in Figure D2, shows in sequence the factors which contribute to rock properties and which, through mass strength and structure, permeability and chemical stability, contribute to the control of landforming processes and engineering performance. The succeeding sections explain in general terms how the variations in rock mass characteristics arise. They are not intended to be thorough from the geological point of view. Geological descriptions of the particular rock types are given in Appendix C.1. The engineering properties such as strength or permeability are not specified in quantitative terms. Significant differences in the engineering properties of the individual rock types may occur, and these are indicated in Section 3.1 and in Table 3.1. However, the principal rock types exposed in the study area, the granites and volcanics, exhibit characteristic trends of mass behaviour. It is the qualitative differences in performance and characteristic terrain which can be interpreted at the planning stage to improve the quality of any planning decision.

D.2.1 *Mode of Generation and Texture*

It is the mode of generation of the rock which is often the major factor which controls the subsequent development of mass characteristics.

The mode of generation influences the grain or crystal size and texture and, hence, the intact strength, physical stability and intact porosity. Weathering is in part a direct function of porosity combined with chemical stability, which is related to mineralogy and mode of generation.

The tectonic history is related to the mode of generation of the rock, and on this depends the development of mass structure over a broad range of scale. Joints and faults are the result of the release of stresses built up during cooling, burial, intrusion, tectonic movement and unloading.

D.2.2 *Joints*

Joints are small fractures involving minimal movement, which generally occur at close spacings in the volcanics and wider spacings in the granites. Differences between volcanic and granite jointing occur and these enable the nature of potential stability problems to be anticipated. Jointing directly influences mass transport through mass strength and structural control, and indirectly through permeability and groundwater flow. In this latter respect, it directly influences weathering development and the form of the weathered profile.

Volcanic rock is subject to a variety and range of tectonic stresses, which generally result in intense jointing of the rock. The volcanic joints, at 0.2 to 1 m spacing, are often not laterally extensive (of the order of 5 m), and their orientations appear to be fairly random. This generally has the effect of allowing fairly uniform permeation of groundwater through the rock mass, although groundwater flow may be locally restricted.

By contrast to the volcanics, joints in granitic rock are often spaced from 2 to 10 m and are laterally extensive. Their wide spacing and open nature tend to concentrate groundwater flow in the joints. Extensive 'sheeting joints', parallel to the ground surface, are characteristic. Being tension cracks, the granite sheeting joints are rough and thus usually have a high apparent angle of friction.

The more randomly oriented, smoother, volcanic joints will influence the stability of cut faces although this may only result in surface 'ravelling'. Granite joints by contrast are less likely to bring about failure in rock unless steeply inclined, due to their high roughness or vertical orientation. Note, however, that weathering on joint planes effectively reduces their roughness, thereby decreasing stability.

D.2.3 *Porosity and Permeability*

Neither the porosity nor the permeability of the rock or soil mass have a significant bearing on large-scale planning decisions. However, the groundwater regime can adversely influence stability if changes of permeability occur, for instance in the construction of piled foundation or basements. Lumb (1964, 1972) discussed building settlements within the Territory.

Porosity relates to the capacity of rock or soil to hold liquid, and is thus an important factor in determining the rate of weathering. Permeability controls the rate of throughflow, which influences weathering and also stability through water pressure. Mass permeability is influenced by jointing in granites, since flow tends to be concentrated in the open joints, whilst in volcanics, water permeation is more uniform. Hence, both porosity and permeability are important factors in weathering decomposition and in the nature of the weathered profile.

D.2.4 *Weathering and the Weathered Profile*

The weathering process and its products exert a significant influence on the performance of the materials and on their response to transport processes. At the planning stage, therefore, consideration of the weathering process and its effects will help to produce feasible layouts for projects, so that they are less influenced by geotechnical threat and, hence, less costly to construct and maintain.

The nature of weathering and its problems may often be inferred from the shape of the terrain, its geology and evidence of existing landforming processes, factors which are all discussed or presented in this Report. The factors shown in Figure D3, some of which are discussed above, all exert varying influences on the weathering process. The rate of weathering breakdown is usually a function of rock porosity and permeability in conjunction with active and fluctuating groundwater flow. The differing chemical stability of various minerals comprising the rock results in non-uniform breakdown of the rock.

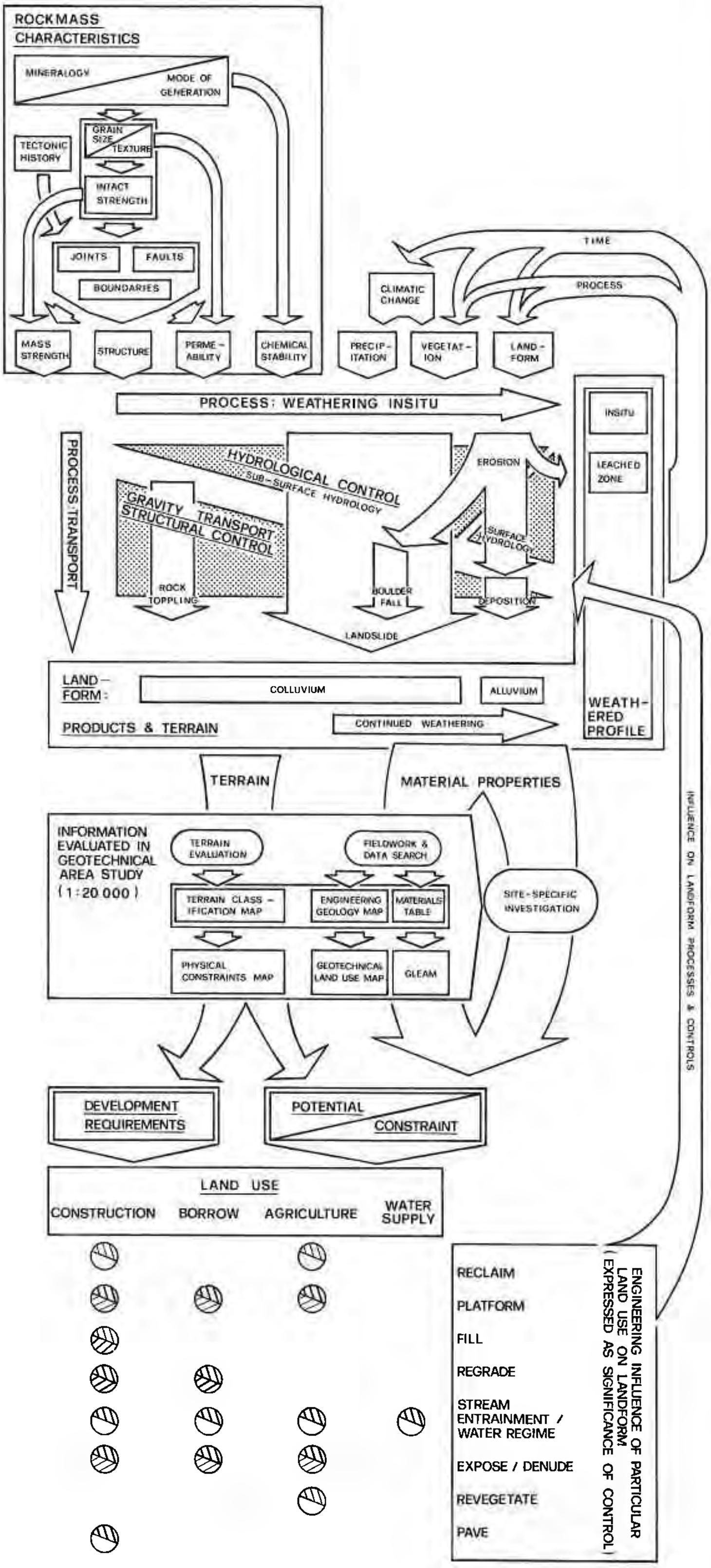
The weathered product of granitic rock is a loose, granular quartz soil because feldspars are broken down during weathering. The proportion of clay in the weathered soil depends on the balance between eluviation and deposition, which is related to the terrain. The texture of weathered granite makes it particularly susceptible to erosion on ridgecrests and other situations where natural vegetation is removed. By contrast, the weathered volcanic rocks have a higher proportion of silt size particles and, due to their clay content, to some extent are more resistant to erosion.

Weathering progresses as a function of porosity and permeability. Mass permeability is important in determining the nature of the weathered profile. Table A3 in Appendix A shows schematically the constituents of a complete weathering profile in granitic rock. Water flowing through the joints initiates breakdown of the intact rock away from the joints and leaves core boulders of relatively unweathered material in a matrix of weathered soil. This particular problem is associated with boulders in granite and granitic colluvium. As weathering progresses, the depth of completely weathered material increases (Zone A) until, in an old profile, Zones B and C may be almost completely absent. The depth of Zone D is thought to be related to the lowest depth of active groundwater flow, although weathering by other processes, may operate below this depth. The depth of the weathered profile in granite may exceed 90 m, which is considerably greater than that established in volcanic rock.

In volcanic rock, where the joint spacing is close and mass permeability is therefore more uniform than in granite, weathering appears to progress more uniformly, so that corestones are not often evident. The reasons for the generally thinner depth of the weathered mantle and for the rapid change from unweathered to completely weathered rock in volcanics are uncertain and are not widely considered in the literature. They may be due to topographic and hydrological factors prevailing during earlier climatic periods as well as to material properties.

Time, climatic change and the landform type combine with the physical characteristics outlined above to influence the processes and the present condition of the terrain. These are important variables, since they may introduce apparent anomalies into the weathered profile. Weathering profiles and landform patterns form over considerable periods of time and are balanced between the processes of weathering and erosion. Hence, rejuvenation or abandonment of an established weathering profile, removal of portions of a weathered mantle, or deposition and subsequent weathering of a colluvial blanket may result in a change in this balance. These changes often result from altered hydrological conditions. Although certain inferences may be made from the shape of the terrain as to trends in depth of the weathered profile (Ruxton & Berry, 1957, Ruxton, 1960), the current terrain may be the result of more recent transport processes, as described in Appendix D.3.

NATURAL AND MAN-MADE INFLUENCES ON LANDFORM EVOLUTION IN HONG KONG ; THE ENGINEERING CHARACTERISTICS AND PROCESSES WHICH INFLUENCE LAND USE POTENTIAL , AND THEIR EVALUATION WITHIN THE GAS PROGRAMME.



NATURAL LANDFORMING INFLUENCES :
SUBSURFACE & SURFACE VARIABLES.

LANDFORMING PROCESSES :
RELATIVE INFLUENCE OF HYDROLOGY, STRUCTURE & WEATHERING ON TYPES OF TRANSPORT PROCESS. (BACKGROUND TRIANGLES SHOW PROPORTION OF INFLUENCE OF CONTROL).

LANDFORM :
INDICATED AS PRODUCTS OF VARIOUS LANDFORMING PROCESSES.

GEOTECHNICAL AREA STUDIES :
CLASSIFICATION OF TERRAIN & ENGINEERING MATERIALS, INTERPRETATION OF LANDFORM IN TERMS OF GEOTECHNICAL POTENTIAL & CONSTRAINT FOR STRATEGIC PLANNING & ENGINEERING FEASIBILITY STUDIES. G A S PROVIDES PRELUDE TO SITE SPECIFIC INVESTIGATION.

INFLUENCES ON LAND USE :
POTENTIAL, CONSTRAINT, DEVELOPMENT REQUIREMENTS.

LAND USE CHART :
INTENSITY OF SHADING INDICATES ENGINEERING INFLUENCE OF PARTICULAR LAND USE ON

HYDROLOGICAL CONTROL
STRUCTURAL CONTROL THROUGH
MODIFICATION OF LANDFORM :

SLIGHT

MODERATE

SIGNIFICANT

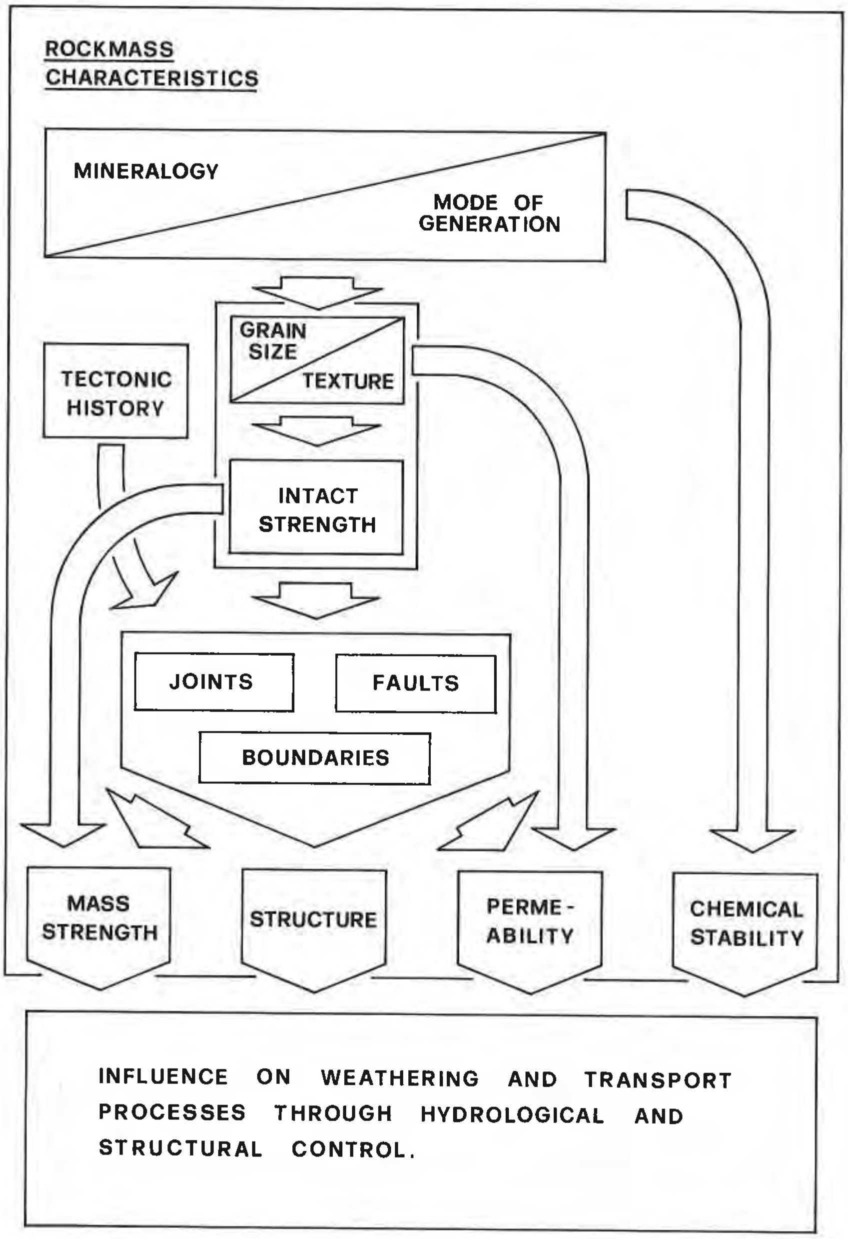
LEGEND :

BOXES INDICATE : CAUSE OR PRODUCT

ARROWS INDICATE : INFLUENCE, PROCESS, OR MECHANISM

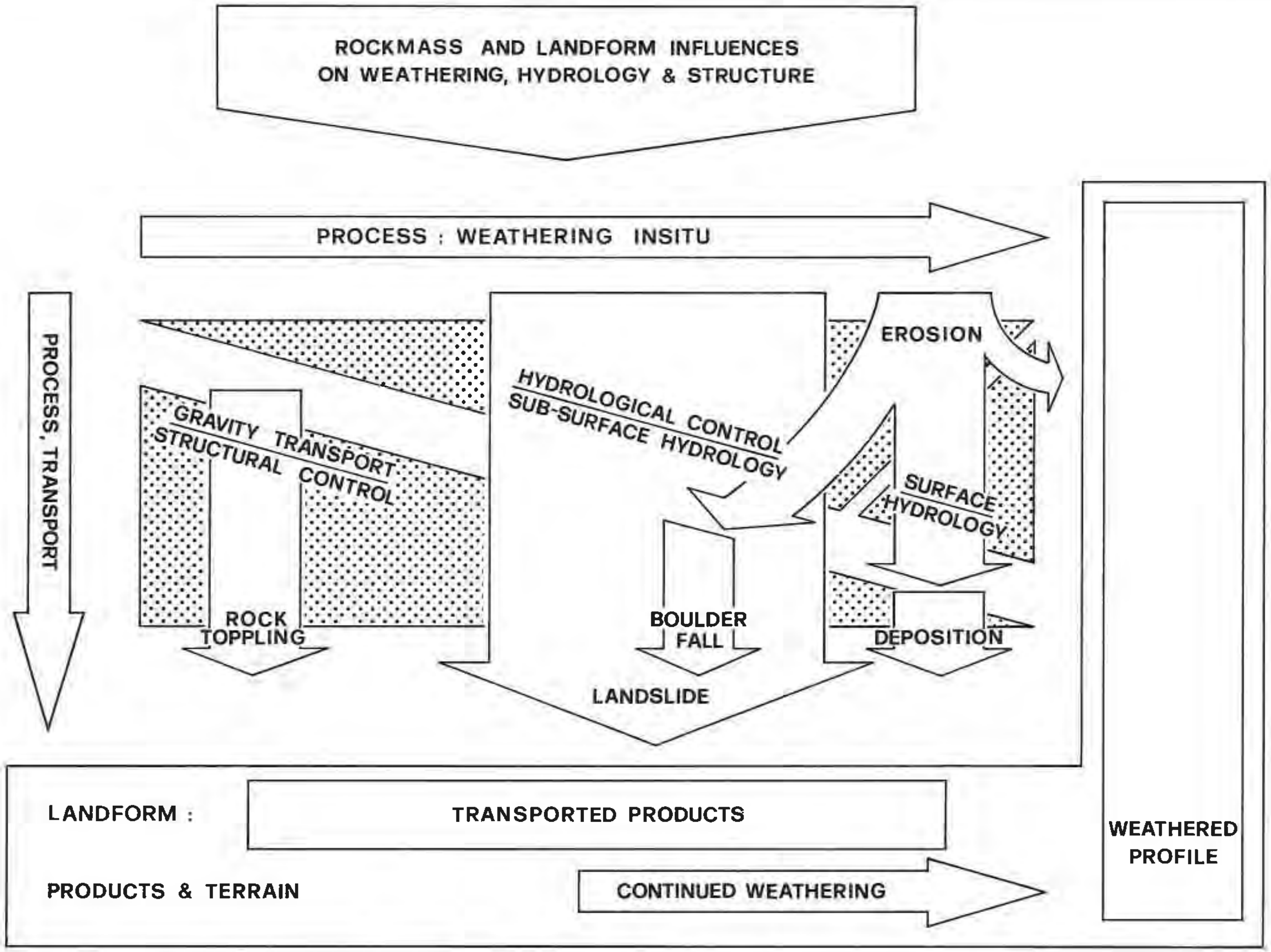
CIRCLES INDICATE : HUMAN INVOLVEMENT

Influence of Landforming Processes — Fig. D1



SUMMARY OF ROCKMASS CHARACTERISTICS WHICH ARE SIGNIFICANT IN INFLUENCING NATURAL LANDFORM AND ENGINEERING WORKS IN HONG KONG. (EXTRACT FROM FIG.D1)

Rock Mass Characteristics	Fig. D2



SUMMARY OF LANDFORMING PROCESSES IN TERMS OF THE RELATIVE IMPORTANCE OF WEATHERING HYDROLOGY AND STRUCTURE. (EXTRACT FROM FIG. D1)

(BACKGROUND TRIANGLES SHOW PROPORTION OF INFLUENCE OF HYDROLOGY AND STRUCTURE)

Landforming Processes	Fig. D3

D.2.5 *Faults*

A fault is a fracture in rock along which there is an observable amount of displacement. Faults rarely occur in isolation, and more extensive faults or fault zones often display associated local shattering of the rock. Hence they may cause concentration of groundwater flow which permits deeper weathering to occur. If so, they often become observable in surface reconnaissance and from aerial photograph interpretation as photo-geological lineaments.

D.2.6 *Boundaries*

Geological boundaries are often reflected geomorphologically and are sometimes enhanced by changes in vegetation. They commonly control the local hydrological regime and this, together with the local variations in structure and rock properties, is of significance in engineering work. Many geological boundaries are also faulted.

D.3 Engineering Considerations for Development Planning

D.3.1 *General*

Geotechnical problems will be minimised if development takes place in a manner which reflects the basic suitability of the terrain for a particular use. The following sections discuss the engineering significance of the major terrain-related factors which influence the suitability of land for development. The discussion relates to those features which are particularly important for planning and engineering feasibility.

In the Territory, the relief of the terrain is dramatic, and the pressures for development are very high. A considerable portion of the currently developed terrain and natural terrain with potential for development is subject to high to extreme geotechnical limitations. These limitations are often associated with, or are related to, either natural or man-made features. For example, Vail & Beattie (1985) discuss the failure and stabilization of earthworks in the Territory. Further development within the study area will necessitate the utilisation of natural or man-made terrain which has geotechnical limitations. Some of these features continually recur across the landscape and have similar engineering problems. This section seeks to identify the major constraints associated with a number of engineering geological factors.

D.3.2 *Geotechnical Constraints to Development*

Within the study area, slope instability is a major geotechnical constraint to development. Instability may be associated with moderate to steeply sloping insitu or colluvial terrain or with land which has been disturbed by man. Landslips and other forms of slope instability are common occurrences on both natural and man-made terrain in the Territory. A number of serious landslip disasters have resulted in considerable loss of life and extensive property damage.

Rock toppling, rock slides and boulder falls are essentially structure controlled, although movement, which is usually sudden and without warning, may be initiated by groundwater pressure. Structural control is also affected by man's influence, because construction exposes release joints along which sliding may occur. Boulder falls usually require the erosion of weathered material or decomposition along planes of weakness through hydrological influence.

Landslips in weathered material pose a considerable hazard, but they are often preceded by signs of distress. Although largely controlled by relict jointing in moderately weathered material, natural failure is often precipitated by the subsurface water regime in conjunction with landslip-prone topography. Leach (1982) and Leach & Herbert (1982) studied the question of groundwater flows on Hong Kong Island.

Whilst erosion alone does not pose as great a hazard as slope instability, it can cause severe problems for engineering work. In addition, changes to the terrain and hydrology through construction or earthworks may cause erosion which may create conditions conducive to mass movement. The loose structure of weathered granites make these more susceptible to erosion than the volcanics when vegetation is removed. Evidence of this occurs in the denuded, eroded and bouldery upper sideslopes of the granitic terrain, where landslips are common at the heads of drainage lines. The debris from such landslips may travel at high velocity for considerable distances, blocking drains and resulting in surface water infiltration.

Deep weathering may be present, particularly where it is accelerated by shattered rock structure or active subsurface groundwater. Although weathering is not a severe constraint, it may pose considerable difficulties during construction, especially if very localised. Localised problems associated with geological photo-lineaments are discussed in Section D.3.4.

The following sections outline a number of specific problem areas which are important for planning and engineering feasibility.

D.3.3 *Fill and Reclamation*

Fill is soil or rock which has been used to provide site formation above the level of the natural terrain. The nature of the fill depends on the source material, the natural terrain, and the quality and control of construction. These factors, together with the history of filling, influence the engineering characteristics of the material.

The locations of fill and reclamation are shown on the Engineering Geology Map and the Physical Contraints Map.

The nature and the engineering problems associated with fill can be categorised into the following:

(i) *Cut and Fill Platforms on Steep Terrain*

This technique is used in the Territory to provide platforms on otherwise steep terrain.

Since the disastrous fill slope failures at Sau Mau Ping in 1972 and 1976 (Government of Hong Kong, 1972 a & b, 1977), fill has been recognised as a potentially hazardous engineering material. Consequently, recent fill platforms and slopes are designed and constructed to stringent requirements. Common problems in older fills on steep terrain are due to the fact that many were 'end tipped'. This results in:

(*a*) Poor compaction – a generally loose structure makes the fills susceptible to liquification resulting from infiltration of rainwater, movement of groundwater, through flow or from fractured water mains. This leads to sudden loss of strength and failure of the slopes. Loose fill is also liable to settlement and possible lateral movement on loading.

(*b*) Stratification parallel to the natural slope – this enables the infiltration of water from the level platform into the fill and also creates inclined planes of potential weakness liable to preferential failure.

Old fill has often been tipped into unprepared natural drainage lines, and the natural groundwater regime may persist beneath the fill, leading to saturation and instability. The material behaviour is also subject to the variability of the source material. Completely weathered rock would result in a fairly uniform fill, whilst fill of less weathered rock may contain boulders and voids.

(ii) *Fill on Low-lying Terrain*

Few engineering problems are envisaged in these areas, with the exception of settlement. Large buildings are generally piled. Deep excavations may experience difficulties due to high groundwater tables in underlying alluvium.

(iii) *Land Reclaimed from the Sea*

Some of the coastal areas are modified by reclamation and considerable recent and proposed development is based on these areas.

Although most areas of reclamation are subject to current or proposed development, it is relevant to note that older reclamation materials may be very variable in quality. The following engineering problems should be anticipated during development in areas of reclamation:

(*a*) Lateral variability of materials—the extension of reclamation areas over a long time may result in material of differing sources and quality being present. Borehole samples should be examined and interpreted with this in mind.

(*b*) Variability of materials with depth—reclamation materials may vary with depth and cause local artificial aquifers and dense or loose zones. These should be anticipated in the choice of construction method and evaluated during site investigation. Boulders, timbers and other extraneous materials may be present in older areas. These may require localised measures during construction, such as hand-dug excavations. Better quality, more uniform material may allow driven piles for low structures such as warehouses, or larger diameter mechanically excavated sleeved caissons for heavier structures.

(*c*) Presence of old structures—within areas of reclamation, features such as old foundations and sea walls may occur. Consultation of archive sources may help avoid local difficulties or anticipate setbacks during the critical foundation construction period.

(*d*) Dewatering problems—the reclamation material, in its loose, permeable, saturated stage, is likely to have water problems which may cause heaving in deep excavations. Grouting or dewatering may therefore be necessary. Dewatering may cause settlement problems in adjacent slabs and unpiled structures. Permanent or temporary impermeable barriers to water flow, such as continuous walling, may also cause problems to adjacent buildings by interrupting groundwater flow and raising water levels.

(*e*) Basements—these require tanking or water resistant design. External drainage may be necessary to prevent an increase in water levels if drainage paths are blocked.

(*f*) Settlement—unpiled structures are subject to settlement and should be designed to redistribute loads or else to be flexible. Foundation stresses are subject to variation from fluctuating water levels in response to the tide. Piled structures may require design for negative friction in recent or deep reclamation.

(*g*) Underlying materials—the problems of construction on reclamation may be aggravated by considerable depths of marine or alluvial deposits and weathered bedrock. The depth of these will vary depending on the original ground profile. The general depth of underlying materials may be determined from site investigation, whilst local variation may be identifiable in the features of the old coastline and the onshore terrain.

(iv) *Sanitary Landfill*

Sanitary landfills are used for the disposal of domestic refuse. Typical engineering problems associated with the development of sanitary landfills include:

(*a*) Heterogeneous materials which are difficult to remove.

(*b*) Unpredictability of stability of landfill slopes and embankments.

(*c*) Unpredictable, large settlements.

(*d*) Fire hazard from methane gas emission.

(*e*) Erratic water flows within landfill.

(*f*) Noxious leachates, posing pollution problems and chemical attack of concrete and steel.

For these reasons, recently completed sanitary landfills and adjacent platforms are probably unsuitable for development other than as open space or recreation areas.

D.3.4 *Geological Photolineaments*

Major geological photolineaments are shown on the Engineering Geology Map for the study area. These features and some more minor lineaments are also shown on the GLEAM if they are significant in the engineering feasibility of potential development areas.

Lineaments are the surface expression of subsurface structural features and, hence, should be carefully examined during planning and engineering feasibility. Differences in rock type, structure or strength are amplified by the landforming processes to produce contrasts in erosion or vegetation, or linear patterns in relief or drainage. Such contrasts are readily identified using API and are often apparent during site reconnaissance. It should be noted that structural features causing lineaments will probably continue beneath superficial deposits such as alluvium, colluvium or fill and their influence should be anticipated in foundation works through these materials.

In general terms, contrasts in the terrain are a reflection of the resistance or susceptibility of the underlying material to erosion. Surface features are often good indicators of local engineering characteristics.

Lineaments tend to be localised and therefore they may often be avoided during the layout and design stages of an engineering project.

Engineering factors which are often associated with lineaments may be classified into the following:

(i) *Deep Weathering*

Shatter and shear zones in the rock tend to concentrate water flow and result in deep weathering. Localised rock shattering may be due to faulting and is likely to appear as a major lineament. The GLEAM shows the influence of structure on drainage in this area; foundation difficulties may occur due to rapidly changing ground conditions.

Many of the photolineaments are major features which are continuous across the study area.

(ii) *Slickensiding*

Slickensiding is evidence of larger scale movements in rock and soil. Smoothing and striation on a fault plane render it more susceptible to failure if a cut slope were to intercept and release a slickensided joint. Whilst this problem may not be obvious prior to excavation, it should be anticipated where fault lineaments are indicated.

(iii) *Changes in Rock Mass Structure and Properties*

Smaller scale lineaments are often identified from preferential drainage caused by a weakness or adjacent strength of the rock mass. This may be due to variation in the rock itself or in its structure. Where the lineament is evidence of a structural weakness, problems may be encountered in the founding of caissons and in the construction of rock cut slopes.

Small scale, as well as major, photolineaments may be associated with anomalies in the general pattern of weathering depth, which may cause differential settlements of raft foundations.

Regular patterns of lineaments are evidence of the regional pattern of structure present at smaller scale. Engineering works in the area may experience instability problems on cut slopes at particular orientations.

In areas of active coastal erosion, the local rock structure is often apparent from the pattern of erosion and instability.

Boundaries between rock types may or may not form photolineaments, partly depending on whether they are faulted or not. Identified rock boundaries are shown on the Engineering Geology Map. Changes in structure are likely at granite/volcanic boundaries due to cooling stresses, and in strength and weathering due to contact metamorphism.

(iv) *Preferential Groundwater Flow*

The preceding engineering features of photolineaments are usually associated with preferential groundwater flow, both at and below the surface. This should be a consideration in the construction of fills in valleys where the subsurface hydrology may be largely unaffected inspite of surface water entrainment.

(v) *Seismic Influence*

Some photolineaments are identified on the Engineering Geology Map (based on Allen & Stephens, 1971) as faults, and other major photolineaments may also indicate faults. Faults may extend laterally for a short distance or many thousands of kilometres. The Government of the Peoples Republic of China has published a national seismic map which shows extensive fault-zones of NE or ENE trend in Guangdong Province and western Fujian Province. One of these fault-zones lies along the northern boundary of the Territory of Hong Kong, while others intersect the coast of Guangdong Province to the east of Hong Kong. Sources in China regard many of the faults of the region as active, the degree of activity being inferred from recent earthquake data, and from that derived from the historical geological record.

Throughout the world, even in seismically 'quiet' areas, many major faults are active to some extent. For example in the UK, which is classified as an area of low to moderate seismicity, a few hundred earthquakes occur every year, although they are rarely felt by individuals. Most of the earthquakes recorded by the Royal Observatory short-period seismograph network originated elsewhere in the Southeast Asian region. The few which actually have been felt by individuals in Hong Kong were mostly related to earthquakes in various parts of China. Nevertheless, minor seismic events originating within the Territory have also been recorded by the Royal Observatory, and these events may be attributed to minor movements on faults at depth giving rise to seismic waves but no apparent ground displacement. To date, no clear relationship is obvious between these local seismic events and known faults within the Territory.

On the basis of observations of the historical geological record and mapping work undertaken to date, it appears that, although minor crustal readjustments have been occurring in Hong Kong, the Territory is not characterised by local major fault movements or related severe seismic events.

D.3.5 *Colluvial Deposits*

Colluvium is a transported material, whose nature and engineering characteristics depend on the origin of the material, the conditions of its deposition and its subsequent history. Various types of colluvium exist within the study area, and their location, nature and material properties are discussed in Sections 2.3, 2.4 and 3.1.4. The extent of colluvium as identified by terrain classification is shown on the Engineering Geology Map.

Colluvium need not necessarily be regarded as a constraint for engineering. Relict colluvium in a completely weathered state may be strengthened by overconsolidation and be virtually indistinguishable in material behaviour from its weathered parent. However, colluvium is inherently variable and, as demonstrated by the Po Shan Road disaster in 1972, when a portion of a large colluvial slope failed, it is usually an extremely difficult material to assess in engineering terms (Government of Hong Kong, 1972 a & b).

Engineering factors which are often associated with colluvium may be classified into the following:

(i) *Physical Properties*

Colluvium is subject to local variations of structure, density, strength and water content, both horizontally and vertically. In particular, concentrations of subsurface water flow may result in voids and pipes caused by the removal of fines, and in local piezometric variation. Stratification of these deposits may cause perched water tables and variations in the strength profile. Settlements under load may be unpredictable. Hence, heavily loaded structures should be founded on caissons through to bedrock. In situations were loading of the colluvium could cause instability, measures should be taken to ensure that loads are not transferred to the colluvium. The variable nature of colluvium will often require the use of hand dug caissons. As discussed for boulder colluvium in Section 3.1.4, measures should be taken to avoid any adverse influence on the groundwater regime.

(ii) *Water Conditions*

The potential for localised flows and perched water tables should be anticipated if piezometers are to be installed. A single piezometer within the profile is seldom adequate to determine the groundwater regime, and the location of piezometers should be based on the observations of the site investigation. In particular, the water pressures should be monitored and interpreted, if significant to design, with respect to strata within the profile. Pressures in underlying weathered material are also important.

(iii) *Stability*

The stability of cut slopes is very susceptible to local variations in strength and water pressure. Since it may not be possible to define these fully from the site investigation, the progress of excavations should be closely monitored to accommodate local variation.

Particular attention should be paid to material boundaries, voids and seepage zones. These may render modelled design conditions doubtful. Many of the cuts in colluvium on footslope terrain show zones of water seepage. Local instability in natural oversteepened colluvial slopes results from emerging groundwater. In cuts in colluvium, such conditions may lead to progressive collapse of a loose soil structure upslope with considerable debris flow.

(iv) *Site Investigation*

In heterogeneous deposits such as extensive recent colluvium and boulders, site investigation alone cannot reveal a comprehensive model of the ground, nor can appropriate strength values be accurately assessed. Carefully monitored trial caissons are often justified in colluvial deposits. Attention should be paid to variations in bedrock and its level in boreholes to ensure that foundations do not rest on boulders.

D.3.6 *Boulders and Rockfalls*

Boulder and rockfalls are a feature of the wet season in the Territory and have on occasion resulted in loss of life and considerable property damage.

Boulders are large blocks of rock which often result from wide joint spacing. They occur often in granitic rocks as the unweathered remnant corestones between completely weathered joints. If exposed on steep hillsides or in drainage lines, they may be liable to movement.

Adverse jointing and an exposed location may result in potential rockfalls in both granitic and volcanic terrain. In this case, weathering, except as a local weakening of the joints, is not a major contributing factor. In granitic rock, the presence of extensive sheeting joints also contributes to the rockfall potential.

Boulders, joint blocks and wedges may also be present in, or as exposed remnants of, both granitic and volcanic colluvium. Boulders may also exist in drainage lines where they are likely to be restrained and interlocked. However, high flows caused by torrential rain are liable to increase the likelihood of movement. Boulders in drainage lines may also trap detritus and torrential flows may cause mud or debris flows.

In areas with potential for development, boulders and rock outcrops are indicated on the GLEAM where they are obvious in aerial photographs. In many situations, boulders are hidden from view by dense vegetation.

Engineering solutions to the boulder and rockfall problem depend largely on the local situation, but may consist of one or a combination of the following:

(*a*) Removal—isolated boulders may be removed from the slope if the situation permits. This could be achieved by blasting or excavation.

(*b*) Restraint—it may be possible to restrain or support isolated boulders and rock wedges by buttressing, anchoring, or cable support.

(*c*) Protection—in areas with long slopes and many potentially unstable boulders or blocks of small to moderate size, identification and removal of critical boulders may not be warranted or may detrimentally affect stability. In such cases, general protection measures may be more appropriate, such as sterile zones, trap ditches or bunds, catch fences, protection nets or deflection barriers.

D.3.7 *Boulders below Ground*

In the granites and colluvium of the study area, boulders are often present within the weathered matrix. Site investigation and construction of load bearing foundations should examine these features. For deep foundations, hand excavation may be required. Blasting of boulders in caissons or cuttings may cause loosening or collapse of the surrounding matrix. Variations in the bedrock level and in the bedrock material may also indicate the presence of boulders.

In bouldery colluvium, voids are likely beneath boulders as a result of the nature of deposition or due to washing out of the matrix in underground drainage lines. This poses particular problems for the construction of deep foundations through these materials.

D.3.8 *Marine Deposits*

Marine deposits are not considered in detail from an engineering point of view in this Report, except in relation to reclamation. Their geological characteristics are discussed in Appendix C.

D.3.9 *Cut Slopes*

Cut slopes and/or slope support structures are an aspect of most large-scale developments in the Territory. Different considerations govern the use and design of slopes depending on the geological material, its state and structure. Hence, the overall form of a development should also relate to the engineering opportunities of the terrain.

The height and angle of a cut slope are a matter for design based on a model of the rock or soil strength and structure as determined by site investigation. Preliminary assessment of the size and form of slopes and retaining structures may be made on the basis of the engineering properties of the local rock type, as indicated on the Engineering Geology Map and in the Materials Table (Table 3.1). At the planning stage, flexibility of layout should be retained, especially where large cuts are involved, so that local variations in strength and structure can be accommodated in design. Lineaments and structural control are indicated on the GLEAM. Structural control may indicate shallow bedrock, and the structure will influence the stability of cuts in rock. Lineaments indicate a local structural feature which may influence the final slope design, probably requiring a shallower angle cut on the weaker rock zone.

In large developments on steep terrain, a more geotechnically economical use of the site can be made by providing a stepped site formation which follows the terrain, rather than a large level formation with very large cuts. The benefits of this approach occur in different ways, for each of the major geological materials occurring on steep terrain:

(i) *Volcanic Terrain*

Weathering depths of less than 15 m are generally noted for steep volcanic terrain in the study area, with rapid transition from weathered to fresh rock. In such terrain, structures can economically be founded at shallow depths and large fresh rock cuts avoided. Where fresh rock cuts are formed, the jointing of the rock may cause some surface ravelling, and net protection or a safety zone may be required to maximize slope angles. Locally persistent or unstable joints may require shallower angled cuts or support measures.

(ii) *Granite Terrain*

Considerable depths of various grades of weathering are encountered in the granitic areas. Large structures founded in this terrain will generally require caisson foundations to bedrock. If large flat site formations are to be created in steep granitic terrain, major cuttings and retaining structures should be provided through a range of weathered rock. The only advantage of this is that shallower caissons can be used, and that extensive flat areas can be created.

The design of cut slopes in less weathered granite (greater than Grade III) may require empirical approximations to model the strengthening influence of boulders. In cuts in fresh rock, sheeting joints are likely to be encountered which require additional support or the draining of water. These local measures enable steep cuts to be made in fresh granite, but the particular form of additional support cannot be determined in advance.

(iii) *Colluvial Terrain*

The creation of extensive cuts in colluvium should be avoided. Aspects of this material affecting stability are noted in Section 3.1.4. Colluvium overlies the insitu rocks in many of the potential development areas outlined in this Report. Colluvium has been associated with a number of serious slope failures in the Territory, and there are many instances where local failure has occurred on cuts formed for development platforms on steeper terrain.

D.3.10 *Maintenance of Natural Drainage*

In colluvial areas and in the vicinity of man-made fills, where stability of excavations and slopes is particularly sensitive to water pressure and localised erosion, the pattern of natural drainage should be maintained as far as is practicable.

Diversion of natural drainage, if poorly maintained or of inadequate capacity, may cause overtopping of channels with consequent erosion and infiltration on slopes during heavy rains when stability is most vulnerable. Many streams in the study area carry large amounts of silt from surface wash, which is often deposited on bends or flatter sections of entrainment schemes.

The pattern of subsurface flow beneath any superficial or partly weathered material is unlikely to be affected by most surface water entrainment schemes. Subsurface flows may enter fill in valleys from beneath, even though surface drainage reduces infiltration. It is possible that the fill slope failures at Sau Mau Ping (Government of Hong Kong, 1972 a & b, 1977) were the result of such subsurface flows.

Even in situations where the natural drainage pattern is not significantly altered, an impermeable surface cover such as a large paved area can considerably increase the quantity of surface runoff and reduce the time of concentration. Flooding and consequent infiltration of slopes may become a problem even though, in the natural terrain, it is not the case. Old nullahs located in developing areas are often subject to overtopping in intense rain for this reason.

The natural and post-development hydrology requires careful investigation and design due to their influence on slope stability.

D.3.11 *Site Investigation*

A 'desk study' is a necessary preliminary to any site investigation. The GASP report summarises, interprets and presents much of the information which would be reviewed in a desk study and, in addition, is reinforced by field reconnaissance.

The 1:20 000 GASP Report is designed for use at a strategic planning and engineering feasibility study stage. The GLUM indicates the general level of site investigation envisaged for each class of map unit and is summarised in Table A2. Information on the engineering geological characteristics, the local geological and terrain constraints, and the general suitability of an area is shown on the EGM, PCM and GLEAM. Only in determining the engineering feasibility of a large uninvestigated area should a preliminary site investigation be based only on a 1:20 000 GASP Report.

When interpreting the GLUM with regard to site investigation, the following points should be considered:

(*a*) In the study area, extensive site investigation for a range of engineering projects is available. Some of the reports are accessible in the GCO's Geotechnical Information Unit (GIU), and many provide a great deal of the background geotechnical information necessary for a new project. Figure C2 gives an indication of the distribution and intensity of site investigation records held in the GIU.

(*b*) A field reconnaissance of the site and the surrounding area is a necessary preliminary to planning a site investigation. On undisturbed sites, much can be inferred with regard to the strength of underlying materials, the pattern of superficial deposits, and local weaknesses in rock from site observations of the contrasts in landform and the pattern of drainage on and around the site.

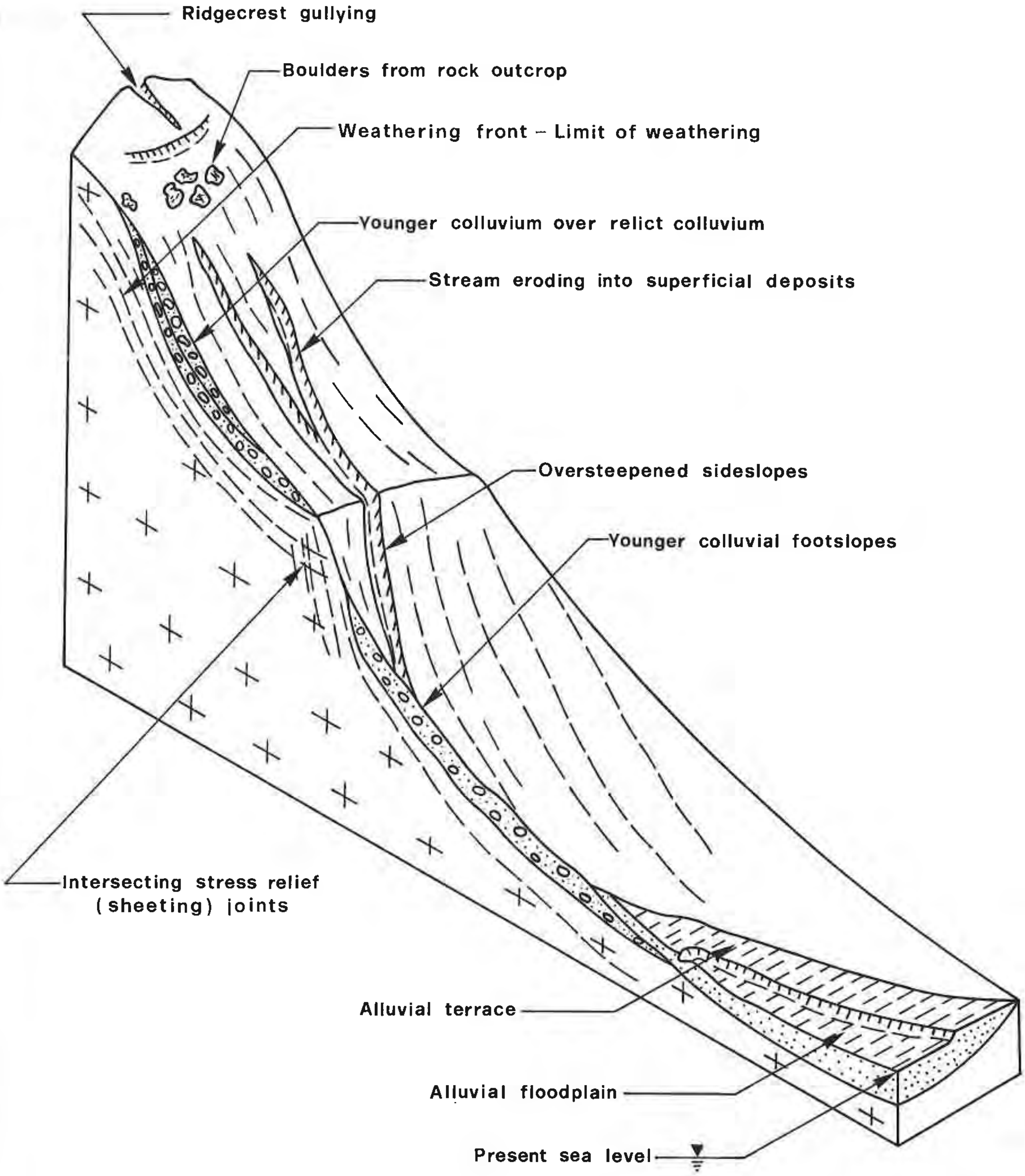
(*c*) The site investigation should be designed to highlight the scope of any available information, the anticipated material, its nature and variability, and the type and form of the engineering project.

D.4 Landform Model of the Terrain in Hong Kong

Landforms are the product of the local balance between weathering, erosion and deposition and are continually evolving. The mechanics of the system and its various components are shown in Figure D1 and described in Appendix D.3.1 (Hansen, 1984 a & b). This section discusses the significance of the sequence of landform evolution to the engineering properties of the materials within the study area. This is achieved in terms of their distribution and thickness. Many of the geomorphological processes act at rates that engineers consider insignificant. However an understanding of the evolutionary system will aid an engineering appreciation of the terrain, because the consequences of slope processes affect the materials with which an engineer constantly deals. Figure D4 provides a simplified hillslope model and relates to the following text.

Slopes that are too steep for the weathered material to remain stable are subject to periodic failure. The magnitude of failure may be isolated and small or catastrophic in nature. Therefore, the recognition of slope process is important in order to highlight the landslip hazard. The origin of many of the oversteepened inland slopes in the Territory lies in the consequences of the fall in sea level that resulted from the growth of the ice sheets during the Pleistocene. During this period, the sea level fluctuated dramatically; there is evidence in southern China that stream incision occurred and produced oversteepened slopes adjacent to the channels. Gradually, the incision progressed inland, taking advantage of structural weaknesses in the underlying geology, with the result that many valleys are narrow with steep sides. The increased rate of erosion removed much of the weathered mantle adjacent to the streams. This, in part, explains the occurrence of shallow weathering depths and slightly weathered bedrock along the floors of many incised valleys in the Territory.

Drainage courses are the main axes of erosion within a valley. The density of drainage pattern responds to and is influenced by the materials and structural control. Incision and removal of material creates over-steepened sideslopes adjacent to the drainage lines by erosion and slope failure. This process continues to induce oversteepening of the terrain, which causes lateral recession of the hillsides. Oversteepening progresses upslope through erosion by instability, as the depth of weathered mantle increases to a limiting value. The terrain on either side of the oversteepened slope section contains different associations of landforms (as shown in Figure D4) as each part of the slope is reacting to a different set of denudational conditions. Below the oversteepened sideslopes, the landforms are comparatively young. Boulders in the colluvium, deposited as a result of landslips and slopewash from the oversteepened slope, are generally unweathered. The oversteepened sideslopes contain many landslip scars, often as recent and relict features, as well as rock outcrops protruding through the thin soils. Above the level of slope oversteepening, the landforms are generally much older. Thus, the spurlines are more deeply weathered and may possess a relict colluvial cover with boulders that are decomposed insitu. In some situations in the study area, younger colluvium overlies older relict deposits. Stream incision occurs at a faster rate than the upslope migration of the oversteepened slopes. This promotes instability adjacent to the stream channels through undercutting. Erosion may result in the exhumation of corestones or boulders which are either distributed across the terrain or are concentrated within drainage lines.



Hillslope Model

Fig. D4

Irregularities in slope profile can also be the result of variations in the resistance to erosion of the underlying rock types. The existence of dykes, faults or more resistant strata are examples. However, these features usually result in a different spatial distribution of landforms and may can be distinguished through the careful use of aerial photograph interpretation and field mapping.

Provided that the debris resulting from the erosion of the oversteepened slope is continually transported away from the slope, instability will continue regardless of changes to the denudational system downslope. If the debris is not removed as fast as it is being deposited, colluvial fans form. If sediment supply decreases or base level is lowered, then incision of the fans results.

With the retreat of the ice sheets at the end of the Pleistocene, the sea level gradually rose. The deepened valleys became sediment traps for the material that was eroded from the sideslopes. Great thicknesses of alluvium (mainly sands and silts with occasional gravel lenses) accumulated, particularly in the lower reaches of the valleys in which there was an abundant sediment supply. Alluvium at the sides of these valleys is interlayered with colluvium deposited by landslips. As both alluvium and colluvium were deposited during the period of lower sea level, they may both exist beneath, as well as intercalating with marine sediments.

APPENDIX E

GLOSSARY OF TERMS

AERIAL PHOTOGRAPH INTERPRETATION

Technique of interpreting data from aerial photographs which are viewed stereoscopically. This method enables the evaluation of the terrain in three-dimensions.

AGGLOMERATE

Pyroclastic rock consisting mainly of fragments greater than 60 mm in diameter; rounded pyroclastics predominate.

ALLUVIAL FAN

Mass of sediments deposited at a point along a river or drainage line where there is a decrease in gradient. The fan is thickest at its point of origin and thins rapidly in a downstream direction.

ALLUVIUM

Sediment transported and deposited by a river or stream.

APHANITE

Rock with microcrystalline or cryptocrystalline texture that is too small to be seen with the naked eye.

AQUIFER

Water-transmitting rock or soil. Type aquifers are those which are normally associated with high transmissivity such as sandstone, limestone and chalk and are often used for water supply purposes.

AREA INSTABILITY INDEX

Proportion of a particular area of land which is affected by instability.

ASPECT

Direction in which a slope faces.

BATHOLITH

Large intrusive igneous rockmass.

BEDROCK (=SOLID GEOLOGY)

Insitu rock exposed at the surface or underlying any superficial material such as topsoil, residual soil, alluvium or colluvium.

BLOCKS

Solid pyroclastic fragments greater than 60 mm ejected from volcanoes by volcanic action.

BOMBS

Partially or wholly molten pyroclastic fragments greater than 60 mm ejected from volcanoes by volcanic action. These fragments often acquire distinctive shapes or surface textures during ejection and subsequent transport.

BRECCIA

Rock consisting of coarse grained (>60 mm) angular fragments implying minimal transport of material. Breccias are poorly sorted and commonly contain rock fragments derived from a restricted source. Also see FAULT BRECCIA.

CATCHMENT AREA

Area from which a river or stream collects surface runoff. Often used synonymously with DRAINAGE BASIN.

CHLORITISATION

Replacement by, conversion into, or introduction of chlorite into the rock substance.

CHUNAM

Cement-lime stabilised soil used as a plaster to protect the surfaces of excavations from erosion and infiltration. The recommended mix for chunam plaster, the proportions being measured by weight, is one part Portland cement, three parts hydrated lime and 20 parts clayey decomposed granite or volcanic soil.

COASTAL PLAIN

Terrain component defined as flat terrain lying between the littoral zone and mountain footslopes.

COLLUVIUM

Heterogeneous deposit of rock fragments and soil material transported downslope through the influence of gravity, including creep and local slopewash.

COUNTRY ROCK (=HOST ROCK)

General term applied to rocks penetrated by and surrounding an igneous intrusion.

CUT SLOPE AND CUT PLATFORM

Surface which remains after volume of soil and/or rock has been excavated. Within the terrain classification system, such units with gradients in excess of 5° are cut slopes, while those with gradients less than 5° are cut platforms.

DACITE

Extrusive equivalent of quartz diorite. The principal minerals are plagioclase, quartz, pyroxene and hornblende. The rock is glassy or fine grained with occasional phenocrysts.

DETRITAL

Term applied to any particles of minerals or, more commonly, rocks which are derived from pre-existing rocks by processes of weathering and/or erosion.

DIP (or TRUE DIP)

Angle of a plane to the horizontal, measured in a direction perpendicular to the strike of the plane.

DIP DIRECTION

Direction or azimuth of dip.

DISCONTINUITY

Interruption, usually of a planar nature, to the homogeneity of a rockmass (i.e. joints, faults). The description and classification of discontinuities is given in the 'Geotechnical Manual for Slopes' produced by the Geotechnical Control Office. (1984).

DISTURBED TERRAIN

Terrain component, defined as land permanently altered from its original state by man. Cut and fill slopes are usually designated as 'disturbed terrain'.

DOLOS

Interlocking precast concrete structures of regular geometric form, normally used for protection against marine erosion.

DRAINAGE PLAIN

Terrain component, defined as an area subject to periodic overland flow of water, and within the GASP it is defined as colluvial in nature. It may be an area of spring activity. In some situations, drainage plains may include deeply incised drainage channels.

DURICRUST (=HARD PAN)

Near surface cemented layer occurring in soils or weathered rocks as a result of groundwater action. The cementing agent may be siliceous, calcareous, ferruginous or aluminous.

DYKE

Wall-like body of igneous rock which is discordant, i.e. cuts across bedding or structural planes of the host rock. Usually near vertical. A set of dykes in a parallel or radial pattern constitutes a DYKE SWARM.

EPHEMERAL STREAM

Stream which only flows for short periods of the year.

EROSION

Natural process which involves the wearing away and/or removal of the land surface by the action of a transporting medium or its entrained debris. The agents of transportation can be water, wind or gravity.

FABRIC

Overall appearance of a rock or soil exposure or hand specimen resulting from the combined features of texture and structure.

FAULT

Fracture in rock along which there has been an observable amount of displacement.

FAULT BRECCIA

Assembly of broken fragments formed by crushing or grinding along a fault plane.

FILL SLOPE AND FILL PLATFORM

Surface which is artificially constructed from soil or rubble transported by man. Within the terrain classification system, such units with gradients in excess of 5° are fill slopes, while those with gradients less than 5° are fill platforms.

FLOODPLAIN

Terrain component, defined as a flat area in alluvial terrain which is subject to periodic inundation.

FOOTSLOPE

Terrain component, which is essentially a zone of deposition and which usually occupies a basal position in the terrain. Within the Regional GASP, footslopes are defined as being colluvial in nature.

GENERAL INSTABILITY

Terrain attribute defined for use in 1:20 000 scale GASP mapping to describe areas where large numbers of small landslips or other instability occur.

GENERALISED LIMITATIONS AND ENGINEERING APPRAISAL MAP (GLEAM)

Map which delineates potential development areas in terms of geotechnical and other constraints.

GEOTECHNICAL AREA STUDIES PROGRAMME (GASP)

Geotechnical study of a specific area by the GCO on the basis of systematic terrain classification using aerial photograph interpretation, fieldwork and engineering assessment.

GEOTECHNICAL LAND USE MAP (GLUM)

Map which delineates the general geotechnical limitations of the terrain for planning purposes.

GRABEN

Downfaulted block between two or more parallel (or subparallel) faults.

GULLY EROSION

Terrain attribute, characterised by incised drainage channels formed by the removal of soil or decomposed rock by the surface flow of water.

HILLCREST

Terrain component, which is convex in shape. The terrain surrounding this component falls away in all directions.

HORNFELS

Fine grained non-schistose metamorphic rock, usually derived from fine grained sediments.

HYDROGRAPH

Graph showing the volume of stream (or channel) discharge against time. A 'flashy' hydrograph has a steep rising limb and indicates a very rapid increase of discharge following rainfall.

IGNIMBRITES (=WELDED TUFFS)

Chiefly a fine-grained rhyolitic tuff formed mainly of glass particles (shards), in which crystals of quartz, feldspar and sometimes other minerals are embedded. The glass shards are welded or bent around the crystals, having been viscous when deposited. The glass shards are often devitrified.

IMBRICATE STRUCTURE

Tabular or sheet structures that overlap each other in response to uni-directional forces.

INCISED DRAINAGE CHANNEL

Terrain component consisting of the channel and banks of a drainage line. Identification of this feature is largely dependent upon the scale of the survey and scale of the aerial photograph.

INDURATION

Process by which a soft soil or rock material becomes hard. Generally includes hardening by baking, pressure or cementation.

INSITU MATERIAL

Material in original position of formation as opposed to loose, disconnected, transported or derived material.

INTRUSION

Body of igneous rock which has forced itself into pre-existing rocks, either along some definite structural feature or by deformation and cross-cutting of the invaded rock.

LAND CAPABILITY

Capacity or potential of a parcel of land to sustain a particular use.

LANDFORM

General shape and characteristic morphology of the land surface.

LANDSLIP (=LANDSLIDE)

General name for downhill movements of soil or rock involving shear failure. Term is generally restricted to failures in soils. Rock failures are more commonly termed ROCKSLIDES or ROCKFALLS.

LAPILLI

Pyroclastic fragments measuring between 2 and 60 mm ejected from volcanoes by volcanic action.

LENTICULAR COLLUVIUM

Colluvial deposit which is essentially confined by valley sideslopes or is marginal to a natural drainage line. These deposits are usually ribbon shaped features.

LITHOLOGY

General physical character of a rock, including mineral constituents, texture and structure.

LITHOSTRATIGRAPHY

Stratigraphy based only on the physical and petrographic features of rocks (as opposed to a biological or age basis).

LITHOTYPE

Rock defined on the basis of certain selected physical characteristics.

LITTORAL ZONE

Terrain component, defined as the area between the highest and lowest levels of spring tides, i.e. beach.

MANTLE

Weathered rock material overlying fresh rock.

MASS WASTING

General term for the dislodgement and downslope movement of soil and rock material.

MATRIX

Finer grained fraction within a soil or rock containing large particles.

MAXIMUM DRY DENSITY

Density obtained using a specific amount of compaction at the optimum moisture content (British Standard Test: BS 1377).

NATURAL SLOPE

Area of sloping ground substantially unaltered by man.

NICK POINT

Point of interruption of a stream profile at the head of a second-cycle valley, usually as a result of a change in base level.

OUTCROP

Part of a geological formation or rock that appears at the ground surface. The exposure of bedrock or strata projecting through the overlying cover of detritus or soil.

PEGMATITE

Igneous rocks of very coarse texture found usually as dykes or veins associated with a large mass of plutonic rock of finer grain size (e.g. granite).

PERENNIAL STREAM

Stream that flows throughout the year.

PHYLLITE

Argillaceous rock of intermediate metamorphic grade.

PHYSICAL LAND RESOURCES

Physical characteristics of land.

PIPE (=SOIL PIPE)

Tubular conduit within the soil mantle, through which groundwater may flow.

POLYCYCLIC

Many cycles of development.

PYROCLASTIC ROCK

Volcanic rock composed of rock fragments (including molten material and fragments of country rock) explosively ejected from a volcano. TUFF is a general name for consolidated pyroclastic ash.

RECLAMATION

Area of land reclaimed from the sea or other waterbody.

RELICT

Term used to describe remnants of earlier landscapes or surface deposits. Also used to describe traces of lithological features in residual soil.

RESIDUAL SOIL

Soil resulting from the weathering of rock insitu.

RILL EROSION

Terrain attribute characterised by subparallel sets of small narrow channels formed by the concentration of surface runoff.

ROCK EXPOSURE (=ROCK OUTCROP as defined for Terrain Classification)

Discrete area of rock exposed at surface.

ROOF PENDANT

Mass of older country rock forming the roof of a major igneous intrusion (e.g. a granite batholith). On a map, a roof pendant is completely surrounded by the rock of the batholith.

SCREE (=TALUS)

Debris resulting from the mechanical weathering of rock which accumulates at the foot of a cliff or a steep slope.

SESQUIOXIDES

Oxides of iron and aluminium which are generally mobilized as ions in solution by groundwater and which, upon precipitation, often act as the cementing agent in the formation of duricrust.

SHEET EROSION

Terrain attribute, characterised by the removal of the surface layers of soil by wind or water.

SHEETING JOINT

Discontinuity produced by pressure release or exfoliation. Sheeting joints may separate large rock masses, e.g. of granite into tabular bodies or lenses, roughly parallel with the rock surface. Often persistent for large distances and generally following the shape of the landform.

SIDESLOPE

Terrain component, used to describe the terrain between footslope and hillcrest. This terrain unit is usually erosional.

SPHERULITE

Small radiating, and usually concentric arrangement of one or more minerals formed by radial growth of acicular crystals.

STRIKE

Azimuth of a horizontal line drawn on a bedding plane. Strike is at right angles to the direction of true dip.

STRUCTURE

Relationship between different features (and their causes) in a rock mass or soil, e.g. bedding, jointing, cleavage, faulting, contacts between different lithologies and, in a regional context, the geographical distribution of these features.

TECTONIC

Relating to a period of deformation or mountain building e.g. granite emplacement. Post-tectonic refers to events occurring after a particular deformation period. Syntectonic implies an event taking place coextensively with a definite period of deformation, intrusion, etc.

TERRAIN ATTRIBUTE

Characteristic of the terrain as defined within the terrain classification system. (Refer to Table A1).

TERRAIN CLASSIFICATION

Systematic terrain evaluation based on the use of terrain attributes for the production of a landscape model for engineering or other purposes.

TERRAIN COMPONENT

Geomorphological unit, e.g. hillcrest, floodplain. One of the attributes by which terrain is classified.

TERRAIN EVALUATION

Assessment of an area of ground for engineering or other purposes. The technique of aerial photograph interpretation is used to assess the landscape features.

TEXTURE

Relationship between the grains of minerals forming a rock, mainly in terms of size, shape and arrangement.

TOR

Landform characterised by an elevated pile of rock slabs or loose boulders formed by weathering and erosion of insitu materials.

TRANSMISSIVITY

Rate at which water is transmitted through a unit width of aquifer, under a unit hydraulic gradient.

TUFF

General rock name given to consolidated pyroclastic ash. Tuffs are classified as being essentially vitric (>50% glassy fragments), lithic (>50% rock fragments) or crystal (>50% crystal fragments) in composition, and fine (<0.06 mm), coarse (0.06–2 mm), lapilli (2–60 mm) and breccia (>60 mm) in size.

VOLCANICLASTIC

Clastic rock containing volcanic material in any proportion without regard to its origin or environment.

HK$150 (US$25 including surface postage)
P591509/7
ISBN 962-02-0057-8

Printed and Published by the Government Printer, Hong Kong 155725—19L—8/88

LEGEND

CLASS	CODE	GEOTECHNICAL LIMITATIONS	SUITABILITY FOR DEVELOPMENT	ENGINEERING COST FOR DEVELOPMENT	INTENSITY OF SITE INVESTIGATION REQUIRED
I		Low	High	Low	Normal
II		Moderate	Moderate	Normal	Normal
IIS		Moderate	Moderate - Low	Normal - High	Normal
III		High	Low	High	Intensive
IV		Extreme	Probably Unsuitable	Very High	Very Intensive

General Features - terrain which is not classified within GLUM system.

- Waterbodies (streams, man-made channels, storage dams)
- Ponds
- Littoral zone (generally subject to tidal action)
- Wave cut platform

$^{2}18$ Universal Transverse Mercator (UTM) Grid Reference

$^{8}46$ Hong Kong Metric Grid Reference

ATTENTION : USERS

The Geotechnical Land Use Map (GLUM) should be used only as a guide to the general level of geotechnical limitation of the terrain for regional planning purposes. It is produced at a scale of 1:20 000 and should not be used to evaluate parcels of land smaller than 3 ha in size.

This Map must never be interpreted, reproduced or enlarged to scales larger than 1:20 000 (i.e. scales of 1:10 000, 1:5 000 or larger). Failure to heed this warning may result in serious misinterpretation of the data.

Please consult the Clear Water Bay Geotechnical Area Studies Programme Report (GASP VII) which discusses in detail the purpose and application of this Map.

Note : The topographic base of this map is derived from Sheet 11 - Edition 2 of 1979, Sheet 12 - Edition 2 of 1980 Sheet 15 - Edition 2 of 1980 and Sheet 16 - Edition 1 of 1976 of the HM20C Series produced by the Survey and Mapping Office of the Buildings and Lands Department, Hong Kong.

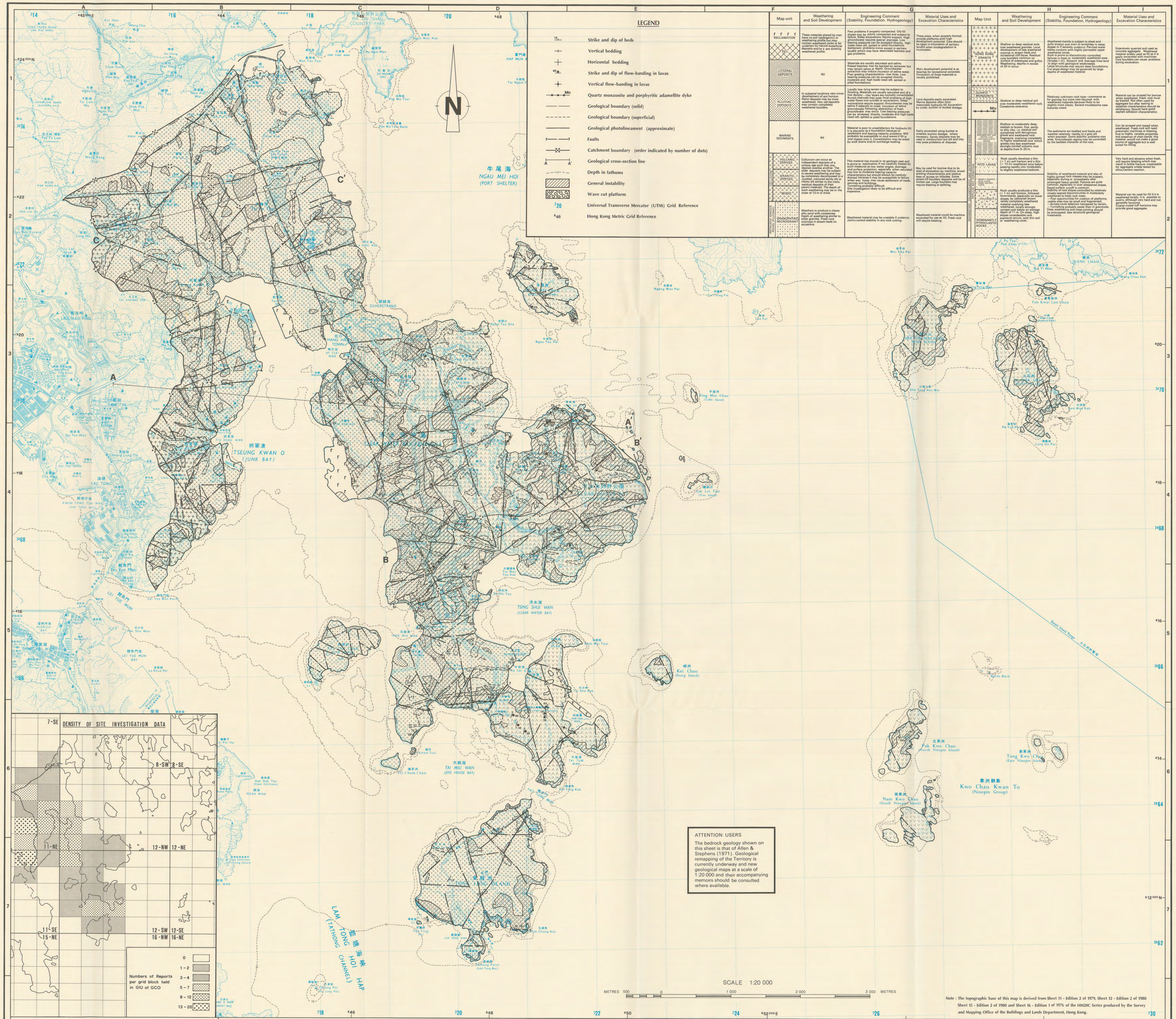
Geotechnical Control Office
Civil Engineering Services Department

GEOTECHNICAL AREA STUDIES PROGRAMME

GEOTECHNICAL LAND USE MAP - CLEAR WATER BAY

Title: GEOTECHNICAL LAND USE MAP – CLEAR WATER BAY	
Compiled: R.J. Purser / A. Hansen / K.A. Emery	Drawn: S.Y. Lam / M.Y. Wong
Scale: 1 : 20 000	Date: Original March, 1985. 2nd Edition June, 1988.
Map Ref. No : GASP/20/VII/1 2nd Edition	Sheet :

Published by the Geotechnical Control Office, Civil Engineering Services Department, Hong Kong.



LEGEND

- Strike and dip of beds
- Vertical bedding
- Horizontal bedding
- Strike and dip of flow-banding in lavas
- Vertical flow-banding in lavas
- Mo — Quartz monzonite and porphyritic adamellite dyke
- Geological boundary (solid)
- Geological boundary (superficial)
- Geological photolineament (approximate)
- f—f Faults
- Catchment boundary (order indicated by number of dots)
- A—A′ Geological cross-section line
- Depth in fathoms
- General instability
- Wave cut platform
- 220 Universal Transverse Mercator (UTM) Grid Reference
- 846 Hong Kong Metric Grid Reference

	Map unit	Weathering and Soil Development	Engineering Comment (Stability, Foundation. Hydrogeology)	Material Uses and Excavation Characteristics
	RECLAMATION / FILL	These materials placed by man have no soil (pedogenic) or weathering profile but may contain weathered rocks or be underlain by natural superficial deposits and/or a pre-existing weathered profile.	Few problems if properly compacted. Old fill slopes may be poorly compacted and subject to failure. Steep excavations require support. High groundwater requires special drainage. Low bearing pressures can be accepted directly, high loads need raft, spread or piled foundations. Settlement problems minor except in sanitary landfill which may have associated leachate and gas problems.	These areas, when properly formed, provide platforms with high development potential. Care should be taken in excavation of sanitary landfill when biodegradation is incomplete.
	LITTORAL DEPOSITS	Nil	Materials are usually saturated and saline. Raised beaches may be leached by rainwater but may remain saline at depth. Groundwater extraction may induce incursion of saline water. Poor grading characteristics—low fines. Low bearing pressures can be accepted directly, moderate and high loads need raft, spread or piled foundations.	Main development potential is as beaches for recreational purposes. Excavation of these materials is usually prohibited.
	ALLUVIAL DEPOSITS	In subaerial locations very minor development of soil horizon. Relict deposits may be more weathered. Very old deposits may contain completely weathered boulders.	Locally low-lying terrain may be subject to flooding. Materials are usually saturated and of a low density – clay layers are normally consolidated. Buried channels may pose local problems of high water flows into tunnels or excavations. Steep excavations require support. Groundwater may be saline if adjacent to coast. Incursion of saline groundwater following abstraction of fresh groundwater may occur. Low bearing pressures can be accepted directly, moderate and high loads need raft, spread or piled foundations.	Land deposits easily excavated. Marine deposits often form reasonable hydraulic fill. Excavation by cutter, suction or bucket dredger.
	MARINE SEDIMENTS	Nil	Material is poor to unsatisfactory for hydraulic fill. It is also poor as a foundation because of settlement and bearing capacity problems. Will probably be susceptible to mud waves if fill is end-tipped onto it. Consolidation may be aided by wick drains and/or surcharge loading.	Easily excavated using bucket or possibly suction dredger where necessary. Sandy deposits may be used in construction but silt and clay may pose problems of disposal.
COLLUVIUM	VOLCANIC DERIVED / GRANITIC DERIVED / MIXED	Colluvium can occur as independent deposits of a unique age such that one deposit overlies another. The older deposits may be subject to severe weathering and may be completely decomposed to a mottled, coloured sandy silt or clayey silt similar to the insitu residual deposits of their parent materials. The depth of such weathering may be in the order of 10 m or more.	This material has moved in its geologic past and is prone to reactivation if not carefully treated by such measures as low batter angles, drainage, and surface protection, especially when saturated. Has low to moderate bearing capacity characteristics but should always be carefully drained because it may be susceptible to failure when wet. Voids may cause settlement of roads, services and buildings. Tunnelling probably difficult. Site investigation likely to be difficult and expensive.	May be used for borrow due to its ease of excavation by machine, broad grading characteristics and relative ease of access on hillsides. Some stream fill bouldery deposits will be of limited use. Large boulders may require blasting or splitting.
INSTRUSIVE IGNEOUS ROCKS (PLUTONIC)	GRANOPHYRIC MICROGRANIT	Weathers to produce a clayey silty sand with corestones. Depth of weathering similar to other granites. Fresh rock outcrops in stream beds on occasions.	Weathered material may be unstable if undercut. Joints control stability in any rock cutting.	Weathered material could be machine excavated for use as fill. Fresh rock will require blasting.
INSTRUSIVE IGNEOUS ROCKS (PLUTONIC)	HONG KONG GRANITE	Shallow to deep residual soils over weathered granites. Local development of less weathered outcrop in stream beds and occasional cliff faces. Residual core boulders common on surface of sideslopes and gullys. Weathering depths in excess of 20 m occur.	Weathered mantle is subject to sheet and gully erosion and even to landslides in steep slopes or if severely undercut. Perched water tables conform with highly permeable upper weathered zones. Rock is prone to discontinuity-controlled failures in fresh to moderately weathered state (Grades I–III). Streams and drainage lines tend to align with geological weaknesses. Large structures may require deep foundations. Cut slope design may be governed by large depths of weathered material.	Extensively quarried and used as concrete aggregate. Weathered material widely used as fill as it is easily excavated with machines. Core boulders can cause problems during excavation.
INSTRUSIVE IGNEOUS ROCKS (PLUTONIC)	QUARTZ MONZONITE / Mo	Shallow to deep residual soil over moderately weathered rock. Corestones extensive.	Relatively unknown rock type—comments as for granites but more care required with weathered materials because likely to be slightly more clayey. Several troublesome case histories noted.	Material can be scraped for borrow when weathered. Fresh rock must be blasted. Not often used for aggregate but after testing to establish characteristics should be satisfactory. Should have good asphalt adhesion characteristics.
SEDIMENTARY VOLCANICLASTIC AND EXTRUSIVE IGNEOUS ROCKS — REPULSE BAY FORMATION	SEDIMENTARY AND WATER-LAID VOLCANICLASTIC ROCKS	Shallow to moderately deep, reddish to brown, fine, sandy to silty clay, i.e. residual soil sometimes with ferruginous gravel and weathered rock fragments, overlying completely to highly weathered rock which grades into less weathered strongly jointed volcanic rock at depths from 5–20 m.	The sediments are bedded and fissile and weather relatively rapidly to a grey silt when exposed. Some stability problems may arise. Groundwater regime may be controlled by the bedded character of the rock.	Can be scraped and ripped when weathered. Fresh rock will need pneumatic machines or blasting. Due to highly variable properties and presence of chert bands, this material would not make a good source of aggregate but is well suited for filling.
SEDIMENTARY VOLCANICLASTIC AND EXTRUSIVE IGNEOUS ROCKS — REPULSE BAY FORMATION	ACID LAVAS	Rock usually develops a thin (< 1 m) soil horizon and a thin (< 10 m) weathered zone before passing rapidly into moderately to slightly weathered bedrock.	Stability of weathered material and also of highly jointed rock masses may be suspect, especially during or immediately after prolonged heavy rainfall. Failures are quite common, especially in over-steepened slopes. Rapid surface runoff is common. Stability of rock slopes controlled by relatively closely spaced discontinuities in moderately weathered to fresh rock mass. —Few opportunities for creation of platforms; usable sites may be small and fragmented. —Access route selection hampered by terrain. —Tunnelling probably easier than in granitoids. Deep weathering and close jointing should be anticipated near structural geological lineaments.	Very hard and abrasive when fresh, will require blasting which may result in brittle fracture. Inadvisable for aggregate unless tested for silica/cement reaction.
SEDIMENTARY VOLCANICLASTIC AND EXTRUSIVE IGNEOUS ROCKS — REPULSE BAY FORMATION	MAINLY BANDED ACID LAVAS SOME WELDED TUFFS / AGGLOMERATE / DOMINANTLY PYROCLASTIC ROCKS	Rock usually produces a thin (< 1 m) soil horizon, followed downwards, especially on lower slopes, by yellowish brown sandy completely weathered material overlying less weathered, locally strongly jointed rock below an average depth of 11 m. On steep, high slopes considerable rock exposure occurs, with thin soil or weathering cover.		Material can be used for fill if it is weathered locally. It is possible to quarry, although very hard and not generally favoured. Coarse crystal tuff horizons may provide good aggregate.

ATTENTION: USERS

The bedrock geology shown on this sheet is that of Allen & Stephens (1971). Geological remapping of the Territory is currently underway and new geological maps at a scale of 1:20 000 and their accompanying memoirs should be consulted where available.

Note : The topographic base of this map is derived from Sheet 11 - Edition 2 of 1979, Sheet 12 - Edition 2 of 1980 Sheet 15 - Edition 2 of 1980 and Sheet 16 - Edition 1 of 1976 of the HM20C Series produced by the Survey and Mapping Office of the Buildings and Lands Department, Hong Kong.

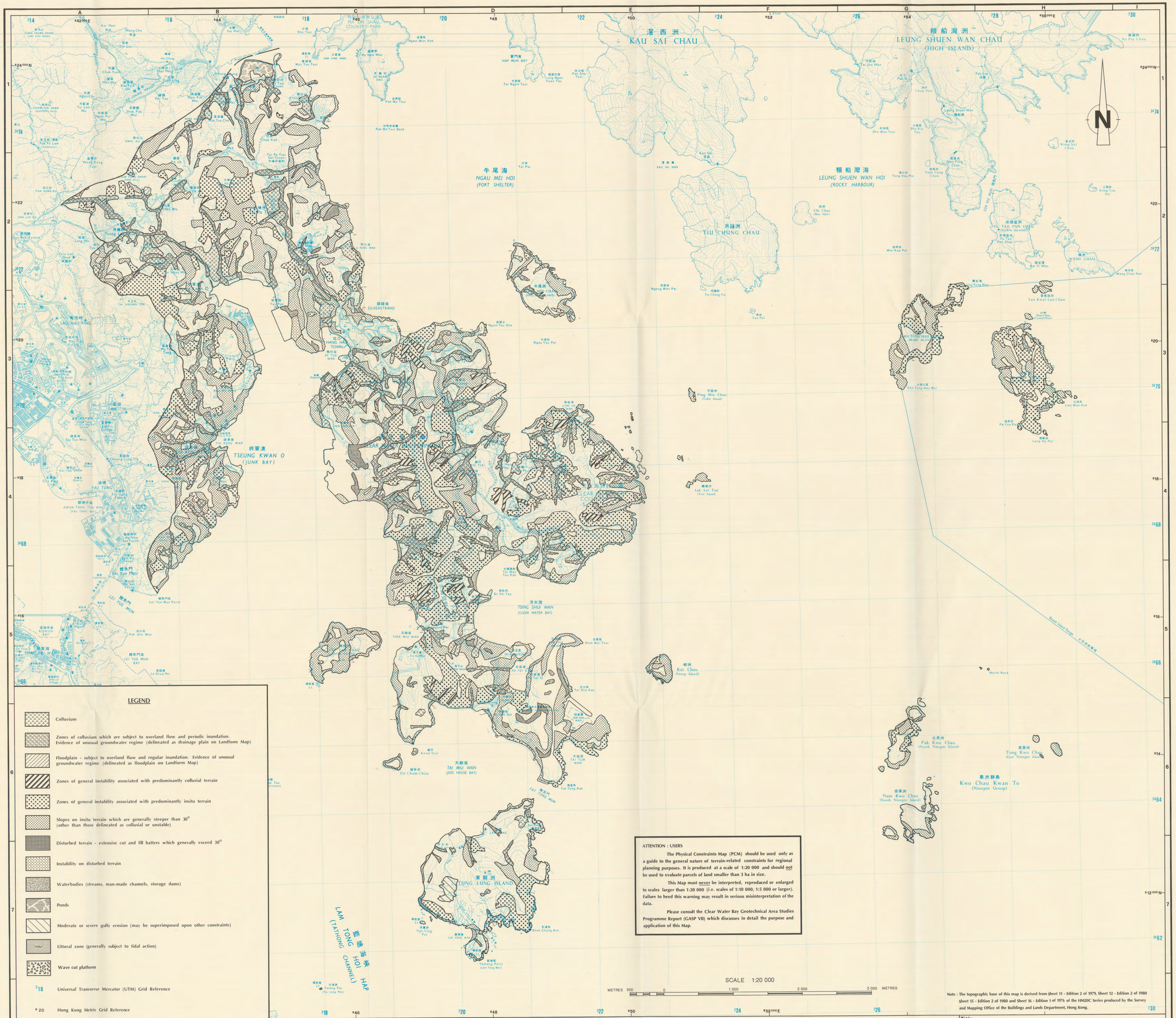
Geotechnical Control Office
Civil Engineering Services Department

GEOTECHNICAL AREA STUDIES PROGRAMME

ENGINEERING GEOLOGY MAP - CLEAR WATER BAY

Title:	ENGINEERING GEOLOGY MAP — CLEAR WATER BAY		
Compiled:	R.J. Purser / A. Hansen	Drawn:	C.Y. Leung / S.P. Poon
Scale:	1 : 20 000	Date:	Original: May, 1985 2nd Edition: June, 1988
Map Ref. No :	GASP/20/GASP VII/2 2nd Edition	Sheet :	

Published by the Geotechnical Control Office, Civil Engineering Services Department, Hong Kong.



LEGEND

- Colluvium
- Zones of colluvium which are subject to overland flow and periodic inundation. Evidence of unusual groundwater regime (delineated as drainage plain on Landform Map)
- Floodplain - subject to overland flow and regular inundation. Evidence of unusual groundwater regime (delineated as floodplain on Landform Map)
- Zones of general instability associated with predominantly colluvial terrain
- Zones of general instability associated with predominantly insitu terrain
- Slopes on insitu terrain which are generally steeper than 30° (other than those delineated as colluvial or unstable)
- Disturbed terrain - extensive cut and fill batters which generally exceed 30°
- Instability on disturbed terrain
- Waterbodies (streams, man-made channels, storage dams)
- Ponds
- Moderate or severe gully erosion (may be superimposed upon other constraints)
- Littoral zone (generally subject to tidal action)
- Wave cut platform
- $^{2}18$ Universal Transverse Mercator (UTM) Grid Reference
- $^{8}20$ Hong Kong Metric Grid Reference

ATTENTION : USERS

The Physical Constraints Map (PCM) should be used only as a guide to the general nature of terrain-related constraints for regional planning purposes. It is produced at a scale of 1:20 000 and should not be used to evaluate parcels of land smaller than 3 ha in size.

This Map must never be interpreted, reproduced or enlarged to scales larger than 1:20 000 (i.e. scales of 1:10 000, 1:5 000 or larger). Failure to heed this warning may result in serious misinterpretation of the data.

Please consult the Clear Water Bay Geotechnical Area Studies Programme Report (GASP VII) which discusses in detail the purpose and application of this Map.

Note : The topographic base of this map is derived from Sheet 11 - Edition 2 of 1979, Sheet 12 - Edition 2 of 1980 Sheet 15 - Edition 2 of 1980 and Sheet 16 - Edition 1 of 1976 of the HM20C Series produced by the Survey and Mapping Office of the Buildings and Lands Department, Hong Kong.

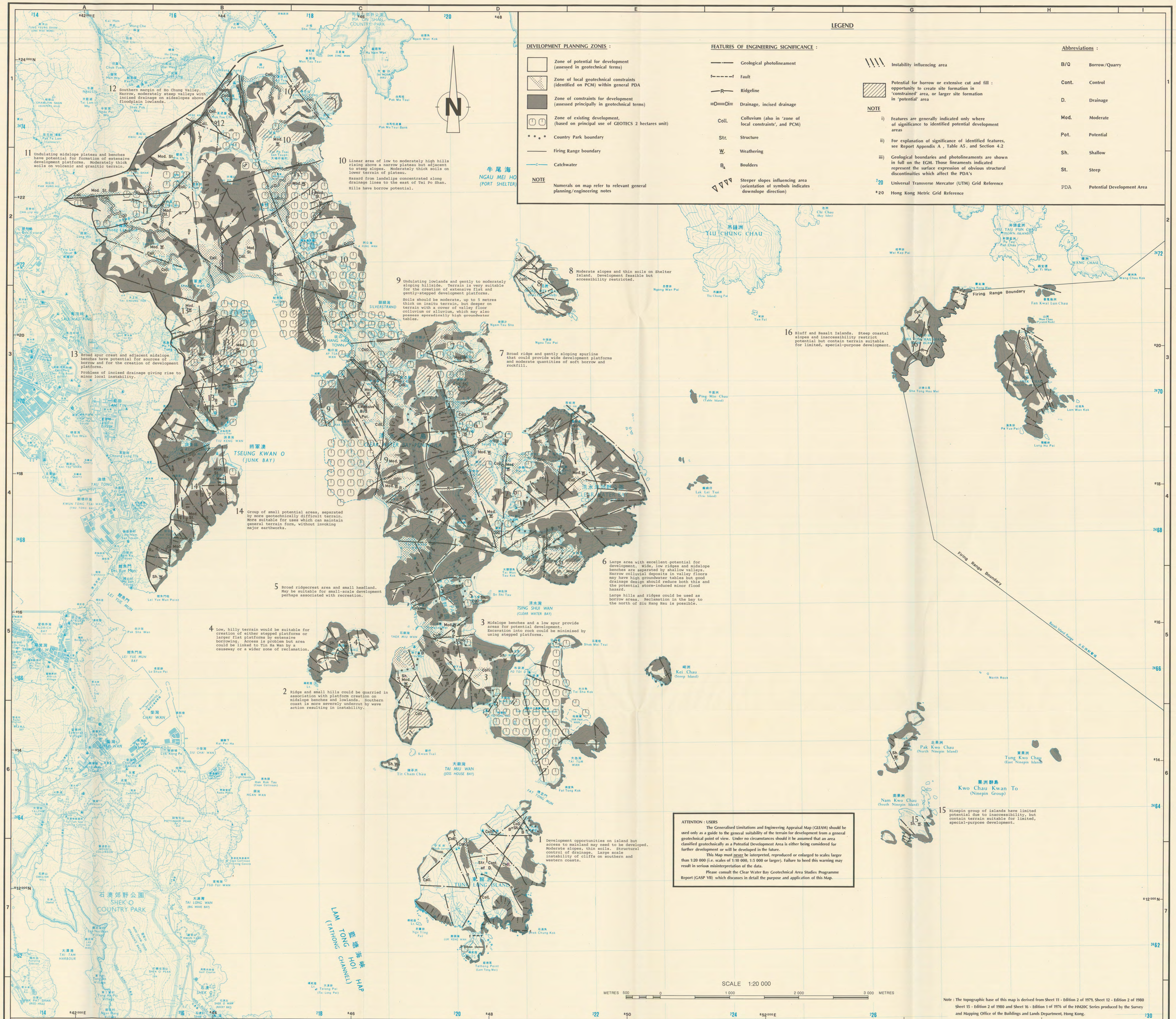
Geotechnical Control Office
Civil Engineering Services Department

GEOTECHNICAL AREA STUDIES PROGRAMME

PHYSICAL CONSTRAINTS MAP - CLEAR WATER BAY

Title: PHYSICAL CONSTRAINTS MAP – CLEAR WATER BAY	
Compiled: R. J. Purser / A. Hansen	Drawn: S.Y.Lam / M.Y.Wong
Scale: 1 : 20 000	Date: Original March, 1985. 2nd Edition June, 1988.
Map Ref. No : GASP/20/VII/6 2nd Edition	Sheet :

Published by the Geotechnical Control Office, Civil Engineering Services Department, Hong Kong.



Geotechnical Control Office
Civil Engineering Services Department

GEOTECHNICAL AREA STUDIES PROGRAMME

GENERALISED LIMITATIONS AND ENGINEERING APPRAISAL MAP CLEAR WATER BAY

Title: GENERALISED LIMITATIONS AND ENGINEERING APPRAISAL MAP CLEAR WATER BAY	
Compiled: R. J. Purser / A. Hansen	Drawn: C. P. Wan
Scale: 1: 20 000	Date: Original March, 1985. 2nd Edition June, 1988.
Map Ref. No: GASP/20/GASP VII/15 2nd Edition	Sheet:

Published by the Geotechnical Control Office, Civil Engineering Services Department, Hong Kong.