GASP Report III

# Geotechnical Area Studies Programme - West New Territories

Geotechnical Control Office
Civil Engineering Services Department
Hong Kong

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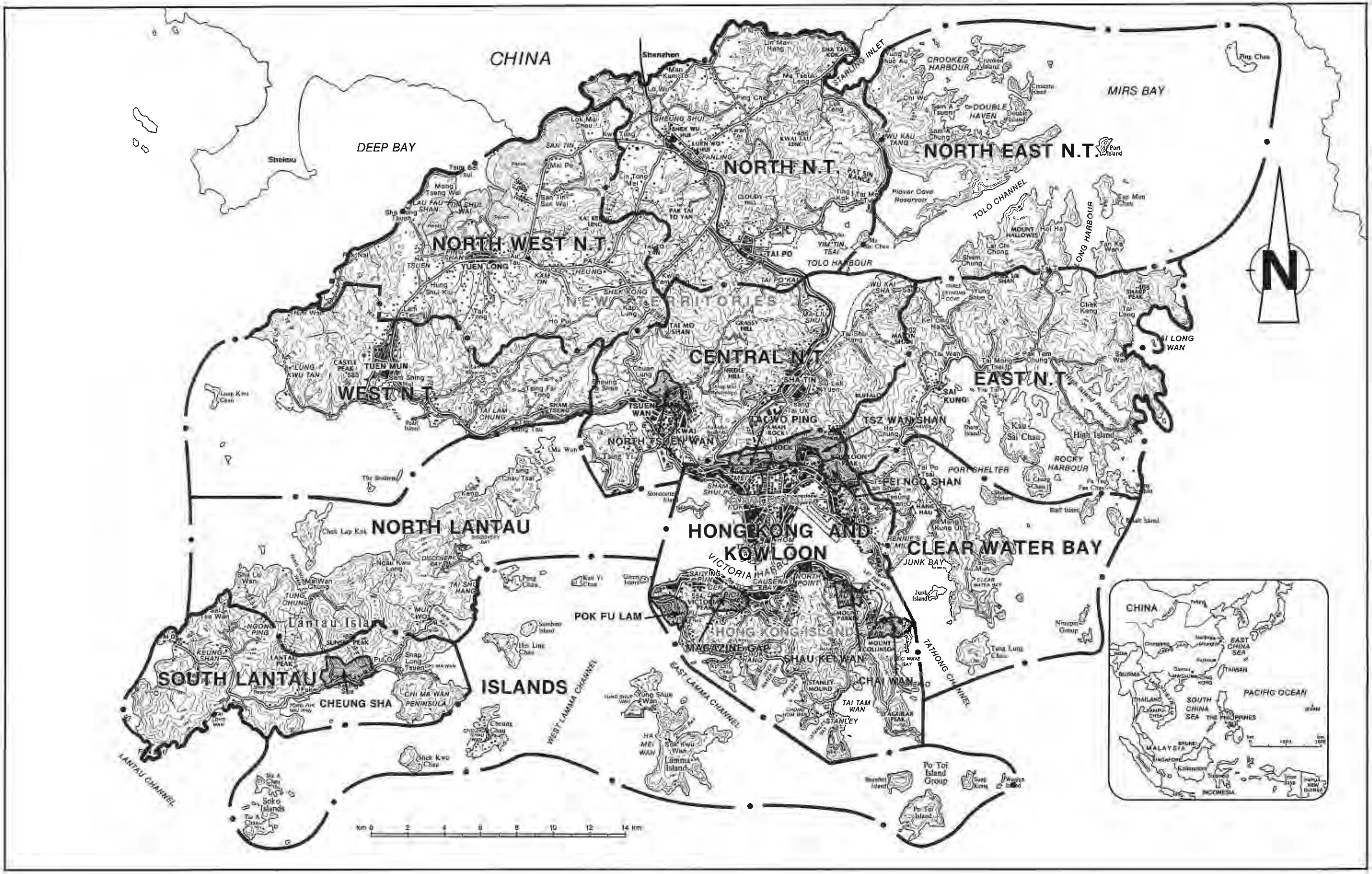


Map of the Territory of Hong Kong Showing the Locations of the Geotechnical Area Studies.
(Boundaries of the Regional Studies are shown by dashed lines and locations of District Studies are indicated by dark screens)

# FOREWORD

This Report aims to provide an adequate geotechnical basis for the planning and land use management of the West New Territories, mainly by way of information presented on a series of maps at a scale of 1:20 000. It is the third 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 will provide more up to date geological information than is available in this Report. The Geological Maps which cover the West New Territories, together with the accompanying Memoir, will be published in the near future.

This Report was originally produced in October 1984, for use within the Hong Kong Government on the basis of information assembled during the period January 1982 to July 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 emphasized 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 G. Atkinson, D. C. Cox, M. J. Dale, A. Hansen, J. M. Nash 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.

The Geotechnical Control Office acknowledges the co-operation and assistance given by the Commissioner of the Soil Conservation Service of New South Wales, Australia, who made available Mr G. Atkinson, a specialist Aerial Photograph Interpreter, to participate in the study. Acknowledgements are also 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, a few of which are reproduced in this Report.

E. W. Brand
*Principal Government Geotechnical Engineer*
*November 1987*

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# 1. INTRODUCTION

## 1.1 The West New Territories Geotechnical Area Study

This Report presents the results of a 1:20 000 scale Regional Geotechnical Area Study of the West New Territories which was carried out in the Geotechnical Control Office between January 1982 and July 1984. The area covered by the study, which is designated as GASP III, 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 maps which cover the area dealt with in this GASP Report will be available in the near future, together with an accompanying Memoir (Langford et al., 1988).

## 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 third of the Reports to be published; nine others will follow in due course. A number of District Studies: Stage 1 have been carried out, and whilst these 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, instability and land use of the West New Territories 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 14 illustrates the system, and Figures 15 to 21 are extracts from the set of maps. The full size originals of these maps are held by the Geotechnical Control Office.

A selection of stereopairs and photographs follow the example figures in the report, and these are presented as Plates 1 to 18. 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 West New Territories 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 15b.

### 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 20a.

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 21a.

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 16a, 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 17a 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. 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 18a 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 19a, 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<br>—Town Planner | —Landscape Architect | —Estate Surveyor<br>—Land Agent | —Civil Engineer | —Geotechnical Engineer<br>—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 Stage 1 Programme are available for areas within the Territory, however, no District Stage 1 Studies have been completed within the West New Territories.

# 2. DESCRIPTION OF THE WEST NEW TERRITORIES STUDY AREA

## 2.1 Geographical Location

The study area occupies approximately 8 952 ha and comprises the coastal and dissected plateau area from Tsuen Wan to Tuen Mun and the extreme western part of the mainland bounded by Tap Shek Kok (Castle Peak Power Station), Lan Kok Tsui (Black Point) and Tai Shui Hang. Much of the study area, as shown in Figure 2, is covered by the Tai Lam Country Park, Tai Lam Chung Reservoir and the Castle Peak Firing Range. The islands of Lung Kwu Chau, Pak Chau, Sha Chau, the Brothers and Reef Island are also included in the study area.

The eastern boundary, which is common with the western boundary of the Central New Territories GASP II, approximately follows the ridgeline from Pak Shek Kiu through Shek Lung Kung to Yau Kom Tau. The irregular northern boundary, which coincides with the North West New Territories GASP IV southern boundary, follows the main drainage divide from Pak Shek Kiu to Wong Nai Tun Reservoir, crosses the Castle Peak Road near Bowring Camp and runs along the 15 000 m Easting before cutting across to the coast near Tai Shui Hang.

The main area of urban development is the Tuen Mun New Town (Plates 1 to 3) which is served by the Tuen Mun Highway and Castle Peak Road.

## 2.2 Topography

The West New Territories can be classified into five topographic areas which can be described as three dissected upland plateaux separated by two major drainage valleys. All three upland areas have hills rising to over 500 m. Tables B1, B3, B4 and B5 in Appendix B give basic physiographic information on slope gradient, aspect and landforms.

The western part of the study area, bounded by Wu Tip Wan, Tap Shek Kok, Lan Kok Tsui and Tai Shui Hang, is dominated by Castle Peak (583 m) which is the highest mountain within the study area. A major ridgeline runs north from Castle Peak. The terrain west of Castle Peak comprises generally low hills with moderate to steep slopes (Plates 4 and 5). The central portion of this terrain is drained by a major network of streams which generally flow in a northward direction. The coastal area is drained by smaller streams which usually flow directly to the coast. Some areas of low-lying coastal and alluvial plain occur along the coastline in this western area (Plates 6 to 8).

The main north to south trending valley east of Castle Peak and the footslopes on either side of the valley contain the major areas of urbanisation (Tuen Mun New Town), development and agriculture. Much of the once low-lying estuarine flats and shallow Castle Peak Bay (Tsing Shan Wan) has, or is, in the process of reclamation (Plate 18).

East of Tuen Mun the terrain rises to an elevation of 511 m with a substantial part of the area above 300 m. Runoff from this area drains into two major streams which flow northward. Both these streams have been dammed to provide water for the Tuen Mun area in the past. Many of the sideslopes especially on the southern flanks, are steep, rising from sea level to over 400 m. General instability is particularly prevalent on sideslope terrain in the granitic areas (Plate 9).

The southwest to northwest trending valleys around So Kwun Wat, Siu Lam and Tai Lam Chung have been dammed in their upper reaches to form Tai Lam Chung Reservoir. These three low-lying valleys, of which So Kwun Wat and Siu Lam are intensively cultivated, are separated by hills of low relief. The hills between So Kwun Wat and Siu Lam are being extensively modified to form platforms for development. The catchment immediately around Tai Lam Chung Reservoir (Plate 10) is made up of generally well-vegetated hills of low relief which are dissected by numerous streams. Some reclamation is evident on the coast near Tai Lam Chung.

The area east of Tai Lam Chung Reservoir generally rises in elevation towards Shek Lung Kung (473 m) and the radio repeater station near Pak Shek Kiu (578 m). A highly dissected upland plateau generally above 200 m, forms the majority of the terrain between Tai Lam Chung and the eastern boundary. This upland area falls away to the coast forming many steep (over 30°) and unstable slopes. The coastal area is dissected by several large streams; with development occurring near Tsing Lung Tau and Sham Tseng. Reclamation also occurs at Sham Tseng. The Tuen Mun Highway (Plates 11 to 13) and Castle Peak Road traverse the coastal region creating large fill and cut slopes. Many small beaches are found along the coast in this region.

## 2.3 Geology

### 2.3.1 *General*

As mapped by Allen & Stephens (1971), the regional geology of the area consists of a sequence of faulted, folded, mildly metamorphosed volcaniclastic rocks (Repulse Bay Formation) which stratigraphically overlie representatives of the Tai O and Lok Ma Chau Formations. These units are intruded by granite. The Tai O Formation consists of sandstones and siltstones which are slightly metamorphosed. Example exposures occur only on East & West Brother Islands. The Lok Ma Chau Formation consists primarily of schists, quartzites, quartzitic breccias, volcanic units and phyllites. These metasediments are often difficult to distinguish from the Repulse Bay Formation and doubt exists as to the exact stratigraphy of the rocks on the eastern flank of the Castle Peak Range. The Lok Ma Chau and Repulse Bay Formations are extensively intruded by younger granitic rocks and both are partially overlain by superficial deposits. These relationships are illustrated in the geological cross-sections presented in Figure C1 in Appendix C.

The rocks of the Lok Ma Chau and Repulse Bay Formations are restricted to the eastern flank of the Castle Peak Range and, in the case of the latter, also to the easternmost part of the study area. According to Allen & Stephens' (1971) mapping, the remainder of the area consists of the Needle Hill, Cheung Chau and Sung Kong Granites and the Tai Po Granodiorite. Undifferentiated Granite outcrops on the islands of Lung Kwu Chau, Pak Chau and Sha Chau, west of the mainland. Granophyric Microgranite occurs in a small outcrop east of Castle Peak Bay within a large body of Sung Kong Granite.

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 than is presented in this Report. These new geological maps of the area are soon to be published, together with an explanatory Memoir (Langford et al., 1988).

As a precursor to the Territory-wide 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 (1985). From an historical perspective Davis (1952) is still of considerable interest. The rocks in the adjacent area of Sheet 7 are described in Addison (1986).

On the basis of this GASP study, the relative proportions of the geological materials are graphically illustrated in the GEOTECS Plot in Figure 6, in the Pie Chart 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, but more detailed 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.

### 2.3.2 *Sedimentary and Metasedimentary Units*

These units within the study area are subdivided according to Allen & Stephens (1971) into the following Formations:

(i) *Tai O Formation (T)*
The Tai O Formation consists of thinly bedded siltstones, shales, sandstones and graphitic sandstones and occur only on East and West Brother and Reef Islands. The Tai O Formation occupies 0.3% of the area.

(ii) *Lok Ma Chau Formation (LMC)*
The Lok Ma Chau Formation consists of a series of low grade regionally metamorphosed rocks which outcrop in the northwest of the study area and form the eastern flanks of the Castle Peak Range. The rocks are deeply weathered and exposures of fresh rock are rare. Rock types include schists and hard quartzites, quartzite breccias and thin volcanic horizons. Graphitic phyllites, sandstone, shale and marble are also reported from this Formation, but the boundary between the Lok Ma Chau and Repulse Bay Formation is not distinct. The Lok Ma Chau Formation occupies 0.3% of the area.

The Lok Ma Chau metasediments in the study area are thought to be affected by folding with the beds possibly being overturned.

### 2.3.3 *Volcanic and Volcaniclastic Units*

The Repulse Bay Formation within the study area is classified by Allen & Stephens (1971) into the following lithotypes:

(i) *Sedimentary Rocks and Water-laid Volcaniclastic Rocks (RBs)*
This class consists of a succession of metamorphosed fine-grained clastic sediments and lapilli tuffs with soft bands of schist. Outcrops are found on the western flanks of Castle Peak Bay and north of Tai Lam Chung Reservoir. This class is generally weaker than other members of the Repulse Bay Formation and is deeply weathered in places, although hard bands of metamorphosed volcanics occur. This class occupies 3.4% of the area.

(ii) *Coarse Tuff (RBc)*
This class includes coarse volcanic ash with generally closely spaced jointing. Weathering of this unit is normally moderate to shallow. Coarse tuff of the Repulse Bay Formation outcrops on the coastal strip in the extreme east and also in the northwest of the study area. This class occupies 1.7% of the area.

(iii) *Agglomerates (RBag)*
Outcropping in the easternmost portion of the study area, this class of the Repulse Bay Formation consists of mainly tuff breccia or blocky lapilli tuff grading into coarse to fine tuff. This class occupies 0.2% of the area.

(iv) *Pyroclastic Rocks with Some Lavas (RBp)*
Rocks of this unit outcrop in two small areas east of Tai Lam Chung Reservoir. These rocks occupy 0.6% of the study area and consist of easily weathered fine tuffs. Mineralisation is common due to the proximity of the intrusive contact.

### 2.3.4 *Intrusive Igneous Units*

According to Allen & Stephens (1971), the igneous rocks may be classified on the basis of lithology, age and intrusive relationship as follows:

(i) *Tai Po Granodiorite (XT)*
This is the oldest intrusive unit and occurs in the eastern part of the area. It forms three distinct outcrops flanked by the younger Needle Hill Granite and also rocks of the Repulse Bay Formation. The rocks are dark grey, medium to coarse-grained and are cut by veins of epidote. This rock type generally exhibits moderate to deep weathering profiles and has widely spaced jointing. This unit occupies 2.7% of the area.

(ii) *Sung Kong Granite (SKm)*
The Sung Kong Granite is typically medium to coarse-grained, pale grey or pink in colour and often porphyritic. The granite is often subject to deep weathering and is heavily jointed. This unit forms a large outcrop on the eastern flank of Castle Peak Bay and west of Tsing Lung Tau on the southernmost coastal area. The Sung Kong Granite occupies 10.7% of the area.

(iii) *Cheung Chau Granite (CC)*
This unit occurs widely throughout the area, principally west of Tuen Mun forming the Castle Peak Range, but also in the northeast and southeast (coastal) areas. This unit occupies 30.4% of the study area and consists of coarse-grained, pale grey to pink, often porphyritic rocks. This granite weathers easily, resulting in deep weathered profiles and is moderately jointed.

(iv) *Needle Hill Granite (NH, NHm)*
The Needle Hill Granite intrusions are located mainly in the eastern part of the area and also, to a lesser extent, in the area northeast of Castle Peak Bay. The unit has fine and medium-grained phases and is generally porphyritic. Needle Hill Granite outcrops occupy 26.3% of the study area and mineralisation is common.

(v) *Granophyric Microgranite (Mc)*
A very small intrusion of this porphyritic fine-grained granite occurs on the eastern side of Castle Peak Bay.

(vi) *Undifferentiated Granite (G)*
This rock type consists of granites which are not easily allocated to any other unit by means of age of lithology. These rocks outcrop on a group of islands to the south and west of the area. Three of the main islands are Lung Kwu Chau, Pak Chau and Sha Chau. Undifferentiated granite occupies 0.7% of the study area.

(vii) *Dykes and Quartz Veins*
These rock types occur throughout the area as linear outcrops, but are not generally identified within the GEOTECS system due to their small size.

In summary, 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. Intrusive igneous rocks occur in approximately 70.8% of the study area.

### 2.3.5 *Superficial Units*

In addition to the bedrock geology, both natural and man-made superficial deposits constitute 22.5% of the land surface. These superficial deposits are classified as follows:

(i) *Colluvium*
The colluvial materials occur over 837 ha 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 heterogeneous in their physical properties and, in this Report, are subdivided only on the basis of the parent rock type as follows:

(*a*) Volcanic colluvium (Cv)—This material occupies 0.5% (43 ha) of the study area and occurs predominantly as bouldery deposits in drainage channels or as large fan-shaped deposits. The detrital material ranges from fresh boulders to completely weathered granular soil and may be highly permeable. In many locations the material displays evidence of instability.

(*b*) Granitic colluvium (Cg)—This material occurs as large fan deposits of variable age and weathering, and also exhibits significant erosion and instability. It occupies approximately 6.0% (541 ha) of the study area.

(*c*) Sedimentary colluvium (Cs)—This material is derived from the sedimentary and metasedimentary rock units and occupies approximately 20 ha (0.2%) of the area.

(*d*) Mixed colluvium (Cm)—This category includes all colluvium of mixed geological origin and makes no distinction between relative proportions of the parent materials. This unit occupies a total of 2.6% (233 ha) of the study area.

(ii) *Alluvium*
This material generally consists of poorly sorted, brownish silty sand and subangular gravels. It occurs extensively within the study area, occupying approximately 5.8% (518 ha) of the area.

(iii) *Marine Deposits*
On the seabed and beneath areas of reclamation, deposits of soft marine muds and shelly sands may be found.

(iv) *Littoral Deposits*
Littoral deposits of medium dense sands and gravels may be found in isolated areas along the coast of the West New Territories and beneath reclamation adjacent to the mainland. They form 0.4% of the study area.

(v) *Reclamation*
Approximately 314 ha (3.5% of the study area) exists as reclamation. The material used to form the reclamation is highly variable and may contain weathered and fresh rocks from any of the previously discussed groups, old masonry sea walling and/or refuse.

(vi) *Fill*
During site formation, areas of fill have been placed which now total approximately 3.5% of the study area. The engineering behaviour of the material is generally dependent on the degree of compaction at the time of placement and any subsequent densification as a result of settlement.

The West New Territories study area contains a wide variety of geological materials, and the engineering behaviour of foundations and slopes can be expected to vary accordingly.

### 2.3.6 *Structural Geology*

The study area consists mainly of granites with essentially similar mineralogy and, in some cases, the age relationships are indeterminate. Therefore the structural or 'stratigraphic' relationships between them are difficult to establish. The sedimentary and volcaniclastic rocks in the study area appear to form "rafted" structures above the granite plutons.

Extensive photolineaments occur within the area, many of which were mapped as faults by Allen & Stephens (1971). In the Castle Peak area, the lineaments trend dominantly north to south but are traversed by a lesser series running approximately east to west and also a curvilinear group trending east northeast to west southwest. A major north south trending fault has resulted in a deep valley which traverses the mid-point of the Castle Peak Peninsula. Allen & Stephens (1971) report a thrust fault in the area forming the boundary between the Repulse Bay Formation and the Cheung Chau Granite where a mylonite and shear zone are exposed. The upper part of the thrust is formed by the granites to the northwest. Some overturning of the metasediments has also occurred in this area.

East of the Tuen Mun valley, lineaments influence topographic control in three main directions. The north to south trending lineaments are mainly confined to the northern part of this area, i.e. northwest of Tai Lam Chung Reservoir. A second series of lineaments trend east northeast to west southwest. Smaller, less distinct sets form subsidiary trends between the major groups. Extensive dominantly east to west trending lineaments in the eastern part of the area tend to show declination southwards and east, until in the eastern area they adopt a north northeast to south southwest orientation. The Tai Lam Chung Reservoir is located on a major structurally controlled valley and the area between the reservoir and the Tuen Mun valley is traversed by narrow shear zones which are possibly tear faults. The granite associated with these zones is locally altered to a weak micaceous, schistose rock which proved difficult to engineer during water tunnel construction in the area.

Rock jointing is well developed in almost all the granites and, as these granites cover the majority of the study area, jointing of one form or another is widespread.

Shear zones are associated with faults, especially in the Castle Peak Peninsula, and a certain amount of rock alteration (mylonisation) is evident.

Within the regional geological context, the orientation of photolineaments matches those found in Guangdong Province.

The Tuen Mun valley is thought to be a fault controlled "graben" structure, with a thrust fault forming the western flank. Site investigation data from within this area has revealed a sharp contact between granite and volcaniclastic rocks, and the presence of shearing, mylonisation and brecciation has been noted in some boreholes within the Tuen Mun New Town.

A description of the geology of the Territory is available in the Report of the Geological Survey of Hong Kong (Allen & Stephens, 1971) and the geological remapping of the West New Territories is soon to be completed by the Geotechnical Control Office. A detailed description of the rock units is presented in Appendix C.

## 2.4 Geomorphology

The geomorphology of the West New Territories reflects a complex Quaternary history of erosional and depositional response to climatic change and sea level (eustatic) fluctuations superimposed on 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.

Table B5 in Appendix B provides data on the distribution of the major landform units.

The various geological materials weather, erode or are deposited in different ways. The regional geomorphology can therefore be described in subdivisions relating terrain type to either bedrock geology or superficial materials. For this study the geomorphology is grouped into the areas defined in Section 2.2 and which generally reflect the dominant rock type or superficial material.

(i) *Wu Tip Wan, Tap Shek Kok, Lan Kok Tsui and Tai Shui Hang*
This area consists mostly of terrain formed on the Cheung Chau Granite. The drainage pattern reflects the strongly developed orthogonal system of structural discontinuities. Streams have incised deeply along these features exposing granite bedrock in most drainage lines.

The slopes on the coastal strip and those around Castle Peak are long and moderately steep to very steep and often give rise to tors and detached joint blocks. The high runoff in these areas, which is commonly associated with orographic rainfall, results in the removal of much of the weathered material from around the granite blocks.

In the central part of this area the slope lengths tend to be shorter, forming a highly dissected upland plateau. There is severe erosion on the ridgecrests with extensive barren areas resulting from sheet erosion and deep gullies. Footpaths along the ridgecrests often promote or aggravate this type of erosion. Boulders and tors are not as common in this area possibly because the rain shadow effect, due to the coastal hills, has reduced the surface runoff and hence the amount of weathered material being removed. Weathering probably extends to considerable depth in this area and the relationship between slope, aspect, erosion and geology is examined in Table B10. The steeper, southeasterly facing slopes exhibit generally higher incidences of instability.

Superimposed on the overall erosional and weathering patterns are several periods of sea level change. This is suggested by the occurrence of knickpoints along the major stream courses. Below these points erosion and incision of the streambed and adjacent banks are common. Above the knickpoints, deposits of alluvium often occur, and streams have often cut through the unconsolidated sandy sediments to bedrock. Some of these upland alluvial areas are swampy during the wet season.

Alluvial floodplains also occur along the coastal areas especially at Lung Kwu Sheung Tan, Yung Long, Tsang Tsui, Nim Wan and around Sha Po Kong. These contain alluvial material deposited by the streams that flow to the coast. Between these alluvial deposits and the coast, an area of coastal plain often occurs. Coastal plain deposits are often a mixture of reworked alluvial sediments, beach and dune sands. The level of this material tends to be several metres above the floodplain, and seawards it grades into beach sands. Where beaches do not occur, some coastal instability is evident in the weathered rock mantle overlying the slightly weathered rock of the steep coastal slopes and cliffs.

(ii) *Tuen Mun Valley*

This area is generally of low relief, with marginal footslopes rising to approximately 150 m. Much of the lower-lying areas are deposits of alluvium and colluvium. Colluvial deposits, are common below the steep granitic slopes of Castle Peak and the north to south trending ridgeline to the west of Tuen Mun. These deposits show evidence of instability on aerial photographs taken prior to development. An example of slope failure associated with colluvial footslope terrain is given in Plates 14 & 15.

The footslopes west of Tuen Mun consist of Repulse Bay Formation sediments and metasediments of the Lok Ma Chau Formation. The boundary between these rocks and the Cheung Chau Granite is very distinct on aerial photographs. The sediments and metasediments erode to more rounded spurlines than the steep granite terrain.

Much of the area around Tuen Mun New Town, once largely estuarine, has been filled and reclaimed since the early 1960's. Delineation between fill on alluvium and reclamation is approximate, because of the variability of the marine deposits and their intercalation with terrestrial sediments.

(iii) *Tuen Mun to Tai Lam Chung Reservoir*

This area consists of Sung Kong Granite with some Needle Hill Granite, Cheung Chau Granite and minor Repulse Bay Formation sediments. The major stream directions are controlled by north to south trending structural discontinuities marked by deeply incised valleys. The east to west discontinuity trends and other offsets, although strongly developed, do not appear to exert a major control on the stream directions. The erosion associated with these granites is not as extensive as the Cheung Chau Granite that outcrops to the west, but some severe erosion occurs around the Wong Nai Tun Reservoir. The erodibility of the various granities appear to vary. (Table B10 in Appendix B). On the slopes facing the coast and Tuen Mun, large granite exposures and tors are found to be vary similar to the terrain west of Castle Peak.

Sideslopes tend to be moderately steep and short in length. Landslips are common and occur usually as a result of the headward extension of the various drainage lines. The landslips tend to be shallow, often associated with sheeting joints. The weathered mantle is probably shallow in this area.

(iv) *So Kwun Wat, Siu Lam and Tai Lam Chung*

The northwest to southwest trending valleys in that area are large, structurally controlled features. Much of the terrain is obscured by the Tai Lam Chung Reservoir, but the size of the valley around So Kwun Wat suggests the main stream now at Tai Lam Chung once flowed via So Kwun Wat. The alluvium is gently sloping and extensively cultivated. Some colluvium on the sides of the valley may interfinger with the alluvial sediments. The deposition of sediment has been greatly reduced by the construction of the reservoir and various catchwaters.

Three granites, namely the Cheung Chau, Needle Hill and Sung Kong, are exposed in this area. Again, the Cheung Chau Granite around Siu Lam and Siu Lam San Tsuen and to the north of the Tai Lam Chung Reservoir, appears to be more deeply weathered than the other granites, producing a more rounded and eroded topography. The Needle Hill Granite surrounding the Reservoir, although deeply weathered in places, appears to be less susceptible to erosion. This may also be a reflection of the denser vegetation cover on the granite. The area is highly dissected by the numerous small streams which flow into the Reservoir. Some severe erosion occurs on the island and banks, in and around the Reservoir, and probably results from the fluctuation in water levels in the Tai Lam Chung Reservoir. Landslips generally occur in and adjacent to the drainage lines but are less extensive in this area.

(v) *Tsing Fai Tong to Tin Fu Tsai*

The area to the east of Tai Lam Chung Reservoir has a complex geomorphology. The terrain is cut by numerous northeast to southwest (orthogonal) trending structural discontinuities; with other directions being less pronounced. The streams that flow along these discontinuities are deeply incised in places, creating oversteep slopes. In the May and August rainstorms of 1982 these slopes were very unstable and more than 100 landslips occurred and in this area alone. Many of the affected slopes are steeper than 30° and these areas are shown on the Physical Constraints Maps (Map Folder). Stream capture is evident in the Quaternary history of this area, resulting in numerous changes of stream direction.

Much of the terrain is underlain by Needle Hill Granite with some exposures of Tai Po Granodiorite, Sung Kong and Cheung Chau Granite and, to the extreme east and north of the area, the Repulse Bay Formation. The differences in terrain between the rock types is not as obvious as in other areas, especially the granodiorites and granites. The boundary between the granites and the Repulse Bay Formation is visible on aerial photographs. The area of volcanics (tuffs, agglomerates and lavas) is mostly covered by grasses and little erosion is visible. Numerous large boulders of coarse tuff and agglomerate litter the gently to moderately steep slopes, and some general instability is also evident.

Numerous small deposits of colluvium and alluvium are also visible in this area, with the alluvial floodplain generally occurring upslope of a knick point in the stream courses. Colluvial slopes often interdigitate with floodplain deposits. In one locality raised alluvial terraces occur, with the stream course having cut through the older sediments following the capture of the stream from another direction.

## 2.5 Hydrology

### 2.5.1 *Surface Hydrology*

The natural drainage pattern in the West New Territories study area is disrupted by development. The Engineering Geology Map shows the location of the major catchments outside of the urban area. Each catchment boundary is annotated with the highest order of stream which exists within it. The system of stream ordering is described in Appendix A. As it is not possible to map the drainage hierarchy within the urban area with reliability, the exact locations of the major catchment boundaries in the developed area are uncertain.

Within the extensive built up areas, the principal changes caused by urban development are the channelisation coupled with possible realignment of drainage paths, together with the formation of an impervious surface to the ground. The climate in the Territory is characterised by periods of intense rainfall, as illustrated in Appendix C.4, and storm channels in urban areas require a large capacity due to the extremely high volume of runoff. Runoff is removed through a system of storm drains into the main channels with very little infiltration into the ground. Discharges within urban channels are high, and the times to peak discharge are short. Peak discharges under these conditions will be much higher than for a natural drainage system, and proposals for development should take this into account. Also, the extension of reclamation causes a reduction in overall gradient of a drainage channel or nullah, thus possibly necessitating regrading to maintain a sufficient gradient for efficient discharge. Alternatively, an increase in channel cross section may be required in the lower reaches to accommodate large flows. Many of the channels are covered, and the routes are not necessarily apparent from a visual inspection of an area. Except in the case of some of the major open nullahs, the drainage pattern is not shown within the urban area on maps produced at a scale of 1:20 000.

Outside the urban areas, disturbance of the natural drainage system consists of the channelisation of some major streams, the construction of catchwaters, the creation of reservoirs and the addition of drainage systems to some unstable or problem slopes.

The West New Territories area can be broadly divided into a number of major catchments. Most of the catchments flow toward the southern or western coastlines. The drainage network near Hung Shui Hang Reservoir and Wong Nei Tong Reservoir form part of catchments which flow toward Yuen Long. Northeast of Tuen Mun, several partial catchments flow towards the northeast between Tai Shui Hang and Sheung Pak Nai. The directions of most of the streams in the West New Territories area reflect a high degree of structural geological control.

The natural catchments east of Tuen Mun have generally been modified so that much of the runoff now flows through catchwaters and drainage tunnels into Tai Lam Chung Reservoir. This Reservoir has the largest storage capacity in the Territory except for the Plover Cove and High Island Reservoirs. The catchwaters east of Tuen Mun have in the past been disrupted by landslips. Consequently, areas below catchwaters may be subject to severe erosion or flooding associated with landslips.

The major catchment areas are summarised below. The catchments are defined by stream order (Strahler, 1952) and are shown on the Engineering Geology Map (Map Folder). The small offshore islands are not included. The system of stream classification is described in Appendix A.8.2.

(i) *Tai Shui Hang to Wu Tip Wan (Butterfly Beach)*
This coastal area consists of six small, coastal, 3rd and 4th order catchments and several smaller 2nd order catchments. The streams are generally less than 1 500 m in length and have moderately steep gradients. Stream flow will, therefore, react quickly to rainfall. Small areas of floodplain occur at Lung Kwu Sheung Tan, Yung Long, Tsang Tsui, Nim Wan and around Sha Po Kong, where localised flooding may occur. These small catchments drain an area of approximately 1 520 ha.

(ii) *Tai Lang Shui to Tai Shui Hang*
This is a 5th order catchment draining approximately 680 ha to the northeast of Castle Peak. The streams generally flow to the north and form a structurally controlled, orthogonal 'trellised' drainage pattern. The major streams have generally eroded to bedrock, and erosion of the streambed indicates high discharges during periods of intense precipitation.

(iii) *Ha Pak Nai to Sheung Pak Nai*
There are two small incomplete catchments containing 4th and 5th order streams which flow to the coast between Ha Pak Nai and Sheung Pak Nai. Together these catchments drain approximately 420 ha.

(iv) *Tuen Mun Valley*
This is also a 5th order catchment draining over 1 500 ha of the Tuen Mun Valley, including the north–south valley containing the Lam Tei Reservoir. A small area of catchment extends across the boundary of the study area into the North West New Territories (GASP IV) area. The major stream has been channelled into an 80 m wide concrete nullah. Many of the agricultural areas occur on low lying floodplain and may be subject to localised flooding, especially if the system of man-made drainage is impeded. The streams on the moderately steep to steep footslopes and sideslopes tend to be short, generally less then 1 400 m in length. A quick response to rainfall is expected in these streams. Runoff from the slopes southeast of Tuen Mun is diverted into a catchwater flowing into Tai Lam Chung Reservoir.

(v) *Sam Shing Estate to So Kwun Tan*
This is a small (200 ha) coastal, 3rd order catchment. The streams are short in length, and flows will respond quickly to precipitation. A catchwater cuts across the upper area of the catchment and channels the runoff into Tai Lam Chung Reservoir.

(vi) *Hung Shui Hang Reservoir*
This is an incomplete catchment, draining approximately 300 ha. The main stream flows north along a structural geological discontinuity. The dam wall forming the reservoir is constructed across the stream on the boundary of the study area.

(vii) *Wong Nai Tun Reservoir*
East of Hung Shui Hang Reservoir, runoff from approximately 220 ha flows into Wong Nai Tun Reservoir through a catchwater system. The essentially parallel streams flow toward the northwest from the main north to south drainage divide. This Reservoir is gravity fed through a tunnel system to Tai Lam Chung Reservoir.

(viii) *Tai Lam Chung Reservoir*
This is the largest catchment within the study area, covering about 2 630 ha. The catchment areas below the Reservoir have been modified by damming of the various tributaries. Consequently, the valleys of So Kwun Wat and Siu Lam are included in this 5th order catchment. The stream directions are largely controlled by major structural geological discontinuities to form an orthogonal 'trellised' drainage pattern. The catchment potential of this area is increased by water channelled across the major drainage divide by catchwaters from the northeast toward Shek Kong and a smaller one from the north. Other catchwaters include one from Tuen Mun and several from the area between Tai Lam Chung and Tsuen Wan. Below the Reservoir and along the coast, lowlying floodplains may be subject to localised flooding, especially if the catchwaters overtop. In the terrain of higher elevation north of the Reservoir, small floodplain deposits may also be subject to localised flooding. Examples occur at Tin Fu Tsai and Sheung Tong.

(ix) *Tai Lam Kok to Yau Kom Tau*
This coastal area is made up of four small 3rd and 4th order catchments which drain directly into the sea. In total, these catchments drain approximately 1 130 ha. As in the case of the Tai Lam Chung catchment, the stream directions are largely controlled by orthogonal structural discontinuities. The streams tend to be short in length and drain areas of moderate to steep slope gradients, therefore, flows are expected to respond quickly to rainfall. Much of the runoff from the terrain above 150 m in elevation drains into a catchwater system which flows into the Sham Tseng Settlement Basin. The water is in turn gravity fed through a tunnel system into the Tai Lam Chung Reservoir.

### 2.5.2 *Groundwater Hydrology*

In general, the rocks and soils occurring within the West New Territories do not constitute well-defined aquifers.

Groundwater flow through the majority of lithotypes is normally by some form of conduit flow. The permeability characteristics of any of the rock or soil masses is thus a function of jointing, fissuring or piping rather than solely intergranular flow. Consequently, zones of groundwater flow and velocities are difficult to predict.

Groundwater flow in the solid rocks within the area, which are mainly granitic in nature, will depend to a large extent on the degree of jointing and fissuring, and flow will almost certainly be concentrated where these features are most prominent. Fault shatter zones may also act as water transmitting conduits, and groundwater flow can be expected to concentrate in areas most affected by faulting. Sheeting joints also tend to concentrate groundwater flow.

The superficial deposits exhibit groundwater flow of a similar nature to the solid rocks but flow within the majority of these deposits is generally due to piping which develops possibly as a result of tunnel erosion. Intergranular flow occurs to a limited extent.

The coarse-grained, loosely compacted soils are most susceptible to piping. This type of groundwater flow is difficult to predict because it may be sporadic and very complex. Pipes and voids may develop and collapse quickly in response to heavy rainfall. This phenomenon, of course, has serious implications for the construction of earthworks and in relation to general slope stability.

Surface flow over bedrock frequently disappears underground on reaching superficial deposits, or indeed bedrock of different, usually softer lithology. This is well illustrated by the common occurrence of tunnel erosion in the superficial deposits and the rocks associated with the Repulse Bay Formation to the west of Castle Peak Bay (Plates 14 and 15).

### 2.6 Vegetation

In this Report a nine class system is used to classify the vegetation. The spatial distributions of these groups are illustrated in the GEOTECS Plot in Figure 7, whilst Figure 4 shows their relative proportions. Over 15% of the area is devoid of vegetation due to man's disturbance, principally through urban development and, to a much lesser extent, erosion.

The vegetation classes are as follows:

(i) *Grassland*
This class generally consists of indigenous or introduced grass species which occur after the clearing of shrubland or woodland. Grassland occupies 4.4% of the study area and occurs in patches throughout the undeveloped terrain.

(ii) *Cultivation*
This group occupies 4.3% of the study area. Urbanisation and abandonment of paddies in inaccessible areas has resulted in the alienation of some agricultural land in the area.

(iii) *Mixed Broadleaf Woodland*
This group contains a wide range of indigenous and exotic species. Areas of woodland occur extensively in the Tai Lam Country Park and in the adjacent foothills. This group occupies 27.9% of the study area and is probably the indigenous vegetation of the South China coast if not for the influence of man.

(iv) *Shrubland (Less than 50% Ground Cover)*
Shrubland occurs as regrowth on areas of disturbed terrain or develops from grassland protected from hill fires. This group makes up 20.5% of the area.

(v) *Shrubland (Greater than 50% Ground Cover)*
Similar to (iv) but has a denser vegetation cover. This class covers 23.5% of the area and occupies some of the upland terrain.

(vi) *No Vegetation on Natural Terrain*
Predominantly bare soil which is presently, or has in the recent past, been affected by moderate or severe soil erosion. This class occupies 0.8% of the area, mainly an ridgecrests and spurs of granitic terrain.

(vii) *No Vegetation due to Man's Disturbance*
Urban expansion, settlements and associated development account for this class which occupies 14.8% of the study area. Some of the natural terrain exhibits no vegetation as a result of surface erosion.

(viii) *Rock Outcrop*
Areas of general rock outcrop may contain sparse intermittent grass and shrub vegetation but the land surface is predominantly rock with little soil. This class occupies 1.3% of the area.

(ix) *Waterbodies*
Natural streams, man-made channels and reservoirs occupy approximately 2.5% of the area.

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.

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 '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 the pie charts in Figure 4, tabulated in Table 2.1, and illustrated in the GEOTECS Plot in Figure 8.

Erosion and instability affect 73.0% (6 533 ha) of the study area. However, approximately 12.4% (1 111 ha) of the study area is currently developed, with erosion occurring on unprotected platforms and slopes. In the study area, almost three quarters of the natural terrain is subject to erosion or instability.

Table 2.1 Erosion and Instability

| Erosion | | % of Total Area | Area (ha) |
|---|---|---|---|
| Instability | | | |
| —well-defined landslips | | 0.6 | 55 |
| —general instability | | 18.0 | 1 614 |
| Appreciable Erosion | Sheet erosion—minor | 15.1 | 1 349 |
| | —moderate to severe | 8.1 | 722 |
| | Rill erosion —minor | 2.4 | 212 |
| | —moderate to severe | 2.7 | 243 |
| | Gully erosion—minor | 20.4 | 1 828 |
| | —moderate to severe | 5.7 | 510 |
| No Appreciable Erosion | | 27.0 | 2 419 |
| | | 100.0 | 8 952 |

### 2.7.2 *Weathering*

Within the regional context, it is important to appreciate the influence of local features on determining the actual depth of weathering at specific location. For example, granite ridgecrests and sideslopes are often weathered to a depth of at least 20 m, but rock exposures are often devoid of a weathered mantle due to erosion.

For any given rock type the depth of weathering is largely controlled by the mineralogy, discontinuity spacing and the 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 rockmass than in one which is narrowly jointed, after being weathered for the same length of time. Erosion removes the soft products of weathering and thus reduces the actual thickness of the weathered profile. Major streams, if not filled with colluvium, generally have fresh rock exposed in their beds. In general, weathering is thickest beneath ridgecrests and reduces towards drainage lines.

In the Territory, weathering is largely a chemical process that transforms hard rock to soft soil, and thus the engineering character of any site is affected by its local weathering characteristics. 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.

2.7.3 *Erosion*

(i) *Sheet Erosion*
This form of erosion produces extensive areas of bare ground devoid of vegetation. Within the study area, sheet erosion is developed mainly in the west and is coincident with the Cheung Chau Granite. Smaller patches occur in the north of the area, again coincident with this rock type. A total of 23.2% (2 071 ha) of the area is affected by sheet erosion.

(ii) *Rill Erosion*
This form of erosion is often associated with cut and fill batters, but also occurs on natural terrain. It is characterised by numerous subparallel drainage rivulets, which produce a striated appearance and result in significant soil loss. Rill erosion is most common in the west of the study are, on the Cheung Chau Granite of the Castle Peak Range. Rill erosion affects 5.1% (455 ha) of the area.

(iii) *Gully Erosion*
This form of erosion produces deep dissection of the surface with consequent disruption of drainage, and may precipitate slope instability. It affects 26.1% (2 338 ha) of the area, and is again concentrated in the west, coinciding with the Cheung Chau Granite. Patches also occur in the north of the area (Cheung Chau Granite) and on the Needle Hill and Cheung Chau Granites south of Tai Lam Chung Reservoir.

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.

Geology, vegetation and microclimatic variations all contribute to the degree of erosion. There is significant variation in the extent of the various rock units within the area and consequently the sample size of some rock types is too small for a generalised comment on erosional characteristics.

2.7.4 *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 1 669 ha of the terrain displays some form of instability, and this represents 18.6% of the area.

(i) *Well-defined Landslips*
Within the study area, 'well-defined landslips' occupy only 55 ha (0.6%) of the land surface and this consists of coastal instability. A relatively large area of slope instability occurs on the eastern facing footslopes of Castle Peak but at the time of mapping was not large enough to delineate as a separate unit.

(ii) *General Instability*
This form of instability relates to colluvial and insitu terrain where numerous failures and other evidence of instability occur, but it is not possible to show each one as a discrete unit on a 1:20 000 scale map due to their small size.

The sub-class of 'general instability recent' occupies 18% (1 614 ha) of the area. Steep terrain is generally susceptible to this form of instability, especially on the eastern flank of the Castle Peak Range and on the granitic terrain around Tai Lam Chung Reservoir. 'General instability-relict' has not been delineated within the area.

## 2.8 Land Use

### 2.8.1 *Existing Development, Land use and GLUM Class*

Existing or planned large scale development currently occupies approximately 62% of the available GLUM Classes I & II terrain within the area.

The existing development and land use can be broadly categorised into twelve groups. These are summarised below, together with an indication of their relationship with the distribution of GLUM classes. A complete listing of land use types and their relation to GLUM class is presented in Table B13 in Appendix B.

(i) *Commercial and Industrial*
These are concentrated along the coast and on areas of reclamation and low ground, and reflect the need for large level sites. High density residential accommodation is often located nearby and supportive light industries are often mixed with commercial and trading areas. Tuen Mun and Sham Tseng are the main areas concerned with these activities. These areas occupy 90 ha of the area and occur on mainly GLUM Class II terrain.

(ii) *Residential*
High density residential areas are often associated with or in close proximity to (i). Lower density housing is often located on higher ground or further afield from commercial and trading areas. Residential areas are located mainly around Tuen Mun and Sham Tseng. Development of this type occupies about 3% of the area. The majority of this land use occurs on GLUM Class II terrain.

(iii) *Quarries and Artificial Slopes*
Aggregate and roadstone requirements in the area are accommodated by the quarries at Lam Tei and north of Pillar Point. These sites occupy approximately 59 ha of terrain, and include a number of steep cut slopes of high GLUM class in addition to remaining cut platforms of low GLUM class. Artificial slopes remaining after completion of excavation and those produced by filling, account for a further 131 ha of land. Excavation of materials completely modifies the terrain, and hence the GLUM Class. Most other developed land uses tend to be more severely influenced by pre-existing geotechnical limitations.

(iv) *Reservoirs*
Several reservoirs within the area provide fresh water for parts of Tsuen Wan and Kowloon. These are located at Tai Lam Chung in the southern to central part of the study area with reservoirs of smaller capacity located south of Lam Tei and Wong Nai Tun. These reservoirs collectively occupy 177 ha of the area, and are unclassified in terms of GLUM class but are generally surrounded by terrain of GLUM Classes III & IV.

(v) *Country Park*
The Tai Lam Country Park occupies a large tract of upland terrain immediately north of the coastal strip in the central and eastern part of the study area. This Country Park occupies 3 240 ha or 36% of the area, and consists of mainly GLUM Classes II, III & IV terrain.

(vi) *Military Firing Range*
A large tract of upland terrain within the Castle Peak Range, west of Tuen Mun is utilised as a firing range. The firing range occupies 1 856 ha (20.7%) of the area, and is predominantly GLUM Classes II & III terrain.

(vii) *Undisturbed Natural Terrain*
Undeveloped natural terrain occurs as the vast majority of the area and includes Country Park and Firing Range. Some 217 ha are GLUM Class I, 3 133 ha are GLUM Class II, 2 311 ha are GLUM Class III and 1 324 ha are GLUM Class IV.

When Country Park and Firing Range are deducted, the area potentially available for development amounts to some 1 924 ha.

(viii) *Agricultural Development*
Certain tracts of land notably along the alluvial coastal fringe are used for intensive agriculture. Similarly, alluvial tracts within stream valleys are developed for agriculture, for example, around So Kwun Wat. Agricultural land occupies 388 ha (4%) of the area and normally occurs as GLUM Classes II & III.

(ix) *Recreational*

Sporting facilities and urban recreational areas occupy a small proportion of the area, amounting to about 16 ha. Parks other than designated Country Parks are included in this group. These categories are found mainly in the urban areas of Tuen Mun.

(x) *Community and Institutional*

This group includes schools, hospitals and other community uses and occupies some 42 ha. They are generally located on large level sites. However, if situated on natural terrain, as opposed to reclamation, construction may have resulted in cut and fill slopes giving rise to GLUM Class III terrain.

(xi) *Squatters*

Squatter areas are mapped on 2% (194 ha) of the study area. Approximately 40% of the terrain occupied by squatter concentrations (as identified by aerial photograph interpretation techniques) occur on GLUM Classes III & IV terrain. Table B13 of Appendix B presents land use and GLUM class data. The general distribution of squatters with respect to terrain is given in the GEOTECS Plot in Figure 11. Squatters seem to have been cleared already from land with potential for development (GLUM Classes I & II). Only 115 ha of squatter areas exist on terrain with low to moderate geotechnical limitations (GLUM Classes I & II).

(xii) *Roads and Services*

These are generally small features, which occupy limited areas and are not normally mapped as discrete units. Service reservoirs are often located within areas of high GLUM class on more elevated terrain.

2.8.2 *Future Development*

Development principles for the Territory 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 curtail development in Country Park and areas of designated 'Green Belt'. Water Supplies Department upland catchments are similarly protected.

Natural and geotechnical constraints also have a restricting influence on the future development of some terrain.

The use of reclamation as a preferred option for the creation of developable land is noticeable in the new developments associated with the Tuen Mun New Town Development (Plate 18). Extensive reclamation occurs in Castle Peak Bay and for the Castle Peak Power Station on the southwest of the Castle Peak Peninsular. A large area of reclamation is designated for residential development at Wu Tip Wan (Butterfly Beach).

The Tuen Mun New Town Outline Development Plan details the largest proposed future development within the study area. The boundary of the outlined zone is shown on the GLEAM and broadly follows the narrow coastal strip of lower ground from the northwestern coast of Castle Peak Peninsular around to the Tuen Mun Valley via Black Point. This boundary is generally coincident with the Castle Peak Firing Range and broadens to take in the majority of the Tuen Mun valley and its lower flanks, narrowing again along the coastal fringe to the east towards Tai Lam Bay.

# 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 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 through 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 remnant from a previous lower 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 are 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 West New Territories study area, the activities of man have greatly 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 wide variety of geological materials found 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.

Soft material in the study area usually results as a by-product of site formation or the stripping of overburden in quarries.

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 the five groups:

(*a*) Colluvium.

(*b*) Other superficial deposits—fill, reclamation, alluvium, littoral and marine deposits.

(*c*) Volcanic and volcaniclastic rocks.

(*d*) Intrusive igneous rocks.

(*e*) Sedimentary and metasedimentary rocks.

### 3.1.2 *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, 2.4 and in Appendix C.1.4.

As well as being derived from a range of rock types, generally colluvium is 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.

From an examination of Table B11 it is apparent that colluvial materials within the study area have a significantly lower incidence of erosion when compared with insitu materials. This reflects the mode of origin of these materials and their occurrence as fan deposits or within drainage lines.

There is relatively little difference in the susceptibility of the different colluvial groups to erosion based on parent rock type, although granitic colluvium shows a slightly higher incidence than the other forms. Older, more decomposed deposits appear more erodible.

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 or related to colluvium is instability. The most dramatic example in the study area of slope failure associated with colluvium occurs on the eastern facing footslopes below Castle Peak. Colluvium consists of material transported by gravity, and the deposits accumulate at approximately the angle of repose of the detrital material. Although the deposits may settle and become more dense with time, they are liable to slope failure if disturbed either by stream undercutting, ground movements or by man's activities.

Slope failures in colluvium on relatively steep terrain 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 granitic colluvium shows a moderately high incidence of instability but considerably less than for the volcanically derived material. The degree of general instability is probably a reflection of the slope angle associated with the parent rock.

## 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, or as platforms and adjacent slopes in otherwise undulating terrain (fill). | These materials placed by man have no soil 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 dependant on source of fill. Generally they can be described as low fines, low plasticity granular cobbly soils. Relative density is dependant on method and degree of compactive effort. $\phi \cong 25^\circ \rightarrow 35^\circ$. 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 fill, 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 intertidal zone forming beaches and sandbars. Occasional raised beaches may occur. | Nil | Generally sand sized granular material, often uniformly graded and well rounded. | Too restricted in size and distribution to be of significance | Main development potential is as beaches for recreational purposes. Excavation of these materials 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 (pedogenic) horizon. Relict deposits may be more weathered. | 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%. SPTs range from 5 to 15 as depth and granular content increase. Material varies from $c' \cong 0 - 10$ kPa, $\phi' \cong 20 - 25^\circ$. | 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. | 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 clay or clayey silt with traces of shell fragments and some sand and gravel horizons especially near shore. | Seabed sediments of variable thickess (0-10's of metres) below low tide mark. | Nil | Usually a soft to very soft normally consolidated soil with a high mositure content and high plasticity (LL > 50%), clay content ranges from 20 - 35%, silt content from 50 - 70%. $C_u < 10$ kPa, $c' \cong 0 - 5$ kPa, $\phi' \cong 25^\circ$. 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 | 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 and clays are to be found on the middle to lower sideslopes and footslopes. | Mainly occupies the lower sideslope and footslope terrain and may underlie much of the alluvial floodplain. Generally gentle 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 deposit 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 gravel. Plasticity varies from PL 22 - 28%, LL 28 - 40%. Typical shear strength values are $c' \cong 0 - 5$ kPa, $\phi' \cong 29^\circ - 42^\circ$. Standard compaction values : OMC ≅ 17 - 20%, MDD ≅ 1 630 - 1 750 kg/m³. CBR ≅ 3 - 8%. | Material that has moved in its geologic past and is prone to reactivation if not carefully treated by use of such measures as low batter angles, drainage, and surface protection, expecially 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. SI 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. |
| | | | COLLUVIUM – GRANITIC DERIVED | | | | | | |
| | | | COLLUVIUM – SEDIMENT DERIVED | | | | | | |
| | | | COLLUVIUM – MIXED | | | | | | |
| BEDROCK | UPPER CRETACEOUS | D | INTRUSIVE IGNEOUS ROCKS – DYKE ROCKS – DOLERITE | Black to very dark grey, fine to medium grained rock. Smooth joints normal to boundaries result from cooling. | Forms linear shallow depressions or ridges due to differential weathering compared to country rocks. | Weathers deeply to a dark red silty clay. | No laboratory information available. Weathered mantle will contain a high proportion of clay and iron oxides leading to low $\phi'$ values. Intact rock strength will be very high. | Restricted extent precludes detailed comment. Weathered mantle will have low relative permeability and will affect near-surface groundwater hydrology by forming barriers, divides and boundary conditions. Sub-vertical dykes may dam groundwater leading to unnaturally high groundwater levels. | Restricted extent precludes deliberate borrow or quarry activities - weathered material would make poor fill but fresh rock would make suitable high density aggregate or railway ballast. |
| BEDROCK | UPPER JURASSIC | E | INTRUSIVE IGNEOUS ROCKS (PLUTONIC) – UNDIFFERENTIATED GRANITIC ROCK | Nature of rock uncertain but similar to granitic rocks discussed below. | Forms areas of moderate to steep relief with broad convex hillcrests. | Shallow to deep residual soils over deeply weathered granite. Local occurrence of less weathered rock outcrop and/or massive boulders on upper sideslopes and incised gully floors. | As for the granite rocks below. | Engineering characteristics as outlined for other granitic rocks. | Excavation and material uses as for other granite rocks. |
| BEDROCK | UPPER JURASSIC | $M_c$ | INTRUSIVE IGNEOUS ROCKS (PLUTONIC) – GRANOPHYRIC MICROGRANITE | Pink to grey fine grained non-porphyritic rock. Pink and white feldspars with quartz with granophyric texture. Jointing similar to other granitic rocks. | Very limited outcrop within area. | 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 ≅ 10%, silt ≅ 30% and sand ≅ 60%. | As for all Hong Kong rock types weathered material may be unstable if undercut. Joints control stability in any rock cutting. | Weathered material can be machine excavated for use as fill. Limited outcrop and urban proximity restricts borrow potential to local site preparation. Fresh rock will require blasting. |
| BEDROCK | UPPER JURASSIC | NH | INTRUSIVE IGNEOUS ROCKS (PLUTONIC) – NEEDLE HILL GRANITE – FINE GRAINED PORPHYRITIC PHASE | Fine grained, pink, with phenocrysts of quartz and potassium feldspar in varying proportions. Pyrite is a common accessary mineral. Jointing is similar to other granites. | Occurs as strongly dissected plateaux or extensively eroded granite ridges and spurs. Narrow but rounded ridge and spurcrests. Moderate to steep planar sideslopes. | Shallow to deep residual soils over deeply weathered granite. Local occurrence of less weathered rock outcrop and/or massive boulders on upper sideslopes and incised gully floors. | The near surface decomposed material has a DD ≅ 1 350-1 400 kg/m², MC ≅ 17-32%, Permeability, $k \cong 24 - 0.1 \times 10^{-6}$ m/s., $c' \cong 0\text{-}30$ kPa, $\phi' \cong 34\text{-}44^\circ$. Fresh rock properties similar to other granites. | Unstable areas result from deep weathering and joint controlled rock slopes. Extensive rill and sheet erosion affects the weathered mantle. Bearing capacity characteristics are generally favourable for moderate to high loads. Materials are generally free draining. | When weathered, the material can be machine excavated to considerable depth and is thus strongly favoured as a source of granular borrow. When fresh or slightly weathered, blasting is required. These rocks are highly favoured for aggregate production. |
| BEDROCK | UPPER JURASSIC | NHm | INTRUSIVE IGNEOUS ROCKS (PLUTONIC) – NEEDLE HILL GRANITE – MEDIUM GRAINED PORPHYRITIC PHASE | Medium grained gradational with above with similar mineralogy and jointing. | | | | | |
| BEDROCK | UPPER JURASSIC | —q | INTRUSIVE IGNEOUS ROCKS – DYKE ROCKS AND VEINS – QUARTZ VEIN | White or translucent microcrystalline quartz rarely over 100mm thick. Can be associated with narrow dykes of microgranite. | Too narrow to have any significant effect on topography. | Quartz veins undergo only mechanical disintegration as they are very resistant to decomposition. Coarse angular gravel is the product. | Generally too small to be discretely sampled and tested. | Generally too small to affect structure but contained sulphides may affect groundwater chemistry and react with concrete and steel in foundations. | Restricted extent precludes deliberate borrow activity for these rocks. Weathering results in mechanical break up only of quartz and a decomposition of sulphides. Fresh rock not suitable for aggregate due to potential sulphide reaction with cement. Molybdenite has been commercially mined. |
| BEDROCK | UPPER JURASSIC | $Mo_q$ | INTRUSIVE IGNEOUS ROCKS – DYKE ROCKS AND VEINS – QUARTZ VEIN WITH MOLYBDENITE | As above with molybdenum sulphide in veins | | | | | |
| BEDROCK | UPPER JURASSIC | $Py_q$ | INTRUSIVE IGNEOUS ROCKS – DYKE ROCKS AND VEINS – QUARTZ VEIN WITH PYRITE | As above with iron sulphide | | | | | |
| BEDROCK | UPPER JURASSIC | —Ka | INTRUSIVE IGNEOUS ROCKS – DYKE ROCKS AND VEINS – DEEPLY WEATHERED PEGMATITE WITH KAOLINITE | Very coarse granite rock composed of quartz, feldspar and mica altered to kaolinite and sand. | Forms narrow local depressed lineaments. | Deep to very deep weathering with kaolinite development. | | May form a local deepening of weathered profile. | |

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

| 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 |
| BEDROCK | UPPER JURASSIC | CC | INTRUSIVE IGNEOUS ROCKS (PLUTONIC) | | CHEUNG CHAU GRANITE | Pale grey or pink, medium to coarse grained, sparingly porphyritic, strong granite. Potassium feldspar is prevalent in this widely spaced rough jointed rock. | Forms extensive areas of moderate relief, broad convex hillcrests are common with high level infilled valleys. Occasionally occurs as steep to precipitous terrain. Drainage is dendritic in nature although structural control does dislocate the general pattern. Sheet and gully erosion is common on hillcrest and sideslope terrain. | Rock sometimes produces a poor, thin (< 1 m) soil (pedogenic) horizon. At depth, the decomposed rock is a silty sand with variable fine gravel content. Depth of weathering i.e. soft material, is often great and an average of 18 m has been quoted. Weathering to produce corestones is common. | The near surface completely decomposed material has a DD ≅ 1 200 - 1 400 kg/m$^2$ and is usually only 35 - 50% saturated. The material is a silty sand containing up to 20% silt with some fine gravel. Typical shear strength values are c' ≅ 0 - 10 kPa, Ø' ≅ 32 - 42°. Strength characteristics of fresh rock are dependent on joint strength as unconfined compressive strength in order of 100 - 150 MPa. DD ≅ 2 500 - 2 600 kg/m$^3$, tangent modulus ≅ 30 000 - 60 000 MPa. Point Load Is(50) ≅ 5 - 8 MPa. Joint c' ≅ 0 kPa, Ø' ≅ 40°, roughness angles 5 - 10° (tectonic joints), 10 - 15° (sheeting joints). | Stability of the weathered material can be suspect, i.e. Zones A & B, where soil type failures may occasionally occur. Insitu material is subject to severe erosion. Special care must be taken in establishing adequate surface protection on newly formed slopes. Bearing capacity characteristics are good for moderate to high loads. Generally free draining. Rock is prone to discontinuity controlled failure in the fresh to moderately weathered state. | When weathered, the material can be machine excavated to considerable depth and is thus strongly favoured as a source of granular borrow. When fresh or slightly weathered, blasting is required. These rocks are highly favoured for aggregate production. |
| | | SK | | | SUNG KONG GRANITE | Pale grey or pink, coarse grained porphyritic strong granite. Medium-grained and non-porphyritic phases exist. Generally displays widely spaced joints. Quartz is often very abundant. | | | | | |
| | | XT | | | TAI PO GRANODIORITE | Grey to dark grey, coarse to medium grained, porphyritic granitoid rock. Large well formed crystals of white feldspar up to 15 mm are present in coarse-grained matrix. Minerals are potassium feldspar, biotite and minor quartz. Xenoliths are common. Jointing is similar to granites in that rough sheeting joints and widely spaced tectonic joints are present. | Forms extensive areas of moderate relief with colluvial and boulder cover. Broad convex hillcrests and well vegetated slopes. | Average depth to Zone C is approximately 15 m but can be over 40 m. Boulders and corestones are common in weathered zones. Weathering product is subangular silty sand. | Little test data available for study area but decomposed granodiorite from Tai Po has the following general properties: DD ≅ 1 300 - 1 400 kg/m$^3$, clay content 2 - 8%, silt content 30 - 55%, sand 40 - 60%. Plasticity varies from non plastic to PL 27 - 37%, LL 40 - 50%. c' ≅ 0 - 14 kPa, Ø' ≅ 33 - 42°. Standard compaction values : OMC 16 - 21%, MDD 1 690 - 1 780 kg/m$^3$, CBR ≅ 8 - 20% Fresh granodiorite has UCS ≅ 125-175 MPa, DD ≅ 2 600-1 700 kg/m$^3$. Point Load Is(50) ≅ 6-9 MPa. | Comments as for granites but a little more care required with weathered materials because they are likely to be slightly more clayey. Special care must be taken in establishing adequate surface protection on newly formed slopes. | Because of the low to moderate content of quartz in the clay, weathered zone could be used for making bricks. Weathered zone material may be used for fill. Fresh rock is suitable for aggregate. Lower quartz content makes this material suitable for ashphaltic concrete. Corestones may be present. |
| | MIDDLE TO LOWER JURASSIC | RBs | SEDIMENTARY, VOLCANICLASTIC AND EXTRUSIVE IGNEOUS ROCKS | REPULSE BAY FORMATION | SEDIMENTS AND WATER LAID VOLCANICLASTICS | 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 ferrugineous 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. | Can locally be indistinguishable from Lok Ma Chau Formation. Typical values are DD = 1 520, LL = 41 - 58%, PL = 28%. Gradings, clay 17 - 22%, silt 40 - 60%, sand 20 - 27%. | The limited extent of these rock types make it unlikely they will be encountered to any significant degree. The sediments are bedded and fissile and weather relatively rapidly to a grey silt when exposed. Some stability problems may arise even at low angles. Groundwater regime may be controlled by bedding characteristics of this 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. |
| | | RBc | | | COARSE TUFF | Grey to dark grey, fine matrix with coarse well formed crystals of feldspar and quartz. Forms massive beds of crystal tuff with no internal stratification. Jointing tends to be moderately closely spaced and smooth. | Massive volcanic hills with deeply dissected slopes forming a system of subparallel ridges and spurs. Crests are narrow and sharply rounded 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 material overlying less weathered, locally strongly jointed rock below an average depth of 11 m. On steep high slopes soil cover and weathering may be very thin with slightly weathered to fresh rock occurring in outcrop. | The near surface completely decomposed material has a DD ≅ 1 500 kg/m$^3$ 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/m$^3$. Point Load Is(50) ≅ 6 - 12 MPa. Tangent modulus ≅ 30 000 - 60 000 MPa. | Stability of weathered material and also of highly jointed rock masses may be suspect, especially during or immediately after prolonged heavy rainfall. Failures are common in oversteepened areas. Rapid surface runoff is common. The stability of rock slopes is controlled by discontinuity orientations and surface properties in the fresh, slightly or moderately weathered state. 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 | Material can be used for fill if it is weathered locally. It is possible to quarry, although very hard and produces elongate fragments when crushed. Coarse tuff may provide useful 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 PYROCLASTICS | The principal rock type is grey to dark grey fine-grained rhyodacitic tuff but welded tuffs, coarse tuffs, lavas and sedimentary rocks may also be found in this unit. Jointing is usually smooth and closely spaced. | | | | | |
| | | T | SEDIMENTARY ROCKS | | TAI O FORMATION | Lower beds consist of black silty shale, white orthoquartzite, black and white siltstones, purple sandy siltstones and some graphitic sandstone. Upper beds consist of massive white fine grained orthoquartzite and very fine grained micaceous sandstone interbedded with siltstone. | Only outcrops on very small islands. | Within the islands of the study area, is likely to be shallow, uniform or gradational, red to red-brown residual clayed soil, overlying completely to highly weathered sediments. | No test data available. | Fresh material is generally stable and has good bearing capacity characteristics. Weathered material subject to creep and some instability, especially when saturated. | Restricted outcrop precludes extensive usage. Weathered horizon can be excavated by machine, fresh rock needs pneumatic tools or blasting. Possible use as borrow |
| | | LMC | METAMORPHOSED SEDIMENTARY AND VOLCANIC ROCKS | | LOK MA CHAU FORMATION | Consists of schist, phyllite, metamorphosed quartzite, indurated siltstone and meta-sediments. Jointing is closely spaced and smooth with some rock cleavage developed. | Generally forms low relief due to low resistance to erosion. Has extensive colluvial cover. Occurs on lower sideslopes and footslopes as dissected low ridges and spurs with broad interfluves. Local areas of surface boulders and occasional rock outcrop exposed on lower slopes and in gully floors. | Generally moderately deep (1-2 m), uniform or gradational, red to red-brown, residual clayey soil, overlying completely to highly weathered metasediments. | The near surface completely weathered residual soil acts as a silt with void ratio of ≅ 0.25 - 0.33. Gradings show 5 - 15% clay, 40 - 60% silt, 20 - 30% fine sand. Plasticity varies from PL 25 - 35%, LL 35 - 40%. Typical shear strength values are c' ≅ 0 - 15 kPa, Ø' ≅ 35°. Completely to highly weathered materials generally have a DD in the range 1 600 to 1 800 kg/m$^3$. Fresh rock UCS ≅ 40 - 90 MPa. Discontinuity strength parameters are approximately c' ≅ 0 - 5 kPa, Ø' ≅ 25 - 30°. | | Weathered horizon can be excavated by machine, fresh rock needs pneumatic tools or blasting. Possible use as borrow but fresh rock not suitable for aggregate. |

*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/m$^3$ - kilogram per cubic metre
MDD - maximum dry density - kg/m$^3$ - kilogram per cubic metre
DD - dry density - kg/m$^3$ - kilogram per cubic metre
CBR - California Bearing Ratio - % - percent
SI - Site Investigation
UCS - Unconfined Compressive Strength
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. This is dramatically illustrated on the footslope terrain below Castle Peak.

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. The grading of the material in relict weathered fans is generally suitable for use as fill as it has good compaction characteristics. The more recent bouldery colluvium in stream channels is of limited use, as the major natural constraints, instability and concentrated groundwater flow, restrict their suitability.

Although the material properties of some deposits may be suitable for development, the major constraint for their use is that the deposits often occur on footslope terrain with difficult groundwater regimes, therefore, the hazard of slope failure is high. Site formation work should not preclude the excavation and use of colluvial materials for soft borrow provided adequate care is taken with the design of the remaining cut slopes. Excavation by machine methods could be difficult of large boulders are encountered.

On a planning 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, especially where they are associated with natural drainage lines.

### 3.1.3 *Characteristics of Fill, Reclamation, Alluvium, Littoral and Marine Deposits*

This group includes all superficial materials that generally occur as flat or slightly inclined deposits. These are fill and reclamation, alluvium, littoral and marine deposits. The first two materials are placed by man and are more fully discussed in Appendix D.3.3.

Due to the complex history of sea level change within the study area, these materials can occur together forming a complex subsoil stratigraphy. In this area, reclamation overlies a complex sequence of marine, alluvial and colluvial materials above the weathered bedrock. Many low-lying areas of alluvium in the Tuen Mun area have been raised by the placement of fill. In coastal regions, marine deposits merge with littoral deposits which are interlayered with alluvium.

In geological terms, all of these materials, are immature, and consequently weathering profiles are not well developed. Some older alluvial materials contain weathered cobbles, but it is not known whether these have been weathered insitu or are detritus from an already weathered source.

Due to their predominantly flat gradient, erosion is not a major problem in these materials in their undisturbed state. Stream flows are normally low or confined to man-made channels or conduits. Littoral deposits are subject to continuous erosion and redeposition by the sea. The GEOTECS data presented in Table B11 and summarised in Figure 4 indicate that of erosion is present in nearly all these materials, particularly if hydrological conditions are adversely altered by construction activity.

The GEOTECS data also indicates that there is no incidence of slope instability in these materials. This is primarily due to the low slope angles associated with most of these deposits. When disturbed, however, these materials are liable to become unstable unless adequate precautions are taken. All steep-sided excavations require strutting or shoring to minimise the likelihood of slope failure, and cut slopes require cutting to low angles or require retaining structures. Serious landslips have been associated with fill within the Territory. Major failures have occurred in the past at Sau Mau Ping in 1972 and 1976 (Government of Hong Kong, 1972 a & b, 1977).

There is a wide range of particle size between materials in this group. Alluvial deposits may contain a high proportion of gravel and cobble sized material, whereas littoral deposits consist of a fairly uniform medium to fine sand. Marine materials range from silty well-graded sand, clayey well-graded silt to silty clay.

The shear strength of these materials is extremely variable. The highest strength is developed in well-compacted fill and the least in marine muds. All these materials are characterised by low values of cohesion. The strength values quoted in column 8 of Table 3.1 are approximate guides only and should not be used for design purposes. It has been demonstrated that these materials are extremely variable in physical properties and frequently occur within a complex subsoil stratigraphy. Consequently, appropriate laboratory testing of representative undisturbed samples is required in order to obtain relevant strength parameters for design.

In general, the natural materials in this class have a fairly high permeability due to the general absence of clay fraction. Groundwater levels tend to be high, and problems of tidal response may occur in the basements of buildings on reclamation.

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 accepted on raft foundations, but problems of differential settlement may be experienced. The appropriate piling technique used to transfer high loads is dependent on the overall stratigraphy, but nearly all members of this group are amenable to driven piles. The exception is that some restricted areas of reclamation may contain old masonry walls, large boulders or construction refuse which may require caisson-type construction to overcome penetration problems.

Due to high permeabilities, rates of settlement are often rapid, although fine-grained marine muds and silts may require considerable time. The magnitude of settlement varies depending on the imposed load, local groundwater conditions and the nature of the materials. Settlements in marine and alluvial deposits are discussed by Holt (1962). Settlement can be induced by the alteration of groundwater conditions.

The materials in this class are easily excavated by machine methods and have potential for use as soft fill. Marine deposits of sand are limited, and marine silts and clays are generally unsuitable for hydraulic fill. The extensive urban development on areas of alluvium, and the use of littoral zones for recreation, generally precludes the use of these materials for borrow.

From a planning point of view, this group of materials, although not free of problems, is generally suitable for development, with the exception of littoral deposits which are essentially unconsolidated and subject to marine erosion.

### 3.1.4 *Characteristics of the Volcanic Rocks of the Repulse Bay Formation*

The location and type of volcanic and volcaniclastic rocks found in the study area are discussed 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 as tors. 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 possibly of less engineering significance. Many of the joints are steeply inclined and may result in unfavourable orientations in relation to construction.

In these rocks, weathering tends to be relatively shallow with average depths in the order of 10 m. The sedimentary units 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 or fracturing may be encountered which will locally depress the weathering profile. The subsurface characteristics of the other photolineaments are not known at present, but it is apparent that large depths of decomposition, unusual water flows, intense fracturing and the possibility of differential movement are common.

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. Due to the relatively large statistical sample and the lack of urban development on these rocks, this is probably a reflection of the erodibility of these materials. The incidence of instability, as measured by GEOTECS, is relatively low as compared to the mean for the area. 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. Due to their fine grain and relatively high strength, these rocks are difficult to crush and are not currently used for aggregate production. 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, their foundation depths are fairly shallow.

Site investigations in the pyroclastic 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.

### 3.1.5 *Characteristics of the Intrusive Igneous Rocks*

The intrusive igneous rocks that underlie much of the area are of similar origin and consequently have similar engineering characteristics. A large amount of site investigation and laboratory information is already available, and these materials are generally quite well understood (Lumb, 1962 a & b, 1965, 1983). In particular, considerable information is available for the Tuen Mun New Town Development Area.

Amongst these rocks, a division can be made between dyke rocks and those occurring in large intrusive bodies. The dyke rocks generally are of limited width although they may cause localised variations in weathering depths and groundwater conditions.

The various granite intrusions and the granodiorite 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.

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

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.

The completely decomposed rock disintegrates into a silty clayey sand, with the grading depending on the original rock type. Weathered Tai Po Granodiorite has higher concentration of clay compared to other members of this group with the exception of dolerite. This is due to the lower free quartz content of the original rocks.

As the residual soil is predominantly sandy, it is highly erodible in nature. The GEOTECS data presented in Figure 4 and in Tables B10 and B11 indicate a general increase in erosion within the intrusive igneous rocks when compared to the other rock types, although there appear to be significant differences between the individual intrusive rocks. Tai Po Granodiorite is generally uneroded in its undisturbed state, but it can be highly erodible if vegetation is removed. The Sung Kong Granite forms areas of moderate to steep relief with, normally, a deeply weathered profile and in this respect it is similar to the Cheung Chau Granite, which exhibits approximately twice the average occurrence of erosion and occurs with a wide range of slope angles. Needle Hill Granite occurs in both fine and medium-grained forms. Areas of heavily eroded ridges and spurs develop with shallow to deep residual soils over deeply weathered profiles on shallow slopes. Engineering criteria and material characteristics are similar to those of other granitic terrain.

Landslips tend to form small joint-controlled failures associated with natural terrain or cut slopes. As a result of the severe rainstorms in 1983, the natural upland terrain of the Tai Lam Country Park suffered over 300 landslips. These probably were initiated by very intense rainfall but indicate that granitic terrain can be as prone to slope failure as volcanic terrain (Hansen, 1984b).

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 difficulties 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 Zones A and 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. 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 the Tai Po Granodiorite, 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 compared to the flat superficial deposits, but the moderate slope angles, ease of excavation, high yield of fill and general stability of slopes is to some extent reflected in the extensive development which already exists on these rocks within the Territory.

### 3.1.6 *Characteristics of the Sedimentary and Metasedimentary Rocks*

Within the study, the following sedimentary and metasedimentary rocks occur:

(i) *Lok Ma Chau Formation*
The metamorphosed sedimentary and volcanic representatives of this Formation exhibit generally close smooth jointing, often with some related cleavage. Clayey soil tends to develop as a result of moderate to deep weathering of these rocks, hence facilitating easy excavation. However, the weathered materials are generally weak and are probably susceptible to slope failure, even on generally moderately sloping terrain. Fresh material may be stable and, where accessible, provide suitable material for low grade bulk fill rather than as concrete aggregate or roadstone material.

The localised nature of these rocks and the proximity of more suitable material sources severely limits the use of this material. Clays derived from the weathering of units within this Formation have been used for the manufacture of bricks.

(ii) *Tai O Formation*

The isolated location and small outcrop of the Tai O Formation rocks within the area effectively negates their use as a material source. Rocks of the Tai O Formation are restricted to the Brother and Reef Islands and constitute thin cross-bedded sandstones with interbedded shales which are folded and metamorphosed. The use of these rocks for any engineering work is unlikely due to the remoteness of the islands. However, closely spaced jointing with some rock cleavage is characteristic of the rock mass. The rocks are normally well weathered and are not resistant to erosion. Any materials derived from this Formation will be weak and unstable when weathered, although fresh rock may be suitable for localised construction purposes.

# 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 level 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 shown in the GEOTECS Plot presented in Figure 10. The proportions of classes are presented in Table B9 and Figure 4.

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 (492 ha) of land with low geotechnical limitations. Another 4 200 ha is subject to moderate geotechnical limitations. Together GLUM Classes I & II occupy 52.4% of the study area and are shown schematically in the GEOTECS Plot in Figure 10. Some 38% of the GLUM Class I land is already developed, as is 12% of the GLUM Class II terrain. This leaves approximately 4 000 ha of terrain which is undeveloped with low to moderate geotechnical limitations.

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, and 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.

GLUM Class I & II terrain is considered to have potential for development on the GLEAM. A discussion of the development opportunities within the study area is presented in Section 4.2.

### 4.1.3 *Land with High Geotechnical Limitations*

Approximately 29.5% (2 638 ha) of the study area has a high level of geotechnical limitation (GLUM Class III). The general pattern is shown in the GEOTECS Plot in Figure 10. Some 7% of this terrain is already 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 areas of potential for development. These are shown on the GLEAM if they are unlikely to affect the overall suitability for development of the area.

### 4.1.4 *Land with Extreme Geotechnical Limitations*

Approximately 15.3% (1 367 ha) of the area is classified as GLUM Class IV. This terrain should not be developed if alternatives exist. The general pattern is indicated in the GEOTECS Plot in Figure 10. Some 2% of this terrain occurs within areas of current 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.

Isolated areas of GLUM Class IV occur within the developed area associated with locally steep terrain, other parcels may be associated with drainage across colluvium or the presence of instability. These features are also 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 efficient construction is important but long term serviceability and safety should be fundamental aims.

From a geotechnical viewpoint, land with potential for development should generally be free of constraints. Engineering design, if possible, should be unhindered by geotechnical limitations. Within the West New Territories there are many areas still unused, but a significant proportion occur within designated Country Parks, Green Belt, Military Land and Water Supply Catchments. Thus, it is essential that a cautious and integrated approach is adopted in order to optimise the use of the remaining areas. This Report attempts to delineate the major geotechnical and terrain-related problems and to define their magnitude for planning and engineering purposes.

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 2 305 ha or 26% of the total area. The areas range in size from about 45 ha up to 430 ha. They occur on different types of terrain, which are not necessarily suitable for the same type of development.

The areas of potential are delineated from the interpretation of terrain and geological features which reflect various levels of difficulty of geotechnical engineering.

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. Areas within which there is significant potential for development 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 area which have potential for development from a geotechnical point of view. These areas constitute approximately 2 305 ha of land.

*Area 1* *Lung Kwu Sheung Tan (60 ha approx.)* The area around Lung Kwu Sheung Tan is currently used for agriculture and is undeveloped apart from a small village settlement. The area falls within the Tuen Mun New Town Western Study Area, and consists of alluvial floodplain and coastal plain. Small scale village or community type development would probably be most suitable. The main constraints to development are difficult access, flood potential and the possibility of instability and boulder falls in the flanking areas. The granite terrain could be cut into platforms to extend this area southwards and the subsequent borrowed fill used to raise low lying terrain. A marine borrow site investigation was conducted offshore of this area, and also included a number of onshore boreholes. This PDA consists of mainly GLUM Class II and is flanked by GLUM Class III terrain.

*Area 2* *Pak Long—Sha Po Kong (60 ha approx.)* The area around Pak Long and Sha Po Kong consists of mainly agricultural land and rural settlement similar to Area 1. Development of Area 1 would be dependent on the prior development of this PDA. The area suffers from similar constraints to development as Area 1. The majority of this PDA is GLUM Class II with peripheral GLUM Class III. This area also falls within the Western Study Area of the Tuen Mun New Town Outline Development Plan (ODP).

*Area 3* *North of Tai Lang Shui (120 ha approx.)* This PDA is remote and therefore access would be difficult. The area currently falls within the Firing Range and hence development is unlikely. Flooding and footslope instability would be likely constraints to development of this area. Borrow would be required from adjacent granite sideslopes to raise areas liable to flooding. Erosion and drainage would require careful engineering control in any development of this area. The area consists of mainly GLUM Class II and GLUM Class III terrain.

*Area 4* *Shek Kok Tsui (45 ha approx.)* The area around Shek Kok Tsui consists of GLUM Classes II & III. The underlying bedrock is both granitic and volcanic (Repulse Bay Formation). The flanks of this area may suffer from boulder falls and some instability associated with the colluvial footslope terrain. Boulder-filled drainage lines and high runoff from the Castle Peak ridgeline may also require careful drainage design prior to development. Access could be via the Lung Mun Road and feeder roads could be constructed quite readily. Site investigation coverage of this area is fairly intensive due to development of the new Butterfly Estate at Wu Tip Wan.

*Area 5* *Leung Tin Tsuen (160 ha approx.)* The area around Leung Tin Tsuen consists mainly GLUM Class II with some Class I and Class III terrain. Drainage lines and steep unstable ground adjacent to this PDA could pose problems for development (as in Tuen Mun Area 19). Groundwater and drainage problems are likely due to runoff from the Castle Peak ridgeline. Development of this area is well under way and further development would probably be restricted to the footslope and sideslope terrain. Some floodplain areas remain undeveloped and cut platforms could be considered in the lower angled sideslopes. Within the Tuen Mun New Town, link roads, light rail systems and housing estates are already planned.

*Area 6* *Nim Wan (150 ha approx.)* This area consists of three coastal/alluvial plains which may be considered as one unit centred upon the village of Nim Wan. The area falls within the Western Study Area of the Tuen Mun New Town ODP, and may be the site of a barraged landfill of 50 m cu. m capacity. Granite borrow from Black Point and domestic refuse would probably be used as fill behind a 4 km long sea wall in Deep Bay. Access to this area is difficult and is best afforded via the northern coastal route. Steep colluvial footslopes and drainage lines flanking this area together with localised instability provide constraints for development. Large-scale development in this area would create considerable environmental impact, as currently it is mainly used for agricultural and fishing activities. The area consists of mainly GLUM Class II & III terrain.

*Area 7* *Bowring Camp (145 ha approx.)* This area consists of footslope and floodplain terrain around Bowring Camp. The PDA mainly is formed of GLUM Class I & II terrain and falls within the Tuen Mun New Town ODP. Boundary and link roads, a light rail system and a university site are under consideration. Deep weathering of sideslope terrain and surface and groundwater problems in the lower areas may be a problem for development and adequate drainage measures should be incorporated in any design. Granite borrow from the adjacent sideslopes could be used to provide fill to prevent flooding of the low-lying areas. Instability on the flanks of the PDA may also constrain development.

*Area 8* *South Hung Shui Hang (50 ha approx.)* This PDA is a remote area within Tai Lam Country Park. The terrain is mainly granitic sideslopes hence deep weathering and drainage problems would require engineering measures. The PDA is centred upon a ridgeline and any development on this feature may have significant environmental impact on the skyline. Access to this area would be best afforded from the north. The area forms the drainage divide between the catchments of two small reservoirs and consists of mainly GLUM Class II terrain.

*Area 9* *North So Kwun Wat (250 ha approx.)* Access to this remote area within the Country Park would probably be from the north. The PDA forms a physiographic unit of undulating plateau and ridgelines. Constraints to development include localised steep sideslopes often with general instability. Deep weathering of the granite especially along the numerous structural geological lineaments would also require considerable engineering input, for example deep foundations to sound bedrock. The area consists of mainly GLUM Class II land.

*Area 10* *North So Kwun Tan (200 ha approx.)* A large valley and coastal area consisting of mainly GLUM Class II terrain forms this PDA and could be used for large scale development for both industrial and residential uses. Access is afforded via the Tuen Mun Highway. The valley section of this PDA is centred upon the village of So Kwun Wat and is mainly alluvial floodplain associated with a river which has been dammed for the Tai Lam Chung Reservoir. Current land use is mainly intensive agriculture and rural village settlement. The valley area is predominantly GLUM Class II. The PDA is divided into two parts by the Tuen Mun Highway. Constraints to development include steep sided flanking sideslopes with some possibility of instability and boulder falls, the likelihood of flooding of the low lying areas, and a catchwater on the northern boundary of the PDA. Cut slopes and platforms associated with the Tuen Mun Highway provide another constraint for development. The area falls within the Tuen Mun New Town ODP and the upper tracts of the So Kwun Wat valley are within the Stage II Extension Study Area.

*Area 11* *Tai Lam Chung—Siu Lam (170 ha approx.)* Similar in physiography to the adjacent Area 10, this PDA occupies the valley of a stream impounded for the Tai Lam Chung Reservoir. The mouth of the valley is traversed by the Tuen Mun Highway which affords suitable access to this PDA. The lower parts of the valley are liable to flooding and the flanks are steep sideslopes of granite which could provide borrow for the infill of lower areas. Slopes formed in connection with the Tuen Mun Highway create a linear constraint to development. Coastal development would be feasible in association with a possible reclamation of Tai Lam Bay. Part of the PDA falls within the Tuen Mun New Town ODP. The area consists of mainly GLUM Class II terrain.

*Area 12* *Sham Tseng (95 ha approx.)* This PDA coincides with a coastal area south of the Tuen Mun Highway which forms its northern boundary. The main constraints to development include colluvium filled drainage lines and steep granitic sideslopes. Access would be afforded via the Tuen Mun Highway and future development could extend the small industrial centre of Sham Tseng. Deep weathering of the granites and drainage entrainment would require careful engineering in this locality. GLUM Class II land predominates with small parcels of Class III.

*Area 13* *North of Tai Lam Chung Reservoir (120 ha approx.)* This PDA forms the northern flank of the Tai Lam Chung Reservoir and occupies mainly granitic sideslope terrain. Ridges and sideslopes suffer from severe gully erosion in places and some instability is also present. The main constraints to development are remoteness, the difficulty of access and the area falls within the Tai Lam Country Park. Development may also encroach on the catchment of the Tai Lam Chung Reservoir. The area consists of mainly GLUM Class II terrain with patches of Class III.

*Area 14* *Tsing Fai Tong (430 ha approx.)* A large plateau forms this PDA, which lies entirely within Tai Lam Country Park and partially forms the adjacent catchment to the Tai Lam Chung Reservoir. Remoteness and difficult access are further constraints to development. Deep weathering of the granite especially along structural lineaments may create geotechnical difficulties during development. Localised instability and steep sideslopes plus the likelihood of drainage problems in some areas could constrain development, however some of these features could be overcome by engineering design. Cut and fill could release tracts of land for large scale development. The area consists of mainly GLUM Class II terrain with pockets of Class III.

*Area 15* *South of Ho Pui Reservoir (180 ha approx.)* In this area of undulating plateau the terrain consists of mainly sideslopes and ridgecrests. Constraints to development include deep weathering especially along structural lineaments, flood potential along drainage lines and floodplain terrain, and some degree of sideslope instability. Cut and fill could provide platforms for construction. Deep foundations and the culverting of drainage lines would probably be required. Access, remoteness and environmental impact are further constraints for development of this PDA which is within the boundary of the Tai Lam Country Park. The area consists of mainly GLUM Class II land with small parcels of GLUM Class III.

*Area 16* *Lin Fa Shan—Shek Lung Kung (70 ha approx.)* This PDA is contiguous with Area 15. The terrain consists of moderately steep sideslopes and the constraints are similar to Area 15. The southern part is directly above a large catchwater, thus imposing a further constraint. Colluvial drainage lines provide linear constraint to development, some drainage control would be required over and above the constraints imposed by deep weathering and localised instability form the sideslope terrain. The area is largely GLUM Class II but has considerable areas of Class III terrain.

### 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 terrain with potential and relating it to the presence of squatters, the GEOTECS Plot in Figure 12 has been produced. The squatter areas which could be cleared to provide land suitable for development are shown.

Squatters occur on approximately 194 ha within the study area. Some 117 ha of this terrain has potential for development from a geotechnical point of view. The GEOTECS symbol (+) also shows the general location of 924 ha of land with development potential on undesignated natural terrain outside of the Country Parks. Squatters occur on approximately 77 ha of geotechnically difficult terrain (GLUM Classes III & IV).

(ii) *Potential Quarry Sites*
The GEOTECS Plot in Figure 13 indicates other areas which exhibit quarry potential on the basis of several terrain attributes. The selection criterion for areas without intensive existing land use is primarily those units with convex, straight or cliff slopes 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 13, 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 2 080 ha of undesignated natural terrain has potential for quarry sites. A further 3 610 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 reduced when rock type is specified.

# 5. CONCLUSIONS

The findings reached during the West New Territories area 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 1 669 ha of the terrain (19%) is associated with or affected by instability. Instability is associated with most of the geological materials. Failures in the colluvium and volcanics are generally characterised by small landslip scars with extensive debris trails. This is probably due to the relatively steep slopes on which failure occurs. Landslips on the granites are also common but tend to be relatively small failures on natural terrain or joint-controlled failures associated with cut slopes.

(*b*) The geology of the area is 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, and the study area is a net importer of borrow materials. There are numerous photolineaments present, many of which are likely to be faults, shear zones or, major joint zones. Surface erosion is more pronounced on the granitic terrain than on the volcanics.

(*c*) Approximately 837 ha of the footslope terrain is covered by extensive colluvial deposits; 22% of the colluvium is affected by instability. Significant geotechnical limitations should be anticipated on the 534 ha which constitute zones of runoff and surface drainage across the colluvium.

(*d*) The granitic terrain has a lower proportion of GLUM Classes I & II (52%) than the volcanics (77%). Of the 837 ha of colluvial terrain which occurs within the study area, some 88% is subject to high to extreme geotechnical constraints (GLUM Classes III & IV).

(*e*) Approximately 26% of the study area is characterised by slopes which have gradients between 0 and 15°. A further 72% of the terrain has slope gradients between 15 and 40°.

(*f*) Granitic terrain is generally suitable as a source of borrow and aggregate. Future expansion of existing quarries is not restricted by geological constraints but by urban development, water supply catchments and Country Park.

(*g*) There is approximately 314 ha of reclamation (4%) within the study area. 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.

(*h*) Approximately 12% of the study area is currently developed in some form or other. Squatters occupy 2% of the area, and 36% is allocated to Country Park. A further 21% consists of undeveloped natural terrain.

## 5.2 Land Management Associated with Planning and Engineering Feasibility

(*a*) Within the Territory, a number of large landslips during the last 20 years 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 West New Territories, 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, but 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 3 205 ha or 26% of the area. 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 over 1 900 ha of currently undisturbed natural terrain, which does not include Country Park or Military Firing Range. Of this figure, GLUM Classes I & II occur on some 48% of the terrain, and of the remainder 965 ha is associated with high to extreme geotechnical limitations (GLUM Classes III & IV). There is approximately 3 240 ha of land within the boundaries of the Country Parks and 1 856 ha of land within the Military Firing Range.

(*e*) Squatters occur on some 194 ha within the study area. At the time of data collection, 40% of this terrain was affected by high to extreme geotechnical limitations.

(*f*) 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.

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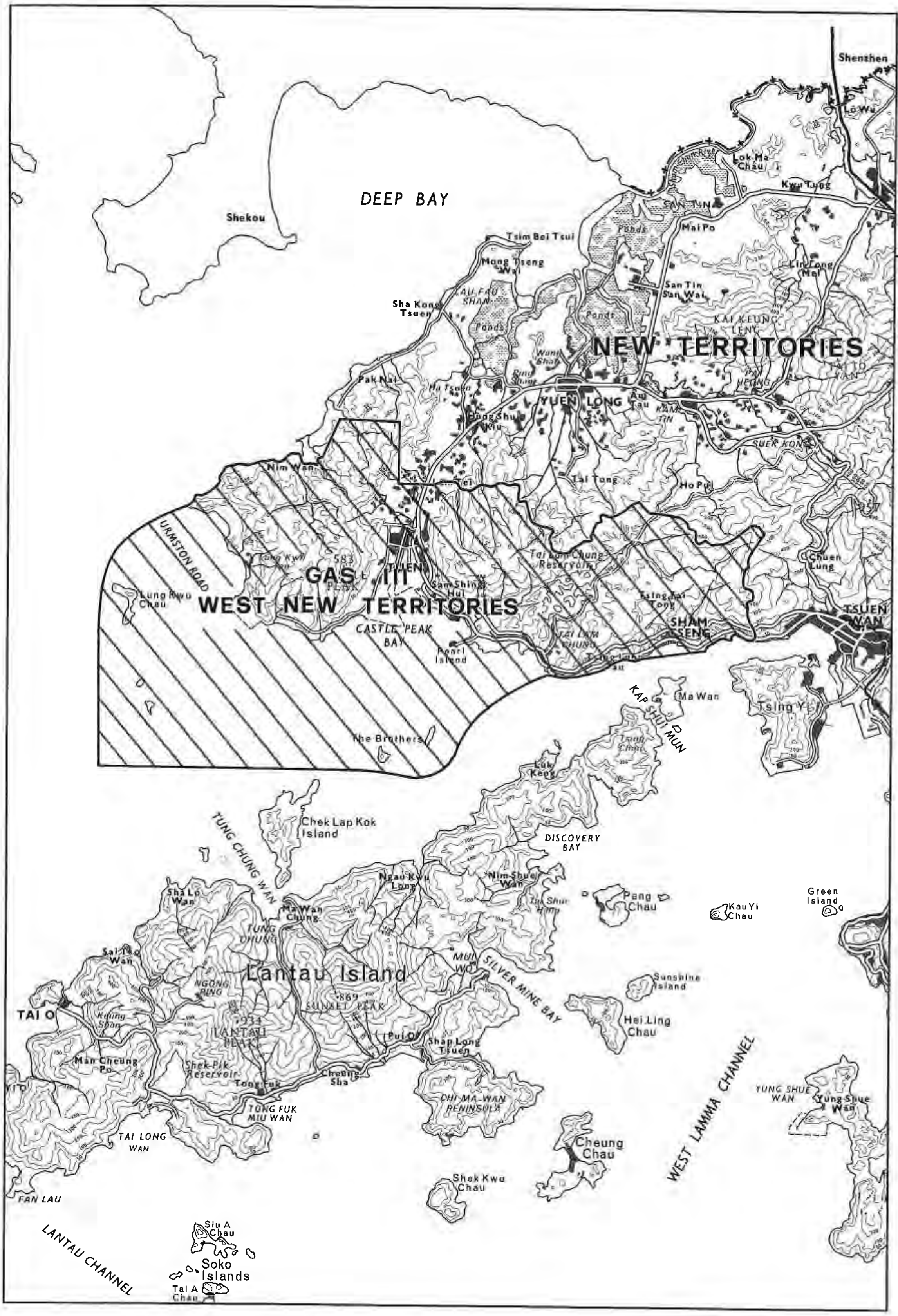
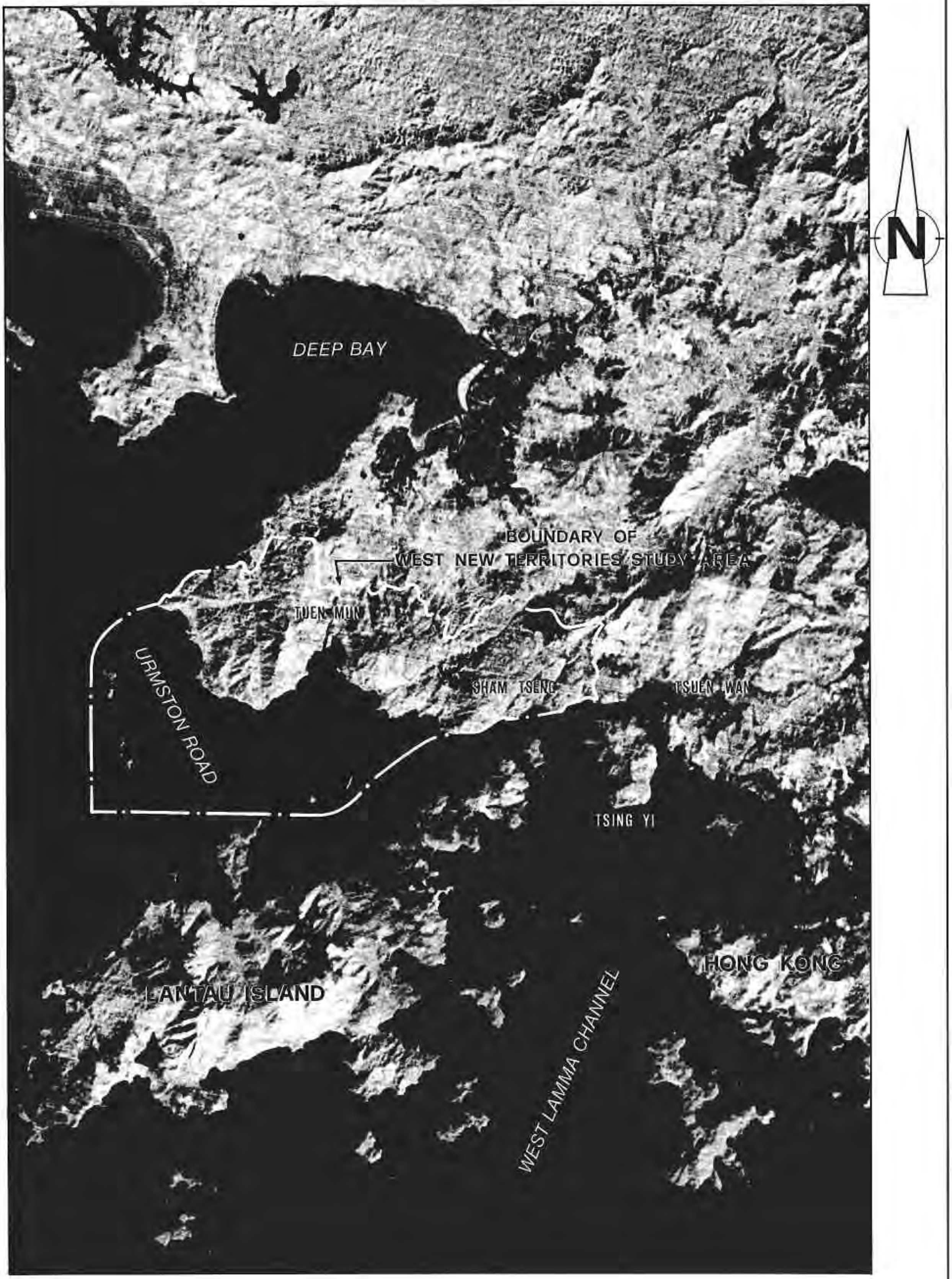
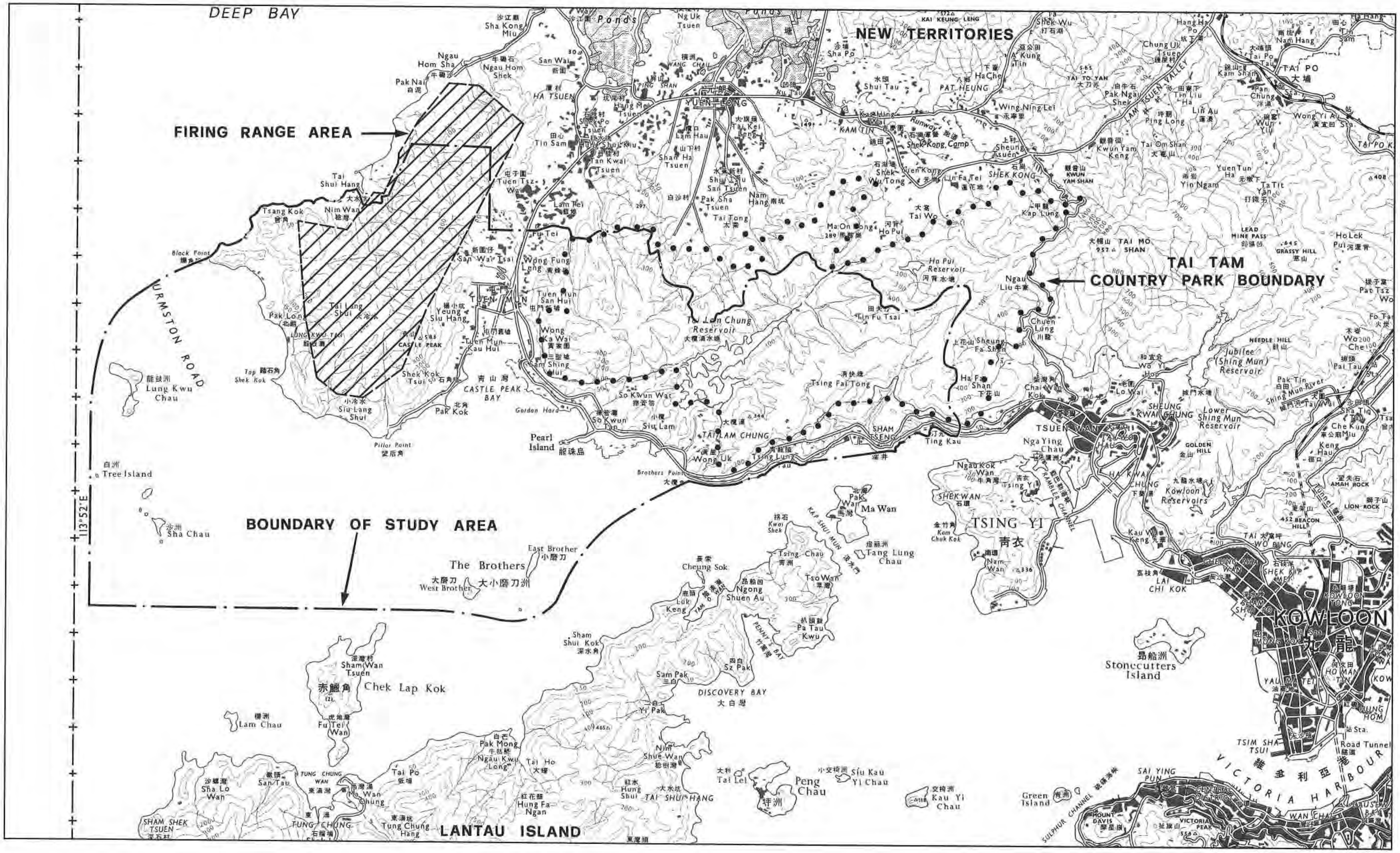


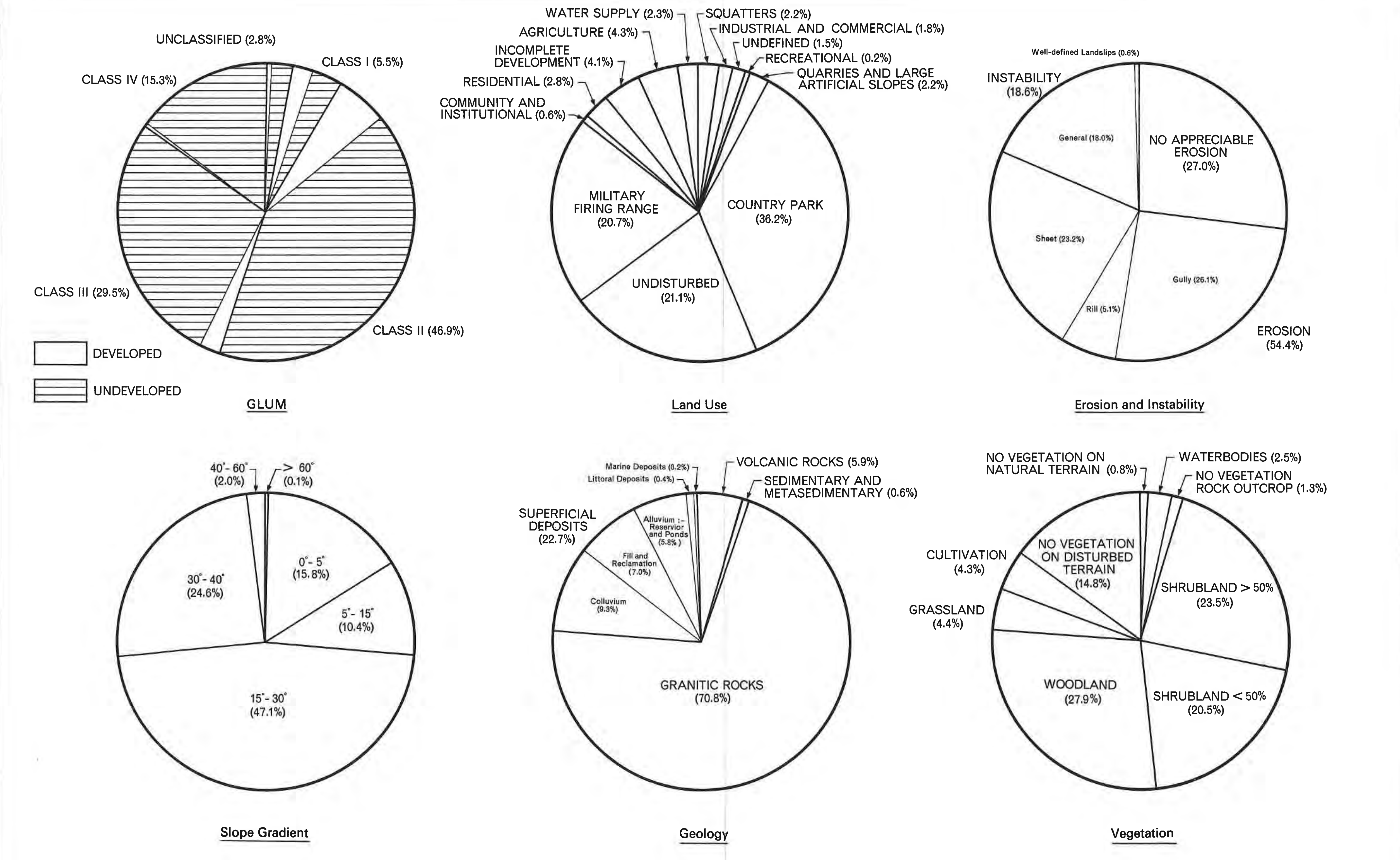

| Scale 1:200 000 | Location Map of the West New Territories Study Area | Fig. 1 |
|---|---|---|




| Scale 1:250 000 | Satellite Image of the West New Territories Study Area | Fig. 2 |
|---|---|---|

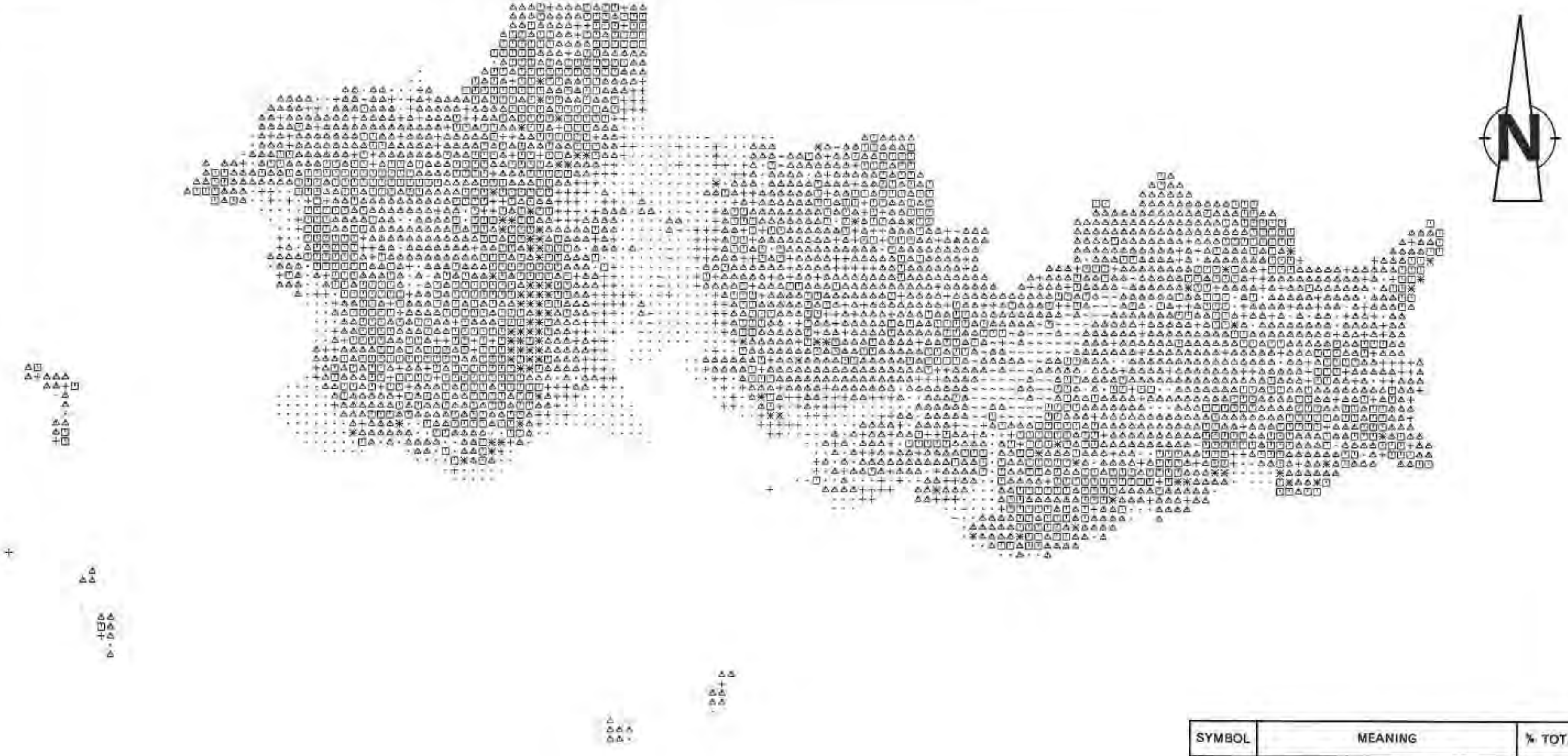



| Scale 1:100 000 | West New Territories Study Area | Fig. 3 |
|---|---|---|



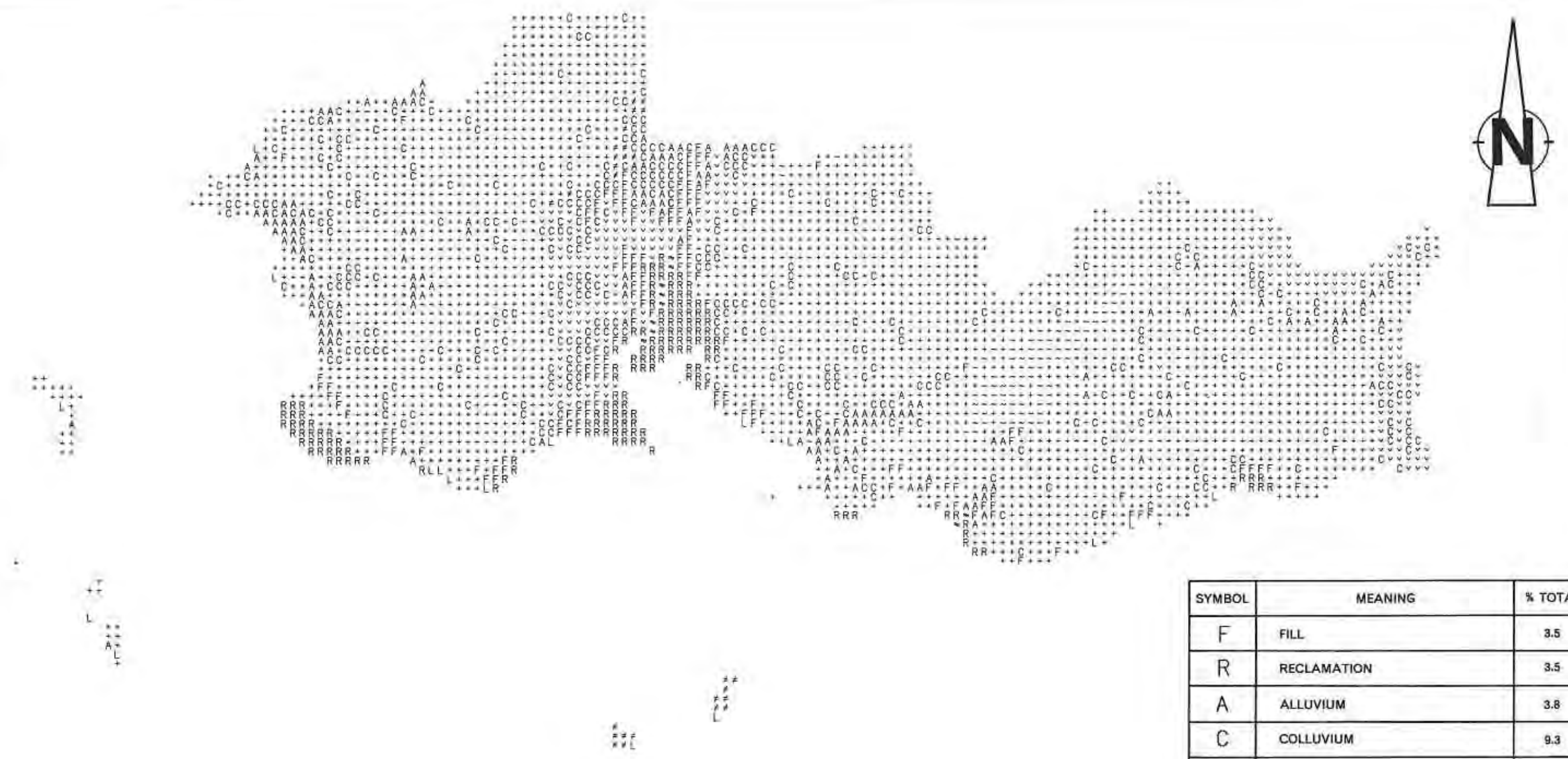

Pie Charts of Selected Attributes of the West New Territories

Fig. 4




| SYMBOL | MEANING | % TOTAL |
|---|---|---|
| · | 0-5° SLOPE GRADIENT | 13.4 |
| + | 5-15° SLOPE GRADIENT | 10.4 |
| △ | 15-30° SLOPE GRADIENT | 47.1 |
| ⊡ | 30-40° SLOPE GRADIENT | 24.6 |
| ✳ | > 40° SLOPE GRADIENT | 2.1 |
| ~ | STREAM, CHANNEL, RESERVOIR OR POND | 2.4 |

| Scale 1:100 000 | GEOTECS Plot - Slope Gradient | Fig. 5 |
|---|---|---|

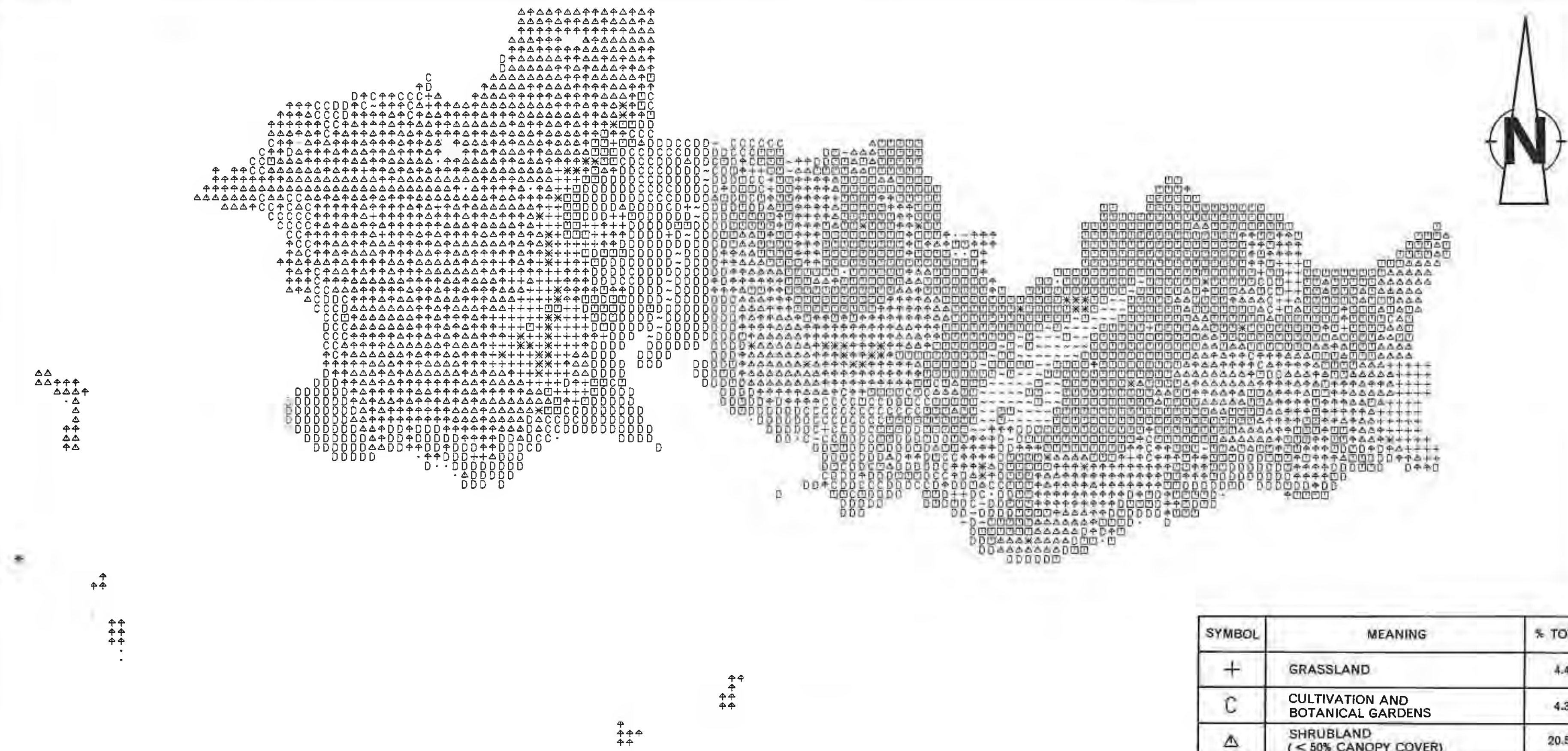


| SYMBOL | MEANING | % TOTAL |
|---|---|---|
| F | FILL | 3.5 |
| R | RECLAMATION | 3.5 |
| A | ALLUVIUM | 3.8 |
| C | COLLUVIUM | 9.3 |
| L | LITTORAL DEPOSITS | 0.4 |
| ≈ | MARINE DEPOSITS (IN CHANNEL ONLY) | 0.2 |
| v | VOLCANIC ROCK | 5.9 |
| ≠ | SEDIMENTARY AND METASEDIMENTARY ROCK | 0.6 |
| + | INTRUSIVE IGNEOUS ROCK | 70.8 |
| ~ | RESERVOIR OR POND | 2.0 |

Scale 1:100 000

GEOTECS Plot - Geology

Fig. 6

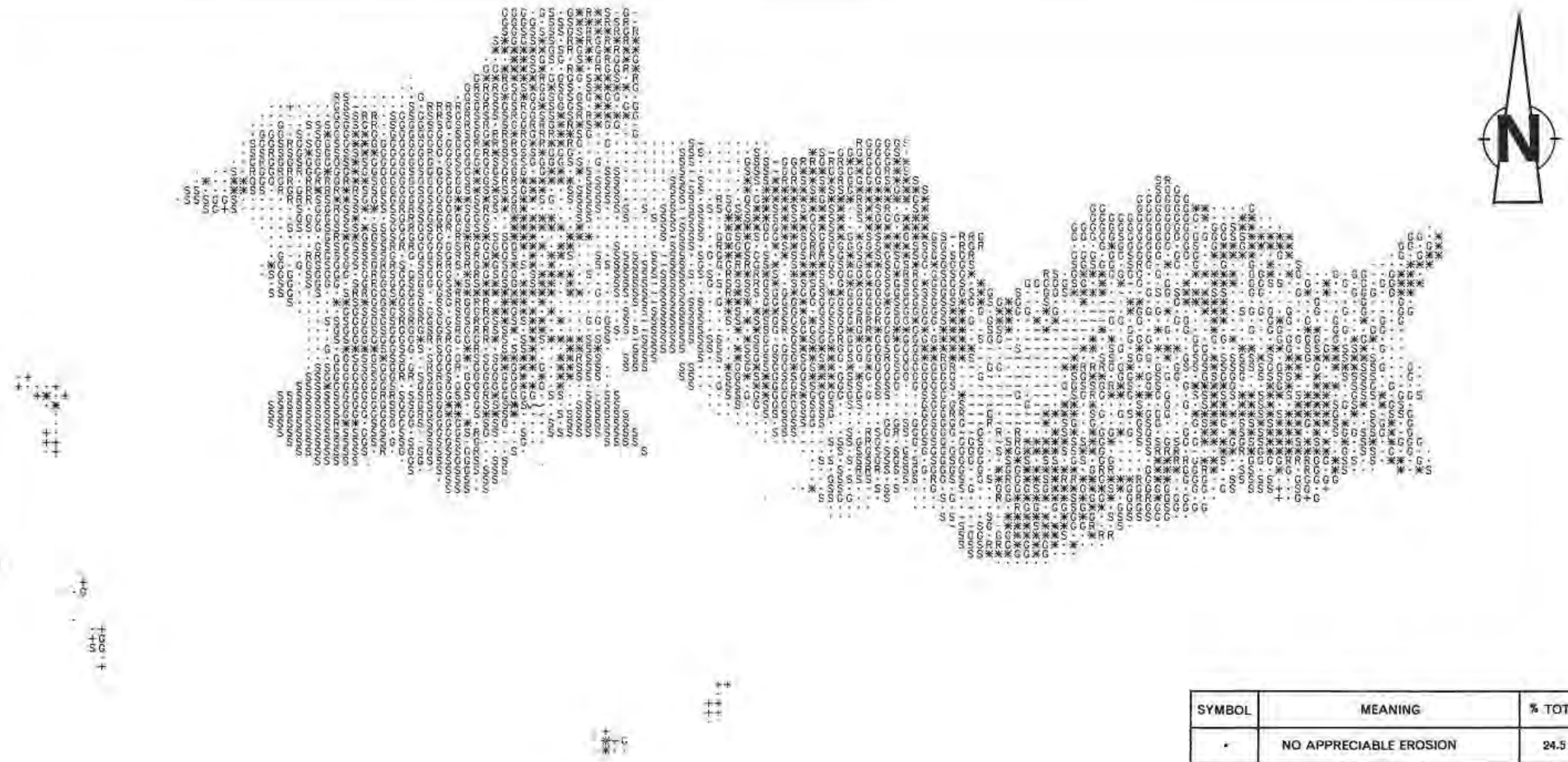


| SYMBOL | MEANING | % TOTAL |
|---|---|---|
| + | GRASSLAND | 4.4 |
| C | CULTIVATION AND BOTANICAL GARDENS | 4.3 |
| △ | SHRUBLAND (< 50% CANOPY COVER) | 20.5 |
| ↟ | SHRVBLAND (> 50% CANOPY COVER) | 23.5 |
| ⊡ | WOODLAND | 27.9 |
| · | NO VEGETATION ON NATURAL TERRAIN | 0.8 |
| D | NO VEGETATION ON DISTURBED TERRAIN | 14.8 |
| ✳ | NO VEGETATION ON ROCK OUTCROPS | 1.3 |
| ~ | WATERBOIDES | 2.5 |

Scale
1:100 000

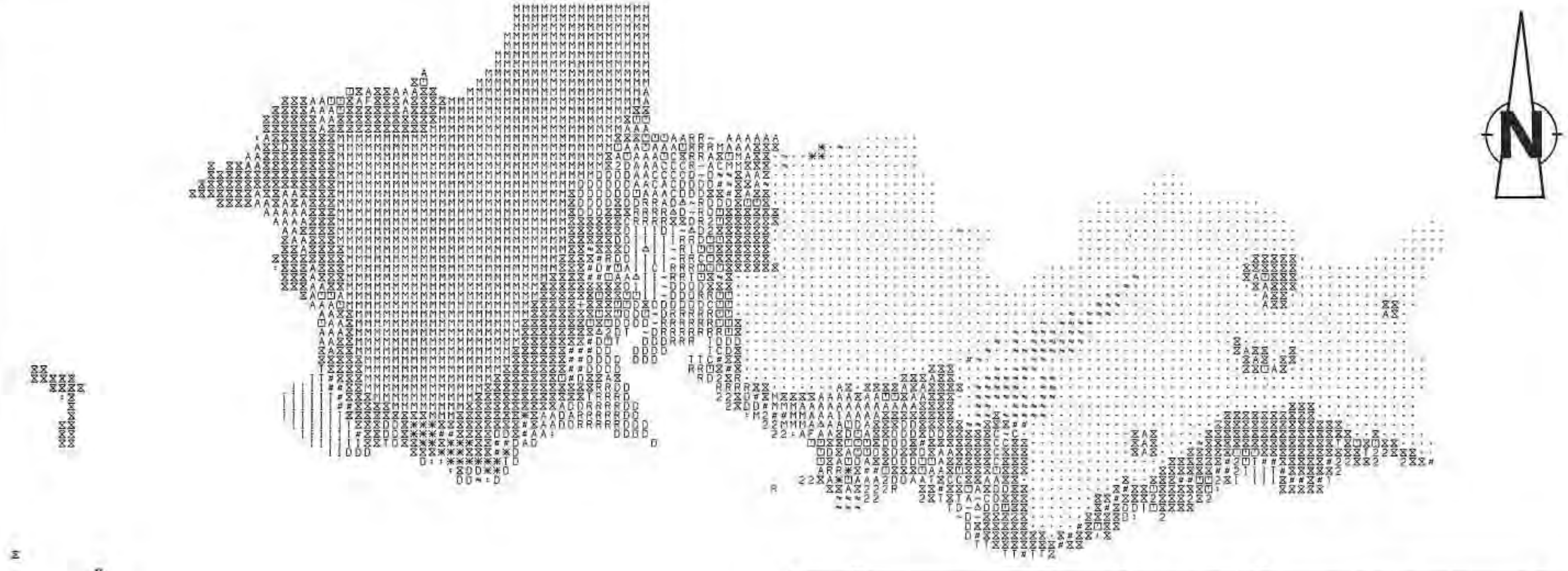
GEOTECS Plot - Vegetation

Fig. 7




| SYMBOL | MEANING | % TOTAL |
|---|---|---|
| · | NO APPRECIABLE EROSION | 24.5 |
| S | SHEET EROSION | 23.2 |
| R | RILL EROSION | 5.1 |
| G | GULLY EROSION | 26.1 |
| + | WELL-DEFINED LANDSLIPS | 0.6 |
| ✳ | GENERAL INSTABILITY | 18.0 |
| ~ | STREAM, CHANNEL, RESERVOIR OR POND | 2.5 |

| Scale 1:100 000 | GEOTECS Plot - Erosion and Instability | Fig. 8 |
|---|---|---|




| SYMBOL | MEANING | % TOTAL | SYMBOL | MEANING | % TOTAL |
|---|---|---|---|---|---|
| R | RESIDENTIAL (AND MIXED COMMERCIAL/RESIDENTIALS) | 2.0 | ✳ | QUARRIES AND BORROW AREAS | 0.7 |
| 1 | SINGLE STOREY HOUSING | < 0.1 | + | CEMETERY | < 0.1 |
| 2 | TOW STOREY HOUSING | 0.8 | A | AGRICULTURE (UNDEFINED) | 4.3 |
| I | COMMERCIAL AND INDUSTRIAL | 1.8 | F | FISH OR DUCK FARMING | < 0.1 |
| C | COMMUNITY AND INSTITUTIONAL | 0.6 | ⧖ | UNDISTURBED NATURAL TERRAIN | 21.1 |
| D | INCOMPLETE DEVELOPMENT (INCL TEMP RESETTLEMENT AREA) | 4.1 | · | COUNTRY PARK | 36.2 |
| ⚠ | SPORTS AND RECREATIONAL | 0.2 | ⍰ | SQUATTERS | 2.2 |
| T | TRANSPORT | 0.6 | ~ | NATURAL STREAMS AND ARTIFICIAL CHANNELS | 0.4 |
| ≈ | WATER SUPPLY (INCL RESERVOIR, SEWAGE AND TREATMENT) | 2.3 | # | LARGE ARTIFICIAL SLOPES | 1.5 |
| M | MILITARY (UNSPECIFIED) | 20.7 | : | LITTORAL ZONES | 0.4 |

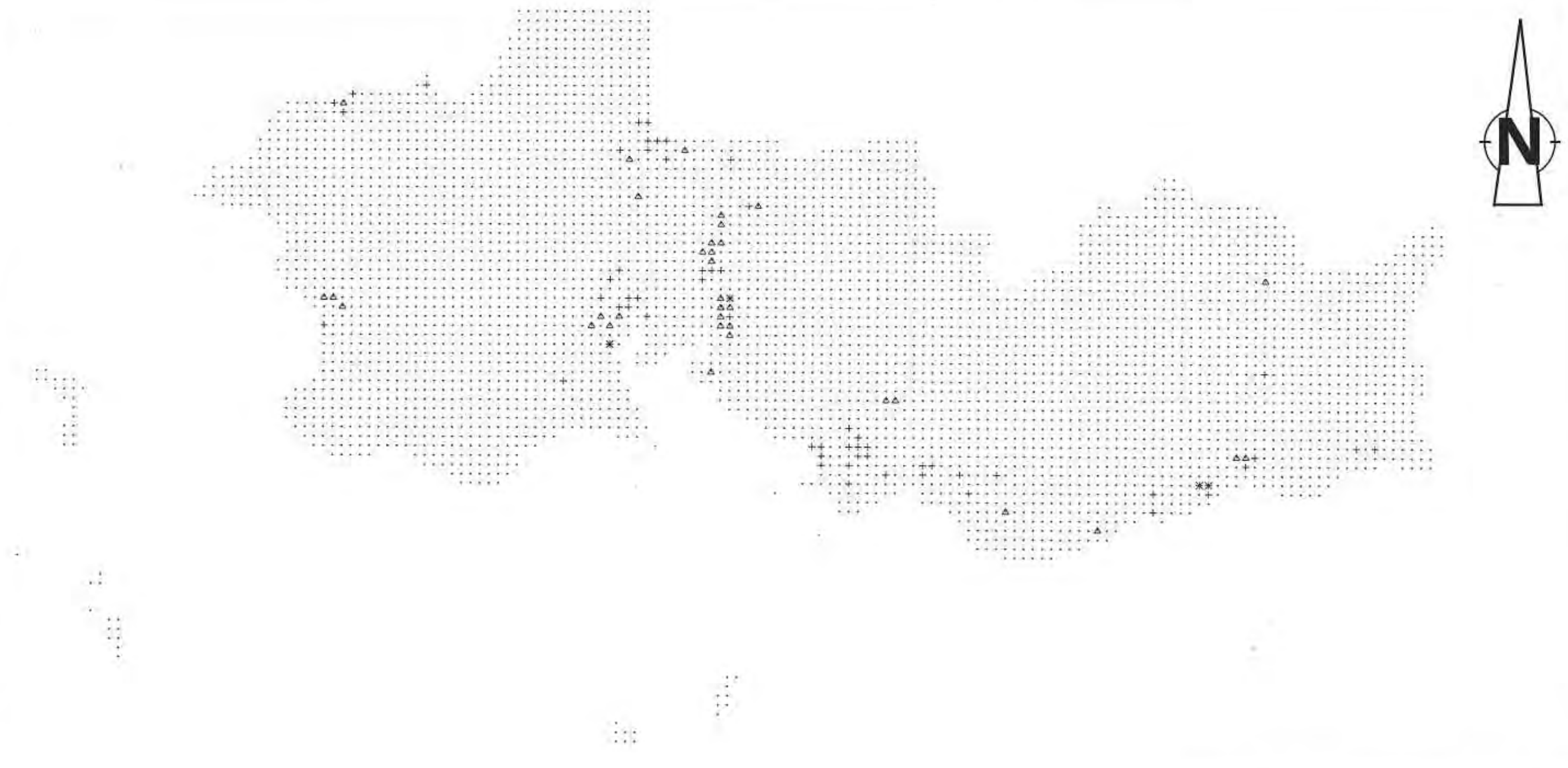
Scale 1:100 000

GEOTECS Plot - Land Use

Fig. 9

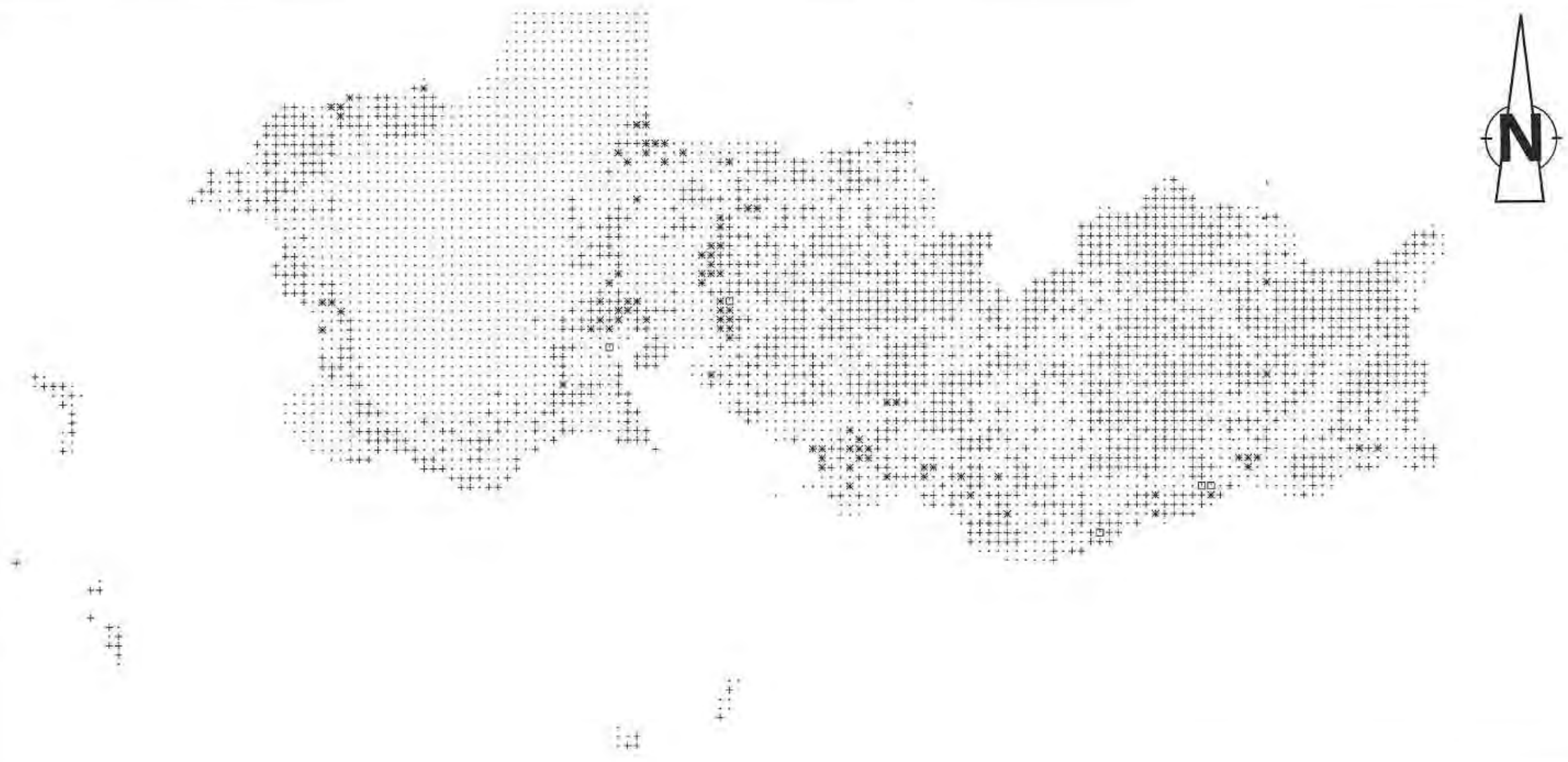
| SYMBOL | MEANING | % TOTAL |
|---|---|---|
| · | GLUM CLASS I | 5.5 |
| + | GLUM CLASS II | 44.1 |
| ⚠ | GLUM CLASS IIS | 2.8 |
| ⊡ | GLUM CLASS III | 29.5 |
| ✳ | GLUM CLASS IV | 15.3 |
| ~ | UNCLASSIFIED | 2.8 |

| Scale 1:100 000 | GEOTECS Plot - Geotechnical Land Use Map | Fig. 10 |
|---|---|---|




| SYMBOL | MEANING | % TOTAL |
|---|---|---|
| + | SQUATTERS ON GLUM CLASS I&II TERRAIN | 1.3 |
| △ | SQUATTERS ON SLOPES < 30° AND GLUM CLASS III TERRAIN | 0.8 |
| ✳ | SQUATTERS ON SLOPES > 30° OR GLUM CLASS IV TERRAIN | 0.1 |
| · | NO SQUATTERS | 97.8 |

| | | |
|---|---|---|
| Scale 1:100 000 | GEOTECS Plot - Distribution of Squatters and Terrain | Fig. 11 |

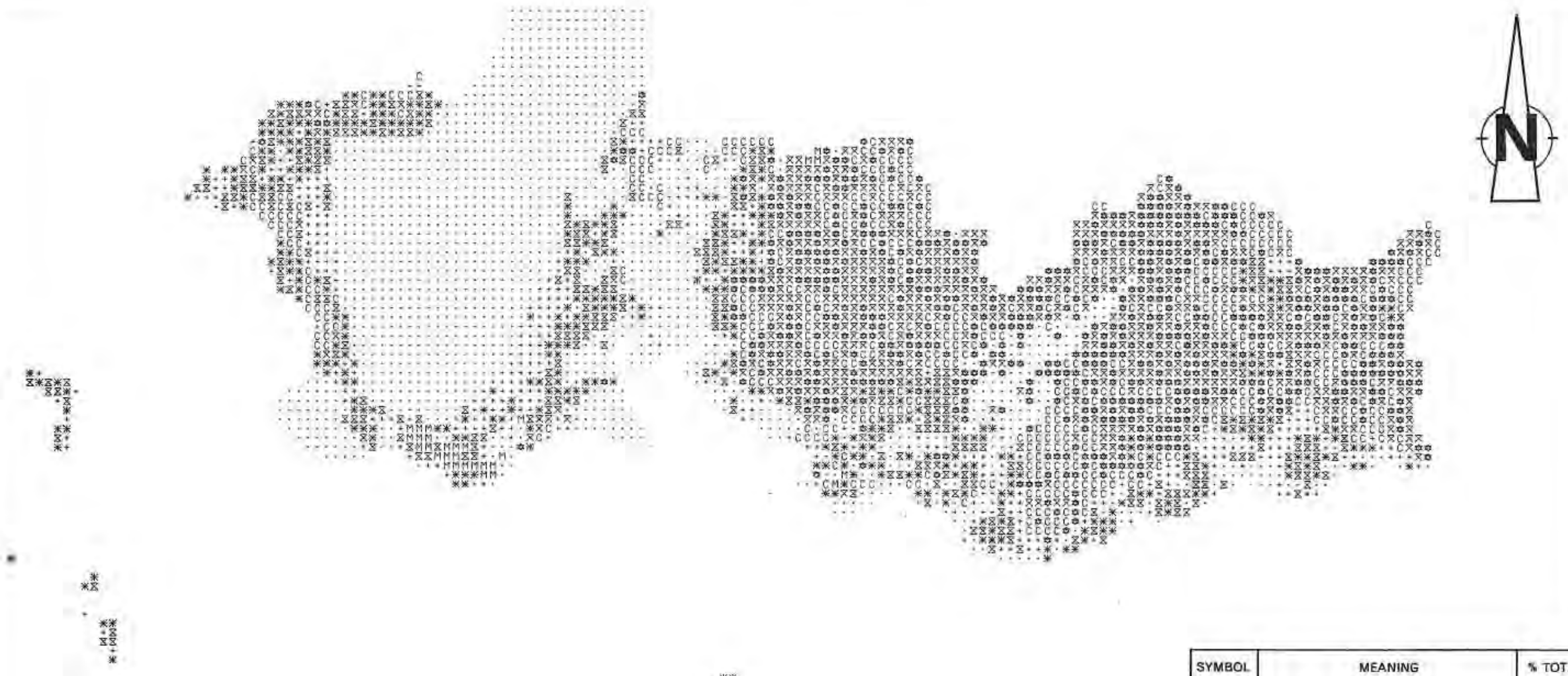



| SYMBOL | MEANING | % TOTAL |
|---|---|---|
| ✳ | DEVELOPMENT POTENTIAL IN SQUATTER AREA | 2.1 |
| + | DEVELOPMENT POTENTIAL IN UNDISTURBED AREA | 37.5 |
| ⊡ | DEVELOPMENT CONSTRAINT IN SQUATTER AREA | 0.1 |
| · | NOT APPLICABLE | 60.3 |

Scale 1:100 000

GEOTECS Plot - Squatters on Land with Potential for Development

Fig. 12

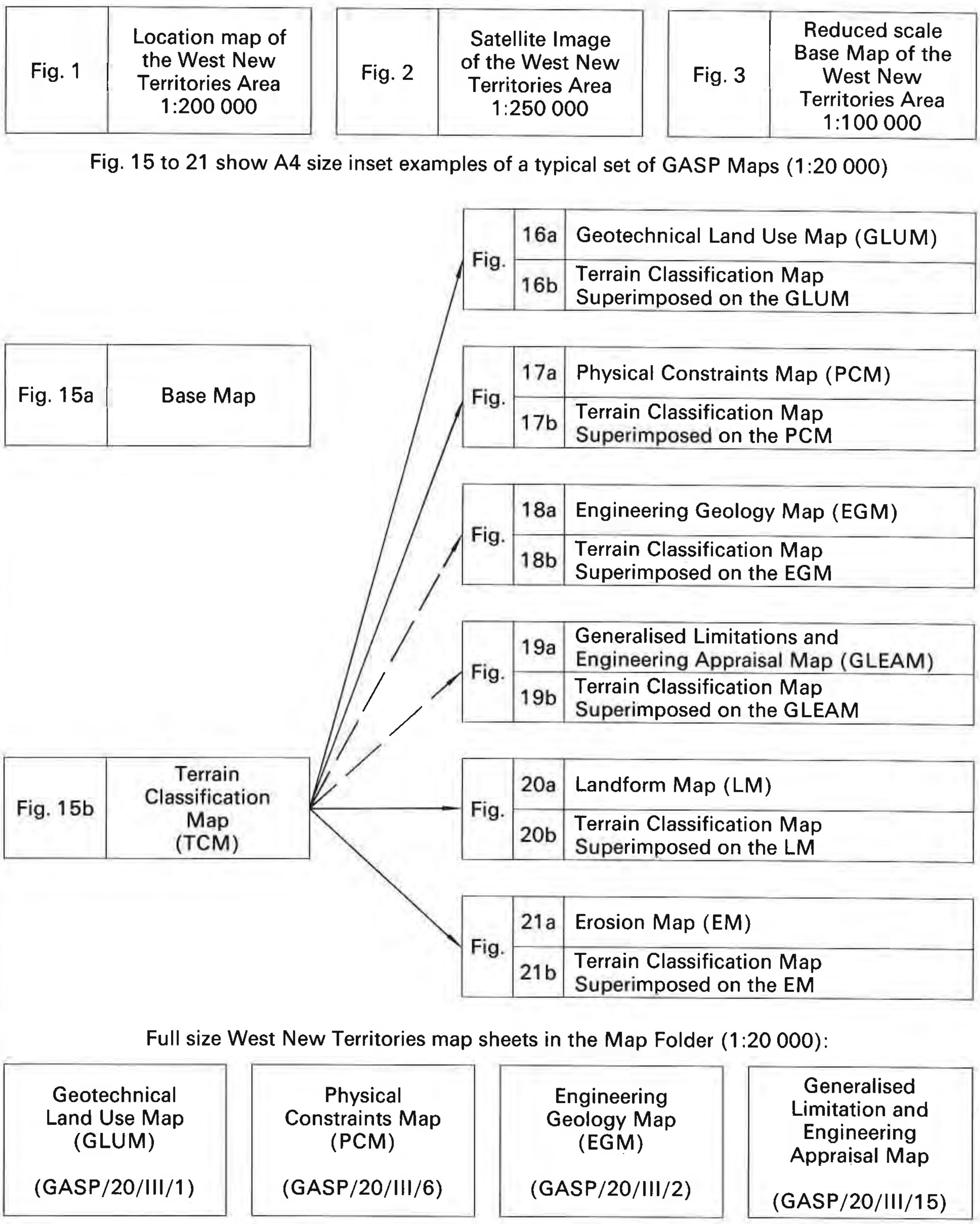



| SYMBOL | MEANING | % TOTAL |
|---|---|---|
| ✳ | POTENTIAL (TERRAIN) NO CURRENT USEAGE | 9.4 |
| ⧖ | POTENTIAL (SLOPE) NO CURRENT USEAGE | 7.1 |
| ✡ | POTENTIAL (TERRAIN) COUNTRY PARK OR CULTIVATION | 15.1 |
| ⧗ | POTENTIAL (SLOPE) COUNTRY PARK OR CULTIVATION | 12.8 |
| · | EXISTING USAGE, RESERVOIR OR CHANNEL | 34.2 |
| M | EXISTING QUARRY OR BORROW AREA | 0.7 |
| C | OTHER TERRAIN IN COUNTRY PARK, CULTIVATION, OR POND | 12.6 |
| + | UNDESIGNATED - MAY HAVE MINOR POTENTIAL | 8.1 |

Scale 1:100 000

GEOTECS Plot - Distribution of Areas with Potential Use as Quarries

Fig. 13



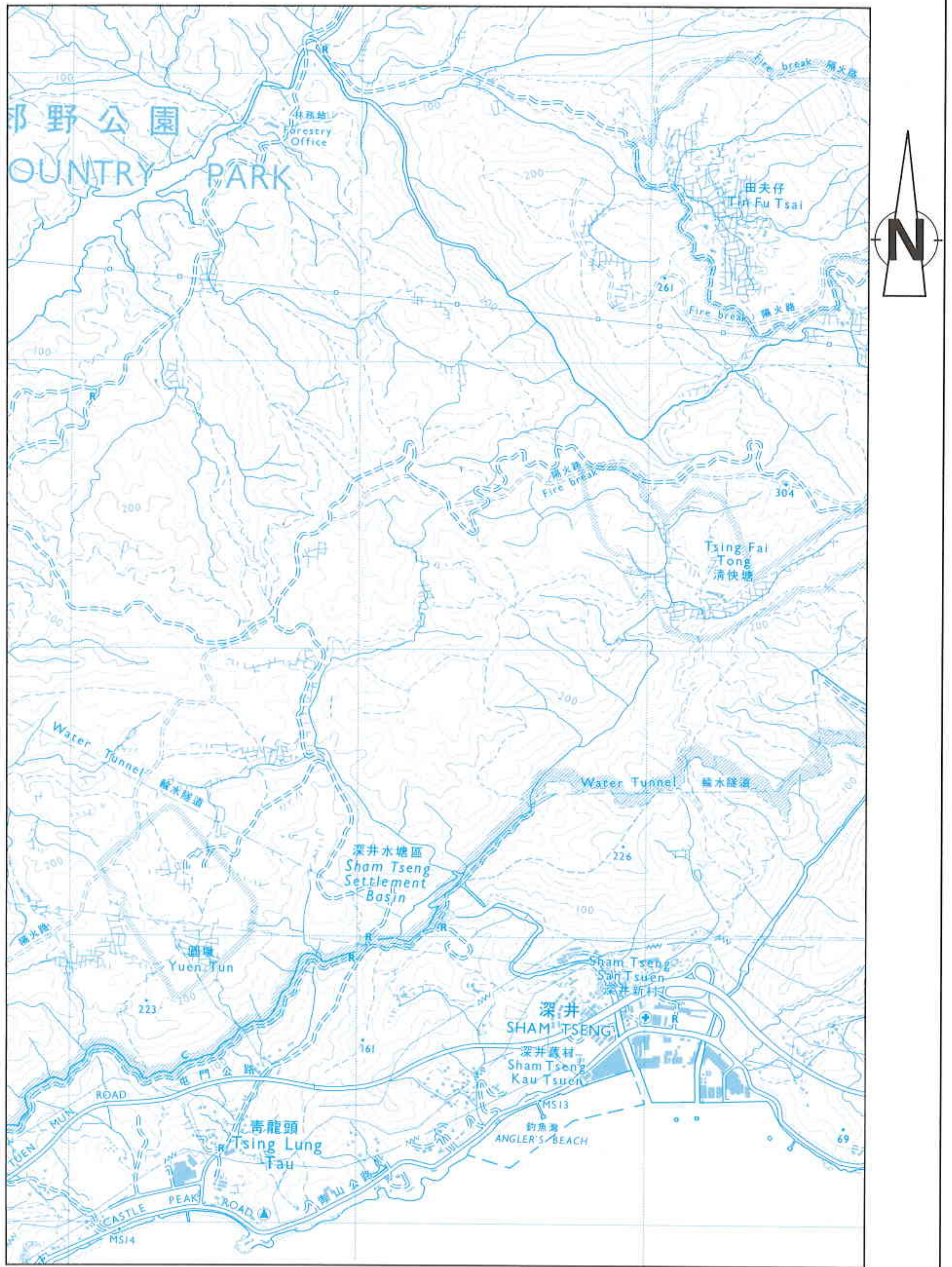

Presentation of Maps — Fig. 14

## LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. 15b)

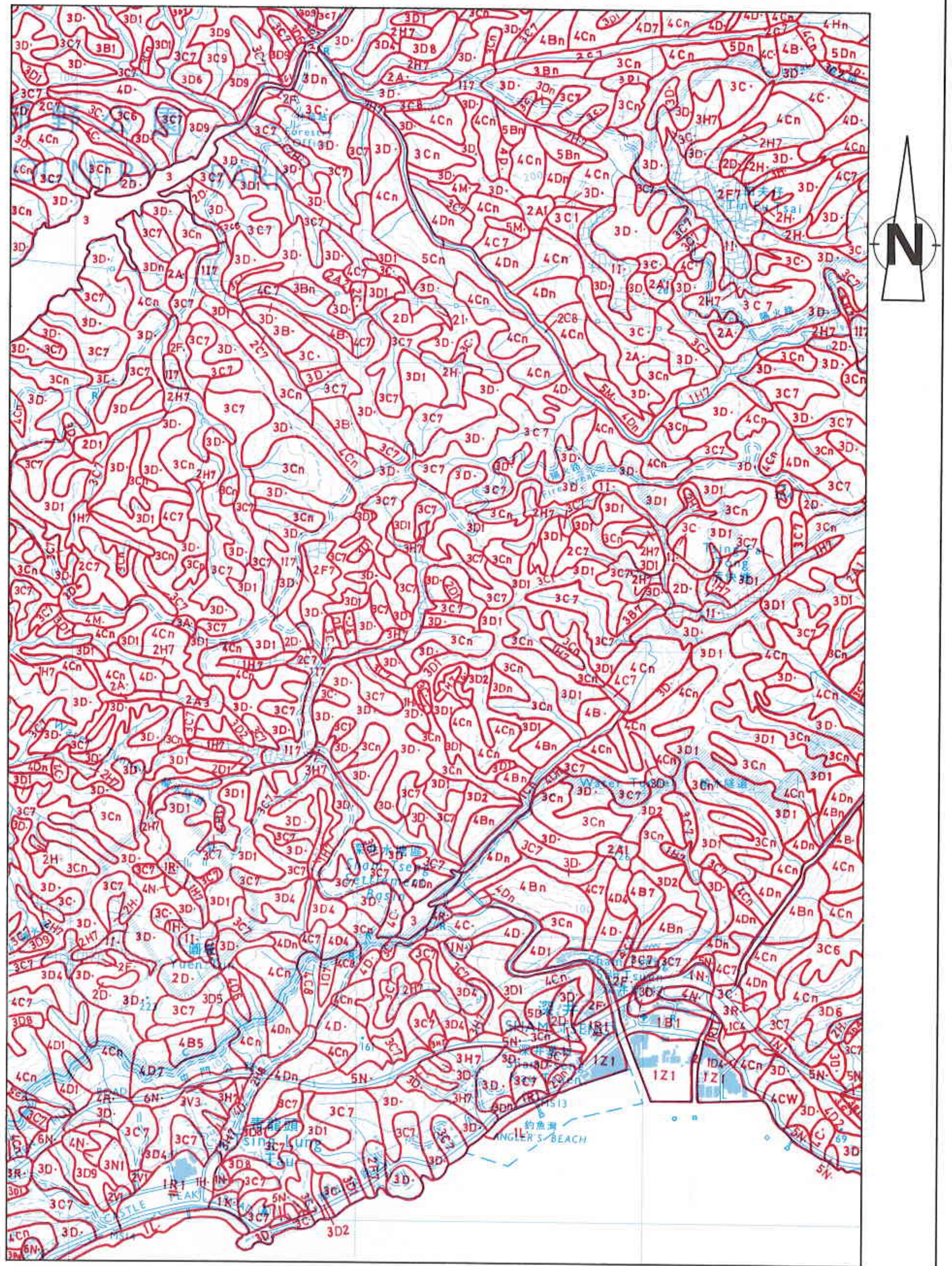
| SLOPE GRADIENT | CODE |
|---|---|
| 0 - 5° | 1 |
| 5 - 15° | 2 |
| 15 - 30° | 3 |
| 30 - 40° | 4 |
| 40 - 60° | 5 |
| > 60° | 6 |

| 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 |
| Reclamation | Z |
| Alluvial plain | X |
| 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<br>1:20 000 | Example of the Base Map | Fig. 15a |



| | | |
|---|---|---|
| Scale<br>1:20 000 | Example of the Terrain Classification Map<br>(TCM) | Fig. 15b |

## LEGEND FOR GEOTECHNICAL LAND USE MAP (Fig. 16a)

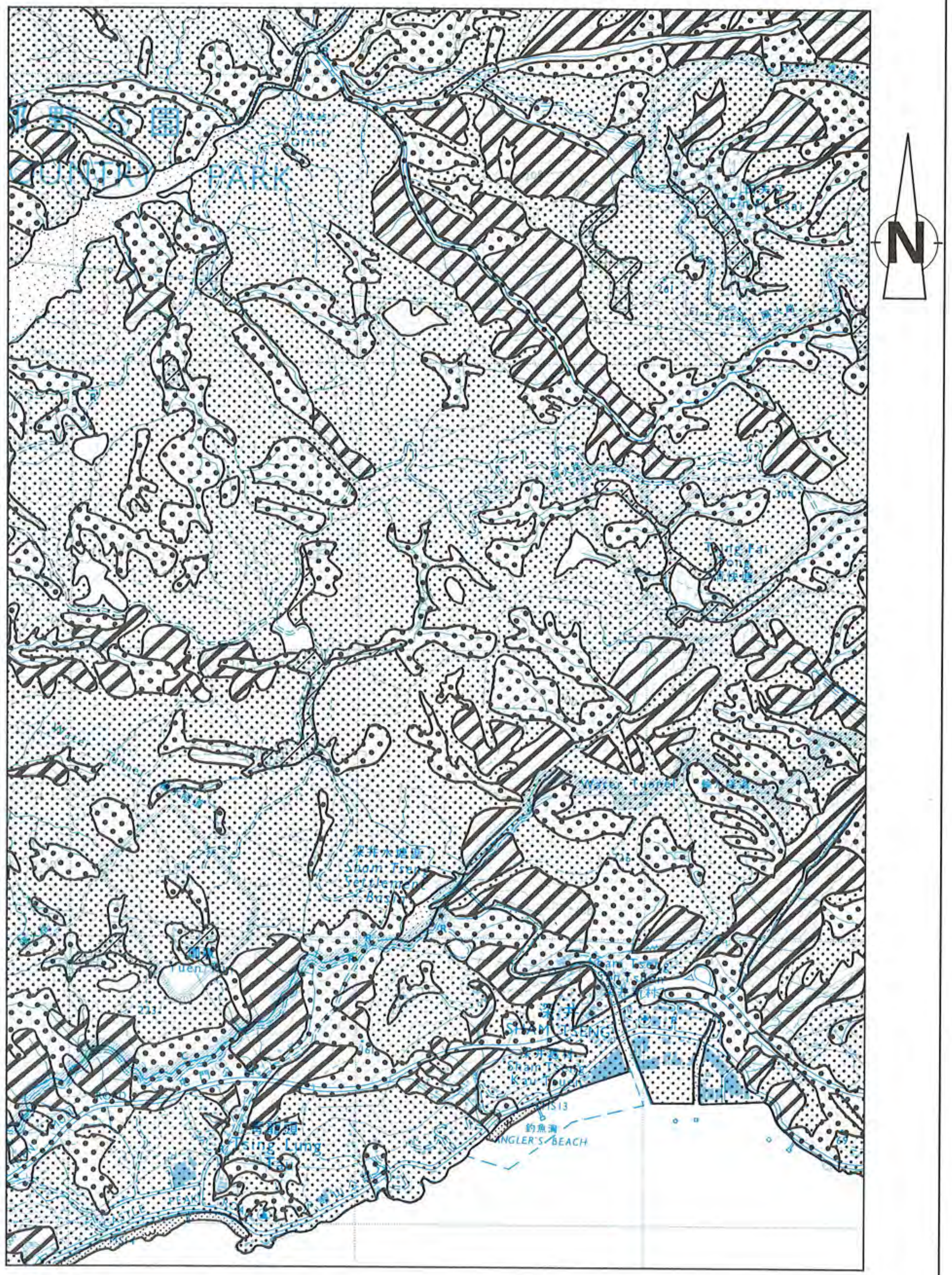
| | |
|---|---|
| Class I - Low Geotechnical Limitations | |
| Class II - Moderate Geotechnical Limitations | |
| Class IIS - Moderate Geotechnical Limitations (including flooding) | |
| Class III - High Geotechnical Limitations | |
| Class IV - Extreme Geotechnical Limitations | |
| Waterbodies (streams,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

## LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. 16b)

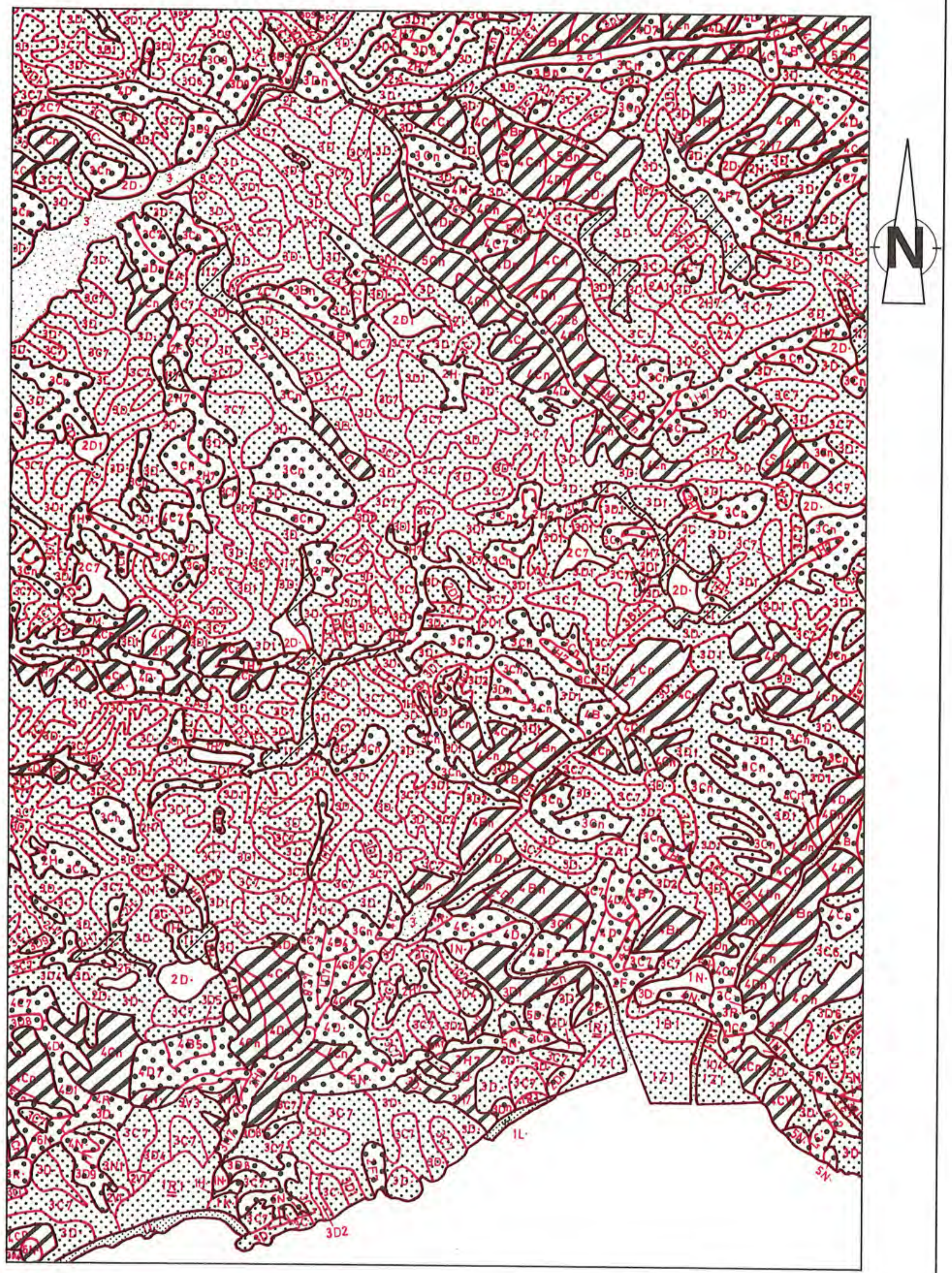
| SLOPE GRADIENT | CODE |
|---|---|
| 0 - 5° | 1 |
| 5 - 15° | 2 |
| 15 - 30° | 3 |
| 30 - 40° | 4 |
| 40 - 60° | 5 |
| > 60° | 6 |

| 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 |
| Reclamation | Z |
| Alluvial plain | X |
| 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. 16a |



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

## LEGEND FOR PHYSICAL CONSTRAINTS MAP (Fig. 17a)

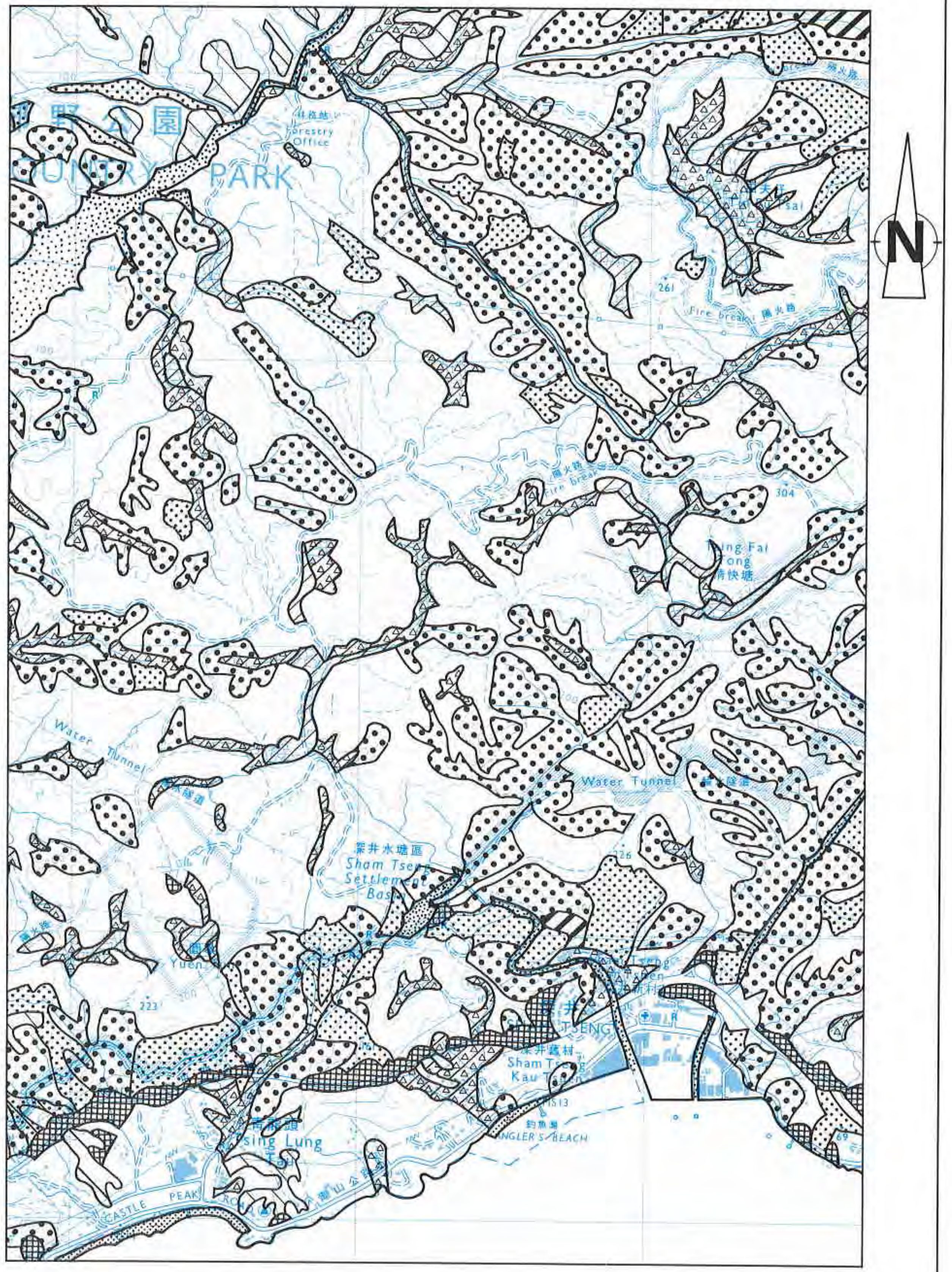
- Colluvium
- Zones of colluvium which are subject to overland flow and periodic inundation. Evidence of unusual groundwater regime (delineated as drainage plain on Landform Map)
- Floodplain - subject to overland flow and regular inundation. Evidence of unusual groundwater regime (delineated as floodplain 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)

## LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. 17b)

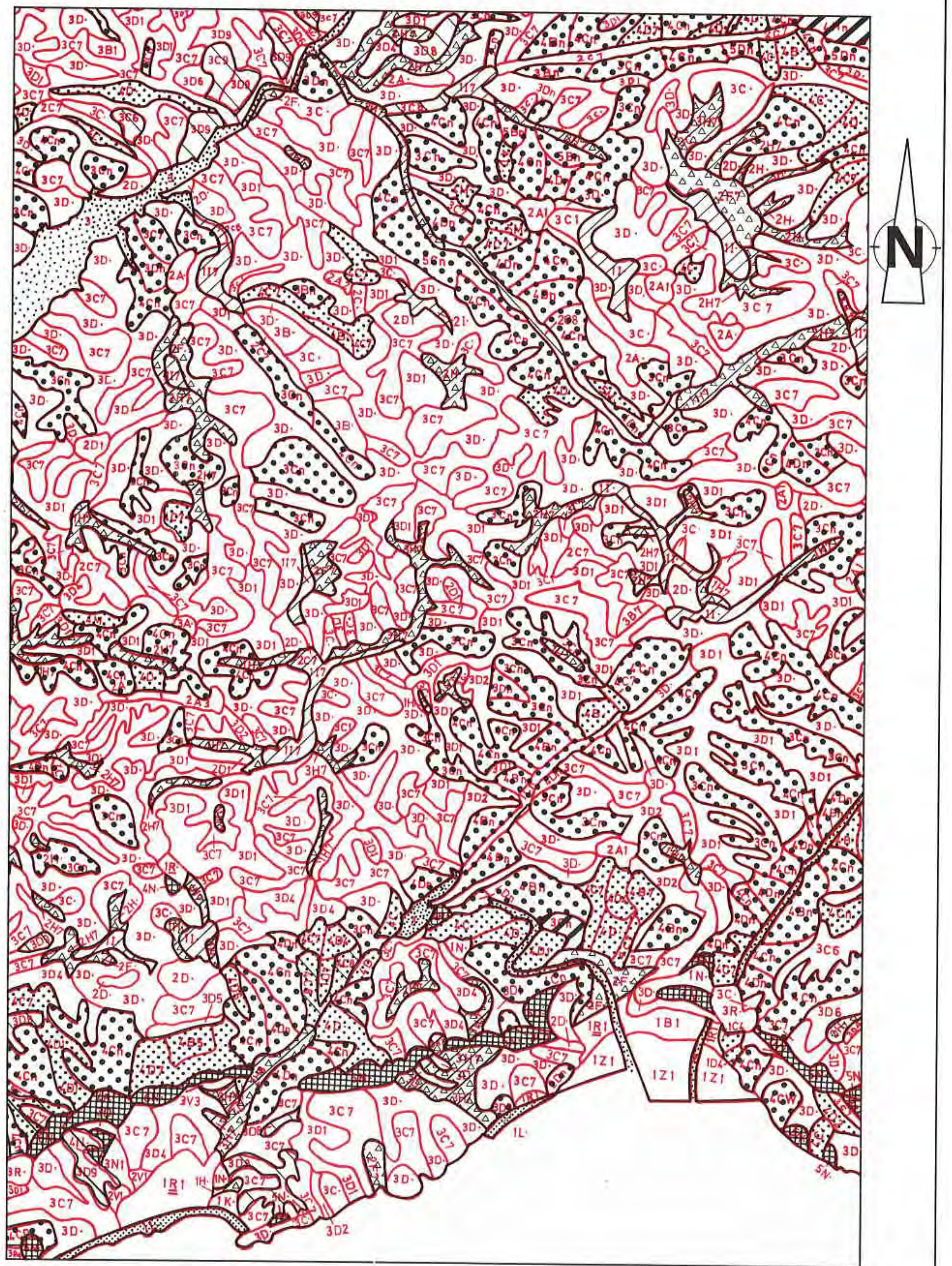
| SLOPE GRADIENT | CODE |
|---|---|
| 0 - 5° | 1 |
| 5 - 15° | 2 |
| 15 - 30° | 3 |
| 30 - 40° | 4 |
| 40 - 60° | 5 |
| > 60° | 6 |

| 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 |
| Reclamation | Z |
| Alluvial plain | X |
| 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 Physical Constraints Map (PCM) | Fig. 17a |
|---|---|---|




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

## LEGEND FOR ENGINEERING GEOLOGY MAP (Fig. 18a)

- Fill
- Reclamation
- Littoral deposits
- Alluvial (undifferentiated)
- Colluvium (undifferentiated)
- Sedimentary rocks and water-laid volcaniclastic rocks ) Repulse Bay Formation
- Coarse tuff ) Repulse Bay Formation
- Agglomerate ) Repulse Bay Formation
- Dominantly pyroclastic rocks with some lavas ) Repulse Bay Formation
- Tai O Formation
- Lok Ma Chau Formation
- Granophyric microgranite
- Undifferentiated granitic rock
- Needle Hill Granite : fine-grained porphyritic phase
- Needle Hill Granite : medium-grained porphyritic phase (NHm)
- Cheung Chau Granite
- Sung Kong Granite
- Tai Po Granodiorite

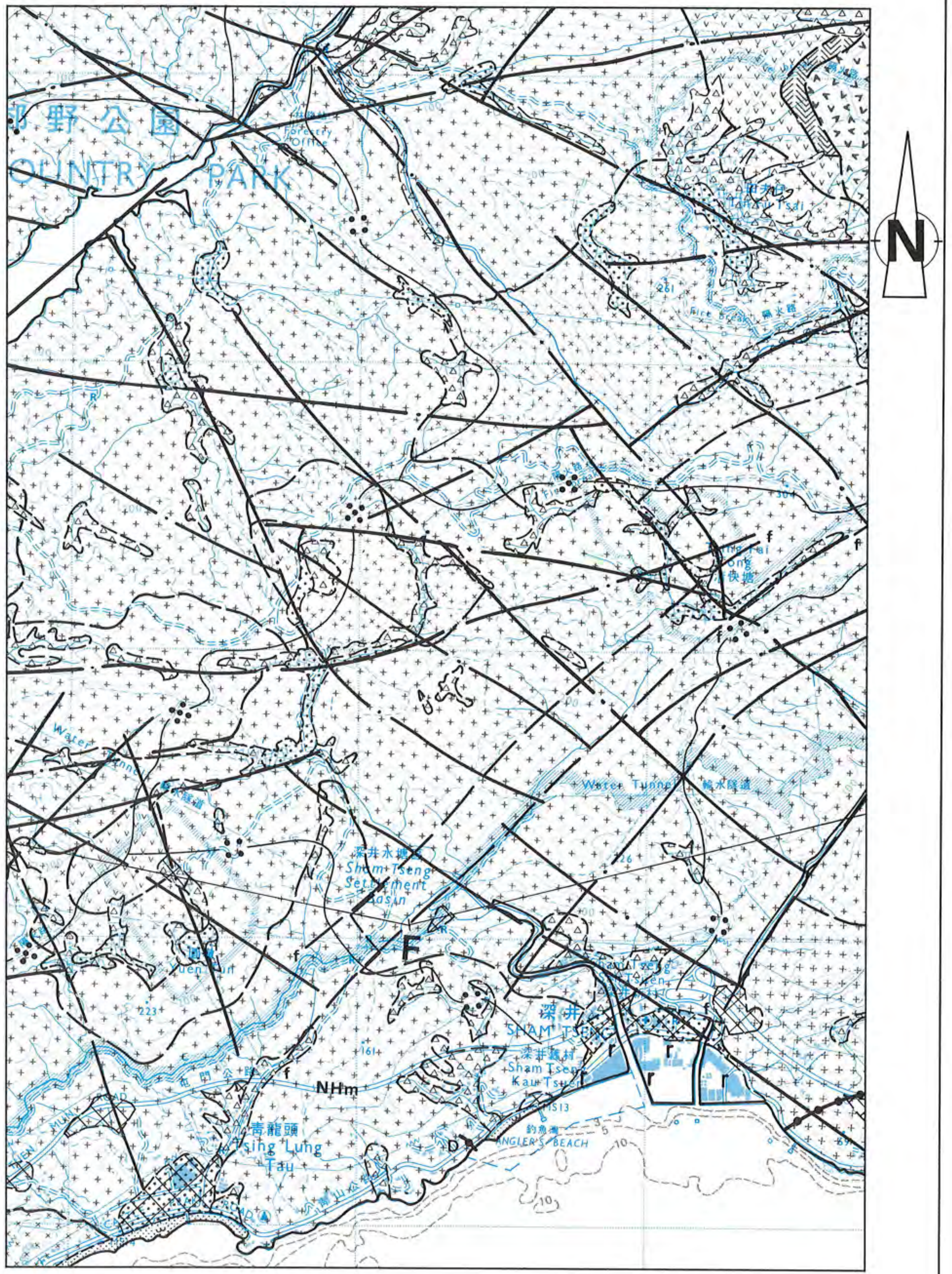
- Dolerite dyke (D)
- Quartz veins (q)
- Quartz veins with molybdenite (mo q)
- Quartz veins with pyrite (Py q)
- Deeply weathered pegmatite with Kaolinite (ka)
- Geological boundary (solid)
- Geological boundary (superficial)
- Faults
- Thrust (teeth pointing to upper plate)
- Geological photolineament
- Strike and dip of beds (30)
- Strike and dip of schistosity (60)
- Strike of bedding - dip unknown
- Vertical bedding
- GAS boundary
- General instability
- Geological cross-section line (A B)
- Catchment boundary (order indicated by number of dots)
- Isopachs of submarine superficial deposits (metres)
- Depth in fathoms

## LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. 18b)

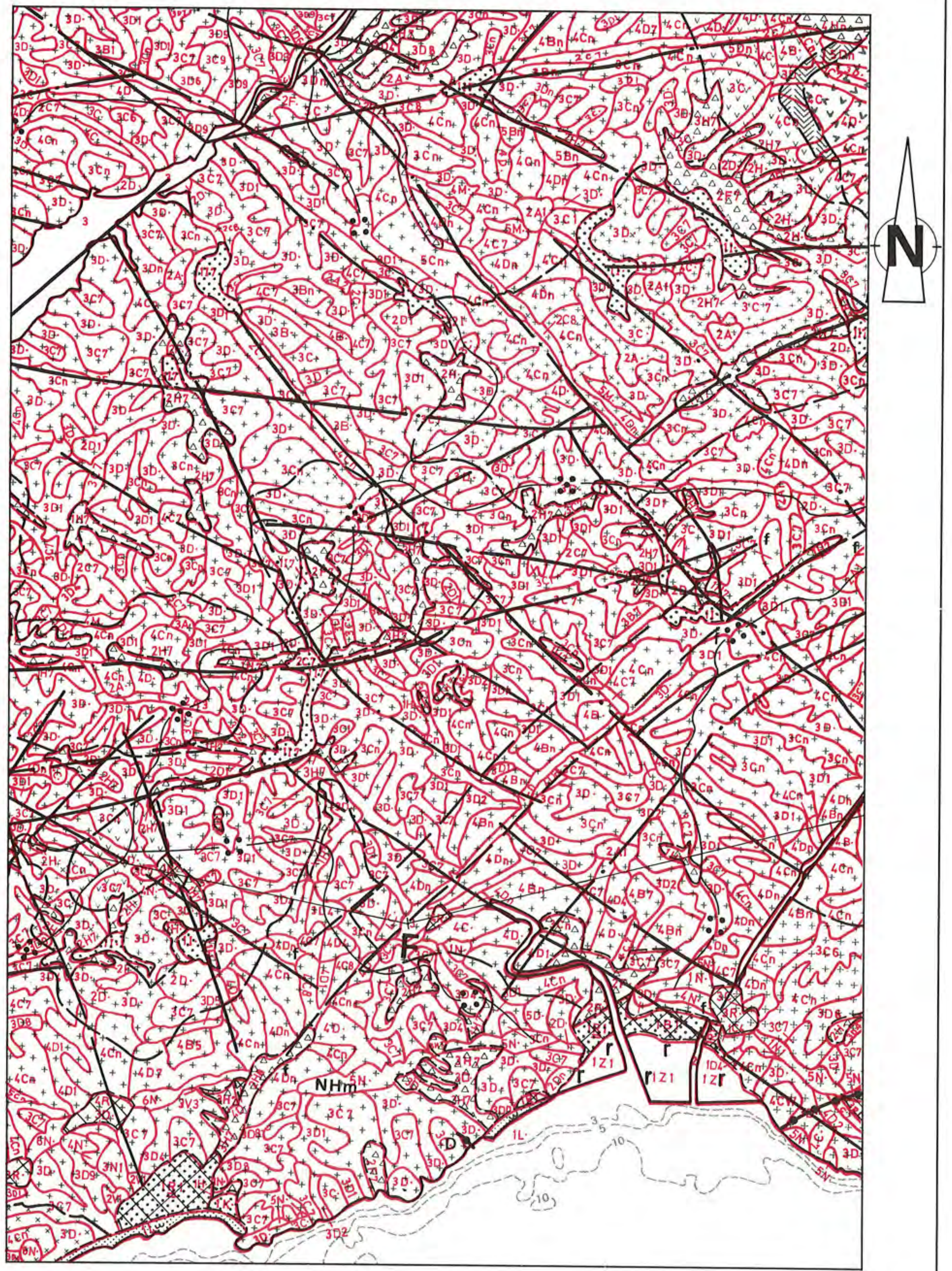
| SLOPE GRADIENT | CODE |
|---|---|
| 0 - 5° | 1 |
| 5 - 15° | 2 |
| 15 - 30° | 3 |
| 30 - 40° | 4 |
| 40 - 60° | 5 |
| > 60° | 6 |

| 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 |
| Reclamation | Z |
| Alluvial plain | X |
| 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<br>1:20 000 | Example of the Engineering Geology Map<br>(EGM) | Fig. 18a |




| | | |
|---|---|---|
| Scale<br>1:20 000 | Example of the Terrain Classification Map<br>Superimposed on the EGM | Fig. 18b |

## LEGEND FOR GENERALISED LIMITATIONS AND ENGINEERING APPRAISAL MAP (Fig. 19a)

**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 hectare unit)

Country Park boundary

—C— Catchwater

Firing Range boundary

NOTE Numerals on map refer to relevant general planning/ engineering notes

**FEATURES OF ENGINEERING SIGNIFICANCE :**

Photogeological lineament

—R— Ridgeline

═D═DI═ Drainage, incised drainage

C Colluvium (also in 'zone of local constraint', and PCM)

W Weathering

B> Boulders

Instability influencing area

Steeper slopes influencing area (orientation of symbols indicates downslope direction)

f— — —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 A6, and Section 4.2.

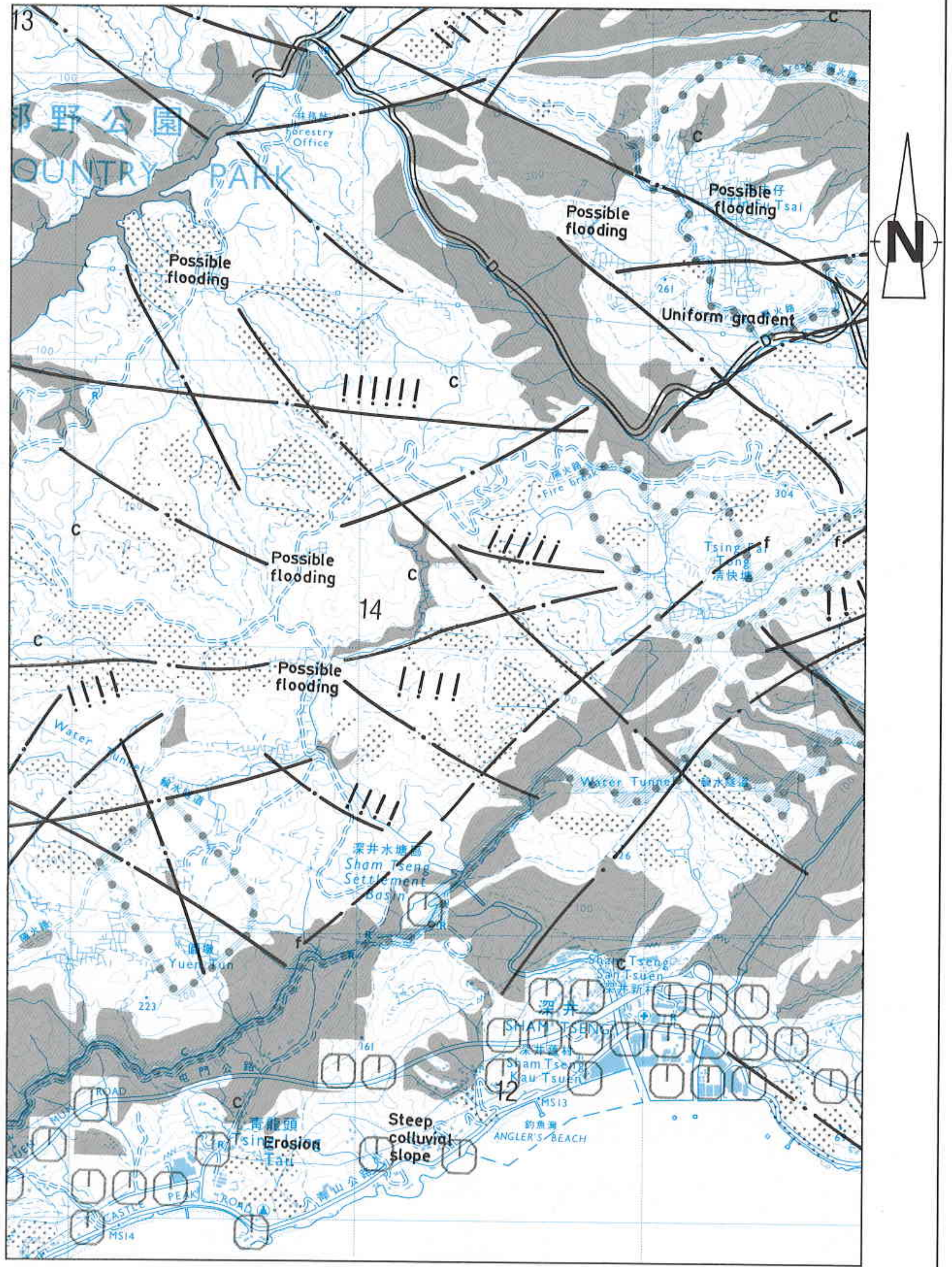
iii) Geological boundaries and photolineaments are shown in full on the EGM. Those lineaments indicated represent the surface expression of obvious structural discontinuities which affect the PDA's.

## LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. 19b)

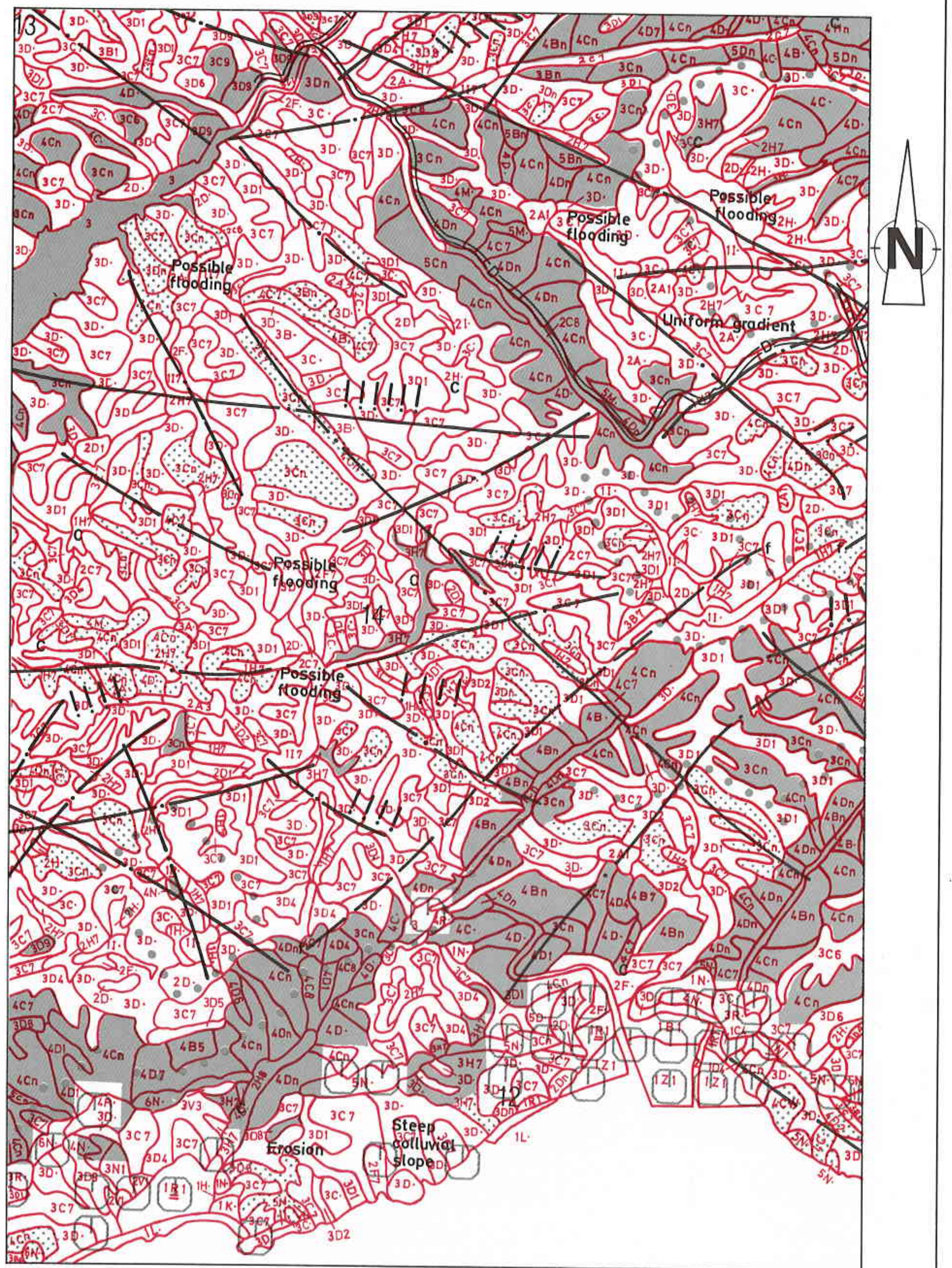
| SLOPE GRADIENT | CODE |
|---|---|
| 0 - 5° | 1 |
| 5 - 15° | 2 |
| 15 - 30° | 3 |
| 30 - 40° | 4 |
| 40 - 60° | 5 |
| > 60° | 6 |

| 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 |
| Reclamation | Z |
| Alluvial plain | X |
| 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 Generalised Limitations and Engineering Appraisal Map (GLEAM) | Fig. 19a




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

## LEGEND FOR LANDFORM MAP (Fig. 20a)

| 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 |

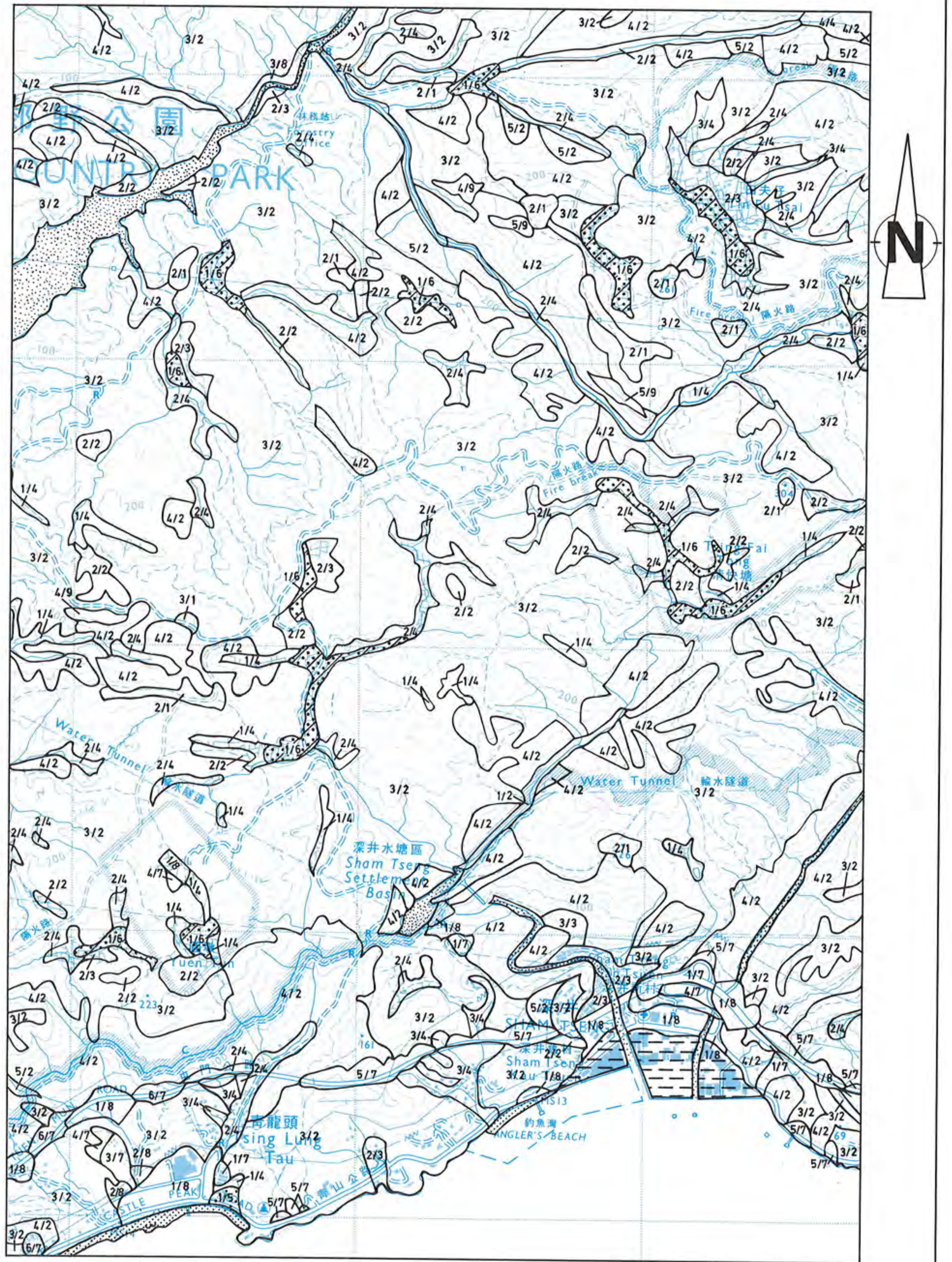
| DESCRIPTION | CODE |
|---|---|
| Crest or ridge | 1 |
| Sideslope - insitu | 2 |
| Footslope - colluvium | 3 |
| Drainage plain - colluvium subject to overland flow and regular inundation. Unusual groundwater regime. | 4 |
| Alluvial plain - includes raised terraces. | 5 |
| Flood plain - portion of 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) | |

## LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. 20b)

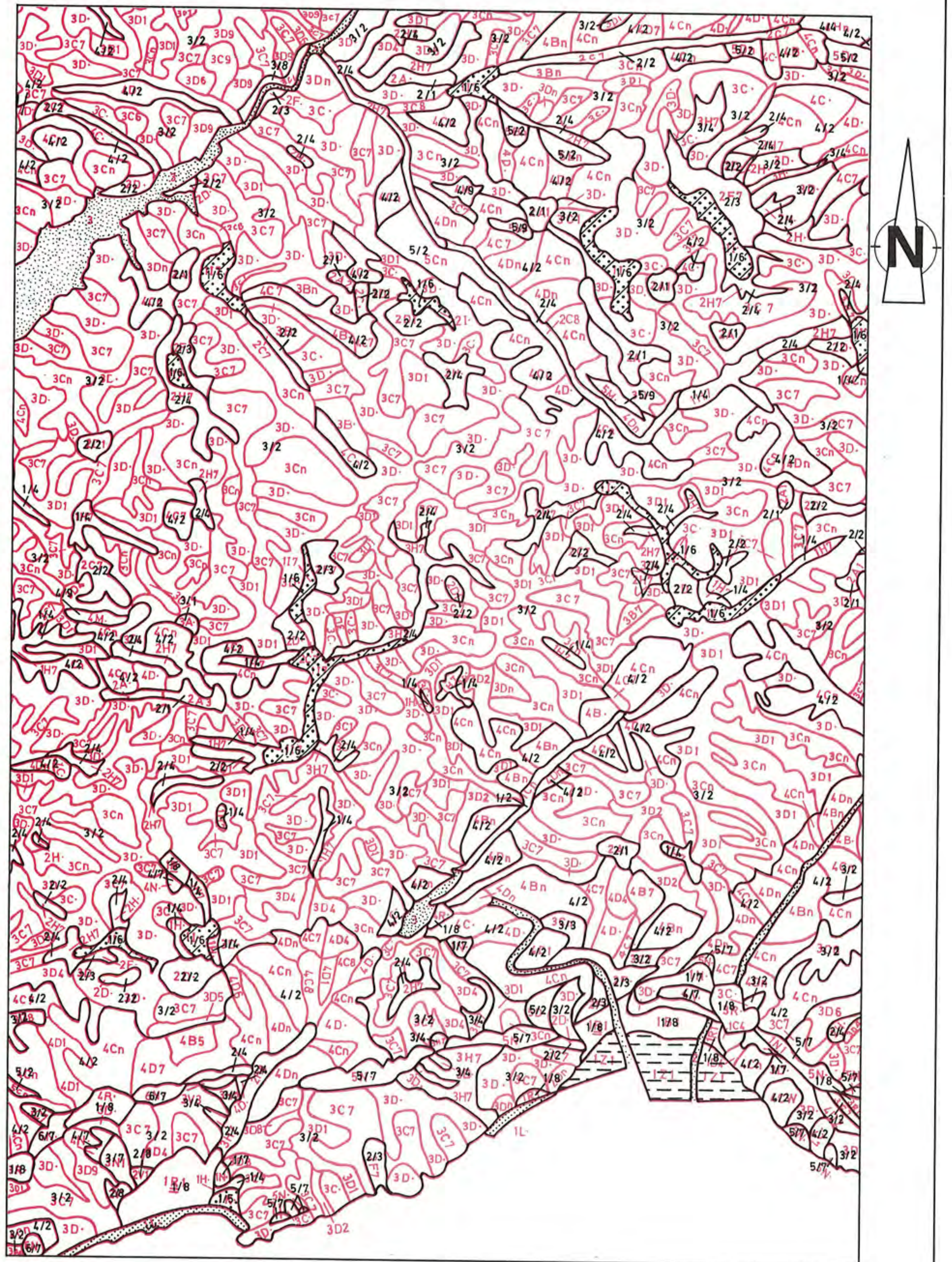
| SLOPE GRADIENT | CODE |
|---|---|
| 0 - 5° | 1 |
| 5 - 15° | 2 |
| 15 - 30° | 3 |
| 30 - 40° | 4 |
| 40 - 60° | 5 |
| > 60° | 6 |

| 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 |
| Reclamation | Z |
| Alluvial plain | X |
| 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 Landform Map (LM) | Fig. 20a




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

## LEGEND FOR EROSION MAP (Fig. 21a)

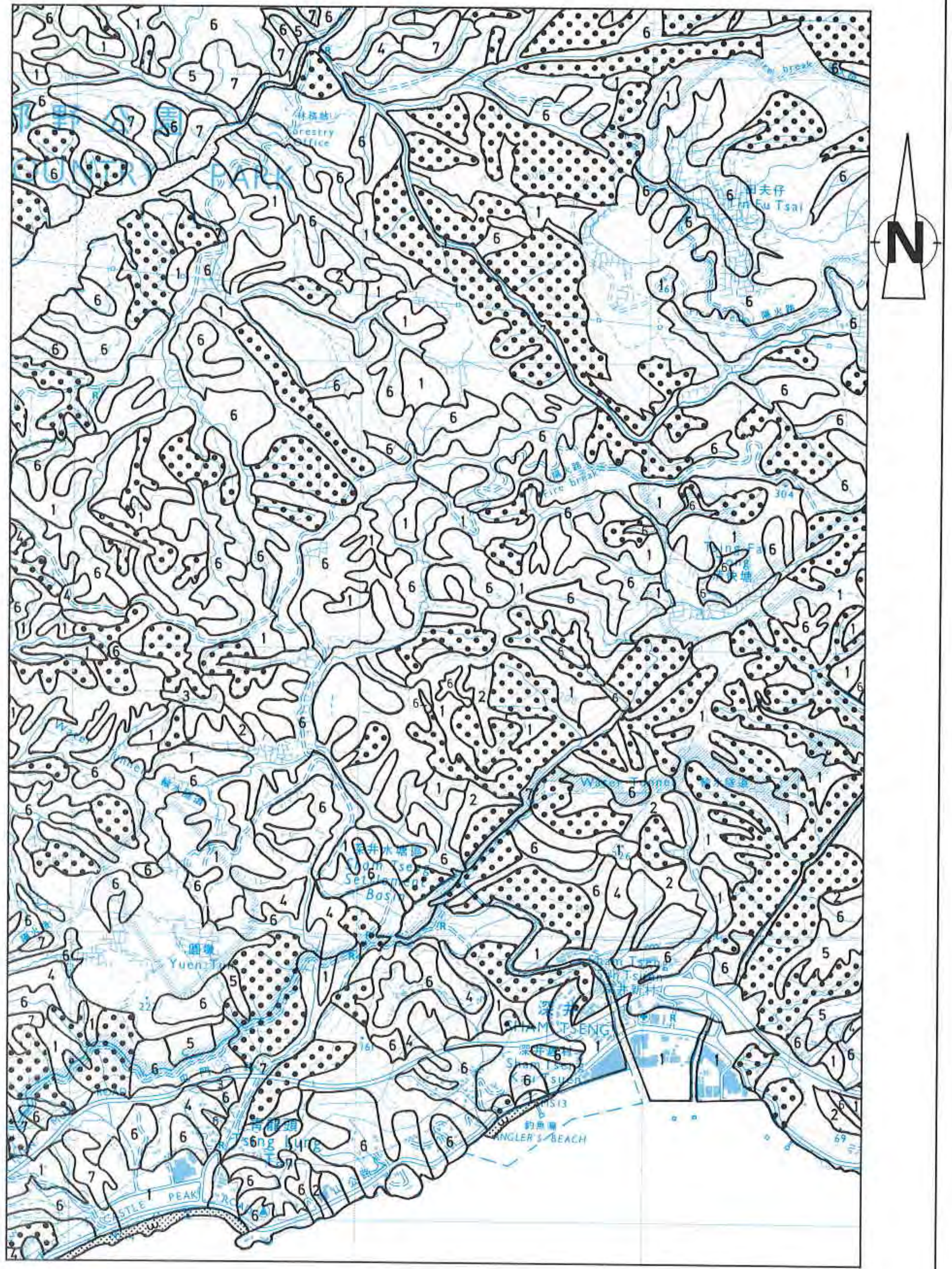
| | |
|---|---|
| | No appreciable erosion |
| 1 | Minor sheet erosion |
| 2 | Moderate sheet erosion |
| 3 | Severe sheet erosion |
| 4 | Minor rill erosion |
| 5 | Moderate to severe rill erosion |
| 6 | Minor gully erosion |
| 7 | Moderate to severe gully erosion |
| | Zones of general instability 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) |

## LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. 21b)

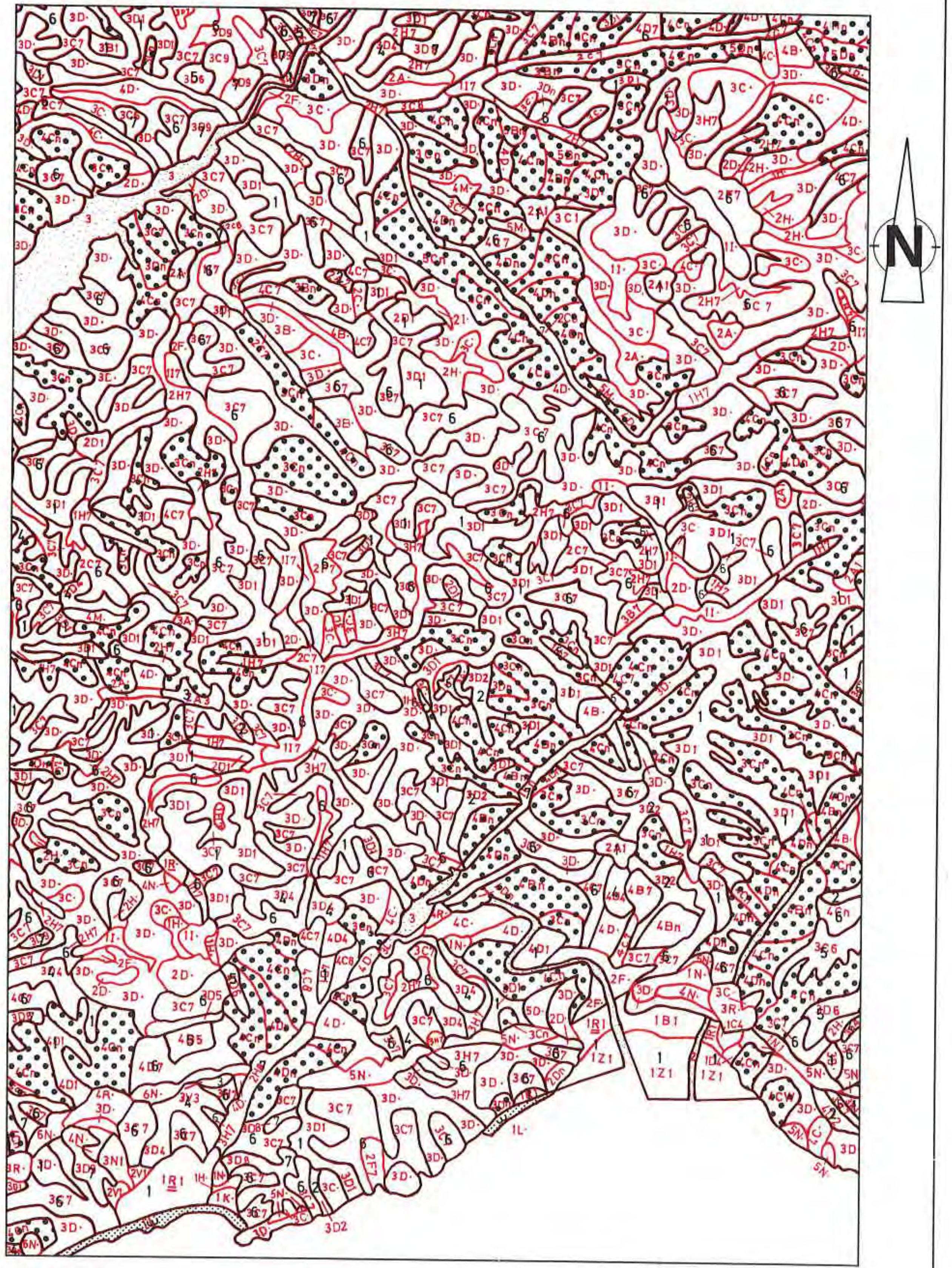
| SLOPE GRADIENT | CODE |
|---|---|
| 0 - 5° | 1 |
| 5 - 15° | 2 |
| 15 - 30° | 3 |
| 30 - 40° | 4 |
| 40 - 60° | 5 |
| > 60° | 6 |

| 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 |
| Reclamation | Z |
| Alluvial plain | X |
| 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 | a |
| > 1ha in size | |
| General ) recent | n |
| instability ) relict | r |
| Coastal instability | w |



| Scale 1:20 000 | Example of the Erosion Map (EM) | Fig. 21a |
| --- | --- | --- |



| Scale 1:20 000 | Example of the Terrain Classification Map Superimposed on the EM | Fig. 21b |
| --- | --- | --- |


*Plate 1. Oblique Aerial Photograph Looking Southwest over Tuen Mun New Town and Castle Peak.* The light coloured foreground is mainly reclamation or fill over alluvium. The ground in the centre consists of rocks of the Repulse Bay Formation, and the high ground in the distance is Cheung Chau Granite. (GCO/OAP 1981/5695)

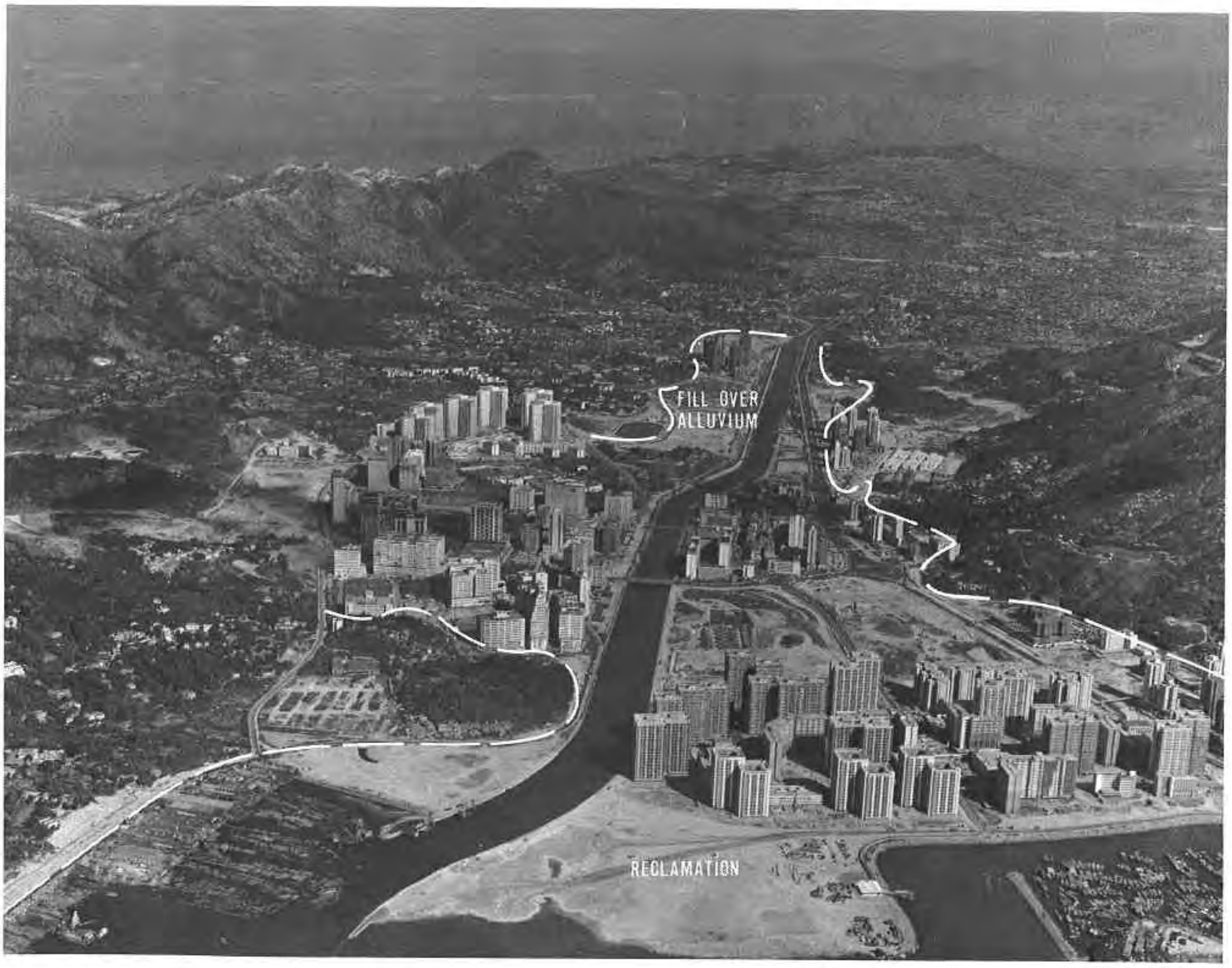



*Plate 2. Oblique Aerial Photograph Looking North across Tuen Mun New Town.* The Tuen Mun/Castle Peak Valley shows extensive areas of reclamation and fill. Recent urban development has centred on these areas (GCO/OAP 1981/5741)

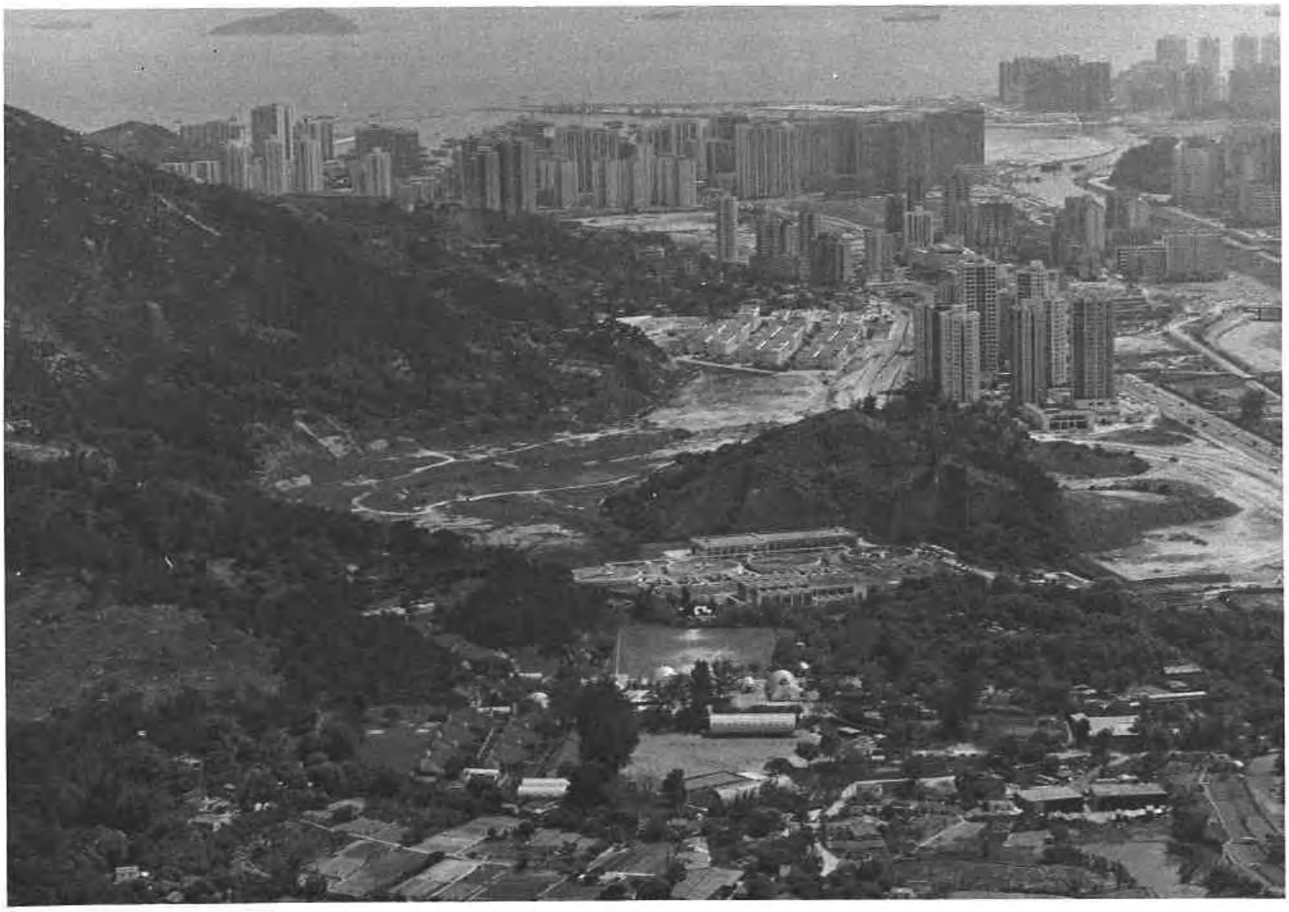


*Plate 3. Oblique Aerial Photograph Looking South over Tuen Mun New Town.* In the foreground, an area of lowland which includes the Bowring Military Camp and the adjacent footslopes, is considered to be an area with potential for development from a geotechnical viewpoint (PDA 7). (GCO/OAP 1983/8632)


*Plate 4. Oblique Aerial Photograph Looking Northeast over Castle Peak Power Station.* The foreground consists of reclamation with a stepped cut slope in Cheung Chau Granite immediately landwards. Marked photolineaments trend in a mainly northeasterly direction. (GCO/OAP 1981/5706)


*Plate 5. Castle Peak Peninsula Looking North.* An extensive photolineament (probably a fault) trends due north. The Cheung Chau Granite shows a high degree of surface erosion especially on ridges. (GCO/OAP 1981/5708)

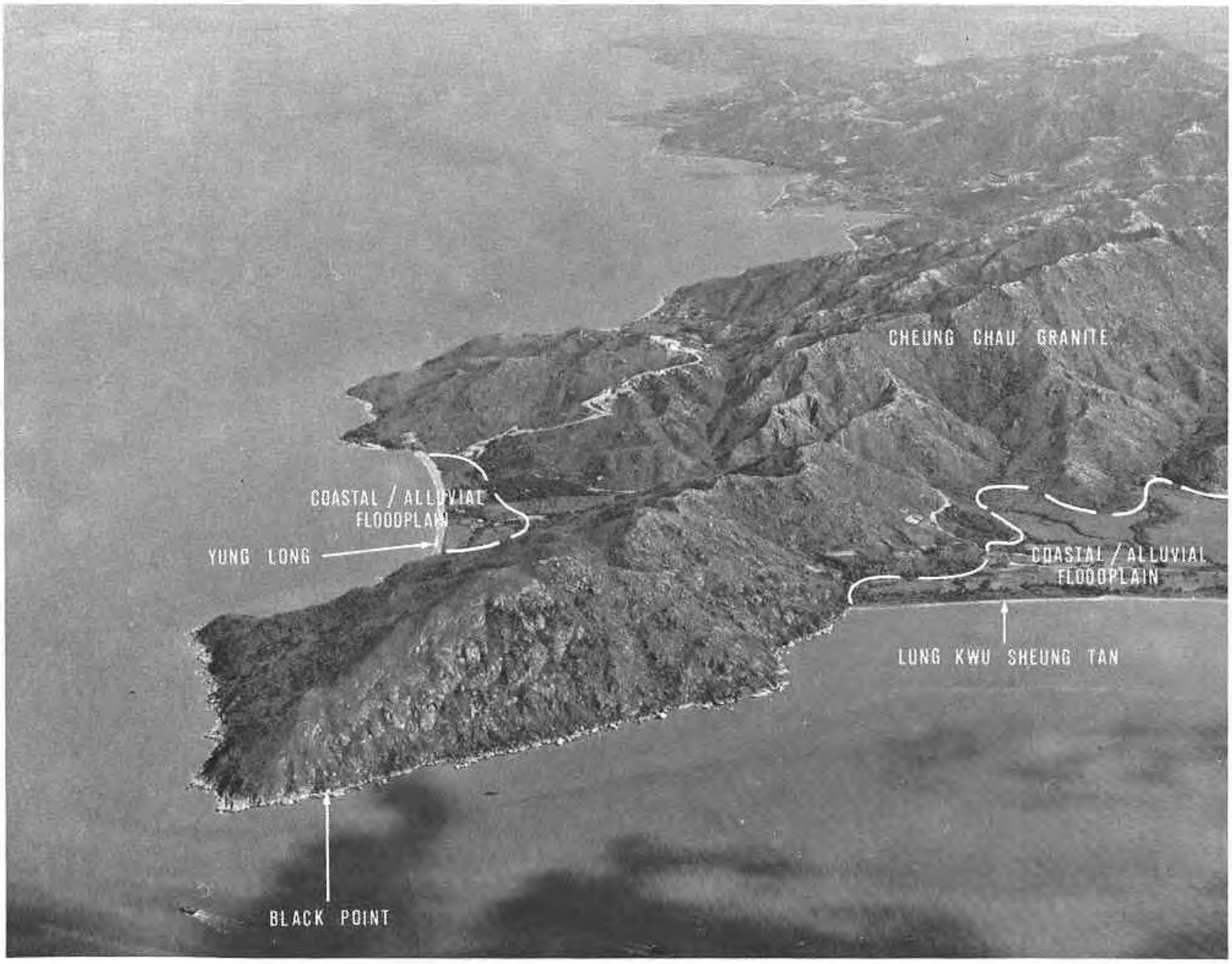



*Plate 6. Oblique Aerial Photograph Looking Northeast across Black Point (Lan Kok Tsui).* The terrain is formed mainly on Cheung Chau Granite. Alluvial/coastal plains occur on either side of the Black Point promontory. (GCO/OAP 1981/5704)

*Plate 7. Coastal Alluvial Plain near Lung Kwu Sheung Tan.* Immediately east of Black Point, this coastal alluvial plain is surrounded by Cheung Chau Granite and forms an area of potential for development (PDA 1). The granite in the background exhibits severely eroded ridgelines and large boulder fields. (GCO/OAP 1983/8598)

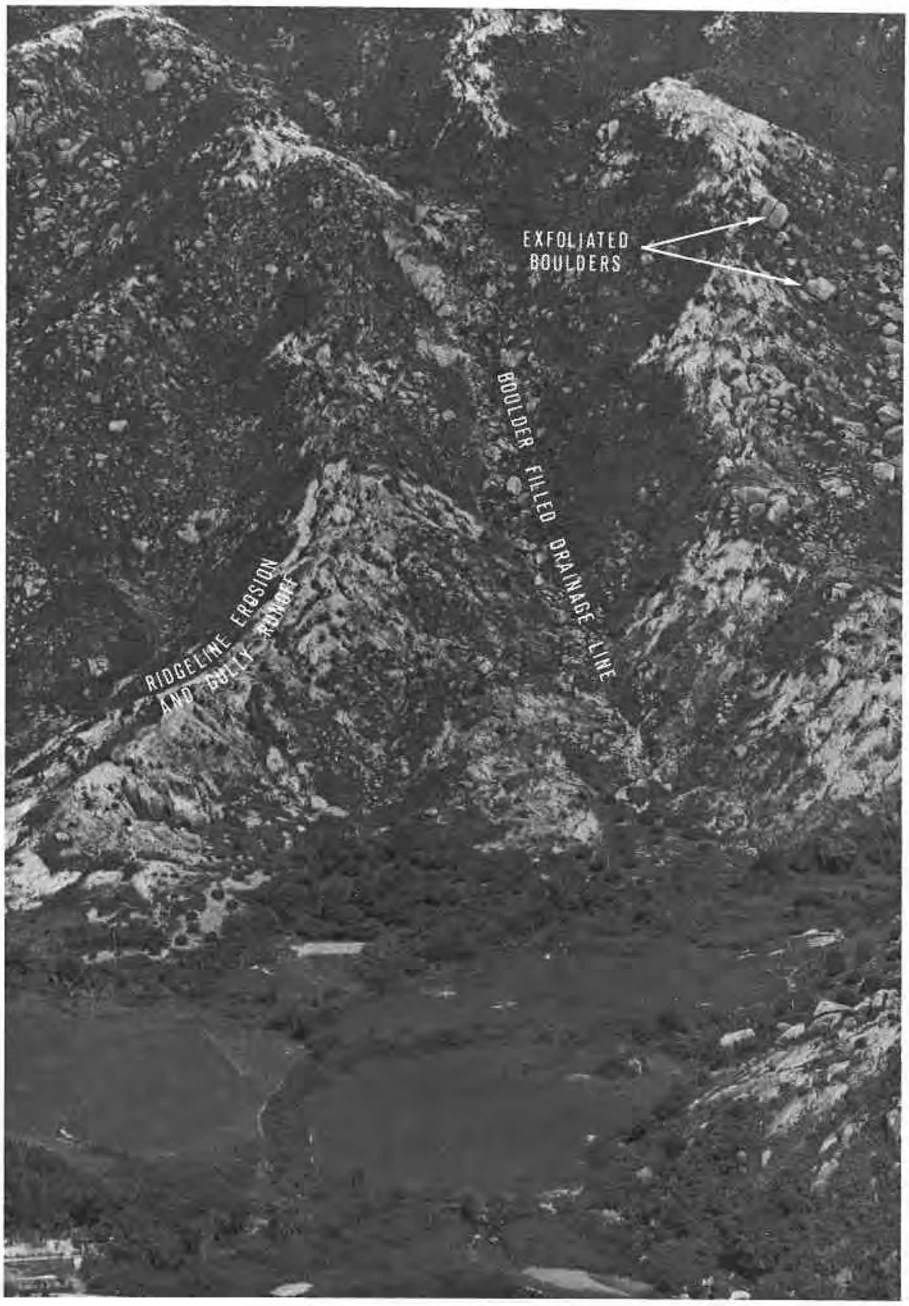



*Plate 8. Alluvial Plain and Granitic Hinterland around Sha Po Kong.* Boulder-filled drainage lines and severely eroded ridgelines with perched exfoliated boulders form a constraint to development on the alluvial plain below. This is part of a potential development area (PDA 2). (GCO/OAP 1983/8645)

*Plate 9. Joint Controlled Landslip in Needle Hill Granite.* The landslip debris contributes material to the lower alluvial valley floor.


*Plate 10. Tai Lam Chung Reservoir Looking South.* (GCO/OAP 1982/5820)


*Plate 11. Castle Peak Road and Tuen Mun Highway Looking East.* The Sung Kong Granite exhibits boulder strewn slopes and exposed exfoliated rock outcrops. The Needle Hill Granite is more deeply weathered. A small structurally controlled valley is evident in the upper right hand portion of the photograph. (GCO/OAP 1983/8591)

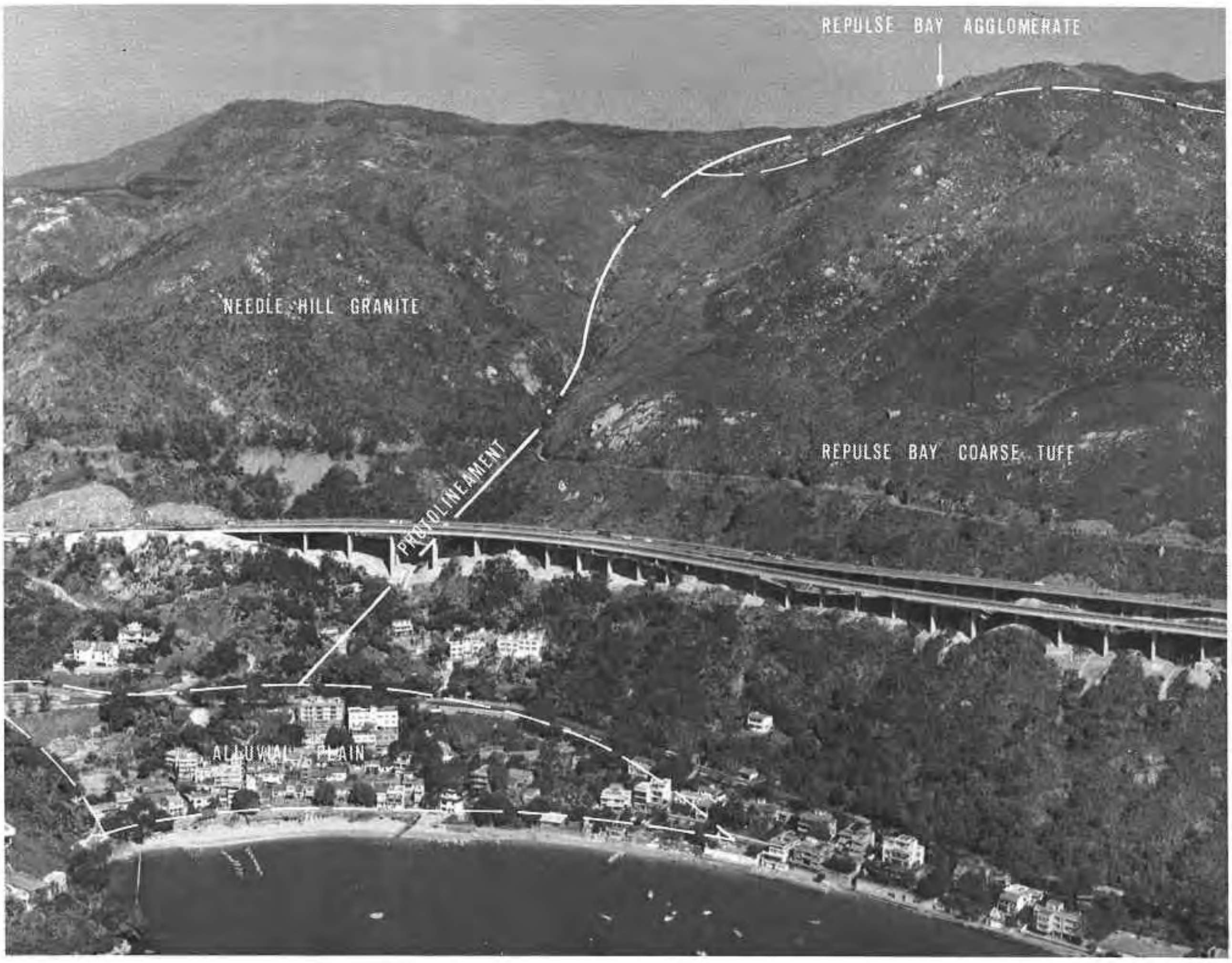



*Plate 12. Oblique Aerial Photograph Looking North towards Ting Kau Beach and an Elevated Section of the Tuen Mun Highway.* A well-developed photolineament traverses the area and marks the contact between the Needle Hill Granite and the Repulse Bay Formation. The upper right portion of the Plate shows the boulder strewn terrain of the Repulse Bay Formation Agglomerates, and the lower slopes to the east of the lineament consist of the Coarse Tuffs of the Repulse Bay Formation. The village of Ting Kau is situated on an alluvial plain. (GCO/OAP 1981/5752)


*Plate 13. Oblique Aerial Photograph Looking North across the Tuen Mun Highway near Gemini Beach.* Fill (A) and cut (B) slopes associated with the Tuen Mun Highway are seen in the middle foreground. The Cheung Chau Granite shows greater surface erosion than the Needle Hill Granite. A structurally controlled valley is identified by a photolineament on the left (western) flank of the Plate. (GCO/OAP 1981/5751)

*Plate 14.* *Stereopair of Aerial Photographs of Tuen Mun New Town Area 19 prior to Development.* Note the large colluvial deposits with well formed drainage channels and evidence of slope instability. Surface drainage disappears at the junction of the Cheung Chau Granite and Repulse Bay Formation (1963/6111–2)


*Plate 15. Tuen Mun Area 19 in 1981.* The area is severely affected by gully, sheet and tunnel erosion and instability. (GCO/OAP 1981/3005)

*Plate 16. Stereopair of Aerial Photographs of Tuen Mun New Town and Environs Showing Areas of the Development Including Works at Area 19.* (1983/47101)

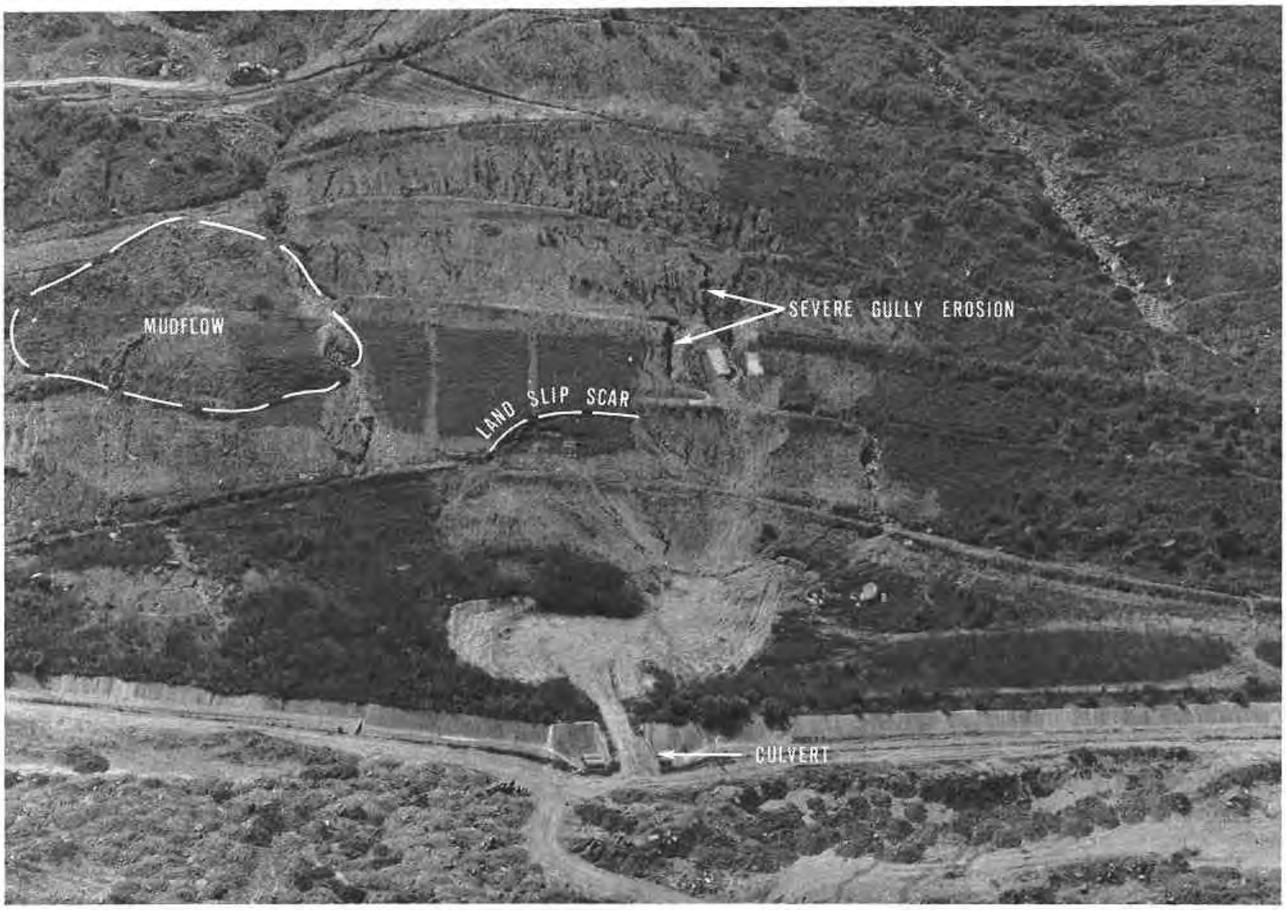



*Plate 17. Tuen Mun Area 19 in 1983.* General instability and marked surface erosion to the right of centre in the mid to upper portion of the Plate are evident. Severe gully erosion is especially prevalent above and to the right of the landslip scar. (GCO/OAP 1983/8583)

(a) *1954—November*
Very little development is evident and reclamation of the inner bay is absent. The community of Tuen Mun is little more than an agricultural and fishing village. (1954/89-81A 552)

(b) *1964—December*
Realignment of the river channel is apparent and some reclamation occurs at the head of the bay. Urbanisation has developed along the flanks of the bay and spread northwards into the river valley. (1964/2568 and 2629)

(c) *1983—January*
Major channelisation works associated with the river are evident and large areas of the middle and outer bay have been reclaimed and developed. Typhoon anchorages and breakwaters have been constructed. The road network has been expanded to cope with the transport demands of a large population. Further reclamation has occurred since 1983. (1983/47101)

*Plate 18. Vertical Aerial Photographs Showing the Development of the Castle Peak Bay Area between 1954 and 1983.*

# APPENDIX A

## SYSTEM OF TERRAIN EVALUATION AND ASSOCIATED TECHNIQUES



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# 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 14.

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). These maps 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 15b. The three terrain attributes adopted for the analysis are:

(*a*) Slope gradient.

(*b*) Terrain component and morphology.

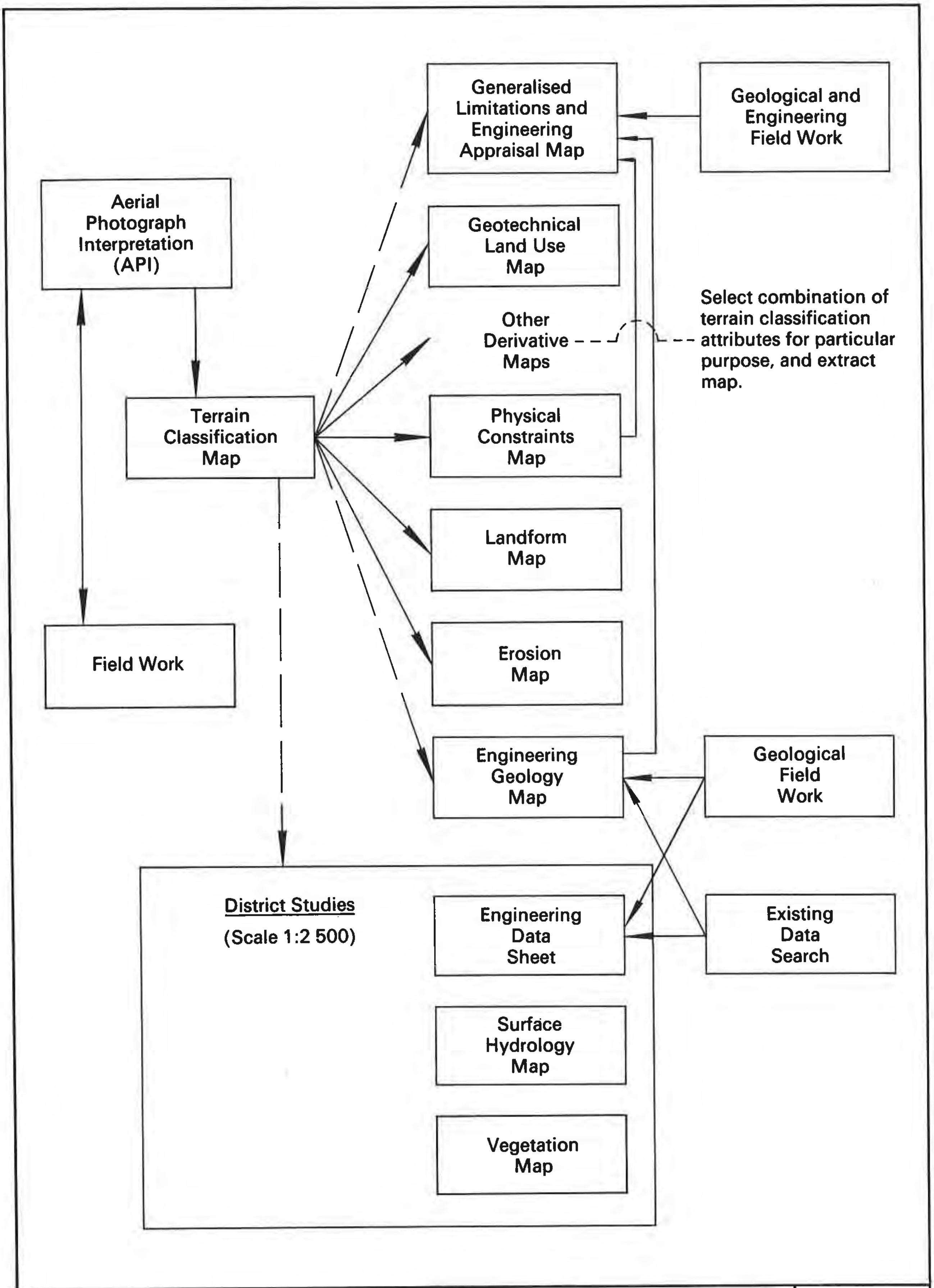
(*c*) Erosion and instability.

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 | Development of general instability —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 | | |
| | | 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 the following 13 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*) 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 them 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 20a) 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.

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 West New Territories. 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 21a.

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).

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 17a.

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 will 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<br>(Some, but not necessarily all of the stated characteristics will occur in the respective Class) | Gentle slopes and insitu soils.<br>Minor erosion on flatter slopes.<br>Undisturbed terrain (minor cut & fill only). | Flat to moderate slopes.<br>Colluvial soils showing evidence of minor erosion.<br>Insitu soils which may be eroded.<br>Reclamation.<br>Rock outcrops.<br>Poor drainage.<br>Cut & fill slopes of low height. | Floodplain subject to periodic flooding and inundation. | Steep slopes.<br>Colluvial & insitu soils showing evidence of severe erosion.<br>Poor drainage.<br>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 16a. 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 particular 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 0.7 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.

## 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 West New Territories 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 geomophology and material properties of the lithological units.

The Engineering Geology Map for the West New Territories GASP is contained in the Map Folder accompanying this Report and an example is located at Figure 18a. 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 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.

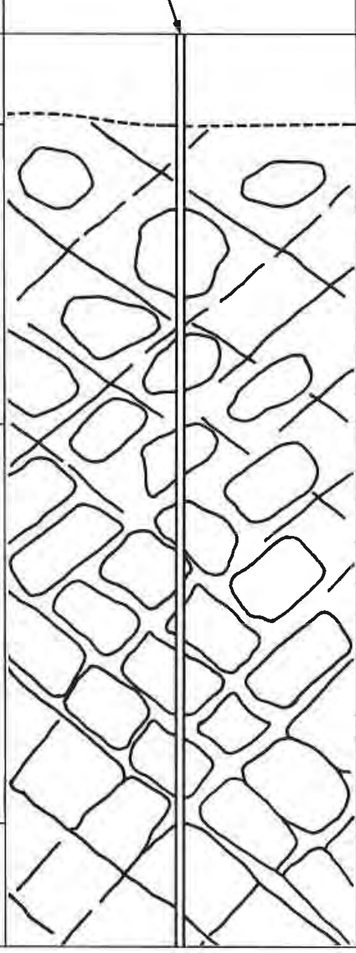
Details of the aerial photographs used for the terrain classification are given in Appendix C.3 and Table C.2.

## 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 the Territory. 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<br>III<br>V<br>III<br>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<br>V<br>II<br>III<br>IV<br>III<br>IV<br>II<br>IV<br>I<br>IV | Zone C |
| Zone D—Material of grades I or II constitutes more than 90% of the mass. | | II<br>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.

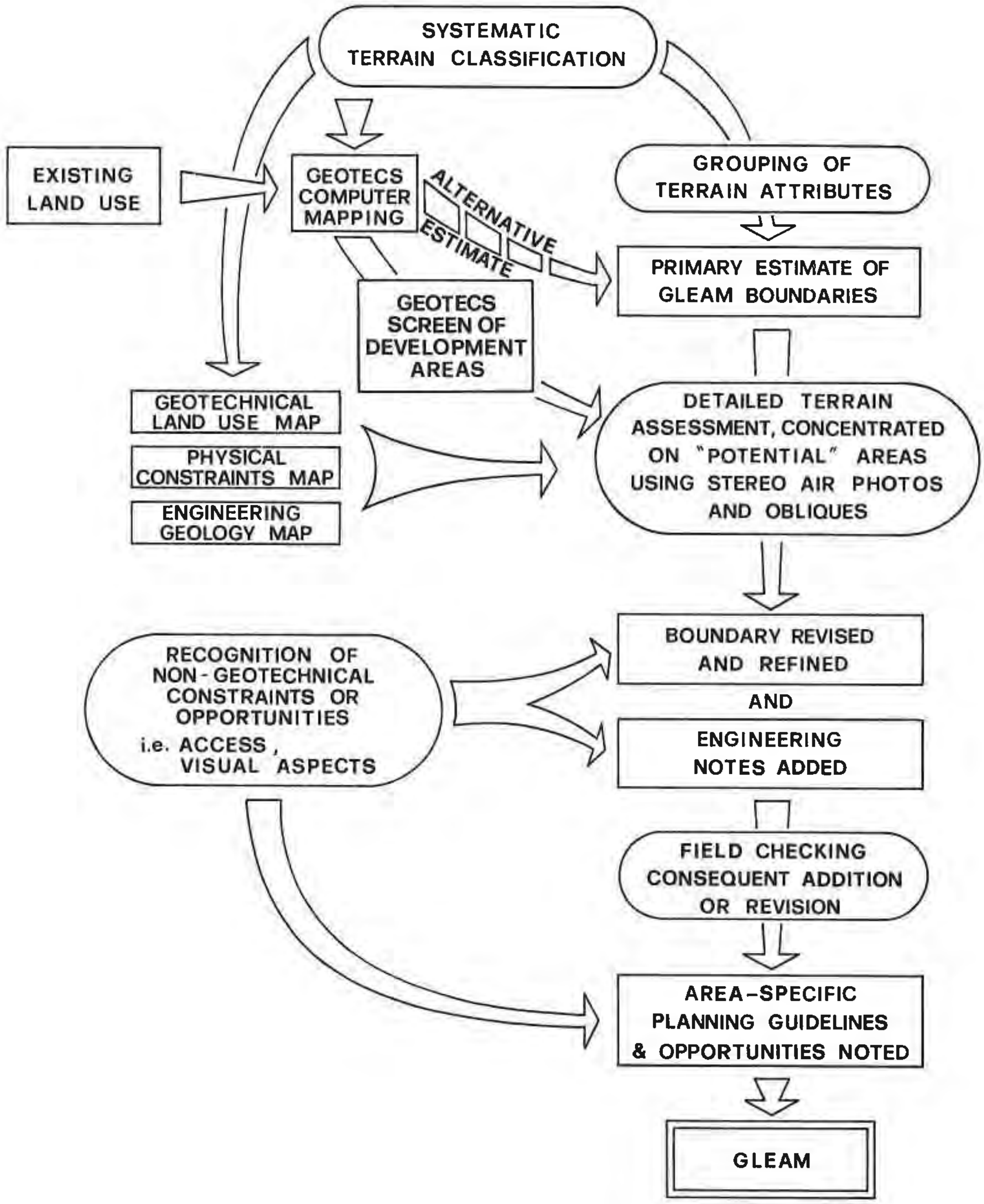
Hence, the GLEAM is a map that is designed to provide a broad indication of development opportunities assessed from a geotechnical point of view and to identify geotechnical considerations with local implications for planning and engineering.

### 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<br>N, O, P | 1, 2, 3 | Yes | No | No |
| | 4, 5, 6 | No | No | No |
| E, F, G, H, I□<br>K□, R, S, T, X□ | 1, 2 | Yes | No | No |
| | 3, 4, 5, 6 | No | No | No |
| N, O, P**<br>R, R, S<br>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.

□ 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 3.1.2 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 III data bank consists of 4 388 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 minimise 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 a third attribute, e.g. slope gradient/aspect versus erosion (Table B10). Within the framework of these tables, it is possible to define a multi-attribute unit based on any user-defined combinations of attributes.

# APPENDIX B

## DATA TABLES FOR THE WEST NEW TERRITORIES GEOTECHNICAL AREA STUDY

## Table B1 Slope Gradient

| Slope Gradient | % of Total Area | Area (ha) |
|---|---|---|
| 0– 5°* | 15.8 | 1 414 |
| 5–15° | 10.4 | 930 |
| 15–30° | 47.1 | 4 213 |
| 30–40° | 24.6 | 2 205 |
| 40–60° | 2.0 | 178 |
| >60° | 0.1 | 12 |
| | 100.0 | 8 952 |

* Approximately 214 ha of reservoirs, ponds and man-made channels are included in the 0–5° Class.

## Table B2 Erosion and Instability

| Erosion | % of Total Area | Area (ha) |
|---|---|---|
| Instability | | |
| —well-defined landslips | 0.6 | 55 |
| —general instability | 18.0 | 1 614 |
| Appreciable erosion: | | |
| Sheet erosion—minor | 15.1 | 1 349 |
| —moderate to severe | 8.1 | 722 |
| Rill erosion —minor | 2.4 | 212 |
| —moderate to severe | 2.7 | 243 |
| Gully erosion—minor | 20.4 | 1 828 |
| —moderate to severe | 5.7 | 510 |
| No Appreciable Erosion* | 27.0 | 2 419 |
| | 100.0 | 8 952 |

* Approximately 214 ha of reservoirs, ponds and man-made channels are included within No Appreciable Erosion Class.

## Table B3 Aspect

| Aspect | % of Total Area | Area (ha) |
|---|---|---|
| North | 6.9 | 620 |
| Northeast | 8.1 | 724 |
| East | 7.1 | 636 |
| Southeast | 13.7 | 1 224 |
| South | 11.1 | 998 |
| Southwest | 12.9 | 1 155 |
| West | 10.9 | 977 |
| Northwest | 13.5 | 1 204 |
| Flat/Unclassified* | 15.8 | 1 414 |
| | 100.0 | 8 952 |

* Approximately 214 ha of reservoirs, ponds and man-made channels 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 | 71 | 349 | 194 | 6 | 0 | 620 |
| Northeast | 86 | 441 | 181 | 12 | 4 | 724 |
| East | 67 | 341 | 208 | 18 | 2 | 636 |
| Southeast | 169 | 708 | 310 | 35 | 2 | 1 224 |
| South | 176 | 567 | 233 | 22 | 0 | 998 |
| Southwest | 116 | 602 | 402 | 31 | 4 | 1 155 |
| West | 131 | 507 | 312 | 27 | 0 | 977 |
| Northwest | 114 | 698 | 365 | 27 | 0 | 1 204 |
| 0–5° (Flat/Unclassified) | | | | | | 1 414 |
| | | | | | | 8 952 |

## Table B5 Landform

| Terrain (Landform) | Slope Gradient | % of Total Area | Area (ha) |
|---|---|---|---|
| Hillcrest | | 1.6 | 143 |
| Sideslope | 0– 5° | 0.1 | 8 |
| " | 5–15° | 3.4 | 306 |
| " | 15–30° | 43.2 | 3 870 |
| " | 30–40° | 22.7 | 2 036 |
| " | >40° | 0.8 | 73 |
| Cliff/Rock outcrop | 0–30° | 0.1 | 10 |
| " | >30° | 1.2 | 110 |
| Footslope (colluvium) | 0– 5° | 0.8 | 71 |
| " | 5–15° | 1.7 | 153 |
| " | 15–30° | 0.2 | 14 |
| " | 30–40° | <0.1 | 6 |
| " | >40° | 0 | 0 |
| Drainage plain (colluvium) | 0– 5° | 0.3 | 27 |
| " | 5–15° | 2.5 | 225 |
| " | 15–30° | 2.2 | 200 |
| " | 30–40° | 0.9 | 82 |
| " | >40° | 0 | 0 |
| Alluvial plain | | 0.7 | 65 |
| Floodplain | | 2.8 | 253 |
| Littoral zone | 0–15° | 0.4 | 35 |
| Cut platform : insitu | 0– 5° | 2.2 | 200 |
| : colluvium | 0– 5° | 0.2 | 14 |
| : alluvium | 0– 5° | 0 | 0 |
| Cut slopes : insitu | >5° | 1.7 | 155 |
| : colluvium | >5° | 0.5 | 45 |
| : alluvium | >5° | 0 | 0 |
| Fill platforms : insitu | 0– 5° | 0.3 | 31 |
| : colluvium | 0– 5° | 0.3 | 29 |
| : alluvium | 0– 5° | 1.6 | 147 |
| Fill slopes : insitu | >5° | 0.5 | 41 |
| : colluvium | >5° | <0.1 | 2 |
| : alluvium | >5° | <0.1 | 2 |
| General disturbed terrain/platforms : insitu | 0– 5° | 0 | 0 |
| : colluvium | 0– 5° | 0 | 0 |
| : alluvium | 0– 5° | 0 | 0 |
| General disturbed terrain/slope : insitu | >5° | 0.5 | 43 |
| : colluvium | >5° | 0.3 | 22 |
| : alluvium | >5° | 0 | 0 |
| Reclamation | | 3.5 | 314 |
| Natural stream | | <0.1 | 6 |
| Man-made channel | | 0.4 | 33 |
| Water storage | | 2.0 | 177 |
| Pond | | 0.5 | 4 |
| | | 100.0 | 8 952 |

## Table B6 Geology

| Geological Unit | % of Total Area | Area (ha) |
|---|---|---|
| Fill | 3.5 | 316 |
| Reclamation | 3.5 | 314 |
| Alluvium: undifferentiated* | 5.8 | 518 |
| Colluvium: volcanic | 0.5 | 43 |
| : granitic | 6.0 | 541 |
| : metasedimentary | 0.2 | 20 |
| : mixed | 2.6 | 233 |
| Littoral deposit | 0.4 | 35 |
| Marine deposit* | 0.2 | 20 |
| Repulse Bay Formation: sedimentary rocks and water-laid volcaniclastic rocks | 3.4 | 302 |
| : coarse tuff | 1.7 | 151 |
| : agglomerate | 0.2 | 20 |
| : dominantly pyroclastic rocks with some lavas | 0.6 | 57 |
| Tai O Formation | 0.3 | 27 |
| Lok Ma Chau Formation | 0.3 | 29 |
| Undifferentiated granitic rocks | 0.7 | 59 |
| Needle Hill Granite: fine-grained porphyritic phase | 16.4 | 1 465 |
| : medium-grained porphyritic phase | 9.9 | 889 |
| Cheung Chau Granite | 30.4 | 2 721 |
| Sung Kong Granite | 1.0 | 90 |
| Sung Kong Granite: medium-grained phase | 9.7 | 863 |
| Tai Po Granodiorite | 2.7 | 239 |
| | 100.0 | 8 952 |

* Approximately 177 ha of reservoirs and 17 ha of man-made channel are classified as being underlain by alluvium, and 16 ha of man-made channel are classified as being underlain by marine deposits.

## Table B7 Vegetation

| Vegetation | % of Total Area | Area (ha) |
|---|---|---|
| Grassland | 4.4 | 396 |
| Cultivation | 4.3 | 386 |
| Mixed broadleaf woodland | 27.9 | 2 501 |
| Shrubland (<50%) | 20.5 | 1 830 |
| Shrubland (>50%) | 23.5 | 2 105 |
| No vegetation on natural terrain | 0.8 | 70 |
| No vegetation due to disturbance of terrain by man | 14.8 | 1 324 |
| No vegetation due to rock outcrop | 1.3 | 120 |
| Waterbodies | 2.5 | 220 |
| | 100.0 | 8 952 |

## Table B8 Geology and GLUM Class

| Geological Unit | Area in GLUM Class (ha) | | | | |
|---|---|---|---|---|---|
| | I | II | III | IV | Unclassified |
| Fill | 0 | 224 | 92 | 0 | 0 |
| Reclamation | 0 | 314 | 0 | 0 | 0 |
| Alluvium: undifferentiated | 0 | 318 | 0 | 0 | 200 |
| Colluvium: volcanic | 0 | 0 | 20 | 23 | 0 |
| : granitic | 0 | 6 | 308 | 227 | 0 |
| : metasedimentary | 0 | 20 | 0 | 0 | 0 |
| : mixed | 0 | 75 | 80 | 78 | 0 |
| Littoral deposit | 0 | 0 | 0 | 0 | 35 |
| Marine deposit | 0 | 0 | 0 | 0 | 20 |
| Repulse Bay Formation: sedimentary rocks and water-laid volcaniclastic rocks | 135 | 125 | 20 | 22 | 0 |
| : coarse tuff | 6 | 88 | 37 | 20 | 0 |
| : agglomerate | 6 | 14 | 0 | 0 | 0 |
| : dominantly pyroclastic rocks with some lavas | 0 | 33 | 10 | 14 | 0 |
| Tai O Formation | 2 | 4 | 21 | 0 | 0 |
| Lok Ma Chau Formation | 19 | 8 | 2 | 0 | 0 |
| Undifferentiated Granitic Rocks | 2 | 25 | 22 | 10 | 0 |
| Needle Hill Granite: fine-grained porphyritic phase | 67 | 820 | 335 | 243 | 0 |
| : medium-grained porphyritic phase | 28 | 463 | 200 | 198 | 0 |
| Cheung Chau Granite | 139 | 973 | 1 238 | 371 | 0 |
| Sung Kong Granite | 10 | 41 | 21 | 18 | 0 |
| Sung Kong Granite: medium-grained phase | 78 | 483 | 208 | 94 | 0 |
| Tai Po Granodiorite | 0 | 166 | 24 | 49 | 0 |
| | 492 | 4 200 | 2 638 | 1 367 | 255 |

## Table B9 GLUM Class

| GLUM Class | % of Total Area | Area (ha) |
|---|---|---|
| I | 5.5 | 492 |
| II | 44.1 | 3 947 |
| IIS | 2.8 | 253 |
| III | 29.5 | 2 638 |
| IV | 15.3 | 1 367 |
| Unclassified | 2.8 | 255 |
| | 100.0 | 8 952 |

## 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 | 43 | 24 | 0 | 0 | 0 | 0 | 67 | 0 |
| | | G | 45 | 106 | 2 | 2 | 0 | 0 | 155 | 0 |
| | | S | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| | | C | 86 | 6 | 0 | 20 | 0 | 0 | 112 | 0 |
| | | A | 447 | 6 | 0 | 57 | 0 | 0 | 510 | 0 |
| | | L | 35 | 0 | 0 | 0 | 0 | 0 | 35 | 0 |
| | | F | 47 | 471 | 0 | 0 | 0 | 0 | 518 | 0 |
| 5–15° | N | V | 6 | 0 | 0 | 0 | 0 | 0 | 6 | 0 |
| | | G | 6 | 17 | 2 | 12 | 0 | 0 | 37 | 0 |
| | | S | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| | | C | 12 | 2 | 0 | 13 | 0 | 0 | 27 | 0 |
| | | A | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 0 |
| | | F | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| | NE | V | 10 | 0 | 0 | 0 | 0 | 0 | 10 | 0 |
| | | G | 2 | 23 | 4 | 14 | 0 | 0 | 43 | 0 |
| | | S | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| | | C | 11 | 2 | 0 | 8 | 0 | 8 | 29 | 0.28 |
| | | A | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| | | F | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| | E | V | 18 | 0 | 0 | 0 | 0 | 0 | 18 | 0 |
| | | G | 0 | 6 | 0 | 2 | 0 | 0 | 8 | 0 |
| | | S | 4 | 0 | 0 | 4 | 0 | 0 | 8 | 0 |
| | | C | 16 | 2 | 0 | 13 | 0 | 0 | 31 | 0 |
| | | A | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| | | F | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| | SE | V | 16 | 2 | 0 | 0 | 0 | 0 | 18 | 0 |
| | | G | 18 | 23 | 2 | 12 | 0 | 0 | 55 | 0 |
| | | S | 4 | 2 | 0 | 2 | 0 | 0 | 8 | 0 |
| | | C | 20 | 14 | 0 | 21 | 0 | 12 | 67 | 0.18 |
| | | A | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| | | F | 0 | 20 | 0 | 0 | 0 | 0 | 20 | 0 |
| | S | V | 10 | 6 | 0 | 0 | 0 | 0 | 16 | 0 |
| | | G | 33 | 35 | 2 | 8 | 0 | 0 | 78 | 0 |
| | | S | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| | | C | 37 | 0 | 0 | 30 | 0 | 4 | 71 | 0.06 |
| | | A | 0 | 4 | 0 | 0 | 0 | 0 | 4 | 0 |
| | | F | 4 | 0 | 0 | 0 | 0 | 0 | 4 | 0 |
| | SW | V | 4 | 0 | 0 | 0 | 0 | 0 | 4 | 0 |
| | | G | 16 | 19 | 6 | 10 | 0 | 0 | 51 | 0 |
| | | S | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| | | C | 16 | 0 | 0 | 35 | 0 | 0 | 51 | 0 |
| | | A | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| | | F | 4 | 6 | 0 | 0 | 0 | 0 | 10 | 0 |
| | W | V | 10 | 0 | 0 | 0 | 0 | 0 | 10 | 0 |
| | | G | 16 | 23 | 4 | 6 | 0 | 0 | 49 | 0 |
| | | S | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| | | C | 31 | 8 | 2 | 22 | 0 | 0 | 63 | 0 |
| | | A | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| | | F | 0 | 6 | 0 | 0 | 0 | 0 | 6 | 0 |
| | NW | V | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| | | G | 10 | 29 | 0 | 6 | 0 | 0 | 45 | 0 |
| | | S | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| | | C | 18 | 6 | 0 | 37 | 0 | 0 | 61 | 0 |
| | | A | 0 | 0 | 0 | 2 | 0 | 0 | 2 | 0 |
| | | F | 0 | 2 | 2 | 0 | 0 | 0 | 4 | 0 |
| 15–30° | N | V | 12 | 0 | 0 | 0 | 0 | 0 | 12 | 0 |
| | | G | 79 | 84 | 16 | 100 | 6 | 37 | 322 | 0.13 |
| | | S | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| | | C | 2 | 0 | 0 | 4 | 0 | 8 | 14 | 0.57 |
| | | F | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| | NE | V | 14 | 0 | 0 | 2 | 0 | 0 | 16 | 0 |
| | | G | 90 | 84 | 18 | 141 | 4 | 51 | 388 | 0.14 |
| | | S | 0 | 0 | 0 | 0 | 4 | 0 | 4 | 1.00 |
| | | C | 6 | 0 | 0 | 8 | 0 | 15 | 29 | 0.52 |
| | | F | 2 | 2 | 0 | 0 | 0 | 0 | 4 | 0 |
| | E | V | 33 | 8 | 0 | 0 | 0 | 0 | 41 | 0 |
| | | G | 49 | 55 | 12 | 110 | 0 | 49 | 275 | 0.18 |
| | | S | 2 | 0 | 0 | 2 | 2 | 0 | 6 | 0.33 |
| | | C | 0 | 0 | 0 | 6 | 0 | 8 | 14 | 0.57 |
| | | F | 2 | 0 | 2 | 0 | 0 | 0 | 4 | 0 |
| | SE | V | 59 | 4 | 2 | 6 | 0 | 0 | 71 | 0 |
| | | G | 120 | 123 | 45 | 204 | 0 | 67 | 559 | 0.12 |
| | | S | 0 | 0 | 0 | 2 | 4 | 0 | 6 | 0.67 |
| | | C | 0 | 0 | 0 | 22 | 0 | 33 | 55 | 0.60 |
| | | F | 6 | 4 | 0 | 0 | 0 | 0 | 10 | 0 |
| | S | V | 25 | 6 | 0 | 14 | 0 | 0 | 45 | 0 |
| | | G | 104 | 112 | 29 | 179 | 2 | 33 | 459 | 0.08 |
| | | S | 0 | 0 | 0 | 0 | 2 | 0 | 2 | 0 |
| | | C | 0 | 0 | 0 | 33 | 0 | 14 | 47 | 0.30 |
| | | F | 2 | 8 | 2 | 2 | 0 | 0 | 14 | 0 |
| | SW | V | 17 | 2 | 0 | 6 | 0 | 4 | 29 | 0.14 |
| | | G | 98 | 136 | 57 | 174 | 2 | 49 | 516 | 0.10 |
| | | S | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 1.00 |
| | | C | 4 | 0 | 0 | 17 | 0 | 14 | 35 | 0.40 |
| | | F | 8 | 10 | 0 | 2 | 0 | 0 | 20 | 0 |
| | W | V | 21 | 0 | 0 | 4 | 0 | 2 | 27 | 0.07 |
| | | G | 90 | 102 | 63 | 141 | 2 | 57 | 455 | 0.13 |
| | | S | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 1.00 |
| | | C | 2 | 0 | 0 | 8 | 0 | 6 | 16 | 0.37 |
| | | F | 2 | 4 | 2 | 0 | 0 | 0 | 8 | 0 |
| | NW | V | 17 | 2 | 0 | 2 | 0 | 0 | 21 | 0 |
| | | G | 141 | 155 | 49 | 210 | 2 | 86 | 643 | 0.14 |
| | | S | 0 | 0 | 0 | 0 | 4 | 0 | 4 | 1.00 |
| | | C | 4 | 0 | 0 | 13 | 0 | 10 | 27 | 0.37 |
| | | F | 0 | 2 | 2 | 0 | 0 | 0 | 4 | 0 |

## 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 | 8 | 0 | 2 | 0 | 0 | 0 | 10 | 0 |
| | | G | 18 | 20 | 4 | 29 | 2 | 106 | 179 | 0.60 |
| | | S | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| | | C | 0 | 0 | 0 | 2 | 0 | 2 | 4 | 0.50 |
| | NE | V | 6 | 0 | 0 | 0 | 0 | 8 | 14 | 0.57 |
| | | G | 16 | 16 | 8 | 41 | 0 | 82 | 163 | 0.50 |
| | | S | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| | | C | 4 | 0 | 0 | 0 | 0 | 0 | 4 | 0 |
| | E | V | 4 | 2 | 0 | 0 | 0 | 6 | 12 | 0.50 |
| | | G | 23 | 27 | 10 | 65 | 0 | 65 | 190 | 0.34 |
| | | S | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| | | C | 0 | 0 | 0 | 0 | 0 | 6 | 6 | 1.00 |
| | SE | V | 0 | 2 | 0 | 0 | 0 | 2 | 4 | 0.50 |
| | | G | 22 | 24 | 8 | 69 | 12 | 149 | 284 | 0.57 |
| | | S | 0 | 2 | 0 | 0 | 0 | 0 | 2 | 0 |
| | | C | 0 | 0 | 0 | 4 | 0 | 16 | 20 | 0.80 |
| | S | V | 0 | 2 | 0 | 0 | 0 | 6 | 8 | 0.75 |
| | | G | 24 | 45 | 29 | 55 | 0 | 67 | 220 | 0.30 |
| | | S | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| | | C | 0 | 0 | 0 | 2 | 0 | 2 | 4 | 0.50 |
| | SW | V | 16 | 0 | 0 | 8 | 0 | 19 | 43 | 0.44 |
| | | G | 33 | 49 | 41 | 90 | 4 | 130 | 347 | 0.39 |
| | | S | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| | | C | 0 | 0 | 0 | 8 | 0 | 4 | 12 | 0.33 |
| | W | V | 4 | 0 | 0 | 0 | 0 | 0 | 4 | 0 |
| | | G | 35 | 53 | 22 | 86 | 2 | 86 | 284 | 0.31 |
| | | S | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| | | C | 0 | 0 | 0 | 10 | 0 | 10 | 20 | 0.50 |
| | NW | V | 4 | 0 | 0 | 0 | 0 | 6 | 10 | 0.60 |
| | | G | 41 | 35 | 4 | 102 | 0 | 157 | 339 | 0.46 |
| | | S | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| | | C | 0 | 0 | 0 | 6 | 0 | 10 | 16 | 0.63 |
| >40° | N | V | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| | | G | 0 | 0 | 0 | 0 | 0 | 6 | 6 | 1.00 |
| | | S | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| | NE | V | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| | | G | 2 | 0 | 0 | 0 | 0 | 12 | 14 | 0.86 |
| | | S | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| | E | V | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| | | G | 6 | 0 | 0 | 0 | 0 | 14 | 20 | 0.70 |
| | | S | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| | SE | V | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| | | G | 8 | 6 | 0 | 4 | 0 | 19 | 37 | 0.51 |
| | | S | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| | S | V | 2 | 0 | 0 | 0 | 0 | 0 | 2 | 0 |
| | | G | 10 | 2 | 0 | 0 | 0 | 8 | 20 | 0.40 |
| | | S | 0 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | SW | V | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| | | G | 19 | 6 | 0 | 0 | 0 | 10 | 35 | 0.29 |
| | | S | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| | W | V | 0 | 0 | 0 | 0 | 0 | 2 | 2 | 1.00 |
| | | G | 2 | 6 | 0 | 2 | 0 | 14 | 24 | 0.58 |
| | | S | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| | NW | V | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |
| | | G | 10 | 0 | 0 | 4 | 0 | 13 | 27 | 0.48 |
| | | S | 0 | 0 | 0 | 0 | 0 | 0 | 0 | — |

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

Table B11 Geology, Erosion and Instability

| Geological Unit | No Apprecia-able Erosion (ha) | Appreciable Erosion (ha) | | | Instability (ha) | | Total Area (ha) | Area Instability Index |
|---|---|---|---|---|---|---|---|---|
| | | Sheet | Rill | Gully | WDL | GI | | |
| Fill | 65 | 237 | 10 | 4 | 0 | 0 | 316 | 0 |
| Reclamation | 14 | 300 | 0 | 0 | 0 | 0 | 314 | 0 |
| Alluvium: undifferentiated | 447 | 10 | 0 | 61 | 0 | 0 | 518 | 0 |
| Colluvium: volcanic | 4 | 0 | 0 | 29 | 0 | 10 | 43 | 0.23 |
| : granitic | 141 | 16 | 2 | 278 | 0 | 104 | 541 | 0.19 |
| : metasedimentary | 18 | 2 | 0 | 0 | 0 | 0 | 20 | 0 |
| : mixed | 106 | 23 | 0 | 35 | 0 | 69 | 233 | 0.30 |
| Littoral deposit | 35 | 0 | 0 | 0 | 0 | 0 | 35 | 0 |
| Marine deposit | 20 | 0 | 0 | 0 | 0 | 0 | 20 | 0 |
| Repulse Bay Formation: : sedimentary rocks and water-laid volcanic-lastic rocks | 233 | 41 | 4 | 4 | 0 | 20 | 302 | 0.07 |
| : coarse tuff | 77 | 14 | 0 | 35 | 0 | 25 | 151 | 0.17 |
| : agglomerate | 20 | 0 | 0 | 0 | 0 | 0 | 20 | 0 |
| : dominantly pyroclastic rocks with some lavas | 33 | 6 | 0 | 4 | 0 | 14 | 57 | 0.25 |
| Tai O Formation | 4 | 0 | 0 | 2 | 17 | 4 | 27 | 0.15 |
| Lok Ma Chau Formation | 17 | 4 | 0 | 8 | 0 | 0 | 29 | 0 |
| Undifferentiated Granitic Rocks | 23 | 0 | 0 | 6 | 26 | 4 | 59 | 0.07 |
| Needle Hill Granite: : fine-grained porphyritic phase | 347 | 283 | 33 | 361 | 0 | 441 | 1 465 | 0.30 |
| : medium-grained porphyritic phase | 210 | 139 | 59 | 248 | 0 | 233 | 889 | 0.26 |
| Cheung Chau Granite | 340 | 747 | 294 | 910 | 12 | 418 | 2 721 | 0.15 |
| Sung Kong Granite | 28 | 10 | 4 | 23 | 0 | 25 | 90 | 0.28 |
| Sung Kong Granite: : medium-grained phase | 100 | 231 | 49 | 293 | 0 | 190 | 863 | 0.22 |
| Tai Po Granodiorite | 137 | 8 | 0 | 37 | 0 | 57 | 239 | 0.24 |
| | 2 419 | 2 071 | 455 | 2 338 | 55 | 1 614 | 8 952 | |

Table B12 Existing Land Use (from aerial photograph interpretation by the Geotechnical Control Office in 1983)

| Existing Land Use | Area (ha) | Existing Land Use | Area (ha) |
|---|---|---|---|
| Government housing estate | 122 | Military (unspecified) | 1 856 |
| Private development | 53 | Quarries – private | 6 |
| 2 Storey development | 74 | Quarries – borrow | 53 |
| 1 Storey development | 2 | Oil storage | 0 |
| Temporary resettlement area | 12 | Power station | 76 |
| Intermixed | 0 | Cemetery | 2 |
| Industrial | 88 | Prison | 12 |
| Commercial | 2 | Service reservoir | 6 |
| Commercial/residential | 0 | Incinerator | 0 |
| Park | 2 | Horticulture | 241 |
| Sports complex | 14 | Undefined agriculture | 147 |
| Golf course | 0 | Fish ponds | 4 |
| Race course | 0 | Undisturbed areas | 1 924 |
| Beach | 0 | Country park | 3 240 |
| Zoological & botanical gardens | 0 | Water storage | 177 |
| School | 6 | Natural stream | 6 |
| Hospital | 16 | Man-made channel | 33 |
| Temple | 10 | Squatters – low intensity | 51 |
| Police/fire station | 10 | Squatters – medium intensity | 82 |
| Airport runway | 0 | Squatters – high intensity | 61 |
| Airport facilities | 0 | Construction | 192 |
| Wharves | 8 | Reclamation (unused) | 76 |
| Railway | 0 | Temporary land fill | 14 |
| Roads | 45 | Temporary land use | 78 |
| Sewerage works | 20 | Artificial slope | 131 |
| | | Total | 8 952 |

Table B13 Existing Land Use and GLUM Class

| Existing Land Use | Area in GLUM Class (ha) | | | | |
|---|---|---|---|---|---|
| | I | II | III | IV | Unclassified |
| Government housing estate | 12 | 110 | 0 | 0 | 0 |
| Private development | 8 | 43 | 2 | 0 | 0 |
| 2 Storey development | 33 | 25 | 14 | 2 | 0 |
| 1 Storey development | 0 | 0 | 0 | 2 | 0 |
| Temporary resettlement area | 2 | 10 | 0 | 0 | 0 |
| Industrial | 23 | 63 | 2 | 0 | 0 |
| Commercial | 0 | 2 | 0 | 0 | 0 |
| Park | 0 | 2 | 0 | 0 | 0 |
| Sports complex | 2 | 12 | 0 | 0 | 0 |
| School | 2 | 2 | 2 | 0 | 0 |
| Hospital | 0 | 16 | 0 | 0 | 0 |
| Temple | 2 | 6 | 2 | 0 | 0 |
| Police/fire station | 4 | 4 | 2 | 0 | 0 |
| Wharves | 0 | 8 | 0 | 0 | 0 |
| Roads | 12 | 31 | 2 | 0 | 0 |
| Sewerage works | 14 | 6 | 0 | 0 | 0 |
| Military | 35 | 579 | 873 | 369 | 0 |
| Quarries – private | 0 | 0 | 4 | 2 | 0 |
| Quarries – borrow | 20 | 14 | 19 | 0 | 0 |
| Power station | 33 | 43 | 0 | 0 | 0 |
| Cemetery | 0 | 2 | 0 | 0 | 0 |
| Prison | 2 | 10 | 0 | 0 | 0 |
| Service reservoir | 0 | 0 | 6 | 0 | 0 |
| Horticulture | 20 | 186 | 33 | 2 | 0 |
| Undefined agriculture | 12 | 112 | 23 | 0 | 0 |
| Fish ponds | 0 | 0 | 0 | 0 | 4 |
| Undisturbed areas | 86 | 838 | 640 | 325 | 35 |
| Country park | 96 | 1 716 | 798 | 630 | 0 |
| Water storage | 0 | 0 | 0 | 0 | 177 |
| Natural stream | 0 | 0 | 0 | 0 | 6 |
| Man-made channels | 0 | 0 | 0 | 0 | 33 |
| Squatters – low intensity | 2 | 37 | 12 | 0 | 0 |
| Squatters – medium intensity | 8 | 35 | 33 | 6 | 0 |
| Squatters – high intensity | 12 | 23 | 24 | 2 | 0 |
| Construction | 39 | 112 | 41 | 0 | 0 |
| Reclamation | 0 | 76 | 0 | 0 | 0 |
| Temporary land fill | 0 | 4 | 10 | 0 | 0 |
| Temporary land use | 13 | 65 | 0 | 0 | 0 |
| Artificial slope | 0 | 8 | 96 | 27 | 0 |
| Total | 492 | 4 200 | 2 638 | 1 367 | 255 |

# APPENDIX C

## SUPPLEMENTARY INFORMATION



## List of Figures



## List of Tables

# APPENDIX C

## SUPPLEMENTARY INFORMATION

### C.1 Description of Geological Units

C.1.1 *Sedimentary and Metasedimentary Rocks*

*(i) Tai O Formation (T)*
According to Allen & Stephens (1971), the Tai O Formation consists of two main units.

(*a*) Lower Member—consists of thinly bedded black and white siltstones, black silty shales, white or grey sandstones and some graphitic sandstones. The graphitic siltstone has an mineral assemblage consisting of quartz, graphite, sericite and clinozoisite. The quartz occurs mostly in a fine-grained state with scattered angular grains. The rock is spotted and characterized by oval areas, up to 2 mm long, free of graphite dust surrounded by dark graphitic rock, sericite being dispersed throughout. Clinozoisite occurs as small sheaves of columnar crystals containing graphite dust. Cross bedding, lensing and interfingering occurs within this member between the white siltstone and purple sandstone.

(*b*) Upper Member—consists of a thick unit formed mainly of sandstone. The sandstones are normally cross bedded, fine-grained, micaceous sandstones, with thin black laminations in places. Interbedded siltstone and silty shales with sporadic beds of sandstone all with dominantly purple colour are comon, although green sandstones are also seen. Black siltstone beds 200 mm thick occur in isolated localities.

The contact between the two members is normally gradational through a thickness of a few metres. Purple rocks, typical of the Upper Member first appear as lenses and nodules of purple mudstone in black silty shale at the top of the Lower Member.

The metamorphic conditon of the Tai O Formation rocks in the study area is confirmed by the presence of clinozoisite and incipient adalusite rocks. Ruxton (1957), suggests these and the graphite within the rocks are formed by thermal metamorphism related to the proximity of granitic intrusions on Lantau Island or Chek Lap Kok.

Stratigraphically, the Tai O Formation lies conformably beneath the Repulse Bay Formation (Allen & Stephens, 1971), however, Ruxton (1960) suggests an unconformity between them. No firm conclusion can be made upon the stratigraphy of this Formation in relation to those above it, and the possibility that the Tai O Formation is merely an intercalation within a larger volcanic succession must be considered.

(ii) *Lok Ma Chau Formation (LMC)*
As mapped by Allen & Stephens (1971), this Formation consists of low grade regionally metamorphosed rocks which crop out throughout the northwestern part of the New Territories. In the study area exposures form low hills rising above the alluvial plain. The boundary between this Formation and the Repulse Bay Formation is indistinct. The depth of weathering in this Formation is normally great, fresh rock being rarely exposed.

The lithology of the Lok Ma Chau Formation is one of weathered schists, quartz veined metamorphic quartzite, quartzite breccia and thin volcanic horizons. Limestone and marble deposits have been reported in the Formation. Phyllites predominate in some localities which exhibit schistosity defined by sericite, the phyllite is locally graphitic.

The lithology of the sedimentary rocks changes towards the northeast of the Territory with arenaceous rocks becoming dominant. The Lok Ma Chau Formation rocks apart from showing normal sedimentary bedding have certain characteristic metamorphic features such as strong cleavage and mica schistosity plus a second weaker cleavage. Mineral assemblage within rocks of this Formation typically reveal sericite, chlorite, biotite and quartz, with some primary minerals remaining unchanged. The assemblage is typical of low grade metamorphism of the greenschist facies.

Further information on the Lithologies referred to as the Lok Ma Chau Formation by Allen & Stephens (1971) may be obtained from the Memoir of Sheets 2, 5 and 6 of the geological remapping programme (Langford et al., 1988) which is due to be published in the near future.

C.1.2 *Volcanic and Volcaniclastic Rocks—The Repulse Bay Formation*

As defined by Allen & Stephens (1971), the Repulse Bay Formation consists of a succession of coarse tuffs, welded tuffs and lavas rich in quartz which were deposited during regional 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 volcanics because they were enveloped by volcanic materials during later periods of eruption.

With the cessation of volcanic activity, the Repulse Bay Formation has been faulted, folded and subjected to local metamorphism by the intrusion of a large multi-phase granitic batholith.

Within this area the Repulse Bay Formation was subdivided by Allen & Stephens (1971) into four units together with a category of 'Undifferentiated Volcanic Rocks'. Each of these units is discussed below. The boundaries presented in the Engineering Geology Map (EGM) are those of Allen & Stephens (1971) and are subject to revision as investigation proceeds on the detailed stratigraphy of this complex volcanic sequence. Geological remapping of this area is currently underway and will result in the publication of new Geological Maps for the 1:20 000 scale Topographic Sheets 2, 5 and 6 and of Memoir No. 3 (Langford et al, 1988. The volcanic sequence in the adjacent area (Sheet 7) is described by Addison (1986).

Due to the variable mode of formation and the heterogeneous nature of volcanic deposits, rapid horizontal and vertical changes in rock lithology are common features.

(i) *Sedimentary Rocks and Water-laid Volcaniclastic Rocks (RBs)*
These rocks are made up of a series of intercalations of volcanically derived sedimentary rocks which can be thin and laterally discontinuous. Thicker units are known from elsewhere in the Territory, but within this area the units are generally thin. Successions consist of a variety of fine-grained clastic rocks of volcanic origin including waterlaid volcanic ash which is red to grey in colour. These rocks weather to a red clay which is easily eroded and forms low relief. Bands of metamorphosed fine-grained rocks are harder and often schistose in nature, these are grey to green in colour and can grade into a muddy siltstone. Sedimentary structures are occasionally present within these rocks and may comprise cross-bedding, slumping and load structures. Fossiliferous black shales have been noted in some localities in the Territory but none are seen within the study area. The rocks are generally fine-grained but coarser grained clastics are present in places. The deposits are generally considered to be fluviatile or lacustrine in origin.

Deep weathering of these rocks (especially in the Tuen Mun valley) and the lack of distinction between these rocks and the Lok Ma Chau metasediments makes positive identification extremely problematic.

(ii) *Coarse Tuff (RBc)*
This rock unit generally forms thick massive beds of coarse-grained crystalline tuff with no internal stratification. Small and medium sized volcanic bombs are frequently found in this unit along with lithic lapilli. The origin of these units may be attributed to episodes of explosive volcanicity.

The rock is generally grey with large, well formed crystals of quartz and white feldspar which are clearly visible, set in a fine grey irregular groundmass.

(iii) *Dominantly Pyroclastic Rocks with Some Lavas (RBp)*
These are a broad group of variable rock types ranging from welded tuffs, lapilli tuffs, fine tuffs, banded tuffs, coarse tuffs, as well as lavas and sediments. It contains lithologies found in other volcanic units of the Repulse Bay Formation. The principal rock type is a fine-grained, grey to dark grey rhyodacitic tuff.

The field exposures are generally closely jointed with extensive planar, smooth joints forming a number of distinct sets. These joints have a dominant influence on engineering behaviour. The weathering depth varies with grain size and topography but is generally shallower than encountered in the granitic rocks. The rocks weather to produce a pale coloured clayey silty soil.

(iv) *Agglomerates (RBag)*
Generally, agglomerates, breccias and tuff-breccia are not common in the Territory and where they do occur they form intermittent beds. However, a large area of tuff-breccia occurs in the eastern portion of the study area. The tuff-breccia in the Western New Territories consists of a blocky lapilli tuff which grades imperceptibly into a coarse tuff and even fine tuff in places. The volcanic agglomerates found elsewhere in the Territory are generally formed from a lapillistone matrix of quartz, feldspar and hornblende and contain angular blocks of tuff and occasional volcanic bombs, which may reach 600 mm in diameter (porphyritic lava). Tuff-breccias with blocks of sedimentary rocks occur in other localities.

The characteristic rock type in the Western New Territories has a light-greyish green fine-grained matrix with blocks of lapilli, fine tuff and quartzite with some porphyritic lava but most abundantly coarse tuff.

### C.1.3 *Intrusive Igneous Rocks*

A number of distinct intrusive rock types occur within the area which constitute the complex multi-phase batholith which underlies most of the Territory. They form a succession of phases of injection which began with the Tai Po Granodiorite and concluded with the emplacement of doleritic dykes. Five discrete phases are summarised in Table C1.

(i) *Tai Po Granodiorite (XT)*

The Tai Po Granodiorite is the oldest intrusive rock type and is intruded by all the younger phases.

The rock is usually coarse or medium-grained, grey to dark grey and porphyritic in nature. Large well-formed crystals of white feldspar up to 15 mm in length are present in a coarse matrix of 2 to 5 mm crystals of potassium feldspar, plagioclase, biotite, amphibole and of occasional remnants of volcanic boulders and cobbles that are partly absorbed by the magma (xenoliths). These appear as patches of fine-grained dark rock rarely larger than 600 mm in size.

The jointing in the Tai Po Granodiorite is similar to other granitic rocks in that it is widely spaced and irregular. In addition to the tectonic joints, sheeting joints that are subparallel to the topography are also present as a result of vertical stress relief.

The weathering is generally deep and produces a sandy clayey silt. The slightly lower quartz content, compared to granite, reduces the quantity of sand sized fragments and slightly increases the plasticity of the soils, which are usually red in colour due to the high content of iron-rich minerals.

(ii) *Sung Kong Granite (SK)*

The Sung Kong Granite is usually pale grey or pink when fresh, coarse-grained and porphyritic in nature. It is difficult to distinguish from other granites except when weathered, because the coarse quartz particles are prominent. As with other granitic rocks, it has widely spaced irregular tectonic joints and shallow open irregular sheeting joints. The weathering may be deep and tends to form large boulders as corestones.

(iii) *Cheung Chau Granite (CC)*

The Cheung Chau Granite is younger than the Sung Kong Granite and probably extends beneath it. The rock is pale grey or pink when fresh and is generally medium to coarse-grained (3 to 5 mm) with very few feldspar phenocrysts. It contains similar minerals to the other granites and is distinguished only by its relationship and boundaries with other intrusive phases. It tends to be characterised by a more extensive system of quartz veins, some of which contain mineralisation. Molybdenite and wolframite are associated with these veins.

In common with other granites, the Cheung Chau Granite weathers rapidly and deeply to produce a pale brown to white silty sand. The resulting topography is particularly susceptible to erosion with ridgelines incised by numerous gullies. Gully formation is pronounced where the ridgecrests are denuded of vegetation. Jointing is similar to the other granitic rocks.

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

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

(iv) *Needle Hill Granite (NH & NHm)*

There are two phases of Needle Hill Granite; a fine-grained porphyritic phase and a medium-grained rock type that are extensively exposed in the study area as well as elsewhere in the Territory. The main area of outcrop in the area is centred on Tai Lam Chung Reservoir, an area of fine-grained rock is exposed at Heather Hill.

The main rock type is pink with phenocrysts of quartz and potassium feldspar but the local variations in the rock produce numerous departures from the main lithotype. Varieties with sparse phenocrysts and a fine-grained matrix grade into varieties with numerous phenocrysts or into a rock with sparse, small phenocrysts and a matrix with a grain size of 1 mm to 2 mm. Pyrite can be an accessory mineral within the rock, quartz veins are often plentiful and may locally contain molybdenite. These varieties of the needle Hill Granite do not appear as mappable units and are probably variations of the main melt. Around the margins of the main intrusions the rock can occur as veins penetrating the country rock and an exact boundary can often be difficult to delineate. Veins in this transitional zone are often associated with heavy jointing and pegmatites are developed. Pegmatites are usually of simple mineralogy and are present as veins and segregations; chlorite and quartz veins are common. One distinctive variety of the granite has a high biotite content and this confers a blackish colour to the rock. Fluorite is an accessory mineral in this instance.

Around Tai Lam Chung Reservoir both the fine and medium-grained granites can be delineated. The medium-grained phase is fairly uniform and contains phenocrysts of quartz and feldspar normally less than 10 mm long. A gradational contact between the medium and fine-grained granite is apparent and may be a result of the differential cooling rates of the melt. The texture of the fine-grained granite varies as described above showing large phenocrysts and weathers to a white clay (kaolinisation).

The Needle Hill Granite is younger than the Sung Kong Granite and intrusive contacts have been noted at various localities outside the present study area, a contact between the Needle Hill Granite and the older Tai Po Granodiorite has also been noted. Contacts between Needle Hill and Cheung Chau Granites have been noted on the east side of Tuen Mun valley but although the contact is sharp in many places no indication of relative ages can be deduced because of the absence of grain size changes towards boundaries. However, in the Tuen Mun to San Hui area the Needle Hill Granite is clearly younger than the Cheung Chau Granite. The only dyke rock known to cut the Needle Hill Granite is dolerite. Quartz monzonite, feldspar porphyry and quartz porphyry are absent from areas of Needle Hill Granite outcrop. Quartz monzonite is considered older as it is intruded by the Needle Hill Granite in localities such as Heather Hill. The rock at this locality is somewhat unusual in that its sparse phenocrysts of feldspar reach 6 mm in length, the quartz and biotite phenocrysts are smaller, all residing in an aphanitic groundmass, the rock is creamy grey in colour, shows banding in places and contains plentiful xenoliths of quartz monzonite.

(v) *Granophyric Microgranite (Mg)*

Fine-grained alkali porphyritic granite is exposed of limited localities throughout the Territory, but in the study area its occurrence is limited to a very small exposure east of Castle Peak Bay. It often takes the form of dykes and small intrusions and this appears to be the case in this area where the outcrop is completely surrounded by Sung Kong Granite, the older rock having been subjected to hydrothermal activity. The Granophyric Microgranite exhibits phenocrysts of microperthite and albite and chloritised biotite occurs, occasionally in association with sericite and calcite. The age of the microgranites is difficult to determine but they probably represent the last phase of igneous intrusion before intrusion of the post tectonic dolerite dykes.

(vi) *Undifferentiated Granite (G)*

The principal area of undifferentiated granite outcrops on the islands west of the main study area. These outcrops are probably an extension of the main area of undifferentiated granite which forms the eastern part of Lantau, where the granite is traversed by a swarm of porphyry dykes. The main feature of the undifferentiated granite is that it is not easily allocated in terms of age relationship or lithology into any of the main granite classes distinguished elsewhere.

(vii) *Dyke Rocks*

Depending on the type of country rock through which the dykes are emplaced their topographic expression may be as ridges or as depressions due to the effects of differential weathering. Dykes often influence the pattern of surface hydrology.

Dolerite dykes form an igneous phase independent of the previously discussed rocks. Dolerite is mineralogically and chemically different from the granitic suite of rocks in that it is undersaturated in silica. No free quartz or potassium (orthoclase) feldspar are present. The rock is fine to medium-grained, black in colour and has a chilled margin about 10 mm in thickness. Dolerite dykes are rarely more than 10 m wide and on weathering decay to dark red clayey soils.

### C.1.4 *Superficial Deposits*

Overlying bedrock and its weathered mantle, unconsolidated, natural and man-made superficial deposits may occur. These form the surface material over a large proportion of the study area and are of significant engineering importance.

(i) *Colluvium*
Colluvium results from the concentration of material that is transported down slope through the influence of gravity. Deposits may be formed by soil creep, slope failure, boulder fall and local slopewash. Colluvium is distributed primarily as broad fan deposits on footslopes associated with steep mountainous terrain but it is frequently found in lenticular deposits associated with drainage lines. Colluvial deposits consist of a wide range of materials from silty and sandy fine slopewash typical of the granites, through sandy cobble and sandy boulder deposits to boulder fields. In some cases voids and tunnels occur within the colluvium. There is usually little or no surface expression of these subsurface features. The colluvium derived from the volcanics (Cv) is characterised by a diverse variety of cobble and boulder size fragments within a matrix of fine material. There is generally no apparent uniformity in weathering of the detrital fragments, although in some of the older (relict) deposits complete weathering may be evident.

(ii) *Alluvial Deposits*
Alluvial deposits occupy the low-lying flood and coastal plains. There is evidence to suggest that the alluvial plains to the south of Black Point are not fluvial in nature but are lacustrine (lagoonal or deltaic) in origin. The general engineering properties of this unit are summarised in Table 3.1. It is generally more variable in properties than other units and a wide range in strength and weathering depth are expected.

(iii) *Marine and Littoral Deposits*
Dark coloured marine deposits of sand and silt containing shell fragments may be found in variable thickness under areas of reclamation and on the existing seabed. Beneath the reclamation the marine deposits are typically medium to coarse sands and gravels, corresponding to beach deposits but where the base of marine deposits extends more than about 4 metres below Principal Datum sandy silt and clayey silt predominate. Most marine or littoral sediments encountered in boreholes are described as loose or soft. Where these deposits are thicker than about 3 metres they may present difficult founding and settlement conditions.

(iv) *Reclamation*
Due to the constraints of the natural topography and intense population pressure, reclamation of land from the sea has been widely practiced in the Territory since 1841. Fill has been derived from a wide variety of sources. In addition to the fill, old buried concrete or masonry sea walls exist along stretches of previous shorelines thus making these areas extremely varied in their engineering behaviour. Domestic and industrial refuse may occur in some of the older areas. Fill has also been placed by barge from elsewhere in the Territory and thus material from any of the geological units may be intermixed. The degree of compaction and the quality of placed material varies according to the date and method of emplacement.

The permeability of the placed fill varies with both material type and compaction technique. Problems of tidal response may indicate very high permeabilities in some areas.

(v) *Fill*
Large areas of the study area are now covered by man-made structures. In order to form land which can be utilized for development, large areas are modified by cut and fill activities. This has resulted in large tracts of the natural terrain being hidden by fill or removed entirely by borrow. Fill for the preparation of most onshore sites is generally derived from within the vicinity of the site. However, areas of landfill have required material to be transported from further afield and often contain geological and man-made material quite different from those occurring on the site. The engineering characteristics of fill will vary dependent on the quality, type of material and the compaction techniques used in emplacement.

## C.2 Site Investigation Data

The most intensive development within the study area is centred upon Tuen Mun and more specifically is associated with the Tuen Mun New Town Development. The Tuen Mun New Town Outline Development Plan No. LTM 1/0/1G boundary extends from north of the Castle Peak Power Station in the west to Tai Lam Bay in the east and incorporates a large proportion of Tuen Mun valley, the western coastal fringe of the Castle Peak Peninsula and the area to the north east of the So Kwun Wat valley.

## LEGEND

| | | |
|---|---|---|
| | Reclamation | |
| | Marine deposit | |
| | Coarse tuff | Repulse Bay Formation |
| | Agglomerate | Repulse Bay Formation |
| | Pyroclastics and lavas | Repulse Bay Formation |
| | Sedimentary rocks and water-laid voloaniclastic rocks | Repulse Bay Formation |
| | Lok Ma Chau Formation | |
| | Needle Hill Granite : fine-grained porphyritic phase | |
| NHm | Needle Hill Granite : medium-grined porphyritic phase | |
| | Cheung Chau Granite | |
| SKm | Sung Kong Granite : medium-grained phase | |
| | Tai Po Granodiorite | |
| | Tai O Formation | |
| – – – – | Lithological boundary | |
| —·— | Geological photolineament (approximate) | |
| f–f | Fault | |

$$\frac{V}{H} = 1$$

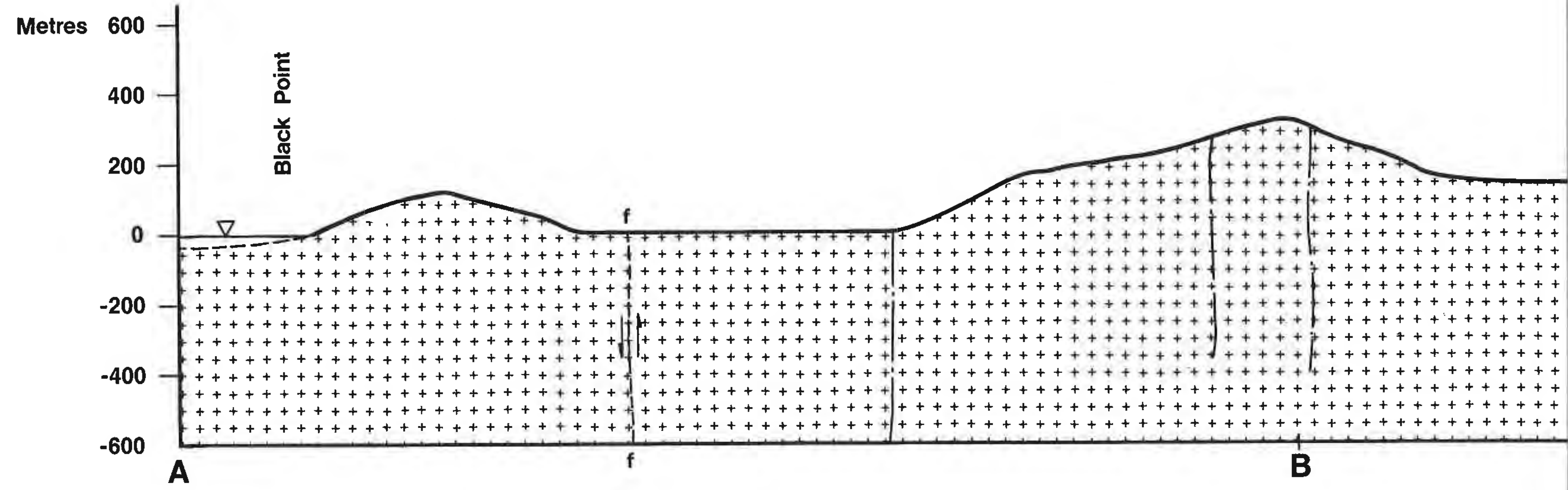
For legend see Figure No. 18.a

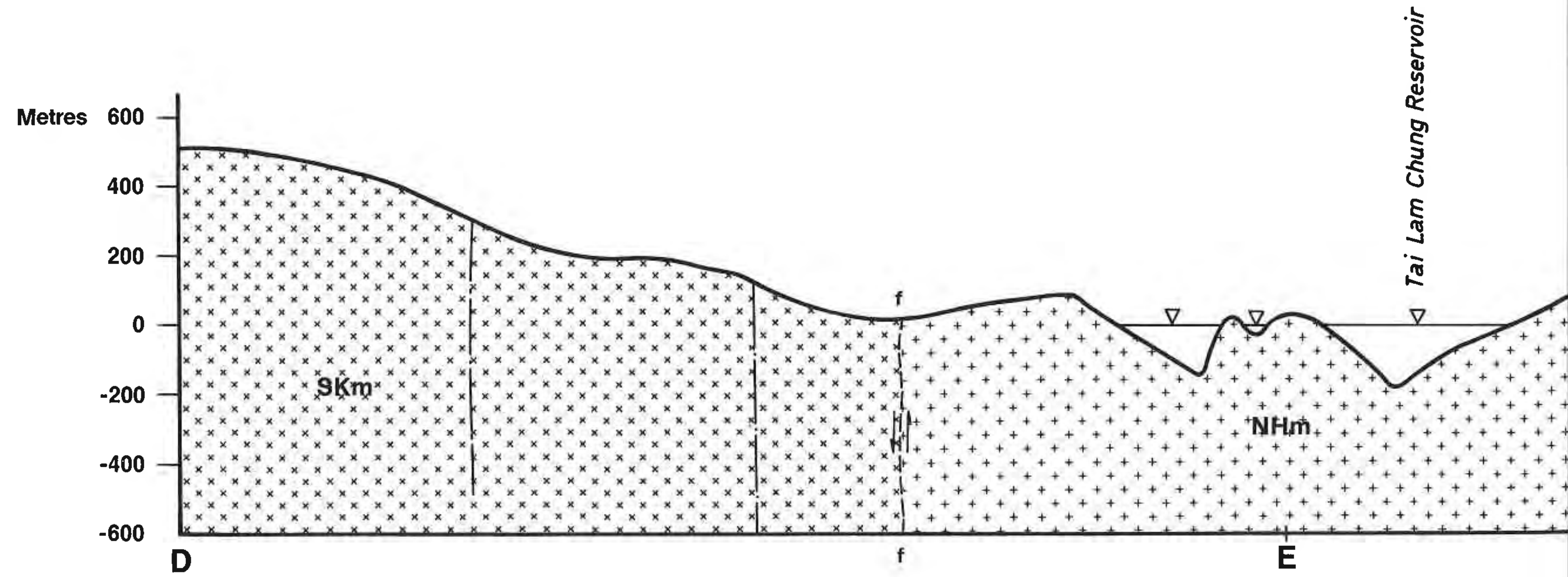
These cross sections are scaled schematic diagrams only. The illustrated relationships are consistent with those presented in Allen & Stephens (1971).

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

**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.**

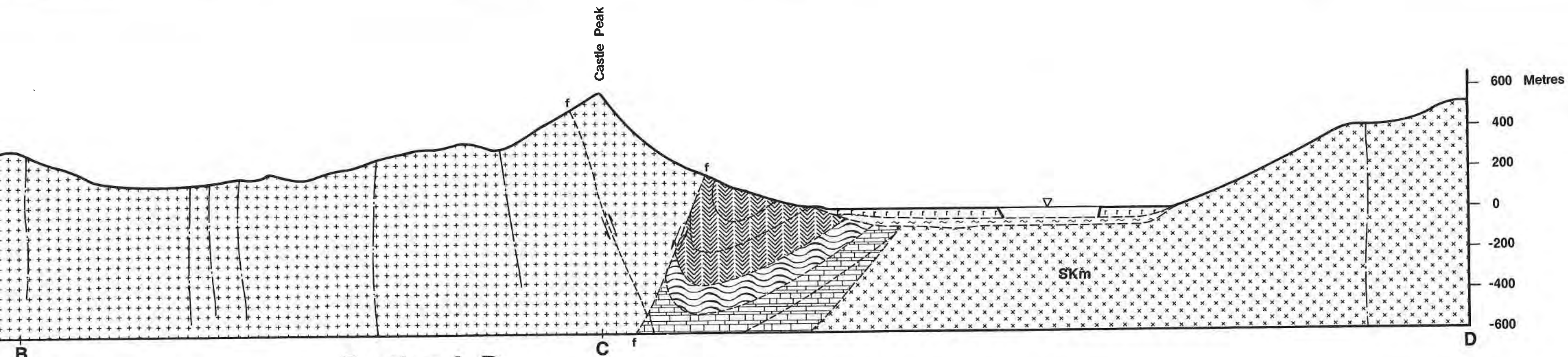


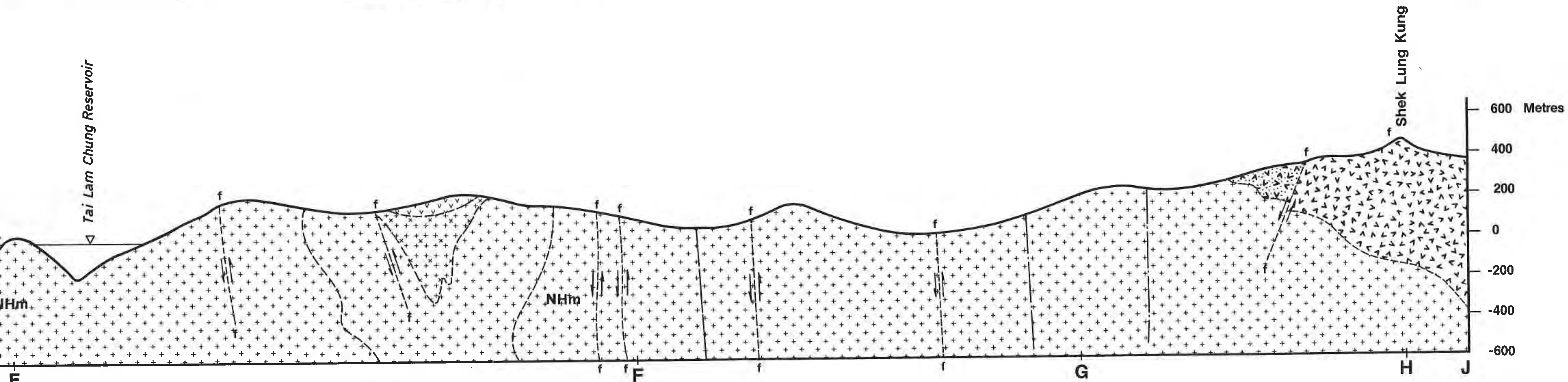

**Scale 1:20 000**

METRES 500 0 1000 2000 3000 METRES

Geologica




## Section A-D




## Section D-J

| | | |
|---|---|---|
| Compiled: J. M. Nash | Drawn: S. M. Wan | Fig. C1 |
| Scale: 1:20 000 | Date: October 1984 | |

Geological Cross-sections – West New Territories

Numerous site investigation progrmmes have been conducted both onshore and offshore by the public and private sector. Over 490 reports and 4 389 borehole logs are held within the Geotechnical Information Unit (GIU) that relate to this area. The large volume of data available precludes a detailed presentation in this report.

The Geotechnical Control Office GIU report 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 West New Territories 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 Survey & Mapping Office, Buildings & Lands Department. An abbreviated list of photographs is presented in Table C2.

### C.4 Rainfall Data Relevant to the West New Territories Study Area

A general appreciation of the monthly rainfall distribution for the West New Territories study area can be obtained from Figure C2. Figure C2 is a histogram of mean monthly rainfall for four selected Royal Observatory rainfall stations. A storm hyetograph is presented at Figure C3, showing the rainfall intensity during a period of heavy rainfall during May 1982. Of the 10 rainfall stations within the study area, data from four stations are shown in Figure C2 and from one in Figure C3. Detailed monthly and annual rainfall information for all of the stations in the study area is available from the Royal Observatory. The locations of Royal Observatory and GCO rainfall stations in the West New Territories are shown at Figure C4.

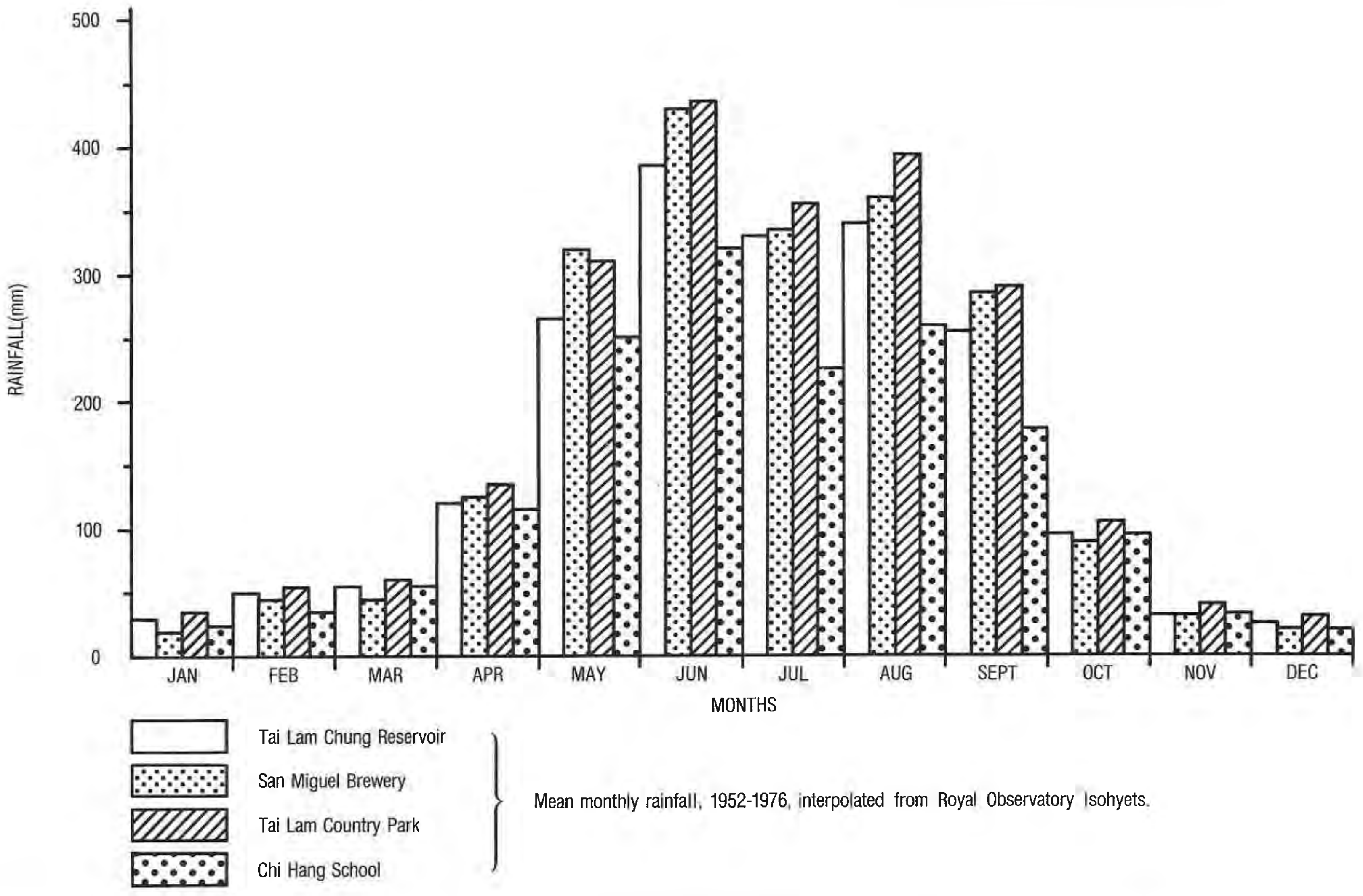
Table C2 Selection of Aerial Photographs

| Year | Photograph Serial Number | Photograph Scale (Approx.) |
|---|---|---|
| 1983 | 47962–47967 | 1:8 000 |
| | 47934–47953 | 1:8 000 |
| | 47915–47930 | 1:8 000 |
| | 47828–47835 | 1:8 000 |
| | 47317–47339 | 1:8 000 |
| | 47093–47109* | 1:20 000 |
| 1982 | 45773–45785 | 1:8 000 |
| | 45749–45769 | 1:8 000 |
| | 44884–44899 | 1:8 000 |
| | 44596–44617* | 1:20 000 |
| | 44551–44550 | 1:20 000 |
| | 43590–43604 | 1:8 000 |
| | 43574–43589 | 1:8 000 |
| | 43558–43572 | 1:8 000 |
| | 42267–42272 | 1:11 000 |
| | 41681–41703 | 1:10 000 |
| | 41245–41277 | 1:8 000 |
| 1981 | 40093–40107 | 1:8 000 |
| | 40065–40068 | 1:8 000 |
| | 39201–39212 | 1:20 000 |
| | 39186–39198 | 1:20 000 |
| | 39155–39165 | 1:20 000 |
| | 33842–33847 | 1:8 000 |
| | 38779–38832 | 1:8 000 |
| | 38152–38166 | 1:20 000 |
| | 36277–36289 | 1:8 000 |
| 1980 | 33132–33147 | 1:8 000 |
| | 32382–32380 | 1:8 000 |
| | 32365–32374 | 1:8 000 |
| | 32348–32361 | 1:8 000 |
| | 31584–31599 | 1:12 000 |
| | 30970–30973 | 1:8 000 |
| | 30601–30633 | 1:11 000 |
| | 30560–30587 | 1:11 000 |
| | 30416–30426 | 1:8 000 |
| | 29034–29085 | 1:8 000 |
| 1979 | 28170–28191* | 1:20 000 |
| | 28109–28121* | 1:20 000 |
| | 27825–27829 | 1:10 000 |
| | 27450–27453 | 1:8 000 |
| | 27214–27230 | 1:8 000 |
| | 26392–26421 | 1:8 000 |
| | 26364–26371 | 1:8 000 |
| | 26300–26328 | 1:8 000 |
| | 26251–26287 | 1:8 000 |
| | 25752–25763 | 1:8 000 |
| | 25114–25214 | 1:8 000 |
| | 25088–25097 | 1:8 000 |
| 1978 | 24086–24095 | 1:8 000 |
| | 24037–24057 | 1:8 000 |
| | 24002–24005 | 1:8 000 |
| | 23569–23613 | 1:8 000 |
| | 23533–23558 | 1:8 000 |
| | 22709–22793 | 1:8 000 |
| | 22522–22531 | 1:8 000 |
| | 22180–22195 | 1:8 000 |
| 1977 | 20060–20065 | 1:8 000 |
| | 19574–19651 | 1:8 000 |
| | 19544–19551 | 1:8 000 |
| | 19154–19157 | 1:25 000 |
| | 18145–18154 | 1:8 000 |
| | 17957–17966 | 1:25 000 |
| 1976 | 16509–16511 | 1:25 000 |
| | 15456–15457 | 1:8 000 |
| | 13317–13326 | 1:8 000 |
| | 13277–13310 | 1:8 000 |
| | 13182–13212 | 1:8 000 |
| | 12379–12416 | 1:8 000 |
| 1975 | 11741–11745 | 1:25 000 |
| 1974 | 10353–10358 | 1:8 000 |
| | 10311–10326 | 1:8 000 |
| | 9817–9831 | 1:25 000 |
| | 9593–9595 | 1:25 000 |
| | 8253–8256 | 1:25 000 |
| | 8227 | 1:25 000 |

Table C2 Selection of Aerial Photographs *(Continued)*

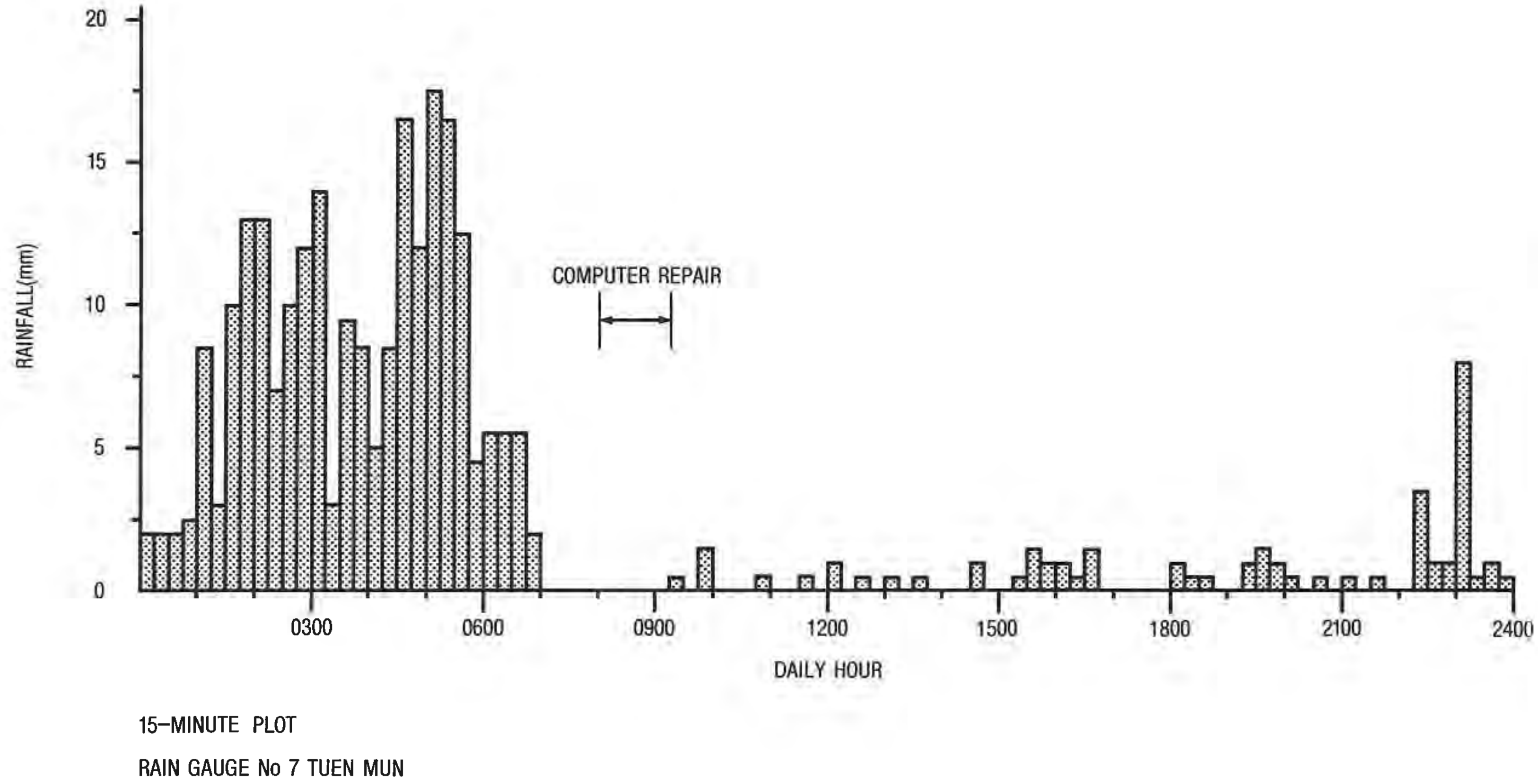
| Year | Photograph Serial Number | Photograph Scale (Approx.) |
|---|---|---|
| 1973 | 7966–7976 | 1:25 000 |
| | 5488–5489 | 1:25 000 |
| | 4820–4823 | 1:12 000 |
| | 3333–3368 | 1:8 000 |
| | 3310–3317 | 1:10 000 |
| | 3266–3287 | 1:10 000 |
| | 3192–3213 | 1:10 000 |
| 1972 | 2683–2692 | 1:12 000 |
| | 2233–2235 | 1:25 000 |
| | 2229–2232 | 1:10 000 |
| | 2226–2227 | 1:10 000 |
| 1964 | 2706–2710 | 1:25 000 |
| | 2625–2636 | 1:25 000 |
| | 2564–2575 | 1:25 000 |
| | 2406–2421 | 1:8 000 |
| 1963 | 8237–8261 | 1:8 000 |
| | 7794–7821 | 1:8 000 |
| | 7684–7727 | 1:8 000 |
| | 6317–6415 | 1:8 000 |
| | 6101–6139 | 1:8 000 |
| | 1080–1106 | 1:8 000 |
| | 0866–0888 | 1:8 000 |
| 1954 | V81A/RAF/522 0116–0119 | 1:25 000 |
| | 0082–0093 | 1:25 000 |
| | 0053–0064 | 1:25 000 |
| 1949 | 81A/134 5050–5055 | 1:11 600 |
| | 81A/125 5170–5185 | 1:11 600 |
| | 81A/125 5065–5082 | 1:11 600 |
| | 81A/125 5042–5055 | 1:11 600 |
| 1945 | 681/5 4074–4089 | 1:12 000 |
| | 681/5 4001–4017 | 1:12 000 |
| | 681/4 3187–3191 | 1:12 000 |
| 1924 | H39-1 | 1:15 000 |
| | H24-15 | 1:14 000 |

Note: Vertical and oblique aerial photographs are available from the Photographic Library, Survey & Mapping Office, Building & Lands Department, 5th Floor, Murray Bldg., Garden Road, Hong Kong.



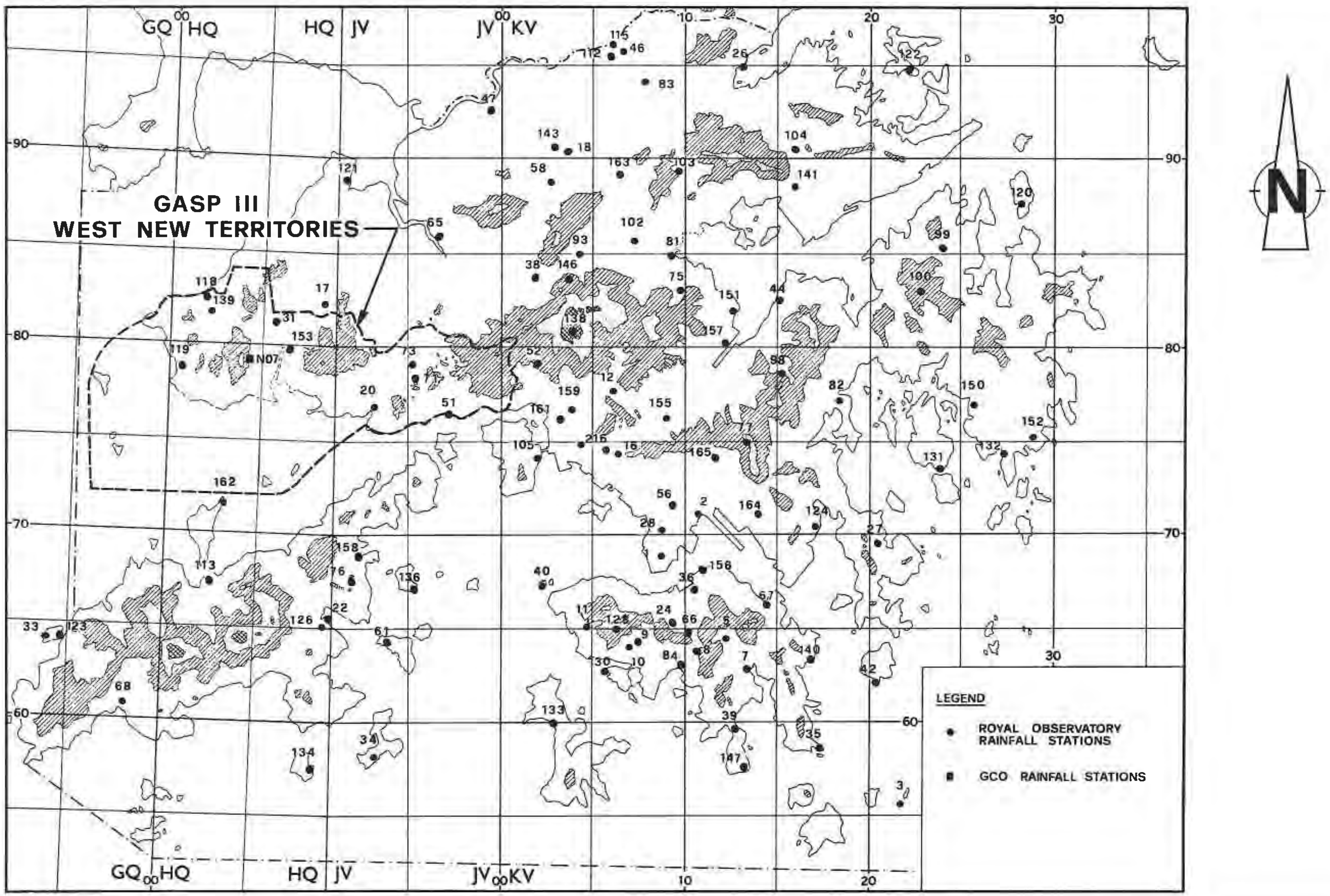

Summary of Mean Monthly Rainfall Data

Fig. C2




Storm Rainfall Hyetograph – 29.5.1982

Fig. C3




Locations of Rainfall Stations

Fig. C4

# 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. Detailed 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 'unravelling'. Granite joints by contrast are less likely to bring about failure in rock unless steeply inclined, due to their high roughness or horizontal 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, whilst not likely to be active at present in Hong Kong, 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.

### 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 this 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 photolineaments 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.

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

NATURAL LANDFORMING INFLUENCES :
SUBSURFACE & SURFACE VARIABLES.

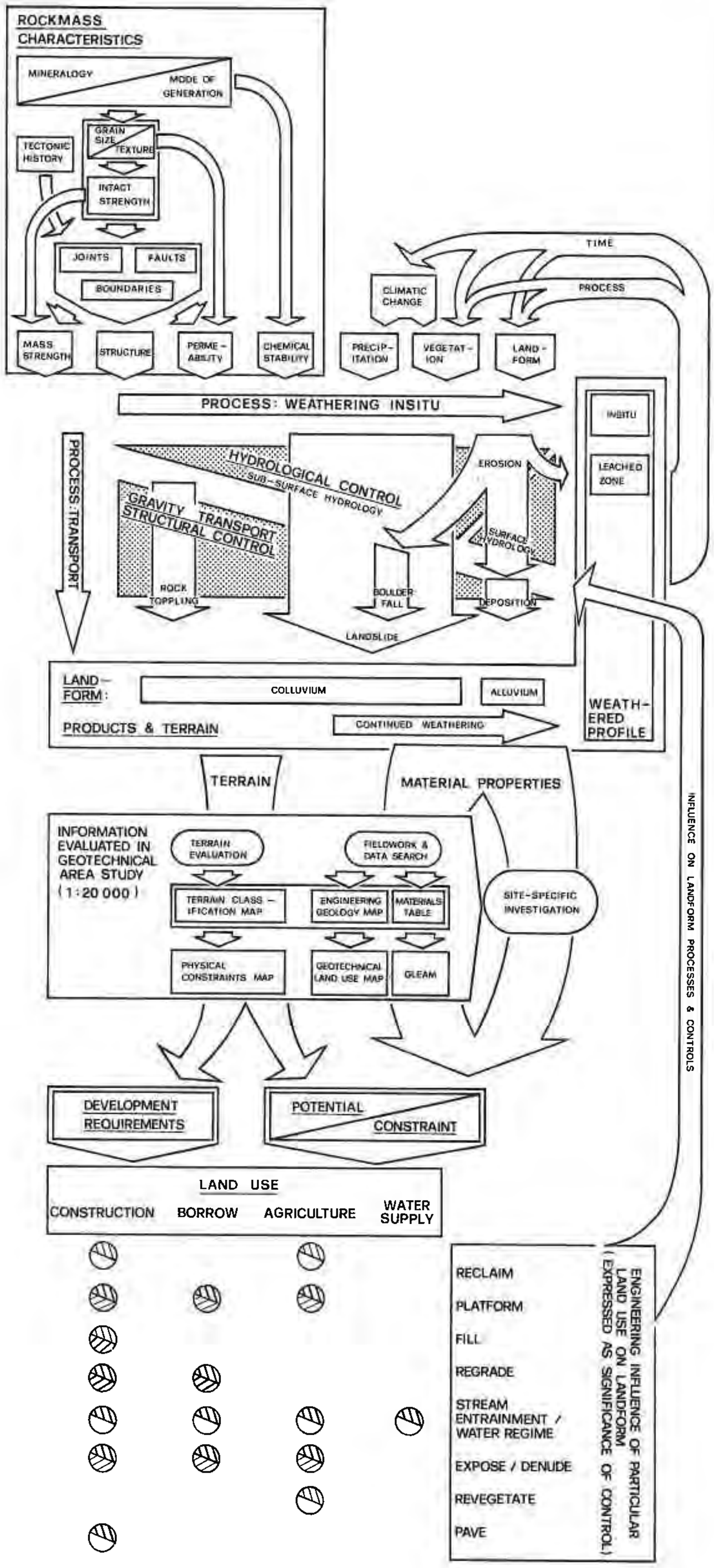
LANDFORMING PROCESSES :
RELATIVE INFLUENCE OF HYDROLOGY, STRUCTURE & WEATHERING ON TYPES OF TRANSPORT PROCESS. (BACKGROUND TRIANGLES SHOW PROPORTION OF INFLUENCE OF CONTROL).

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 FEASABILITY STUDIES. G A S PROVIDES PRELUDE TO SITE SPECIFIC INVESTIGATION.

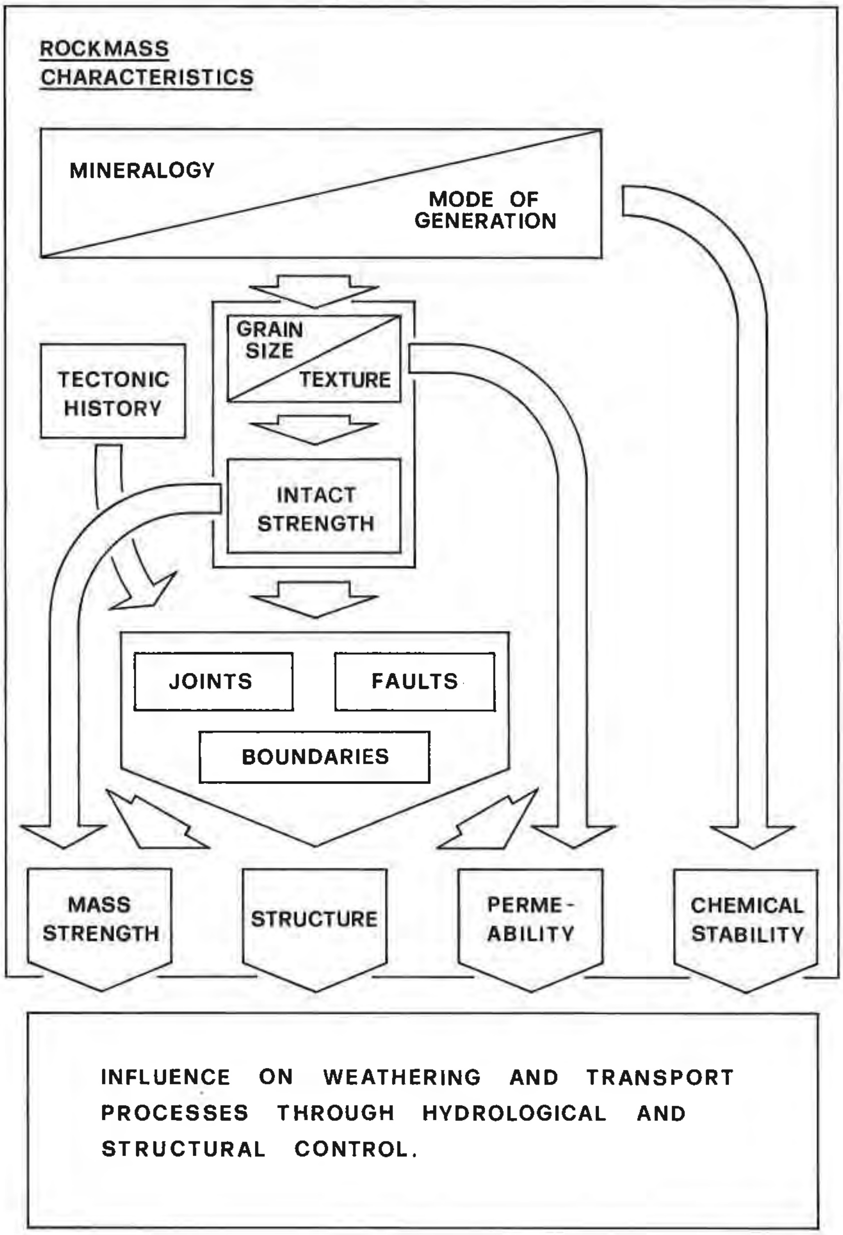
INFLUENCES ON LAND USE :
POTENTIAL, CONSTRAINT, DEVELOPMENT REQUIREMENTS.

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



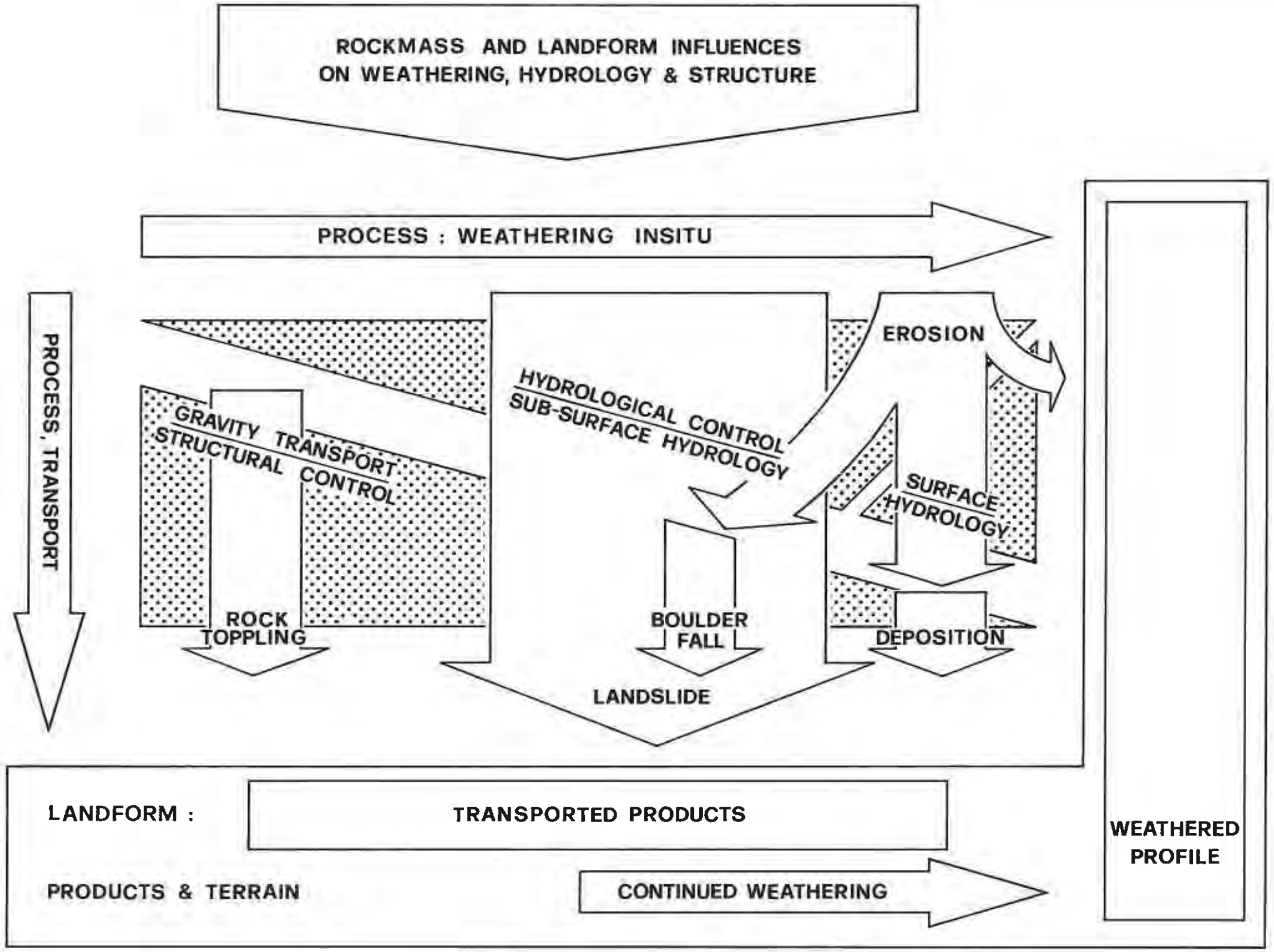

LEGEND :
BOXES INDICATE : CAUSE OR PRODUCT
ARROWS INDICATE : INFLUENCE, PROCESS, OR MECHANISM
CIRCLES INDICATE : HUMAN INVOLVEMENT

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 |

The locations of fill and reclamation are shown on the Engineering Geology Map and the Physical Contraints Map. Large areas of fill are associated with the Government Housing Estates which occur around the Castle Peak footslopes.

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 level platforms on otherwise steep terrain. A typical example is the Tuen Mun Highway, where numerous cut slopes, platforms, fill slopes or retaining walls mask the natural slope profile. Plates 11 & 12 demonstrate the use of these platforms.

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 recognized 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, throughflow 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.

It is unlikely that new construction would occur on most old fill slopes, and even on old fill platforms, major reconstruction would probably have to comply with current practice.

Large areas of fill platform are used on the Castle Peak footslopes for industrial and high density housing areas. Although they are generally located on more gently sloping terrain than those discussed above, they are very extensive in nature and obliterate the natural drainage pattern. Most of these areas are designed for their current land use.

(ii) *Fill on Low-lying Terrain*
The Tuen Mun valley formerly consisted of a few isolated hills separated by alluvial areas. Most of these have long since been drained or raised to prevent flooding. 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*
Most of the valley terrain of the coastal areas is modified by reclamation and considerable recent and proposed development is based on these areas. In the Tuen Mun valley, reclamation has gradually extended the coastal strip southwards from near Tseng Tau.

The historial development of reclamation is recorded on the Engineering Geology Map and is illustrated in Plate 18. At present, reclamation forms 3.5% of this area.

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 state, 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 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 such as the north-trending lineament that passes near Pillar Point (Plate 5). Other larger lineaments are present in the study area. For example, major features traverse the Castle Peak Peninsula and the Tai Lam Country Park. 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 lineaments 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, lineaments 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 lineaments, partly depending on whether they are faulted or not. Identified rock boundaries are shown on the Engineering Geology Map and the GLEAM. 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 lineaments 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 lineaments are identified on the Engineering Geology Map (after Allen & Stephens, 1971) as faults, and other major lineaments may also have been caused by ground movements.

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 3.1.2. 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.

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 usually require the use of hand dug caissons. As discussed for boulder colluvium in Section 3.1.2, 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 the Castle Peak footslopes 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 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. Clearance of the vegetation on the colluvial slopes above Tuen Mun Area 19 has revealed the existence of boulders on the surface of the colluvium.

Boulders may also exist in drainage lines where they are likely to be restrained and interlocked. However, high flows caused by torrential rain is 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 is 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 unravelling, 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 granitic terrain. 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 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 3.1.2. Colluvium overlies the insitu rocks to some extent in most 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 are 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.

(*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.

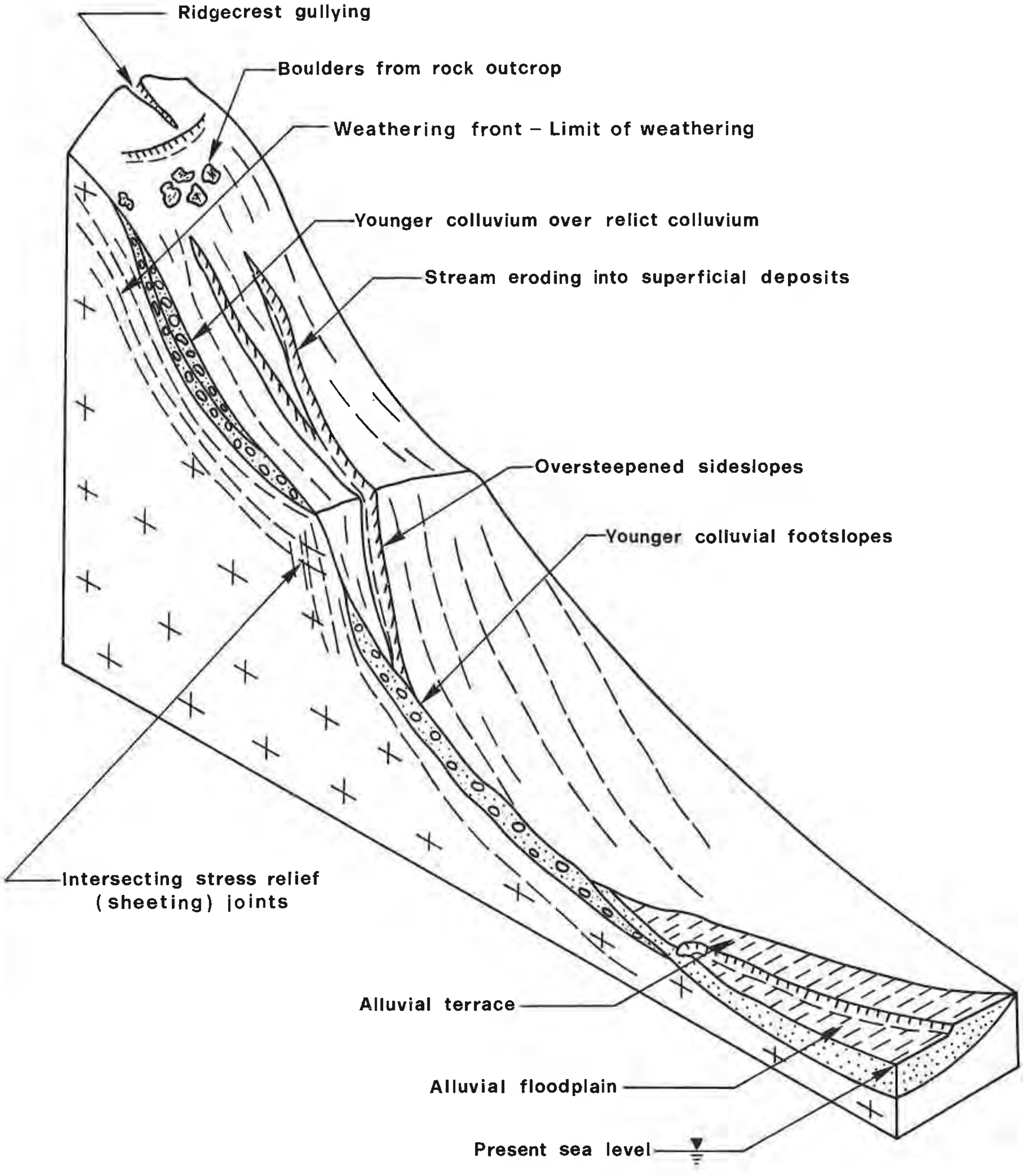
(*c*) The site investigation should be designed to highlight the scope of any available information, the anticipated material, its nature and variability, and the type and form of the engineering project.

## 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 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.

ALLUVIUM

Sediment transported and deposited by a river or stream.

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.

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

Angular 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.

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'.

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.

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.

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

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.

INCISED DRAINAGE CHANNEL

Terrain component consisting of the channel and banks of a drainage line which has been cut down by erosion deep into the landsurface. Identification of this feature is largely dependent upon the scale of the survey and the 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.

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.

PHYSICAL LAND RESOURCES

Physical characteristics of land.

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 (e.g. $Fe_2O_3$ & $Al_2O_3$) 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.

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.

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.

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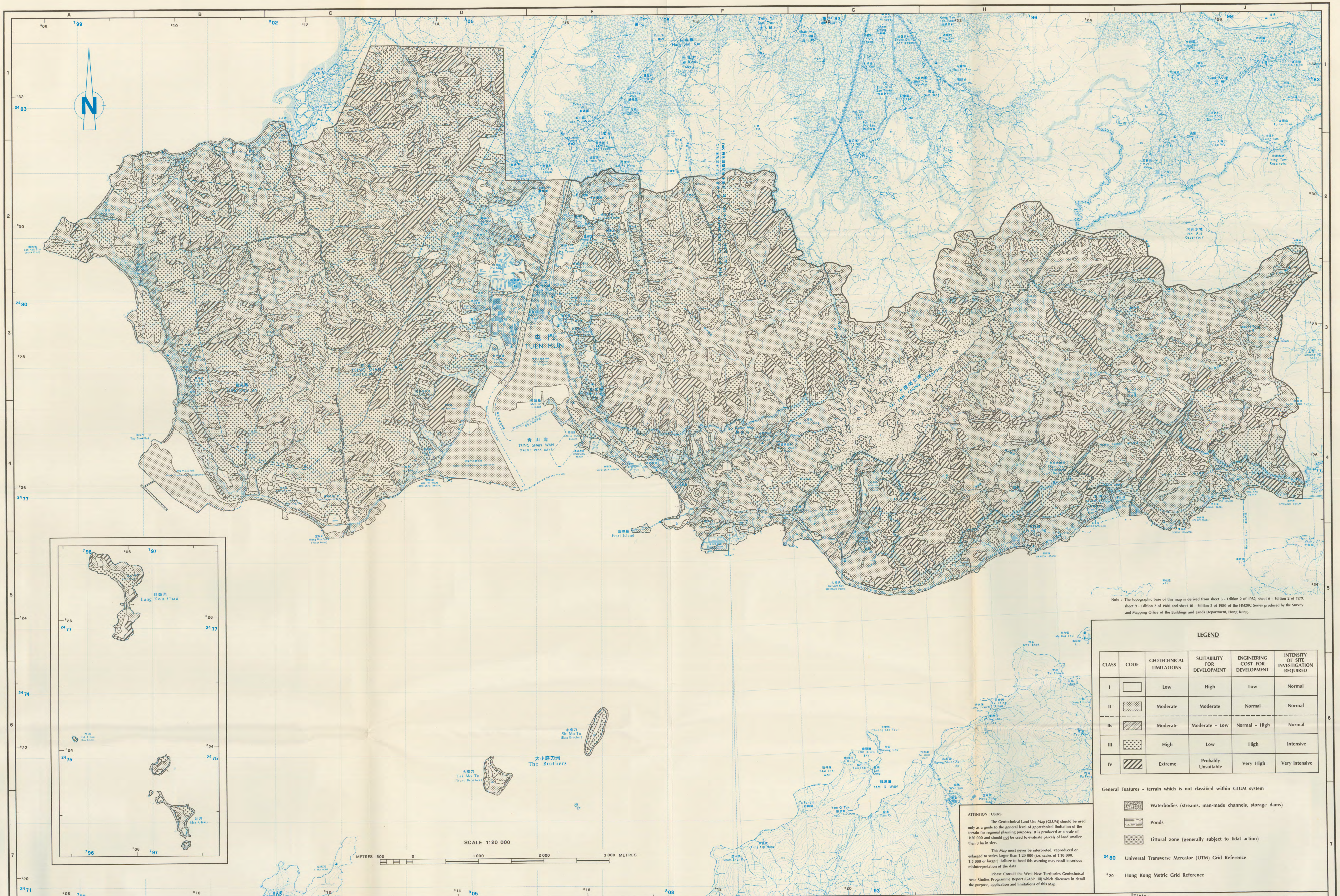


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## LEGEND

| 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)

$^{24}80$ Universal Transverse Mercator (UTM) Grid Reference

$^{8}20$ 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 West New Territories Geotechnical Area Studies Programme Report (GASP III) which discusses in detail the purpose, application and limitations of this Map.

Geotechnical Control Office
Civil Engineering Services Department

GEOTECHNICAL AREA STUDIES PROGRAMME

# GEOTECHNICAL LAND USE MAP — WEST NEW TERRITORIES

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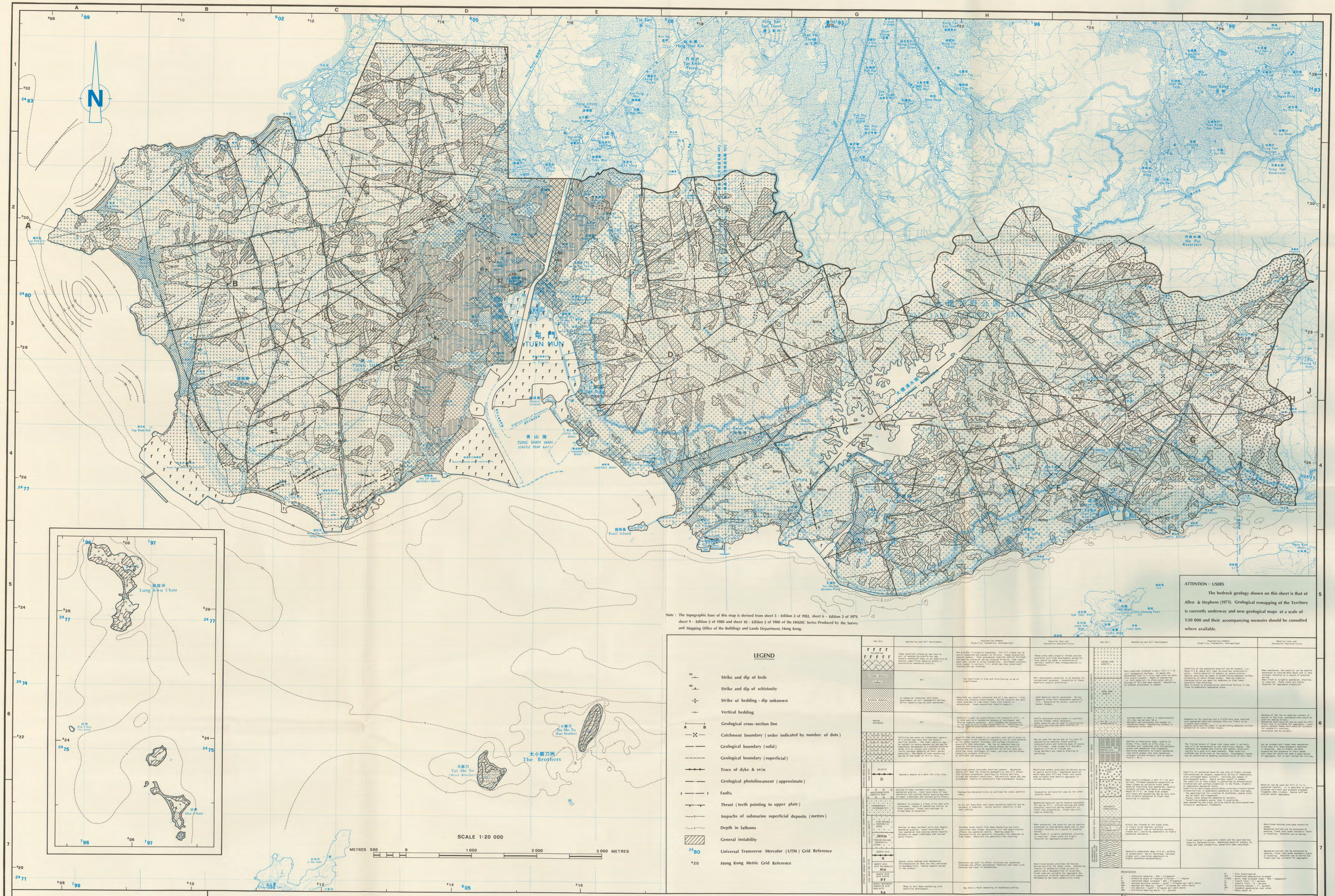


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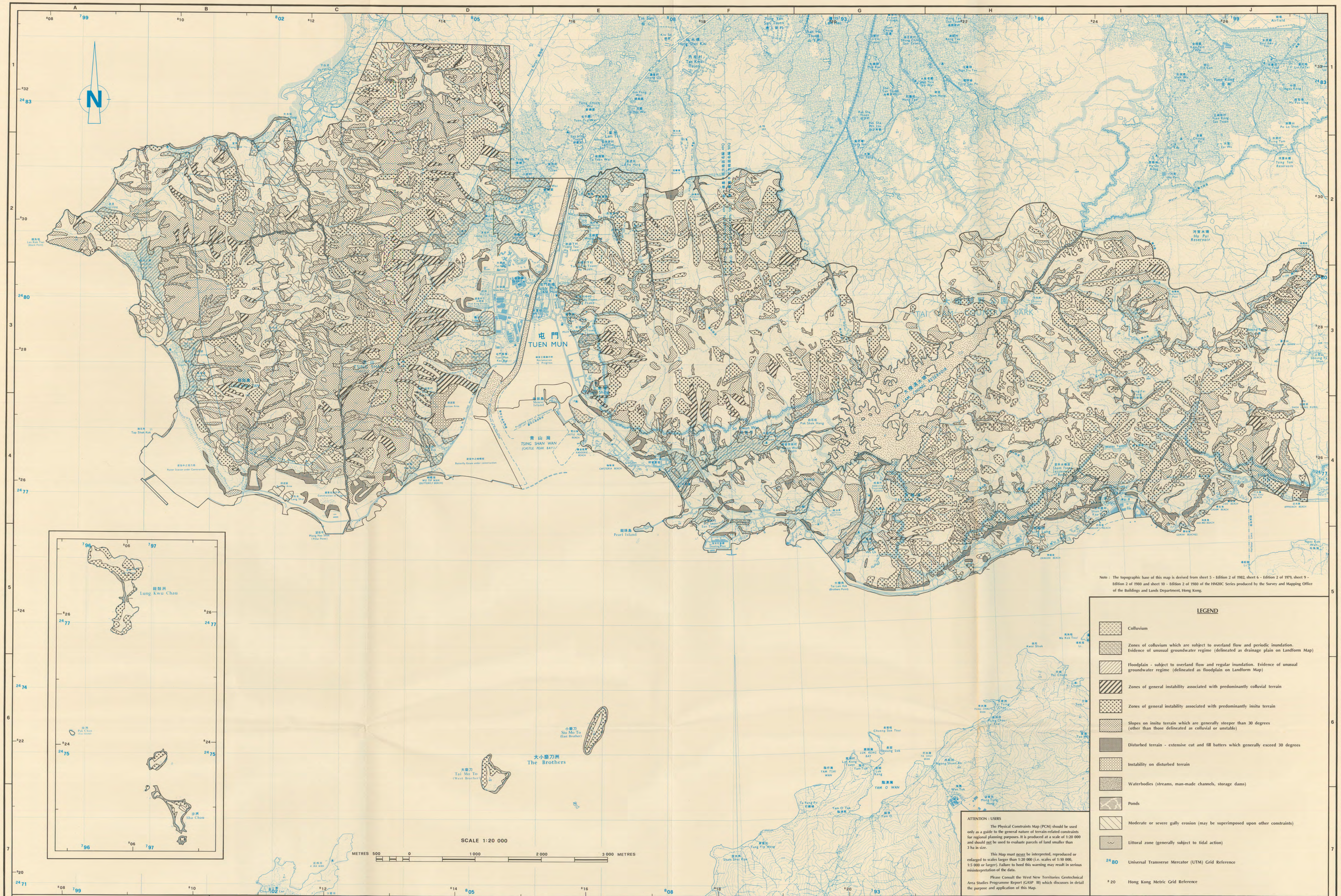


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## LEGEND

- 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 degrees (other than those delineated as colluvial or unstable)
- Disturbed terrain - extensive cut and fill batters which generally exceed 30 degrees
- 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)
- 24 80 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.

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GEOTECHNICAL AREA STUDIES PROGRAMME

# PHYSICAL CONSTRAINTS MAP — WEST NEW TERRITORIES

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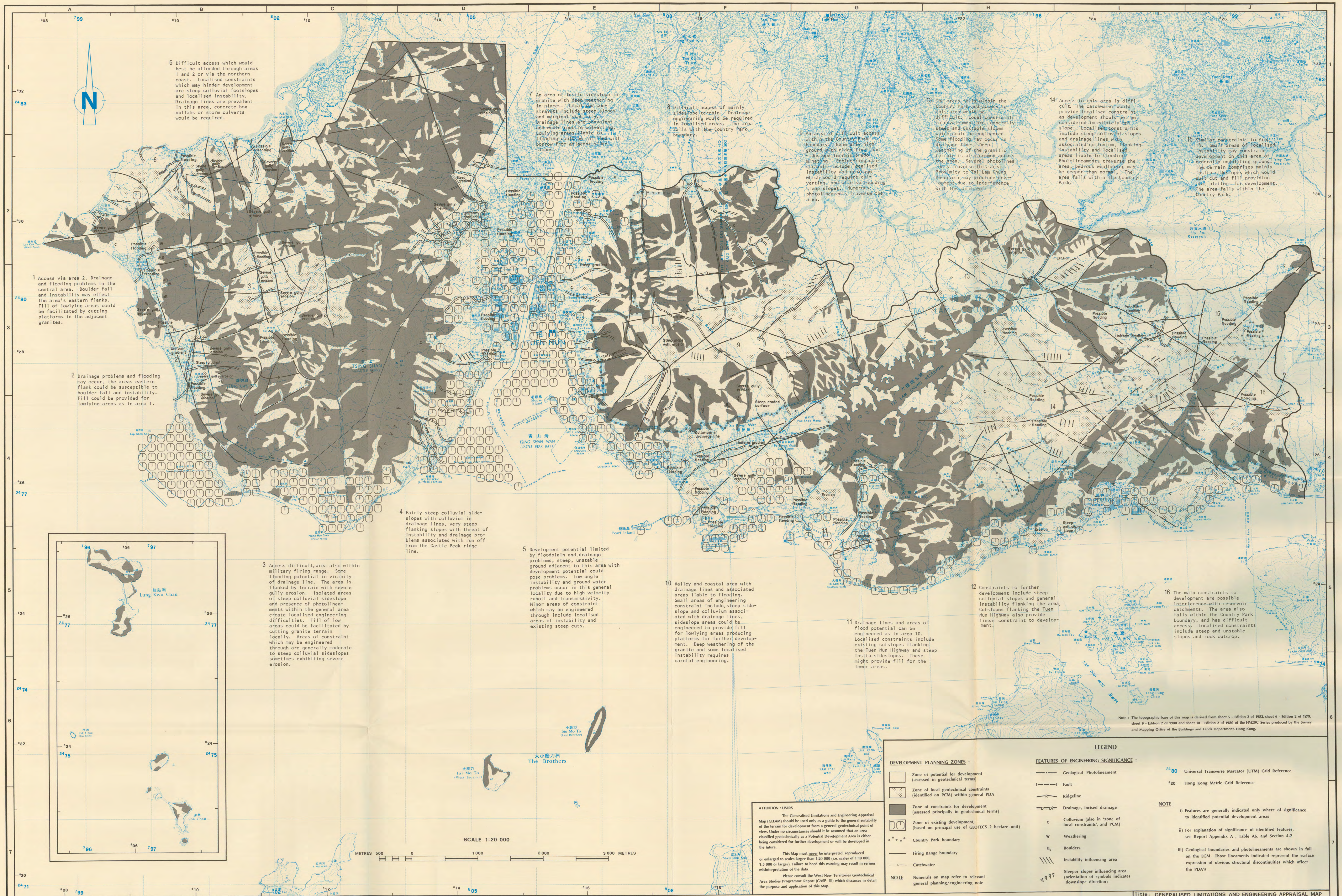


Geotechnical Control Office
Civil Engineering Services Department

GEOTECHNICAL AREA STUDIES PROGRAMME

# GENERALISED LIMITATIONS AND ENGINEERING APPRAISAL MAP – WEST NEW TERRITORIES

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| Title: GENERALISED LIMITATIONS AND ENGINEERING APPRAISAL MAP WEST NEW TERRITORIES | |
| Compiled: J. M. Nash | Drawn: C. P. Wan |
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