Geotechnical Area Studies Programme

GASP Report XI

South Lantau

Geotechnical Control Office
Civil Engineering Services Department
Hong Kong

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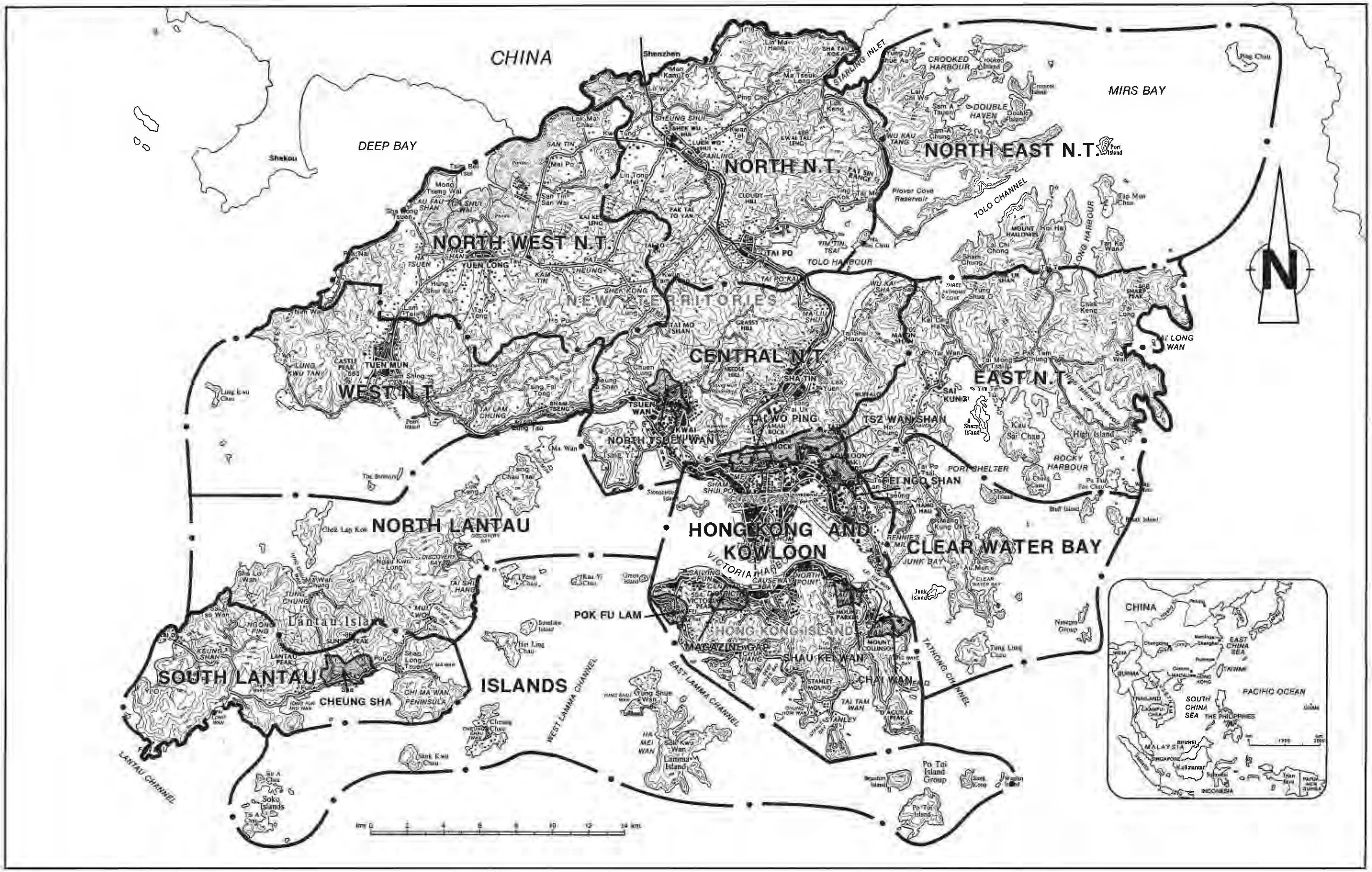

Map of the Territory of Hong Kong Showing the Locations of the Geotechnical Area Studies.
(Boundaries of the Regional Studies are shown by dashed lines and locations of District Studies are indicated by dark screens)

FOREWORD

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

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

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

Users of GASP Reports should make reference to the new 1:20 000 scale Hong Kong Geological Survey Maps and Memoirs which are being prepared by the Geotechnical Control Office. These provide more up to date geological information than is available in this Report. The Geological Maps which cover the South Lantau area, together with the accompanying Memoir, will be published by 1991.

This Report was originally produced in October 1987, for use within the Hong Kong Government on the basis of information assembled during the period October 1984 to December 1985. This fact should be borne in mind by users, who should also note that the contents of the Report have for the most part not been updated. Further, although every effort has been made to ensure the accuracy of the information contained in the Report, this cannot be guaranteed. The Geotechnical Control Office cannot therefore accept any liability for errors in the data or for misinterpretations made during the study.

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

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

Acknowledgements are due to the Survey & Mapping Office, Buildings & Lands Department of the Hong Kong Government, who provided most of the aerial photographs used in the study, one of which is reproduced as the front cover of this Report.

E. W. Brand
Principal Government Geotechnical Engineer
December 1988

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1. INTRODUCTION

1.1 The South Lantau Geotechnical Area Study

This Report presents the results of a 1:20 000 scale Regional Geotechnical Area Study of the South Lantau area, which was carried out in the Geotechnical Control Office between October 1984 and December 1985. The area covered by the study, which is designated as GASP XI, 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 and the accompanying Memoir, will be published by 1991.

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 fûture 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 eleventh of the Reports to be published; one more will follow. A number of District Studies: Stage 1 have been carried out, and whilst these District Study: Stage 1 Reports are only for use within Government, some information in map form is available on request (see Sections 1.7 and 1.8).

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 South Lantau area. A detailed description of the Allen & Stephens (1971) geological units is provided in Appendix C.

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

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

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

A selection of photographs follows the example figures, and these are presented as Plates 1 to 33. 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 South Lantau study area. Appendix D discusses landform evolution and its relationship to engineering. A glossary of terms used in the Programme is presented in Appendix E.

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

1.5 Maps Produced within the Regional Study

1.5.1 *General*

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

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

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

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

1.5.2 *Terrain Classification Map (TCM)*

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

1.5.3 *Landform Map (LM)*

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

1.5.4 *Erosion Map (EM)*

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

1.5.5 *Geotechnical Land Use Map (GLUM)*

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

Table 1.1 GLUM Classification System

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

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

1.5.6 *Physical Constraints Map (PCM)*

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

1.5.7 *Engineering Geology Map (EGM)*

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

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

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

1.5.9 *Computer-generated Maps*

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

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

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

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

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

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

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

* Located in the Map Folder accompanying this Report.

1.7 GASP District Studies Relevant to the Study Area

One GASP District Study: Stage 1 has been undertaken within the study area at a scale of 1:2 500. The area covered is shown in Figure 3. Approximately 273 ha of the geotechnically complex terrain within the Cheung Sha area have been assessed, and the results are summarised in a general form in Table 1.3. Some 66% of the terrain evaluated is subject to high to extreme geotechnical limitations. As an indication of the magnitude of the slope stability problem associated with this terrain, some 49 landslips were recorded during the District Study.

Although District GASP Reports are not available to the public, some of the maps produced at 1:2 500 scale are available through the Geotechnical Information Unit of the Geotechnical Control Office.

Table 1.3 GLUM Classes and Landslips within the GASP District Study Located in the South Lantau Regional Study Area

Study Area	District Stage 1 GASP Report No.	Geotechnical Limitation (GLUM Class—ha)				No. of Landslips	Total Area (ha)
		Low I	Moderate II	High III	Extreme IV		
Cheung Sha	4	24.6	69.3	117.4	62.1	49	273.4

1.8 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 also available for areas within the Territory.

2. DESCRIPTION OF THE SOUTH LANTAU STUDY AREA

2.1 Geographical Location

The study area consists of 7 589 ha forming the western and southern parts of Lantau Island, including the Chi Ma Wan Peninsula. The terrain is characterised by large tracts of uplands and an irregular coastline with several small islands. This study area shares a land boundary with GASP VI—North Lantau, and a marine boundary to the south with GASP X—Islands. The boundary with GASP VI runs from the coast to the south of San Shek Wan, over the main watershed marked by Lantau and Sunset Peaks, to the coast southeast of Mui Wo.

2.2 Topography

Lantau Island is divided by the main east-west watershed formed by Lantau Peak (Fung Wong Shan, 934 m) and Sunset Peak (Tai Tung Shan, 869 m). Major areas of steep terrain exist around the prominent ridge which trends southwest from Lantau Peak, and on the upper sideslopes to the southeast of Sunset Peak (Plates 6 & 7). The GEOTECS Plot at Figure 5 illustrates the distribution of slope gradients. This Plot also highlights the major areas of slopes steeper than 30° on the Chi Ma Wan Peninsula (Plates 4 & 5) and around the broad ridge to the west of Shek Pik Reservoir (Plates 17 to 24). In total, some 44.5% of the terrain in South Lantau is steeper than 30°. More data on the distribution of slope gradients is given in Tables B1, B4, B5 and B10 in Appendix B.

Terrain of less than 30° slope gradient is scattered throughout the study area. The main lowland areas are: Fan Lau to Yi O; Tai O; Keung Shan; Tai Long Wan to Shek Pik; the low hills north and south of Shui Hau and the footslopes and coastal lowlands from Shui Hau to Pui O, Ham Tin and Chung Hau. A broad ridgecrest containing several areas larger than 10 ha, with slope gradients less than 15° and slope gradients generally less than 30° degrees, trends from Ngong Ping to Ling Wui Shan and for a further 1 500 m in a southwesterly direction.

2.3 Geology

2.3.1 *General*

In simple terms, the regional geology of the study area consists of a thick sequence of volcanic and volcaniclastic rocks overlying older sedimentary rocks. These rocks have been intruded by granite, quartz monzonite and feldspar porphyry. The area is structurally affected by two main fault trends. Allen & Stephens (1971) identify two sets of faults trending NE–NNE and NNW–NW, to the west of Cheung Sha. Additional geological photolineaments, and the locations of the various geological materials are presented in the Engineering Geology Map located in the Map Folder of this Report. The general distribution of the major geological units is summarised in the GEOTECS Plot in Figure 6.

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

The Geotechnical Control Office is currently preparing a new series of geological maps at a scale of 1:20 000 which will result in a more precise definition of the distribution of the geological units within the Territory. The study area will be remapped as part of this revised Geological Survey of Hong Kong. The new maps and accompanying Memoir will be published by 1991.

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

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

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

The nature of the individual rock types is summarised below, their distribution is tabulated in Appendix B, and further geological descriptions are given in Appendix C. Their general engineering behaviour and planning significance are discussed in Section 3.1, and summarised in Table 3.1.

2.3.2 *Sedimentary Units*

The oldest rocks in the study area are known as the Tai O Formation. The exposed thickness of this sequence of metamorphosed siltstones, mudstones and sandstones is about 350 m, and it outcrops along the coast to the north and northeast of Tai O. These strata crop out on some 80 ha (1.1%) of the study area.

2.3.3 *Volcanic and Volcaniclastic Units*

The Repulse Bay Formation outcrops extensively within the study area and underlies most of the terrain to the north and west of Pui O. The Repulse Bay Formation is divided into five major lithotypes by Allen & Stephens (1971) and an additional category of undifferentiated Volcanic Rocks. This latter term was used by Allen & Stephens (1971) for areas where the density of vegetation cover or proliferation of boulders precluded detailed mapping. Undifferentiated volcanic rocks form some 1 342 ha (17.7%) of the area. The five major lithotypes are:

(i) *Sedimentary Rocks and Water-laid Volcaniclastic Rocks (RBs)*
This class consists of a succession of fine-grained clastic sediments and lapilli tuffs. The main rock types are thinly banded siltstones, sandstones and mudstones. The purely sedimentary and volcanically-derived sedimentary rocks (volcaniclastics) are often conformably interbedded. To the east of Shek Pik Reservoir, the sedimentary rocks are mainly siltstones, mudstones and volcanic sandstones, which form units up to 100 m thick. Further west, two units occur, separated by a lava flow and tuffs. The upper unit is dominated by volcanic sandstones, while the lower unit contains bands of coarser volcanic debris within the sequence of siltstones, mudstones and sandstones. These rocks, which are generally weaker than other units of the Repulse Bay Formation, form 788 ha (10.4%) of the terrain.

(ii) *Acid Lavas (RBv)*
Two thick rhyolite flows occur to the west and north of Shek Pik Reservoir, and a flow of dacite exists to the north of Tong Fuk. These rocks occupy 567 ha (7.5%) of the study area.

(iii) *Coarse Tuff (RBc)*
This rock type consists of coarse volcanic ash, often termed coarse-grained crystal tuff. Closely spaced jointing and a shallow weathering profile generally characterise this rock type. Coarse tuffs crop out between Pui O and Tong Fuk in a band parallel to the Cheung Sha coastline. This rock type forms approximately 133 ha or 1.7% of the terrain.

(iv) *Agglomerate (RBag)*
Impersistent beds of agglomerate occur on the southern flanks of Sunset Peak and on the northern flanks of Lantau Peak, occupying some 10 ha.

(v) *Dominantly Pyroclastic Rocks with Some Lavas (RBp)*
The pyroclastic rocks consist of a sequence of varied rock types including fine tuffs, ash flows, lapilli tuffs and lavas. The pyroclastic rocks outcrop extensively in the western part of the study area; the lowest unit identified by Allen & Stephens (1971) is a massive fine tuff about 1 000 m thick. These rocks form 1 881 ha or 24.8% of the study area.

2.3.4 *Intrusive Igneous Rocks*

The igneous rocks which intrude the volcanics, are divided by Allen & Stephens (1971) on the basis of lithology, age and intrusive relationship. The 10 ha of plutonic rocks which comprise the island of Peaked Hill were not mapped in detail and are designated as 'Undifferentiated Granitic Rocks'. The major portion of the intrusive igneous rocks are classified as follows:

(i) *Tai Po Granodiorite (XT)*
This granodiorite is a porphyritic rock with a moderately high silica content. It outcrops only along the catchwater at Tong Fuk and at the Cheung Sha headland. It forms approximately 24 ha (0.3%) of the terrain.

(ii) *Sung Kong Granite (SK)*
The Sung Kong Granite is typically coarse-grained, pale grey or pink in colour and is often porphyritic. The granite is generally strongly jointed and often subject to deep weathering. This granite occupies 173 ha (2.3%) and only outcrops on the southern periphery of the study area at Fan Lau, near Lo Kei Wan, and to the north and east of Ham Tin.

(iii) *Cheung Chau Granite (CC)*
This medium-grained, slightly porphyritic, pink granite forms some 667 ha of the terrain in the Chi Ma Wan Peninsula, where it is often deeply weathered.

(iv) *Ma On Shan Granite (MS)*
This is essentially a fine-grained porphyritic granite and is generally pink to mauve in colour. Metasomatic mineralization is often associated with this phase of igneous activity. Small outcrops of the granite occur northeast of Pui O, where it forms 8 ha (0.1%) of the terrain.

(v) *Fan Lau Porphyritic Granite (FL)*
The outcrop is limited to 18 ha of the Fan Lau peninsula. This granite is pale pink, fine-grained and porphyritic.

(vi) *Quartz Monzonite (Mo)*
Quartz Monzonite outcrops at Fan Lau Sai Wan, the Lo Kei Wan Peninsula, Tong Fuk, Ham Tin and along the major valley to the east of Pui O. The Quartz Monzonite consist of grey to pink, fine or medium-grained rock, often with phenocrysts, but with a lower quartz content than the granites (less than 15%). This unit occupies 347 ha or 4.6% of the study area.

(vii) *Feldspar Porphyry (La), Quartz Porphyry (Pq) and Dolerite (D) Dykes*
Of the dyke rocks in the area, quartz porphyry predominates although some granodioritic porphyry dykes also occur. The dykes generally follow a northeasterly trend and may exist in swarms within which it is difficult to trace individual dykes for any great distance. The Feldspar Porphyry Dyke Swarm outcrops over 182 ha (2.4%) of the study area. The outcrop of individual dykes is usually too small to be recorded in the GEOTECS system.

In total the intrusive igneous rocks outcrop across 1 429 ha and cover approximately 19% of the area.

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

2.3.5 *Superficial Units*

Superficial deposits, both natural and man-made, cover 17.9% of the study area. The isolated nature and current low population of South Lantau have resulted in the urbanisation of only small areas such as Tai O, or in development for specialist uses such as Shek Pik Reservoir and the various prisons. Hence man-made superficial deposits (fill and reclamation) occupy only 1.4% of the study area.

(i) *Colluvium*
This material occurs on 796 ha (10.4%) of the study area. Colluvial deposits are formed by gravity transport of rock and soil debris downslope. They occur as recent or relict deposits and are heterogeneous in their physical characteristics. The deposits may range from a mixture of clay, sand and gravel, to large boulder fans containing single units several metres in thickness.

In the study area, the colluvium is subdivided on the basis of parent rock type, into four basic types.

(*a*) Volcanic Colluvium (Cv)—This material occurs extensively and forms some 649 ha (8.5%) of the terrain. Volcanic colluvium often forms large boulder fields and fan-shaped lobes, whose constituent rock type is mainly pyroclastic material. Boulders reach several metres in size and are particularly resistant to weathering.

(*b*) Granitic Colluvium (Cg)—The occurrence of this material is restricted by the distribution of the outcrop of the intrusive igneous rocks. Granitic colluvium occurs to the south and east of Pui O, on the Chi Ma Wan Peninsula and near Lo Kei Wan and Fan Lau Sai Wan. This material forms 84 ha (1.1%) of the terrain.

(*c*) Sedimentary Colluvium (Cs)—This material occupies 24 ha (0.3%) of the study area. Deposits are restricted to areas downslope of the sedimentary rocks of the Repulse Bay and Tai O Formations. This type of colluvium is very limited and occurs mainly in the western part of the study area.

(*d*) Mixed Colluvium (Cm)—This material occurs downslope of areas where more than one source rock outcrops. Mixed colluvium is located mainly in the west and south and forms 39 ha (0.5%) of the terrain.

(ii) *Alluvium (A)*
Several extensive areas of alluvium exist within the study area. Major deposits are located at Tai O, Shek Pik, Shui Hau and Ham Tin. Smaller patches of alluvium occur at the mouths of river valleys or in sections of low gradient valley floor within the upland plateaux. Alluvium forms 4.1% (312 ha) of the terrain.

(iii) *Littoral Deposits (L)*
These deposits of generally medium-grained sands and gravels, are found on fairly extensive beaches at Cheung Sha and Pui O and elsewhere in the bays and inlets along the indented coast. Littoral deposits occupy 2.0% (149 ha) of the study area.

(iv) *Marine Deposits (M)*
These deposits occur on the sea bed and consist of soft marine muds or shelly sands with occasional deposits of coarser-grained sands or sandy gravels adjacent to the coast.

(v) *Reclamation (R)*
Areas of reclamation occur at Shek Pik and Tai O. Reclamation occupies some 0.5% (35 ha) of the study area. It consists of a mixture of man-placed artificial and natural fill, the properties of which vary according to the source material.

(vi) *Fill (F)*
Small areas of fill material are associated with areas of construction. Filling is generally undertaken to raise ground level to create flat platforms. Low, raised platforms are common in the villages of Tai O, Ngong Ping, Shui Hau, Tong Fuk, Cheung Sha, Pui O and Ham Tin. Recent filling is evident on the alluvial floodplains at Shek Pik, Tai O, Pui O and at Shui Hau. At Ham Tin, the fill material includes large boulders over 1 m in diameter (Plate 33). The material varies according to the source of fill and degree of compaction. Fill forms approximately 67 ha within the study area.

The 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 rocks of the Repulse Bay Formation with some intrusive igneous rocks in the south and east.

Two main regional structural trends are identified by Allen & Stephens (1971). Burnett & Lai (1985) discuss possible correlations of the major structural elements with those identified in the South China region.

(i) *Northeasterly Trending Fault Zone.*
It is possible that the trace of the southwest continuation of the Wuhua—Shenzhen fault zone, passes to the north of Lantau Island. A number of parallel faults exist, of which the Starling Inlet—South Lantau fault zone may include the Tung Chung—Shek Pik and Yam O Wan—Pui O Wan faults. Within the mainland area of the Territory, these fault zones have been recognised as possessing steeply-dipping, intensive crush zones (Burnett & Lai, 1985). Whilst no actual crush zones are recognised within the study area, the faults provide strong control to the orientation of valleys and drainage lines and indicate a considerable degree of rock fracturing.

(ii) *Northwest to North Northwesterly Trending Faults.*
This set of faults was identified in the area between Ngong Ping and Fan Lau by Allen & Stephens (1971). Burnett & Lai (1985) record additional faults aligned from Tung Chung to Cheung Sha, Sham Wat to Shek Pik, and Tai O to Tai Long Wan. Faults with this orientation are noted by Burnett & Lai to possess steeply dipping, narrow crush zones. The traces of many of these faults are identifiable as linear depressions on aerial photographs.

Numerous geological photolineaments are evident on aerial photographs and some are identified as faults. Most of the photolineaments are probably normal faults, although some may be tear faults. Major jointing may also produce some of the photolineaments. The distribution of geological photolineaments and faults is shown on the Engineering Geology Map (EGM).

The general dip of the rocks of the Repulse Bay Formation east of Shek Pik Reservoir, is in a north northwesterly direction, although variations in the angle of dip indicate locally intense folding. Fold axes appear to be aligned in an east northeasterly direction (refer to the geological cross-section, Figure C1).

A description of the geology of the entire Territory is available in the Report of the Geological Survey of Hong Kong (Allen & Stephens, 1971). This work is, of course, being updated by the revised geological mapping. A detailed description of the rock units is presented in Appendix C.

2.4 Geomorphology

2.4.1 *General*

The geomorphology of the area reflects a complex Quaternary history of erosional and depositional response to climatic change and eustatic sea level fluctuations. Individual landforms are continually evolving, as determined by the local balance between rapid weathering rates and denudation from intense seasonal rainfall. A description of the mechanics of the weathering process and its engineering significance are contained in Appendix D.

The geomorphology of South Lantau is divided into mountainous, undulating hillcrest, dissected granitic, colluvial and alluvial terrain.

Table B5 in Appendix B provides data on the distribution of the major landform units. The distribution of slope gradients is illustrated in the GEOTECS Plot Figure 5.

2.4.2 *Mountainous Terrain*

Zones of steep mountainous terrain rising to elevations between 300 and 934 m exist on the upper sideslopes of the Sunset Peak to Lantau Peak ridge and associated spurlines, and around the margins of the Ngong Ping to Ling Wui Shan uplands. Stream erosion rates are generally high because of the steep gradients resulting from the short distance between the uplands and the sea. Several of the deeply incised valleys are cut along lines of structural weakness. These may be areas where fractured rock exists along a fault line, creating preferential paths for groundwater movement and associated deep weathering. Downcutting of streams adjacent to the major valleys has created a very irregular topography with narrow convexities on ridgecrests and spurlines, flanked by steep (often greater than 30°) concave sideslopes. These steep sideslopes often show evidence of instability (Plates 6, 7 & 26.) Soils on the steep slopes are generally very thin, with a high percentage of angular rock fragments and boulders on the surface. Soil movement is particularly active on slopes steeper than 35° and occurs in the form of soil creep and slopewash. Rockfalls are a hazard below the major cliffs.

2.4.3 *Undulating Hillcrest Terrain*

Broad areas of undulating hillcrests with shallow intervening valleys occur in several areas of South Lantau. The largest area extends from Ngong Ping to beyond Ling Wui Shan, and is over 6 km long by up to 1.5 km wide. Smaller areas of similar terrain exist to the east of Tai O and between Shap Long Kau Tsuen and Shui Tseng Wan to the east of Pui O. Low undulating hillcrest terrain occurs between Fan Lau and Tsin Yue Wan, near Shui Hau and Lo Kei Wan, and around Cheung Sha.

Slope angles within these areas are generally less than 30°, and quite large parcels of terrain are less than 15° in gradient. Where this terrain exists at elevations over 200 m, narrow valleys incised to bedrock occur at the steep upslope margin with the mountainous terrain. Where streams flow for several hundred metres or more across the undulating uplands, the broad, shallow valleys may possess thick superficial deposits of colluvium and alluvium, such as at Ngong Ping.

Soils on these moderate angle slopes and ridgecrests are usually 1–2 m thick on the volcanic areas, but up to 3 m thick where the terrain is underlain by intrusive igneous rocks. In addition, weathered rock of low strength may exist to some 8 m depth in the volcanic terrain, and to 10–15 m in the intrusive igneous terrain. In all areas, the depth to rockhead is variable because of local variations in the density of jointing. Broad ridgecrests and shallow valley floors are likely to possess thicker weathered profiles than the intervening sideslopes where isolated outcrops of rock may exist.

2.4.4 *Dissected Granitic Terrain*

The terrain of the Chi Ma Wan Peninsula reflects strong structurally-controlled stream dissection. Many of the streams are short and occur along faults and major joints. This creates very uneven relief and a high drainage density. The majority of valley sideslopes are short, steep and prone to instability, with rockfalls a hazard below the many cliff faces. Soils may be thick in areas where erosion rates are lower, for example on the broader ridgecrests. The granular soils typical of this terrain, are susceptible to erosion.

2.4.5 *Colluvial Terrain*

Colluvial deposits exist in many of the valley floors and on footslopes below steep slopes. A thin veneer of colluvium exists on many of the sideslopes and instability is common, especially adjacent to drainage lines. Some of the colluvial deposits may exceed 10 m in thickness, but 1–3 m is more common. Boulders often exist at the surface as the result of landslips, or rockfalls or by exhumation from the thick colluvial cover.

Significant deposits of colluvium mantle the lower slopes to the east of Tai O and along the footslopes from Tong Fuk to Pui O.

Small streams in areas of bedrock may disappear upon reaching colluvial deposits. Large natural 'tunnels' or 'pipes' occur as voids in the colluvium. Some areas of colluvium display a hummocky, irregular surface which may reflect potential or previous instability, and these are indicated on the Engineering Geology Map and the Physical Constraints Map.

2.4.6 *Alluvial Terrain*

This terrain is usually flat or gently sloping but may have a veneer of fill in areas of development. A complex interrelationship exists between the colluvium and alluvium which may occur in alternating layers. Alluvial floodplains exist on many of the valley floors, and the most significant are at Tai O, Shek Pik, Tong Fuk, Cheung Sha and Ham Tin. Flooding may be a problem adjacent to streams in alluvial fan areas.

Small areas of alluvium also exist on the floors of the upland valleys. The largest deposit of this type occurs at Ngong Ping.

2.5 Hydrology

2.5.1 *Surface Hydrology*

The natural drainage regime has been extensively modified to increase the volume of fresh water available for human consumption. This has involved diverting some of the streams into reservoirs through a network of water tunnels and catchwaters. Shek Pik Reservoir was constructed by damming a broad valley.

The largest natural catchments in South Lantau, which discharge at Sham Wat, Tai O, Tong Fuk and Ham Tin, contain fourth order drainage networks (Appendix A.8.2). The Ngong Ping to Sham Wat catchment has a maximum stream length of approximately 4.5 km, an area of some 600 ha, and relief of over 950 m. The dimensions of the original Shek Pik catchment were similar, but have been substantially modified since construction of the reservoir. The Man Yuen to Ham Tin catchment, which is the next largest, with an area of approximately 500 ha, has a significant relief of over 700 m. The steepest drainage network flows through Tong Fuk and has a catchment area of only 350 ha. The longest stream in this area is approximately 3 km long and drains into the sea from the upper sideslopes of Lantau Peak, an elevation of over 900 m. Most of the other catchments are in the order of 100–200 ha or less in size.

Many catchments contain thin soils, steep slopes and a high density of drainage paths. Rainfall quickly exceeds the available surface storage and infiltration capacities of the soil, and rapidly contributes to the stream discharge, producing 'flashy', multi-peaked hydrographs, where peak stream discharge is reached in a very short time. This can give rise to flooding on many of the coastal lowland areas.

2.5.2 *Groundwater Hydrology*

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

Groundwater flow through the majority of lithotypes within the area is normally by some form of sheeting or conduit flow. The permeability characteristics of most of the rock or soil masses are probably a function of jointing, fissuring or piping rather than intergranular flow. Consequently, zones of groundwater flow and velocities are difficult to predict. Flow in the bedrock will almost certainly be concentrated in zones where joints and fissures are open and more closely spaced, e.g. fault and shear zones.

In the superficial materials, groundwater flow will either be by intergranular flow, or by conduit flow as a result of tunnel erosion (Nash & Dale, 1984). The type and velocity of flow and aquifer permeability depend largely on the grainsize of the deposit. Boulder fields are the most permeable, and overconsolidated colluvial clay the least permeable. Within the study area there are approximately 293 ha of footslope colluvial terrain which may be affected by piping or conduit flow. Within the alluvial deposits, groundwater may flow along old, buried stream courses, or occur as intergranular flow. These alluvial deposits will probably have high groundwater tables.

2.6 Vegetation

In this report, a nine class system is used to distinguish the categories of vegetation. The spatial distribution of these groups is illustrated in the GEOTECS Plot at Figure 7, whilst Figure 4 shows their relative distribution.

The natural vegetation of this area has been successively modified by man, and numerous exotic species have been introduced in addition to the large number of indigenous tropical and sub-tropical species. The data is presented in Table B7 at Appendix B.

Vegetation classes are:

(i) *Grassland*
This class consists of indigenous and introduced species, grasses are the dominant vegetation type within the study area and occupy 39.5% (3 001 ha) of the terrain. Although grasslands may result from the clearing of shrub and woodland, the extensive grasslands of the uplands and the southwestern peninsula may reflect the severity of the prevailing winds on the exposed terrain.

(ii) *Cultivation*
This class occupies only 1.2% (94 ha) of the study area, mainly on the alluvial lowlands. The largest of these areas are near Tai O, Fan Lau, Shui Hau, Tong Fuk, Pui O and Shap Long San Tsuen. Abandoned agricultural areas also exist on the alluvial lowlands, extending upslope onto the colluvial footslopes, and may also occur on low-angle sides and floors of valleys and depressions within the upland areas.

(iii) *Shrubland (Less than 50% Ground Cover)*
Shrubland occurs as regrowth on areas of disturbed terrain or in areas regenerating after damage by hillfires. This class occupies 13.8% (1 044 ha) of the study area and occurs in small tracts of middle and upper slopes and more extensively in the valley floors and low hills in the south and southwestern parts of South Lantau.

(iv) *Shrubland (Greater than 50% Ground Cover)*
Similar to (iii) but with denser cover, generally indicating greater maturity and a longer period of colonisation, although there may be other causes. This class occupies 2.7% (208 ha) of the study area and occupies a few middle and upper slopes and upland plateaux, but it is more extensive in the lowlands near Shui Hau and on the Chi Ma Wan Peninsula.

(v) *Mixed Broadleaf Woodland*
This class occupies 33.3% (2 524 ha) of the study area and covers extensive tracts of valley floor and lower to middle sideslope terrain, especially in the Chi Ma Wan Peninsula. This class of vegetation is probably the indigenous vegetation of the South China coastal region.

(vi) *No Vegetation on Natural Terrain*
This is usually the result of erosion and affects only 2.1% (161 ha) of the study area. Types of erosion are discussed in Section 2.7.2.

(vii) *No Vegetation on Disturbed Terrain*
This class is normally associated with urbanisation, and consequently occupies only 2.6% (196 ha) of this relatively undeveloped area.

(viii) *Rock Outcrop*
These are defined as areas where rock outcrops constitute over 50% of the unit. Areas which predominantly consist of rock outcrops occur on approximately 3.0% (226 ha) of the terrain.

(ix) *Waterbodies*
Approximately 25 ha of the study area is occupied by ponds and 106 ha by the Shek Pik and other smaller reservoirs. Only 4 ha of natural stream channels is recorded within the GEOTECS system.

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

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

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

2.7 Erosion and Instability

2.7.1 *General*

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

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

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

Erosion and instability affect 54.3% (4 125 ha) of the study area. However, only 3.9% (293 ha) of the study area is currently developed, and within this area erosion is generally restricted to unprotected platforms and slopes. Approximately 1 150 ha of natural terrain is subject to erosion.

Table 2.1 Erosion and Instability

Erosion		% of Total Area	Area (ha)
Instability			
—coastal instability		2.7	202
—general instability		36.2	2 748
Appreciable Erosion	Sheet erosion	14.7	1 118
	Rill erosion	0.4	33
	Gully erosion	0.3	24
No Appreciable Erosion*		45.7	3 464
		100.0	7 589

* Approximately 131 ha of reservoirs and ponds are included within No Appreciable Erosion.

2.7.2 *Erosion*

(i) *Sheet Erosion*
This form of erosion produces extensive areas of bare ground devoid of vegetation. Within the study area, extensive areas of sheet erosion occur on sideslopes and ridgelines, especially on the pyroclastic and sedimentary rocks of the Repulse Bay Formation. Erosion is often encouraged by the development of footpaths which concentrate runoff. Sheet erosion occurs on 14.7% (1 118 ha) of the study area.

(ii) *Rill Erosion*
This form of erosion results from the entrainment of loose soil particles by overland flow as runoff is concentrated into small channels. It commonly occurs on cut slopes in decomposed rock and on fill slopes with inadequate surface protection (Geotechnical Control Office, 1984, p. 118). On areas of natural ground, rill erosion occurs in similar locations to sheet erosion. It is characterised by numerous subparallel drainage rivulets which produce a striated appearance and result in significant soil loss. This type of erosion often develops on slopes devegetated by hillfires. Within the study area rill erosion occurs on 33 ha.

(iii) *Gully Erosion*
This form of erosion produces deep dissection of the land surface with consequent disruption of drainage lines, and it may result in tunnel erosion, soil piping and precipitate instability. Gully erosion affects only 0.3% (24 ha) of the study area.

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

2.7.3 *Instability*

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

The term 'well-defined landslip' refers to the scar and debris associated with a slope failure. Only landslips larger than 1 ha are delineated at the mapping scale of 1:20 000. It is difficult to define very small features and individual landslip scars within a terrain classification system designed for use at 1:20 000 scale, because often, these features are too small in comparison with 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 2 950 ha of the terrain displays some form of instability, and this represents 38.9% of the study area.

(i) *Well-defined Landslips*
None of these features are mapped within the study area. The landslips which occur are smaller than the 1 ha which is the minimum size required for delineation at 1:20 000 scale.

(ii) *Coastal Instability*
This form of instability is common because of the drowned nature of the ria coastline. The more exposed coastal sections along the eastern seaboard are most susceptible, especially in the steeper sections. Coastal instability occupies 202 ha (2.7%) of the study area.

(iii) *General Instability—Recent*
This form of instability relates to colluvial and insitu terrain where many small landslips and other evidence of instability occur, but it is not possible to show them as discrete units on a 1:20 000 scale map due to their small size. This class of instability occupies 15.0% (1 138 ha) of the study area. *General Instability—Recent* occurs over much of the steep terrain, especially in areas around stream sections, and often occurs at the headward extension of drainage lines.

(iv) *General Instability—Relict*
This form of instability occupies 21.2% (1 610 ha) of the study area and occurs in similar areas to *'General Instability—Recent'.* The two classes are closely related. This class of instability is no less important in terms of constraints on development than *General Instability-Recent.* This type of instability may be reactivated by construction, site formation, or changes to the drainage or hydraulic regime.

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

2.8 Land Use

2.8.1 *Existing Development*

Within the South Lantau study area, existing urban development is restricted to the areas around Tai O, Shek Pik, Tong Fuk and Pui O. A few scattered fishing and agricultural communities occur on the coastal lowlands, valleys and some upland areas. Some service installations associated with the Shek Pik Reservoir and South Lantau Country Park are also present. The general distribution of landuse is shown in the GEOTECS Plot at Figure 9 and in Table B12 of Appendix B.

2.8.2 *GLUM Class and Existing Land Use*

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

(i) *Residential*
These areas are identified within the GEOTECS system as either one storey, two storey, private development and public housing estates. These generally occur in and around long-established village areas. Residential accommodation occupies 1.1% of the area and is located mainly on GLUM Classes II & III terrain.

(ii) *Quarrying*
There are no active quarries in the area although small areas were used for borrow requirements associated with the construction of Shek Pik Reservoir.

(iii) *Reservoirs*
The Shek Pik Reservoir contributes fresh water to Hong Kong and the outlying islands, and was constructed in the early 1960's. Covering 106 ha, this waterbody is unclassified within the GLUM system, but the surrounding area is mainly GLUM Classes III & IV terrain.

(iv) *Country Park*
Lantau South Country Park occupies a total of 75.6% (5 732 ha) of the study area, and consists of mainly GLUM Classes III & IV terrain.

(v) *Military*
There are no designated military land uses within the area.

(vi) *Undisturbed Natural Terrain*
Undeveloped and undisturbed natural terrain occupies most of the study area and includes most of the areas comprising Country Park. Outside of the Country Park, some 17.8% (1 355 ha) of the study area is currently undisturbed natural terrain, of which 61 ha is GLUM Class I, 456 ha is GLUM Class II, 473 ha is GLUM Class III and 243 ha is GLUM Class IV, the remainder is unclassified coastal terrain. The potential for development on currently undeveloped terrain outside of Country Park and within GLUM Classes I & II terrain is 661 ha.

(vii) *Agricultural*
Certain tracts of land, notably those in the alluvial coastal valleys and upland river valleys, are used for intensive agriculture. In other areas, agricultural land has fallen into disuse. Agricultural land makes up 2.0% (149 ha) of the study area and consists of mainly GLUM Classes II & III terrain.

(viii) *Recreational*
Sporting facilities and recreational areas other than the Country Park, are generally located near the main beaches of Cheung Sha and Pui O, and are of limited extent.

(ix) *Institutional and Community*
This group includes prisons, schools, hospitals and associated uses, and occupies approximately 1.0% of the study area. With the exception of the prisons, located at Shek Pik, Tong Fuk and Chi Ma Wan, these facilities are located within the main towns of Tai O and Pui O, and to a lesser extent in the rural villages. Individual facilities (except the prisons) are usually too small to be mapped within the GEOTECS system.

(x) *Roads and Services*
These are generally thin linear features and are rarely mapped as discrete units at 1:20 000 scale. Car parks and picnic areas within the Country Parks often occur within areas of high GLUM class.

2.8.3 *Future Development*

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

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

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

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 affect 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 of the weathered profile. In areas of active coastal erosion, the weathering profile is usually absent, but it may be developed beneath the marine and/or offshore terrestrial deposits laid down during a period of 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 Figures 4 and 11, 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 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 geological materials found in such great variety in the study area, all have some potential for use in engineering activities. The geological suitability of these materials is summarised in column 10 of Table 3.1, but other factors also have to be considered when making any recommendation regarding suitability for use. These factors are: suitability of terrain and how it affects adjacent areas (e.g. instability), volume of material available, ratio of hard and soft materials, environmental considerations, accessibility, potential for development or reinstatement, and finally, possible effect on water catchments.

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

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

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

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

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

(*c*) Colluvium.

(*d*) Intrusive igneous rocks.

(*e*) Volcanic and volcaniclastic rocks.

(*f*) Sedimentary rocks.

3.1.2 *Characteristics of Fill, Reclamation, Alluvium, Littoral and Marine Deposits*

This group includes all superficial materials that generally occur as flat or slightly inclined deposits, namely alluvium, littoral and marine deposits, and also includes man-placed fill and reclamation. The latter two materials are of relatively limited extent and are present mainly in the Tai O and Pui O areas. Minor fill and reclamation are also associated with the installations of the Shek Pik Reservoir, and to a limited extent in some of the rural settlements.

The history of sea level changes results in a complex subsoil stratigraphy of these materials. In geological terms, all these materials are immature and consequently weathering profiles are poorly developed. Older alluvial materials may display weathered cobbles which may be derived from previously eroded material.

Erosion of these deposits is generally not a major problem in their undisturbed state because of their predominantly gentle gradient. Stream velocity is normally low, but where necessary, streams are confined to man-made channels. Littoral deposits are subject to continuous erosion and redeposition by the sea. The GEOTECS data presented in Table B11 and summarised in Figure 8 indicates that these materials are not subject to any marked degree of erosion. However, should hydraulic conditions be altered, for example by construction, then erosion may be initiated.

The GEOTECS data also show that there does not appear to be any incidence of instability in these materials, primarily due to the low slope angles associated with them. If disturbed however, these deposits may exhibit instability. Excavations may require strutting, and slopes probably need to be cut at low angles or provided with retaining structures.

There is a wide range of particle sizes between members of this group. Alluvial deposits contain a significant proportion of gravel and cobble-sized materials. These may exist as lensoidal deposits within a succession of finer-grained materials. Littoral deposits generally consist of a fairly uniform medium to fine sand, such as those at Cheung Sha and Pui O beaches. Marine deposits range from silty clay to coarse sand and gravel, depending on the nature and environment of deposition.

These deposits exhibit a wide range of shear strengths; the lowest values correspond to the marine muds and the highest values to alluvial horizons. Consolidation is rapid in the alluvium and littoral deposits, but may be very slow and quite considerable in the marine deposits. The absolute magnitude of settlement is dependent on the imposed load, local groundwater conditions and the local stratigraphy. Undisturbed samples are required for laboratory tests to determine the material strength characteristics applicable to individual sites. Site investigations in alluvium may be enhanced by the application of geophysical techniques such as resistivity or shallow seismic refraction. Offshore, marine seismic techniques are useful in obtaining profiles of marine sediments.

None of the materials in this group have high bearing capacities and all large loads need to be transferred to underlying bedrock. Low to moderate loads can be accommodated by raft foundations, but problems of differential settlement may be experienced. The pile type most appropriate for high loads will be dependent on the overall stratigraphy, but nearly all members of this group are suited to driven piles. Marine deposits of sand have been extracted or covered by reclamation, and the marine silts and clays are generally unsuitable as hydraulic fill.

The members of this group of materials generally have a fairly high permeability, except where the clay fraction is particularly high. Groundwater levels tend to be high, and rates of settlement are often rapid or upredictable if the materials are dewatered. Finely-graded marine sediments are an exception, and may require considerable time for settlement; this depends to a large degree on the magnitude of the load. Settlement in marine and alluvial deposits is discussed by Holt (1962).

Excavation of these materials is relatively easy using machine methods, and they have potential as soft fill. Development tends to occur on areas of alluvium, thereby reducing the use of these materials, except from offshore locations. Littoral deposits tend to occur adjacent to areas of alluvium.

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

3.1.3 *Characteristics of Colluvium*

Colluvium is a complex heterogeneous material which is highly variable in its engineering character. The distribution is described in Sections 2.3 and 2.4 and in Appendix C.1.3.

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

The South Lantau study area exhibits a large range of colluvium because it contains a variable suite of rock types including several intrusive igneous rocks and various volcanic, volcaniclastic and sedimentary representatives. An examination of Tables B10 and B11 in Appendix B, reveals that colluvial materials are less subject to surface erosion than are the insitu rocks in the study area. This may reflect the mode of origin of the material, as colluvium often occurs adjacent to drainage lines where the greater availability of water probably maintains a better protective vegetation cover. No appreciable differences are evident in the susceptibility to erosion of the different types of colluvium in the study area.

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

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

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

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

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

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

An aid to anticipating the presence of these pipes is to observe the behaviour of streams that intercept the colluvial mass. If these streams disappear underground, as can be observed on the colluvial footslopes to the northeast of Tai O, there is a reasonable chance that subterranean pipes are present.

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

Colluvium in the study area is often up to 10 m thick and is essentially unconsolidated; therefore it has some potential for use as a soft borrow material. However, these deposits usually occur at the base of steep slopes and are the result of the accumulation of landslip debris, any excavation for borrow may destabilise the adjacent terrain. Older colluvial deposits may have suitable grading characteristics for use as fill, but the younger streambed deposits, generally lacking in matrix, are probably unsuitable. Excavation by machine methods could be difficult if large boulders are encountered.

A major constraint to the use of colluvial areas is that they occur on footslope terrain with possible complex groundwater conditions which may give rise to slope instability.

In areas where elevated terrain exists adjacent to the coast and where the sideslopes pass abruptly into the coastal cliffs, stream erosion is relatively active and colluvial deposits are likely to be thin and discontinuous. Within areas of undulating upland, colluvial deposits may be more substantial, provided that erosion of the deposits by stream action is less than the rate of colluvial accumulation.

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.

3.1.4 *Characteristics of the Sedimentary Rocks*

Sedimentary rocks within the study area include the Tai O Formation and sedimentary units within the Repulse Bay Formation. Lithologies present include sandstones, silty shales and occasional conglomerates. The Tai O Formation has undergone low grade metomorphism which has produced a slight hardening of the strata, particularly within the finer-grained materials.

Very little test data is available for these sediments, however some general comments may be made. Moderate to steep natural slopes are likely to possess zones of rock outcrop amid areas of slightly deeper weathering. This is due to variations in the joint spacing and grain size of different layers within the sedimentary sequence. Weathering is likely to extend to a greater depth in the sedimentary horizons of the volcanic sequence than in the tuffs or lavas. Where conditions are favourable to the evolution of a deeper weathered mantle, sediments may be partially weathered to depths in excess of 10 m. This could occur on low gradient slopes without local stream or marine undercutting.

The bearing capacity of these rocks is reasonable for low to moderate loads, except when they are weathered. Stability is strongly controlled by discontinuities such as joints and bedding planes. When weathered, the finer-grained representatives may slake, and these may be machine excavated to considerable depth. Fresh rock, especially the coarser-grained material, may be suitable as a source of fill but is unlikely to be suitable for use as roadstone or aggregate.

3.1.5 *Characteristics of the Volcanic and Volcaniclastic Rocks*

The location and type of volcanic and volcaniclastic rocks found in the study area are discussed in Section 2.3.3 and in Appendix C.1.2. The rocks of the Repulse Bay Formation tend to have similar material characteristics except for the minor sedimentary member.

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 wide' (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. Locally, the joint spacing is very variable, often ranging from wide to narrow over distances of less than 10 m. Most exposures contain several sets of joints, each set exhibiting a range of orientations. This range is generally related to the persistence of the joints, with less persistent joints being the most variable in orientation. Joints can sometimes be seen to curve in larger exposures. Persistent joints which exist in well-defined sets tend to be fairly smooth, although they are occasionally striated. Smaller, discontinuous joints are often irregular and stepped, and are of less engineering significance. Many of the joints are steeply inclined and may result in 'unfavourable' orientations in relation to construction. Site investigations for projects involving rock cut slopes should be designed to identify and define the dominant joint sets prior to engineering design.

In these rocks, weathering tends to be relatively shallow, with average depths in the order of 8 to 10 m. The volcaniclastic rocks are generally more deeply weathered, and up to 20 m of weathered material is common. As discussed in Section 3.1.1, the depth of weathering is largely dependent on the joint spacing. Along

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 and crushed quarry rock. Often a mixture of silt, sand, gravel and cobbles. Some building waste, mine waste or sanitary fill may also be included.	Extensive planar deposits adjacent to the coast (reclamation) or as platforms and adjacent slopes (fill) in otherwise undulating terrain.	These materials placed by man have no soil (pedogenic) or weathering profile but may contain weathered rocks or be underlain by natural superficial deposits and/or a pre-existing weathered profile.	These materials are highly variable dependent on the source of fill. Generally they can be described as low fines, low plasticity granular cobbly soils. Relative density is dependent on method and degree of compactive effort. Ø ≅ 25–35°. Properties for sanitary landfill cannot be quantified.	Few problems if properly compacted. Old fill slopes may be poorly compacted and subject to failure. Steep excavations require support. High groundwater requires special drainage. Low bearing pressures can be accepted directly, high loads need raft, spread or piled foundations. Settlement problems minor except in sanitary 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 the intertidal zone, forming beaches and sandbars. Occasionally raised beaches may occur.	Nil	Generally sand sized granular material, often uniformly graded and well rounded.	Materials are usually saturated and saline. Raised beaches may be leached by rainwater but may remain saline at depth. Groundwater extraction may induce incursion of saline water. Poor grading characteristics—low fines. Low bearing pressures can be accepted directly, moderate and high loads need raft, spread or piled foundations.	Main development potential is as beaches for recreational purposes. Excavation of these materials usually prohibited.
SUPERFICIAL DEPOSITS	QUATERNARY – PLEISTOCENE?	A	ALLUVIAL DEPOSITS	Generally brownish-grey silty sand with subangular gravel. Occasionally contains cobble and boulder horizons.	Material forms broad floodplains with local fan deposits upslope. May be present more continuously as horizons interdigitated with marine muds or forming channel infill deposits.	In subaerial locations, very minor development of soil horizon. Relict deposits may be more weathered. Very old deposits may contain completely weathered boulders.	Very variable soil type which is often sandy and gravelly at its base and clayey towards its top. Clay fraction varies from 5–40% and silt 15–55%. SPTs range from 5 to 15 as depth and granular content increase. Material varies from medium to non-plastic. c′ ≅ 0–10 kPa, Ø′ ≅ 20–25°.	Locally low-lying terrain may be subject to flooding. Materials are usually saturated and of a low density – clay layers are normally consolidated. Buried channels may pose local problems of high water flows into tunnels or excavations. Steep excavations require support. Groundwater may be saline if adjacent to coast. Incursion of saline groundwater following abstraction of fresh groundwater may occur. Low bearing pressures can be accepted directly, moderate and high loads need raft, spread or piled foundations.	Land deposits easily excavated. Marine deposits often form reasonable hydraulic fill. Excavation by cutter, suction or bucket dredger.
SUPERFICIAL DEPOSITS	QUATERNARY – PLEISTOCENE?	M	MARINE SEDIMENTS	Usually dark grey silty sand or clay with traces of shell fragments, and some sand horizons, especially near shore. A mixed succession with alluvium and/or colluvium may be present.	Seabed sediments of variable thickness (0–10's of metres) below low tide mark.	Nil	Usually a soft to very soft normally consolidated soil with a high moisture content and high plasticity (LL > 50%), clay content ranges from 20–35%, silt content from 50–70%. Cu < 10 kPa, c′ ≅ 0–5 kPa, Ø′ ≅ 25°. SPT < 10 but increases with depth.	Material is poor to unsatisfactory for hydraulic fill. It is also poor as a foundation because of settlement and bearing capacity problems. Will probably be susceptible to formation of mud waves if fill is end-tipped onto it. Consolidation may be aided by wick drains and/or surcharge loading.	Easily excavated using bucket or possibly suction dredger where necessary. Sandy deposits may be used in construction but silt and clay may pose problems of disposal.
SUPERFICIAL DEPOSITS	QUATERNARY – PLEISTOCENE?	C	COLLUVIUM: SEDIMENTARY DERIVED; VOLCANIC DERIVED; GRANITIC DERIVED; MIXED	Composed of a range of materials which vary from boulder colluvium, to gravelly colluvium with clay and sand, to finer textured, gravelly sands and clay slopewash. The boulder colluvium with sand and gravel occurs on the higher sideslopes, while the gravelly sands and sandy silts and clays are to be found on the middle to lower sideslopes and footslopes. Coarse boulder colluvium exists in many stream channels.	Mainly occupies the lower sideslope and footslope terrain and may underlie much of the alluvial floodplain. Generally gently to moderately steep, broad, low, rounded dissected outwash fans and interfluves with undulating and hummocky surfaces; elsewhere irregular planar to shallow concave colluvial footslopes, leading upslope to gentle to moderately steep outwash slopes.	Colluvium can occur as independent deposits of a unique age such that one deposit overlies another. The older deposits may be subject to severe weathering and may be completely decomposed to a mottled, coloured sandy silt or clayey silt similar to the insitu residual deposits of their parent materials. The depth of such weathering may be in the order of 10 m or more.	Only very general guidelines can be given for the matrix or finer components of this variable material. MC's average 20–30%, DD varies from 1 300 to 1 700 kg/m³. Grading ranges from 2–40% clay, 10–60% silt, 40–80% sand and medium gravel. Plasticity varies from PL 22–28%, LL 28–40%. Typical shear strength values are c′ ≅ 0–5 kPa, Ø′ ≅ 29–42°. Standard compaction values: OMC ≅ 17–20%, MDD ≅ 1 630–1 750 kg/m³. CBR ≅ 3–8%.	This material has moved in its geologic past and is prone to reactivation if not carefully treated by such measures as low batter angles, drainage, and surface protection, especially when saturated. Has low to moderate bearing capacity characteristics but should always be carefully drained because it may be susceptible to failure when wet. Voids may cause settlement of roads, services and buildings. Tunnelling probably difficult. Site investigation is 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 bouldery stream deposits will be of limited use. Large boulders may require blasting or splitting.
BEDROCK	UPPER JURASSIC – INTRUSIVE IGNEOUS ROCKS – DYKE ROCKS	Pq	QUARTZ PORPHYRY	Grey to greenish-grey when fresh, weathers to a pale pink. Fine groundmass with up to 20% large phenocrysts of quartz and minor feldspar.	Generally occur as linear structural features transecting the volcanic and granite units. May be of slightly depressed or elevated topographic form due to variable resistance to erosion compared to country rocks. This geological structure often controls local surface runoff and may act as loci for subsurface water concentration.	Generally weathers faster than volcanic rocks but slower than granitic rocks. Develops a thick reddish soil. Weathering depths are generally in the range 7–15 m.	No laboratory information available. Weathered mantle should contain coarse quartz sand along with silt and clay. Fresh rock parameters should be similar to granites.	Surface hydrology can be affected by these rocks with drainage networks aligning with the strike of the dykes. Subsurface hydrology and foundation levels will be affected by the variable rockhead.	Restricted extend precludes deliberate borrow or quarry activities. May be suitable as aggregate when fresh. Excavation conditions may be difficult and expensive.
BEDROCK	UPPER JURASSIC – INTRUSIVE IGNEOUS ROCKS – DYKE ROCKS	La	FELDSPAR PORPHYRY	Grey to greenish-grey. Fine-grained groundmass with up to 20% large (8–10 mm) phenocrysts of feldspar.			Little laboratory information available. Parameters should be similar to granite but with a higher proportion of clay.		
BEDROCK	UPPER JURASSIC – INTRUSIVE IGNEOUS ROCKS – PLUTONIC	Mo	QUARTZ MONZONITE	Grey to pinkish-grey, fine to medium-grained, porphyritic, strong acid plutonic igneous rock. Phenocrysts are plagioclase. Generally displays wide rough joints.	Dissected essentially planar-concave terrain with moderately broad ridgecrests.	Shallow to deep residual soil over moderately weathered rock. Corestones extensive.	Coarser grained fresh rock has an unconfined uniaxial compressive strength of 100–150 MPa and a DD of 2 600–2 750 kg/m³. Point Load, Is (50) ≅ 5–8 MPa.	Relatively unknown rock type, comments as for granites but more care required with weathered materials because likely to be slightly more clayey. Several troublesome case histories noted.	Material can be scraped for borrow when weathered. Fresh rock must be blasted. Not often used for aggregate, but after testing to establish characteristics should be satisfactory. Should have good asphalt adhesion characteristics.
BEDROCK	UPPER JURASSIC – INTRUSIVE IGNEOUS ROCKS – PLUTONIC	G	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.	Generally moderately weathered rock in the order of 10 m thick. Upper weathered zone porous and permeable.	As for the other granitic rocks.	Stability of the weathered material can be suspect, i.e. Zones A & B, where soil type failures may occasionally occur. Insitu material is prone 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.
BEDROCK	UPPER JURASSIC – INTRUSIVE IGNEOUS ROCKS – PLUTONIC	FL	FAN LAU PORPHYRITIC GRANITE	Pale pink, fine-grained groundmass with phenocrysts of feldspar and quartz making up about half of the rock. Euhedral feldspars commonly exceed 10 mm in length; quartz usually occurs as large pools of intergrown crystals.	Small outcrops at Fan Lau form low, rounded hills and coastal cliffs.	Moderate to deep weathering on ridgecrests and slopes protected from erosion. Shallow weathering on rocks exposed to wave erosion. Soils contain large percentage of coarse quartz sand.	No laboratory information available. Parameters should be similar to the other granites.		

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

Type	Age	Symbol	Map Unit		Map Unit	MATERIAL DESCRIPTION: General Lithological Description	MATERIAL DESCRIPTION: Topographic Form	MATERIAL DESCRIPTION: Weathering and Soil Development	EVALUATION OF MATERIAL: Material Properties	EVALUATION OF MATERIAL: Engineering Comment (Stability, Foundation, Hydrogeology)	EVALUATION OF MATERIAL: Material Uses and Excavation Characteristics
BEDROCK	UPPER JURASSIC	MS	INTRUSIVE IGNEOUS ROCKS (PLUTONIC)		MA ON SHAN GRANITE	Grey to pinkish-grey fined-grained porphyritic strong granite. Phenocrysts are quartz and feldspar. Generally displays smooth tectonic joints.	Forms extensive areas of moderate relief, broad convex hillcrests are common. Occassionally occurs as steep to precipitous terrain. Drainage is dendritic in nature although structural control may dislocate the general pattern. Sheet and gully erosion are 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^3 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, ϕ' ≅ 32–40°. Strength characteristics of fresh rock are dependent on joint strength as unconfined compressive strength is 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, ϕ' ≅ 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 occassionally occur. Insitu material is prone 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.
		CC			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.					
		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 a coarse-grained matrix. Matrix minerals are potassium feldspar, plagioclase, biotite and minor quartz. Xenoliths are common. Jointing is similar to granite in that rough sheeting joints and widely spaced tectonic joints are present.	Forms 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.	No test data available for study area but decomposed granodiorite has the following general properties: DD ≅ 1 300–1 700 kg/m^3, clay content 2–8%, silt 30–55%, sand 40–60%, MC ≅ 15%–35%. Plasticity varies from non plastic to PL 27–37%, LL 40–50%. c′ ≅ 0–14 kPa, ϕ' ≅ 33–43°. Standard compaction values: OMC 16–22%, MDD 1 690–1 780 kg/m^3, CBR ≅ 8–20%. Fresh granodiorite has an unconfined compressive strength of 125–175 MPa and a DD of 2 600–2 700 kg/m^3. Point Load Is(50) ≅ 6–9 MPa.	Relatively unknown rock type in study area, comments as for granites but a little more care required with weathered materials because they are likely to be 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 asphaltic concrete.
	LOWER TO MIDDLE JURASSIC	RBs	SEDIMENTARY, VOLCANICLASTIC AND EXTRUSIVE IGNEOUS ROCKS		SEDIMENTARY AND WATER-LAID VOLCANICLASTIC ROCKS	Generally 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. Conglomerates also found.	Forms areas of moderate relief to west of Shek Pik Reservoir.	Shallow to moderately deep, reddish to brown, fine, sandy to silty clay i.e. residual soil sometimes with ferruginous gravel and weathered rock fragments, overlying completely to highly weathered rock which grades into less weathered strongly jointed volcanic rock at depths from 5–20 m.	No test data available but likely to be variable, dependent on individual stratigraphic unit.	The sediments are bedded and fissile and weather relatively rapidly, when exposed, to a grey silt. Some stability problems may arise. Groundwater regime may be controlled by the bedded character of the rock.	Can be scraped and ripped when weathered. Fresh rock will need pneumatic machines or blasting. Due to highly variable properties and presence of chert bands, this material would not make a good source of aggregate but is well suited for filling. Scarn mineralisation with magnetite has been mined.
		RBv		REPULSE BAY FORMATION	ACID LAVAS	Dark green or bluish-grey, fine-grained with light phenocrysts, banded, strong rhyolite. The rock often displays closely spaced smooth joints.	Forms areas of moderate relief, rock outcrops common. Thin beds often forming prominent rises on hillsides.	Rock usually develops a thin (< 1 m) soil horizon and a thin (< 10 m) weathered zone before passing rapidly into moderately to slightly weathered bedrock.	No laboratory results available but should be similar to other volcanics as below.	Stability of weathered material and also of highly jointed rock masses may be suspect, especially during or immediately after prolonged heavy rainfall. Failures are quite common, especially in over-steepened slopes. Rapid surface runoff is common. Stability of rock slopes controlled by relatively closely spaced discontinuities in moderately weathered to fresh rock mass. —Few opportunities for creation of platforms; usable sites may be small and fragmented, —Access route selection hampered by terrain, —Tunnelling probably easier than in granitoids. Deep weathering and close jointing should be anticipated near structural geological lineaments.	Very hard and abrasive when fresh, will require blasting which may result in brittle fracture. Inadvisable for aggregate unless tested for silica/cement reaction.
		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.					
		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 peaks with deeply dissected slopes forming a system of subparallel ridges and spurs. Crests are narrow and sharply convex with steep to very steep valley slopes. Rock outcrops are common on the upper slopes.	Rock usually produces a thin (< 1 m) soil horizon, followed downwards, especially on lower slopes, by yellowish brown sandy completely weathered material overlying less weathered, locally strongly jointed rock below an average depth of 11 m. On steep, high slopes considerable rock exposure with thin soil or weathered mantle occurs.	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, ϕ' ≅ 30–35° Fresh rock properties are approximately as follows: Unconfined compressive strength ≅ 150–250 MPa. Joint strength parameters are c′ ≅ 0 kPa, ϕ' ≅ 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.		Material can be used for fill if it is weathered locally. It is possible to quarry, although very hard and not generally favoured. Coarse crystal tuff horizons may provide good aggregate.
		RBp			DOMINANTLY PYROCLASTIC ROCKS	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.					
		RB			UNDIFFERENTIATED VOLCANIC ROCKS	Rock types not mapped in detail by Allen & Stephens (1971), but probably similar to the above volcanic units.					
		T	SEDIMENTARY ROCKS		TAI O FORMATION	Lower beds are black silty shale, white orthoquartzite, black and white siltstones, purple sandy siltstones and some graphitic sandstone. Upper beds include massive white fine-grained orthoquartzite and very fine-grained micaceous sandstone interbedded with siltstone.	Occurs on footslope and sideslope terrain forming relatively dissected relief. Incision is evident along drainage lines. Terrain is essentially planar-convex in morphology, broad convex spurs are common.	Generally moderately deep (5–10 m) uniform or gradational, red to red-brown residual clayey 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. May break down to silt if weathered material is over-compacted.	Restricted outcrop precludes extensive usage. 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
ϕ' —effective angle of internal friction—°—degree
Cu —undrained shear strength—kPa—kilopascal
OMC —optimum moisture content—kg/m^3—kilograms per cubic metre
MDD —maximum dry density—kg/m^3—kilograms per cubic metre
DD —dry density—kg/m^3—kilograms per cubic metre
CBR —California Bearing Ratio—%—percent
Is (50) —point load strength index—MPa—megapascal
LL —liquid limit—%—percent
PL —plastic limit—%—percent
MC —moisture content—%—percent
SPT —standard penetration test value
≅ —above equal to

geological photolineaments (shown on the Engineering Geology Map) very close jointing may be encountered which locally depresses the weathering profile. This effect increases the erodibility of the material by streams. These streams tend to preferentially follow such lines of weakness, and can be seen on aerial photographs as lineaments.

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 content of these rocks when in their partially decomposed form, tends to reduce the incidence of erosion, even though they may occur on steep slopes. The GEOTECS data given in Tables B10 and B11 at Appendix B and Figure 11, indicates that the Repulse Bay Formation rocks are only moderately affected by erosion. With the exception of the Coarse Tuffs which are exposed on the low gradient slopes adjacent to Cheung Sha, and the Acid Lavas which outcrop on the undulating uplands between Ngong Ping and Fan Lau, the volcanic rocks show a high incidence of instability. The morphological forms associated with slope failure in decomposed volcanic rock are similar to those in colluvium; namely, they are characterised by small landslip scars with extensive debris trails (Plates 6 & 7), and a large length to width ratio.

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

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

Site investigations in the volcanic rocks should be designed to determine the depth and degree of weathering, the frequency and orientation of jointing, and the position and seasonal fluctuations of the water table. The Standard Penetration Test can be a useful indicator of the depth of successive zones of decomposition of the rock mass. Direct shear tests on the discontinuities of Zone C/D rocks, and direct shear and triaxial tests on Zone A/B rocks, can be used to determine the shear strengths of the 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.

3.1.6 *Characteristics of the Intrusive Igneous Rocks*

The intrusive igneous rocks that underlie much of the urbanised portion of the study area are of similar origin, and consequently they 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). The distribution and lithology of the intrusive igneous rock types is discussed in Section 2.3.4.

Amongst these rocks, a division can be made between dyke rocks and those occurring as large intrusive bodies. The dyke rocks are generally of limited width, although they may cause localised variations in weathering depths and groundwater conditions. Usually they are not of great engineering significance except when they occur as a dyke swarm. In this case, rapid local variation in ground conditions may result in a complex piezometric surface.

The various granite intrusions tend to have similar jointing patterns. Joints in these rocks generally range from medium to very widely spaced but tend to be widely spaced overall. Two distinct joint groups are present: sheeting joints and tectonic joints. The sheeting joints tend to be rough and wavy, orientated subparallel to the topography, and spaced at about 1 to 3 m intervals. They are best developed near the surface. Tectonic joints are generally orientated normal to the sheeting joints. They are usually 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 with 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); only a summary is presented here.

As stated in Section 3.1.1, there is an extremely wide range of weathering depths of intrusive igneous rocks within the study area. In general, for similar types of 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 and this, 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 of which depends on the original rock type. Weathered monzonite and Tai Po Granodiorite have higher concentrations of clay compared with other members of this group apart from the dolerite. This is probably 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 Figures 11 and in Tables B10 and B11 indicate relatively high levels of erosion within the intrusive igneous rocks when compared with the other rock types, although there also appear to be significant differences between the individual intrusive rocks. When exposed during excavation, the Tai Po Granodiorite appears susceptible to erosion. This may be due to the dispersive properties of the clays and the grain size distribution of the weathered material.

In general, slope instability associated with these rocks is not as extensive as in the colluvial and volcanic materials. Landslips generally occur as small rotational failures or washouts in the thick residual soils, perhaps with some influence of clay-covered relict joints. Joint-controlled failures occur in more competent rock. Length to width ratios are generally 1 to 2:1. Quartz Monzonite is noted in other parts of the Territory, as prone to instability. This is possibly due to its higher clay content when weathered, and a lower angle of shearing resistance than the other granitic rock types. In the South Lantau area, the outcrops of the Quartz Monzonite are restricted to areas of low, undulating relief and do not show a significant degree of instability.

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. During construction artificial lowering of groundwater can also adversely affect steep cuttings and predicted settlements. A further problem for the construction of deep foundations or trench excavations below the groundwater table is the potential for piping within the coarse-grained, loose or medium dense decomposed granite. This may lead to problems with bored piles and other foundation problems.

Site investigations in the granite should identify weathering grades as well as the nature and orientation of joints. Standard Penetration Tests (SPT) can give useful information in those materials which are 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, because 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 the shear strength of discontinuities. In Zone A or B, the strength and compressibility of the intact, decomposed materials are more important, and these should be investigated by appropriate laboratory tests.

This group of rocks is extensively used for construction materials. 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. The unweathered granitic rocks are generally favoured as a source of aggregate, because of the ease of crushing and the morphological characteristics (Brand et al, 1984). Quartz Monzonite has a lower quartz content than the other granitic rocks within the study area, and may be suitable as a source of roadstone because of favourable asphalt adhesion properties.

Feldspar porphyry and quartz porphyry dyke rocks form a minor unit within the suite of intrusive igneous rocks of the study area. These rocks are characterised by areas of slightly subdued relief with weathering depths between 7 and 15 m. Few diagnostic properties are available, although weathering, jointing, discontinuity and material characteristics are similar to those of the granites. Depth to rockhead, permeability and strength properties, are extremely variable within the dyke swarm. This is due to the close proximity of different rock types and local variations in the degree of jointing and grain size of individual lithologies.

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

4. GEOTECHNICAL ASSESSMENT FOR PLANNING PURPOSES

4.1 Geotechnical Limitations and Suitability for Development

4.1.1 *Introduction*

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

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

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

4.1.2 *Land with Low to Moderate Geotechnical Limitations*

Within the study area, there exists a relatively small area (204 ha) with low geotechnical limitations and approximately 2 613 ha with moderate geotechnical limitations. Terrain with low to moderate limitations (GLUM Classes I & II) forms 37.2% of the study area. Some 3.8% of the GLUM Class I & II terrain is developed and 2 711 ha of the GLUM Classes I & II terrain is substantially undeveloped.

Land with a low degree of geotechnical limitation 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; however in certain situations, foundation conditions could be more complex than for GLUM Class I. Nevertheless the 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, and insitu terrain of moderate steepness, or flat or gently sloping alluvial terrain. Areas of reclamation are also included in GLUM Class II.

The major areas of GLUM Classes I & II terrain outside the developed parts of the study area are discussed in the description of potential development areas in Section 4.2.

4.1.3 *Land with High Geotechnical Limitations*

Approximately 23.9% (1 814 ha) of the study area has a high level of geotechnical limitation (GLUM Class III) and of this, some 2.7% is currently developed.

GLUM Class III terrain is expected to require intensive geotechnical investigation, and the costs associated with site investigation, site formation, foundation and drainage work will probably be high. Typical GLUM Class III land is steeper than 30° on insitu terrain without evidence of instability, and is 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 and these would need to be determined during site investigation.

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

4.1.4 *Land with Extreme Geotechnical Limitations*

Approximately 35.1% (2 666 ha) of the area is classified as GLUM Class IV. This terrain should not be developed if alternatives exist. Only 10 ha of this class occurs within areas of existing development.

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

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

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

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

4.2 Potential Development Areas

4.2.1 *General Planning Considerations*

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

From a geotechnical viewpoint, land with potential for development should generally be free of constraints. Engineering design should ideally be unhindered by geotechnical limitations. Within the South Lantau study most of the terrain is undeveloped and occurs within Country Park and Water Supply Catchments. These artificial constraints are noted, but are not used to exclude areas that have potential from a geotechnical point of view based on their natural terrain attributes.

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

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

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

The GLEAM identifies 19 areas within the study area which have potential for development from a geotechnical point of view. This represents approximately 1 700 ha or 22% of the total area. The areas range in size from about 45 ha up to 220 ha. They occur on different types of terrain, which are not necessarily suitable for the same type of development.

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

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

4.2.3 *Development Opportunities*

There are 19 areas within the study area which have potential for development from a geotechnical point of view. These areas constitute approximately 1 700 ha of land.

Area 1 *Chi Ma Wan Peninsula* (65 ha approx.) This peninsula consists of dissected upland terrain with low to moderate relief and narrow valleys. Many of the ridgecrests and spurlines are narrow and subject to moderate to severe erosion. Slope gradients are frequently greater than 30°. Many of the sideslopes have large areas of bedrock outcrop and are prone to landslips and rock or boulder falls. Areas of broad ridges and sideslopes less than 30° exist in the northern and eastern parts of the peninsula.

Many of the valleys are stucturally controlled, and there is a strong east northeasterly trend resulting from the many feldspar porphyry dykes that have intruded the granitic rocks. Potential for aggregate production exists, particularly where there are fewer dykes. Soft borrow may be won from the more deeply weathered terrain.

Favourable terrain for platform development occurs in the northeast and east of the peninsula and on the alluvium and colluvium of Tai Long Wan and Mong Tung Wan. These could be expanded by reclamation.

Area 2 *Lai Chi Yuen Tsuen to Shap Long San Tsuen* (220 ha approx.) Undulating upland terrain of moderate relief with narrow, colluvium/alluvium-filled, structurally controlled valleys, exists to the north of the floodplain at Shap Long San Tsuen. Slope angles are generally less than 30° and significant areas of hillcrest and sideslope are less than 15° in gradient.

Landslips are restricted to a few locally steep inland slopes and to the generally steeper terrain along the coast. Boulders exist in significant numbers on many of the slopes but only present a hazard in a few locations where steeper slopes occur above terrain of low slope gradient.

Geologically, the area is dominated by feldspar porphyry dykes, the larger quartz monzonite intrusions and the older granitic and volcanic rocks. This area is therefore lithologically complex and is unlikely to be a suitable site for aggregate production, but the rocks are generally moderately deeply weathered and may be suitable for soft borrow.

The existing areas of low, valley floor terrain could be expanded by reclamation, particularly near Ngau Kwu Wan and Shap Long San Tsuen. Moderately sized platforms of 3 to 5 ha could be formed with shallow stripping of the sideslope and rolling hillcrests. Stepped platforms could be constructed on the adjacent 15 to 30° sideslopes. Access to the upland terrain could be constructed from the existing South Lantau Road.

Area 3 *Pui O and Ham Tin* (50 ha approx.) Large colluvial fan deposits form footslopes adjacent to a wide alluvial floodplain. Superficial deposits are very thick and are prone to high, fluctuating groundwater conditions. Filling is necessary on the floodplain to minimise the flood risk. Moderate to large settlements can be expected on the alluvial deposits which are more than 15 m thick in places.

Storm discharges in the rivers may contain large quantities of boulders and other landslip debris, particularly in the main channel at Lok Uk Tsuen.

Area 4 *Mau Yuen* (50 ha approx.) Several broad mid-slope spurs possess moderate potential for platforms, with access from South Lantau Road. Rock which is at least moderately decomposed may be greater than 5 m thick along spur lines.

Volcanic rocks are not generally considered favourable for aggregate, but they could be crushed and used as fill for platform expansion.

Area 5 *Cheung Sha Lowlands* (105 ha approx.) Low hills and shallow valleys to the west and east of the Cheung Sha headland provide potential for expansion of existing development. Many of the footslopes possess a colluvial mantle, generally up to 5 m thick, at a gradient of less than 15°. High groundwater tables may occur. The larger rivers may transport large boulders derived from landslips on the steep slopes to the north. Colluvial deposits, and moderately decomposed volcanic rock from the footslopes and lower sideslopes, could be used for soft fill.

Significant potential exists for the formation of small and moderately-sized stepped platforms. Larger platforms with deeper cuts would require excavation into bedrock.

Area 6 *Tong Fuk* (60 ha approx.) Alluvial terrace and floodplain lowland terrain have good development potential, particularly if the main river is controlled. Colluvial valley floor terrain to the north of a constricted section of valley could be used either for platforms or as a source of soft fill. Adjacent sideslope benches may also provide some potential for platform development.

Volcanic rocks in this area are moderately decomposed to depths of 2 to 5 m, but the fresh rock is not generally used for aggregate within the Territory. Cutting of the spurs could provide fill for raising the level of the floodplain.

Area 7 *Lo Kei Wan Peninsula* (80 ha approx.) Undulating hills of low to moderate relief with thick bouldery soils, have development potential. Large areas of hillcrests and sideslopes of less than 30° exist, together with many small areas sloping at less than 15°. Instability is mainly restricted to the steep coastal slopes; but because of the very bouldery terrain, the hazard of falling boulders is much more widespread.

Strong north northeasterly structural control of the quartz monzonite bedrock may affect the groundwater regime. Highly and completely decomposed rock is generally up to 10 m thick, giving good potential for soft fill which could be used for reclamation of the very shallow Tong Fuk Miu Wan.

Area 8 *Shui Hau* (90 ha approx.) A wide floodplain containing thick alluvium exists to the south of several gently sloping, broad spur crests which are separated by short, moderately steep slopes.

Volcanic rocks are at least moderately decomposed to depths generally between 5 and 18 m. This material has the potential to provide large quantities of soft fill.

Spur crests have excellent potential to provide wide plaforms or gently-stepped terraces, with surplus material being left available for fill on the alluvial floodplain or for reclamation in Tong Fuk Miu Wan.

Area 9 *Upper Shek Pik Catchment* (110 ha approx.) The northern and western slopes of the reservoir catchment consist of gently to moderately sloping sideslopes, footslopes and colluvial fan terrain. This area could be affected by minor landslips on adjacent steep slopes, the effects of which are likely to be concentrated along drainage lines.

Volcanic and sedimentary rock are at least moderately decomposed to depths usually exceeding 5 m, and they are prone to erosion if unprotected.

The western slopes have been extensively used as a borrow area for the construction of the Shek Pik Reservoir dam, and downstream, for reclamation and filling. Development of this area could eliminate many of the oversteep slopes that remain as a result of this borrowing and quarrying.

The main restriction on development is that this area lies within the catchment for the Shek Pik Reservoir. The provision of access to the northwestern parts of the PDA, which are not currently served by a road, would not present any significant problems however.

Area 10 *Ngong Ping* (100 ha approx.) This area includes an upland plateau with extensive alluvial cover, together with several small hills. Some constraints result from possible landslips and boulder falls from the mountainous sideslopes to the east.

The volcanic and sedimentary rocks of the plateau and low hills, are moderately decomposed to depths generally exceeding 5 to 8 m. Borrow potential may be limited by the generally low relief and slope gradients.

Although access exists to the plateau, this traverses a steep slope. Also the area is remote from other centres of population.

There is some potential for development of the broad spurs and ridgecrests to the north of the Ngong Ping plateau. Long access routes across moderately steep sideslopes would be required. This area is marked as 10A on the GLEAM.

Area 11 *Sham Wat* (60 ha approx.) The very shallow bay of Sham Wat lies between three valleys which could be linked by reclamation. The northeastern valley of Nam Tin could be developed in conjuction with San Shek Wan and possibly Sha Lo Wan which lies to the north, within the GASP VI North Lantau area. The southern valley contains a narrow strip of alluvial floodplain constrained by adjacent steep sideslopes that are prone to landslips. To the south, the alluvial floodplain passes into a gentle colluvial slope and a low spur of moderately decomposed volcanic and volcaniclastic rocks. The northwestern end of the Sham Wat valley catchwater traverses a high level colluvial slope and adjacent spur. This spur possess moderate development potential.

The volcanic and volcaniclastic bedrock of this area is usually only moderately decomposed to depths of 2 to 4 m. The sediments of the Tai O Formation which outcrop along the coast have been slightly hardened by metamorphism and hydrothermal activity.

Access to this area is feasible by upgrading the existing road. Reclamation of the shallow bay, using colluvial fill from the large fan deposits may be a development option.

Area 12 *Eastern Tai O Uplands* (60 ha approx.) Approximately 1.5 km to the east of Tai O, an area of undulating uplands presents significant potential for development; however, it is constrained by difficult access and by the overall remoteness of western Lantau. Small hillcrests above the general level of this upland are separated by shallow depressions containing thin colluvial deposits. Although the steep slopes around the margins of this upland are prone to landslips and boulder falls, within the uplands themselves, there is little evidence of boulder-threat or slope instability.

The tuffs of this area are likely to be at least moderately decomposed to depths of up to 5 m. With crushing, these rocks could be used with the excavated soil to create stepped platforms. Access could be provided by traversing the sideslopes to the east of Luk Wu.

Area 13 *Tai O* (60 ha approx.) Already partially reclaimed, the alluvial flats and shallow bay possess potential for further reclamation. The lowland terrain is covered by more than 20 m of alluvium and marine deposits, possibly overlying 5 to 15 m of completely and highly decomposed volcanic rock.

Large settlements can be anticipated if loads are placed upon soft, compressible material.

Sources of soft fill could be won by excavation in PDA's 12, 13, 14, 15 or 16, or transported by barge from more distant areas. Locally, the colluvial slopes to the east and south of Tai O could provide large quantities of soft material. Smaller quantities could be won from the colluvial coastal slopes to the northeast.

Area 14 *Keung Shan Valley* (160 ha approx.) This area includes shallow valleys and low hills. It includes the extensive sideslopes of gentle to moderate gradient of the Keung Shan valley, which rise gradually eastwards to the undulating hillcrest and spur crest terrain around the junction of the Tai O and Ngong Ping roads.

Volcanic and volcaniclastic rocks of this area vary from Grade II to III on the steeper sideslopes at the margins of the area. Over 5 m of moderately decomposed volcanics occurs on the low hills and spurs. Colluvial and alluvial deposits along the valley floors may be up to 5 m thick and have usually been formed into agricultural terraces.

Landslips and boulder falls are only a constraint on and below the steep sideslopes around the southern perimeter of the PDA.

The terrain is suitable for either the creation of multiple, small, stepped platforms requiring only a small amount of cutting and filling, or, if large scale borrowing and crushing is undertaken, large platforms can be created with the surplus fill for use outside the area.

Area 15 *Man Cheung Po to Ling Wui Shan Upland* (210 ha approx.) This upland consists of a large area of undulating terrain dissected by the upper sections of several river valleys. Hillcrests generally rise 20 to 60 m above the general level of these uplands and most of the slopes are between 15° and 30° in gradient.

The volcanic, volcaniclastic and sedimentary bedrock is generally moderately decomposed only to shallow depths. Landslip and boulder falls are common on the steep slopes around the margins of this upland area.

Platform development would require extensive blasting as the soils are unlikely to be sufficiently thick to allow large scale ripping.

The provision of access would be difficult, involving long traverses of steep sideslopes on the southern side of the Keung Shan valley.

Area 16 *Shui Lo Cho to Yi O Kau Tsuen* (50 ha approx.) The Yi O villages occur around a narrow alluvial floodplain adjacent to a shallow bay. A large colluvial fan deposit to the east of the floodplain could be utilised as a source of fill for the lower parts of the floodplain and for reclamation.

Road access would require reclamation of a coastal strip or a traverse across steep sideslope terrain near Nga Ying Kok.

Development of this area would probably favour specialised uses.

Area 17 *Tsin Yue Wan to Fan Lau* (60 ha approx.) A small hill to the south of Tsin Yue Wan could provide a source of rock fill for reclamation and platform development. Only shallow thicknesses of at least moderately decomposed material are expected, although shortfalls in soft fill could be supplemented by excavation into the colluvial fan deposits to the east of Tsin Yue Wan. Development on the very gently sloping superficial deposits at the neck of the Fan Lau Peninsula is also possible, but, as with the other remote sites in southwest Lantau, the area would be more suited to specialist uses.

Area 18 *South Ling Wui Shan* (65 ha approx.) Two areas of moderately sloping, dissected sideslopes have some potential for use as borrow areas. The volcanic and volcaniclastic rocks are likely to be moderately decomposed to depths of 1 to 5 m, but the rocks are generally closely or very closely jointed. Steep haul roads would be required.

Area 19 *Tai Long Wan Tsuen to Tung Wan* (45 ha approx.) The floodplain and adjacent reclamation to the south of Shek Pik dam has been largely developed; however, the adjacent valleys to the east and west possess potential for additional development.

Tai Long Wan Tsuen is located on the side of a bowl-shaped valley. There are extensive colluvial deposits on the valley sides, and alluvium in the valley floor. The access road to the east of Tai Long Wan Tsuen crosses a gentle slope with a thin colluvial mantle which also has some potential for development. The sideslopes surrounding this valley show small-scale landslip activity.

To the southeast of Shek Pik Prison, the flat alluvial valley floor of Tung Wan has considerable potential for development. Tung Wan can easily be connected to Shek Pik by extending the reclamation of the shallow bay. This valley is surrounded by steep sideslopes which show some evidence of shallow landslip activity. The alluvium in the valley floor is likely to interdigitate with coarser colluvium.

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) *Geology, Erosion and Instability*
Figure 11 is GEOTECS Plot showing the distribution of sheet, rill and gully erosion, and instability on the four main geological units. This could be used for a preliminary assessment of the rate of reservoir sedimentation or to provide landscape managers with an indication of areas requiring monitoring or investigation to prevent soil loss.

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

Approximately 1 000 ha of undesignated natural terrain has potential for quarry sites. A further 4 200 ha with potential for quarrying occurs within existing Country Parks or areas under cultivation. These figures indicate that many options exist, but the number of options would be reduced when rock type is specified.

5. CONCLUSIONS

The findings reached during the South Lantau 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 2 950 ha of the terrain (38.9%) is associated with or affected by instability. Instability is associated with most of the geological materials. Slope failures in the colluvium and volcanics are generally characterised by small landslip scars with extensive debris trails. In the case of volcanic rocks, this is probably due to the relatively steep slopes on which failure occurs. Landslips on the intrusive igneous rocks are also common, but tend to be relatively small rotational or joint-controlled failures, often associated with cut slopes. Slope failures in intrusive igneous rocks usually cause less impact on the terrain than failures in volcanic rock or colluvium.

(*b*) The geology of the area is complex, and several aspects require careful investigation. Weathering depths vary according to bedrock lithology, with very deep weathering occurring in some granitic areas. The competition from alternative land uses restricts the future excavation of borrow and rock materials. There are numerous photolineaments present, many of which are likely to be faults, shear zones, major joint zones or dykes. Surface erosion is more pronounced on the granitic terrain than on the volcanics.

(*c*) Approximately 796 ha of the footslope terrain is covered by extensive colluvial deposits; 10.4% of the colluvium is affected by instability. Significant geotechnical limitations should be anticipated on runoff zones and where surface drainage crosses the colluvium. These areas occupy some 37% (294 ha) of the generally low angle colluvial footslope terrain.

(*d*) The volcanic terrain has a lower proportion of GLUM Classes I & II (38.7%) than the intrusive rocks (48%). Of the 796 ha of colluvial terrain which occurs within the study area, some 96.4% is subject to high to extreme geotechnical constraints (GLUM Classes III & IV).

(*e*) Approximately 19.4% of the study area is characterised by slopes which have gradients between 0 and 15°. A further 75.8% of the terrain has slope gradients between 15 and 40° and 4.8% is steeper than 40°.

(*f*) Within the South Lantau study area, surface erosion is more pronounced on the weathered intrusive igneous rock terrain than on terrain with colluvium or volcanic bedrock. However, some areas of weathered volcanic rocks are affected by soil erosion.

(*g*) Intrusive igneous rock terrain is often suitable as a source of borrow, and the unweathered bedrock is generally suitable for aggregates. Volcanic rock terrain could also be considered for extractive uses. Sedimentary rocks are unlikely to be suitable as aggregates, but may be useful as a source of soft fill.

(*h*) Reclamation and other developments are of a minor nature in the study area because the emphasis is on recreational land use. Only 2.7% (200 ha) of the study area is currently developed. Shek Pik Reservoir is not included in this figure.

Squatters occupy only a minor part of the study area and are mainly located in non-designated villages.

(*i*) Country Park occupies approximately 5 732 ha (75.6%) of the study area, with only 17.8% (1 355 ha) being undisturbed and undeveloped natural terrain. Water Supplies Department catchment zones occupy a relatively large proportion of the study area, most of which occurs within Country Park.

5.2 Land Management Associated with Planning and Engineering Feasibility

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

(*b*) Opportunities do exist for urban expansion in the study area, 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 19 areas which have overall potential for development from a geotechnical point of view. These represent a total of 1 700 ha or 22% of the terrain. Some areas of GLUM Class III, and possibly Class IV terrain occur within these areas, but an integrated approach to planning and engineering design should minimize the hazard of slope failure.

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

(*d*) This study indicates that there is 7 289 ha of currently undeveloped terrain, which also includes small areas of cultivation, unused reclamation and temporary land uses, as well as the undisturbed natural terrain. Only 1 557 ha of undeveloped terrain occurs outside the Country Parks, of which GLUM Classes I & II occur on some 42.1% of the terrain, and 755 ha is associated with high to extreme geotechnical limitations (GLUM Classes III & IV). There is approximately 5 732 ha of land within the Country Parks and, of this figure, 2 056 ha is classified as either having low or moderate geotechnical limitation (GLUM Classes I & II).

(*e*) Physical land resources are considered a 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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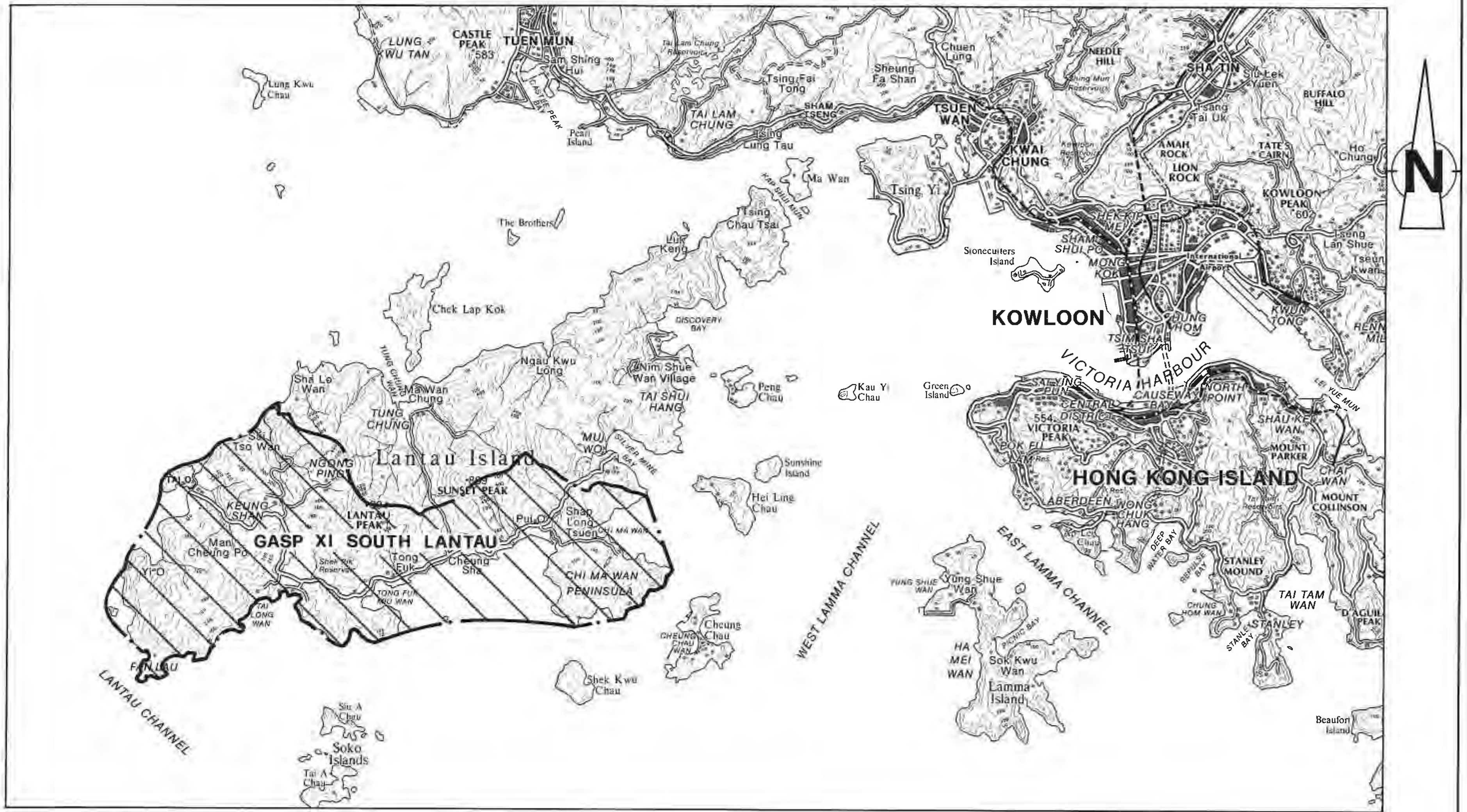
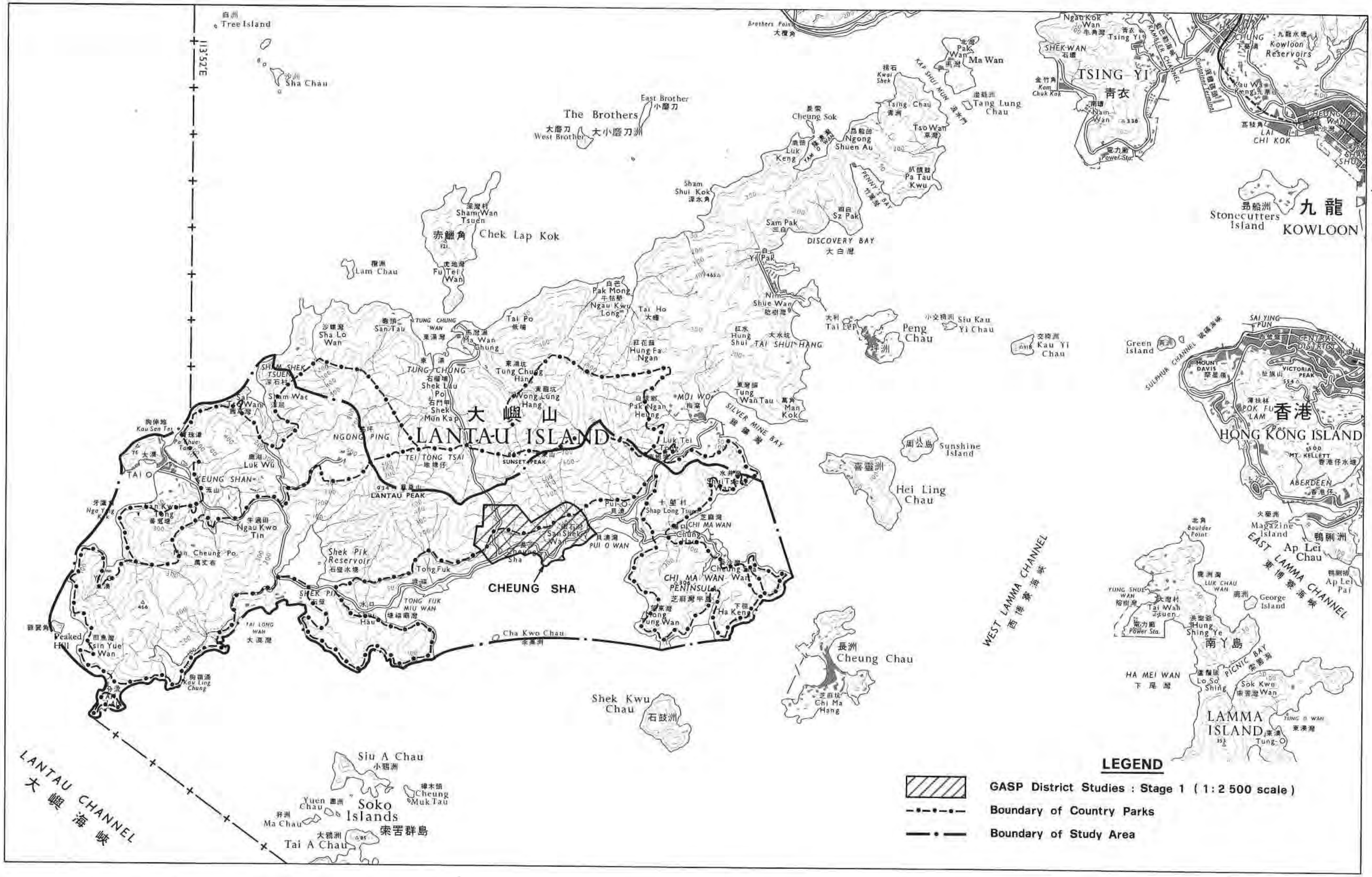
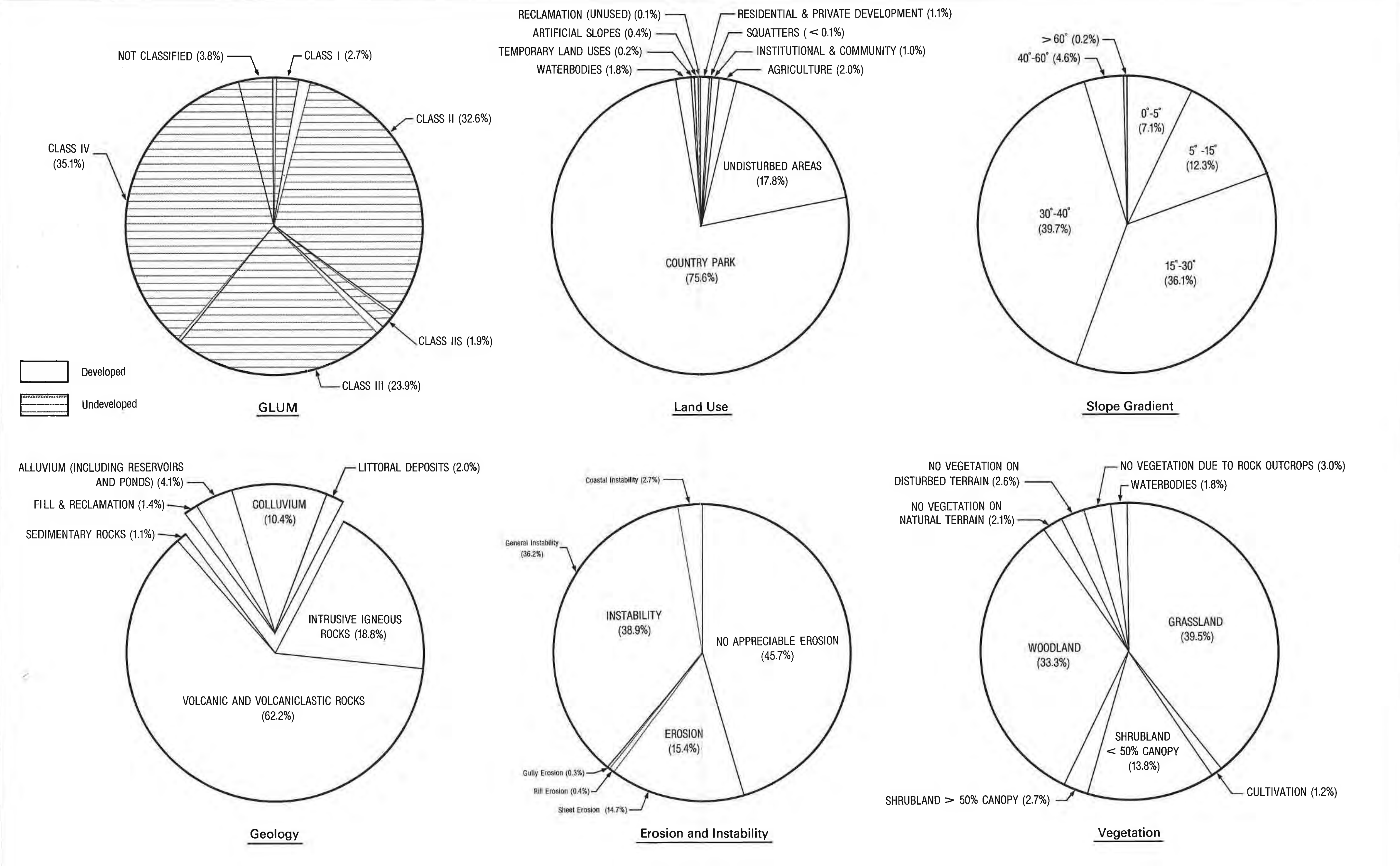


Scale 1:200 000	Location Map of the South Lantau Study Area	Fig. 1

Scale 1:100 000	Aerial Photomosaic of the South Lantau Study Area	Fig. 2



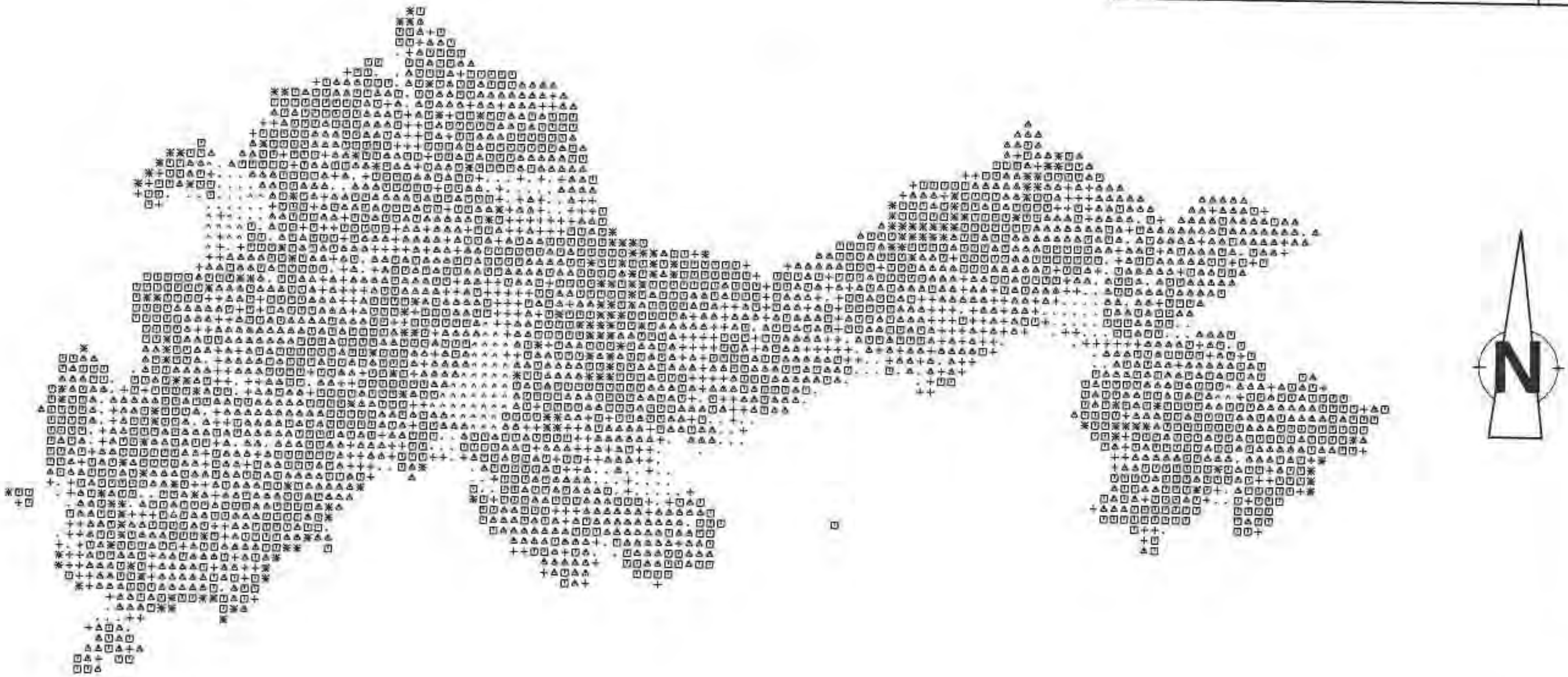
Scale 1:100 000	South Lantau Study Area	Fig. 3



Pie Charts of Selected Attributes of South Lantau

Fig. 4

SYMBOL	MEANING	%TOTAL
·	SLOPE ANGLE < 5°	5.4
+	SLOPE ANGLE 5-15°	12.3
△	SLOPE ANGLE 15-30°	36.1
□	SLOPE ANGLE 30-40°	39.7
✳	SLOPE ANGLE >40°	4.8
^	RESERVOIR OR POND	1.7

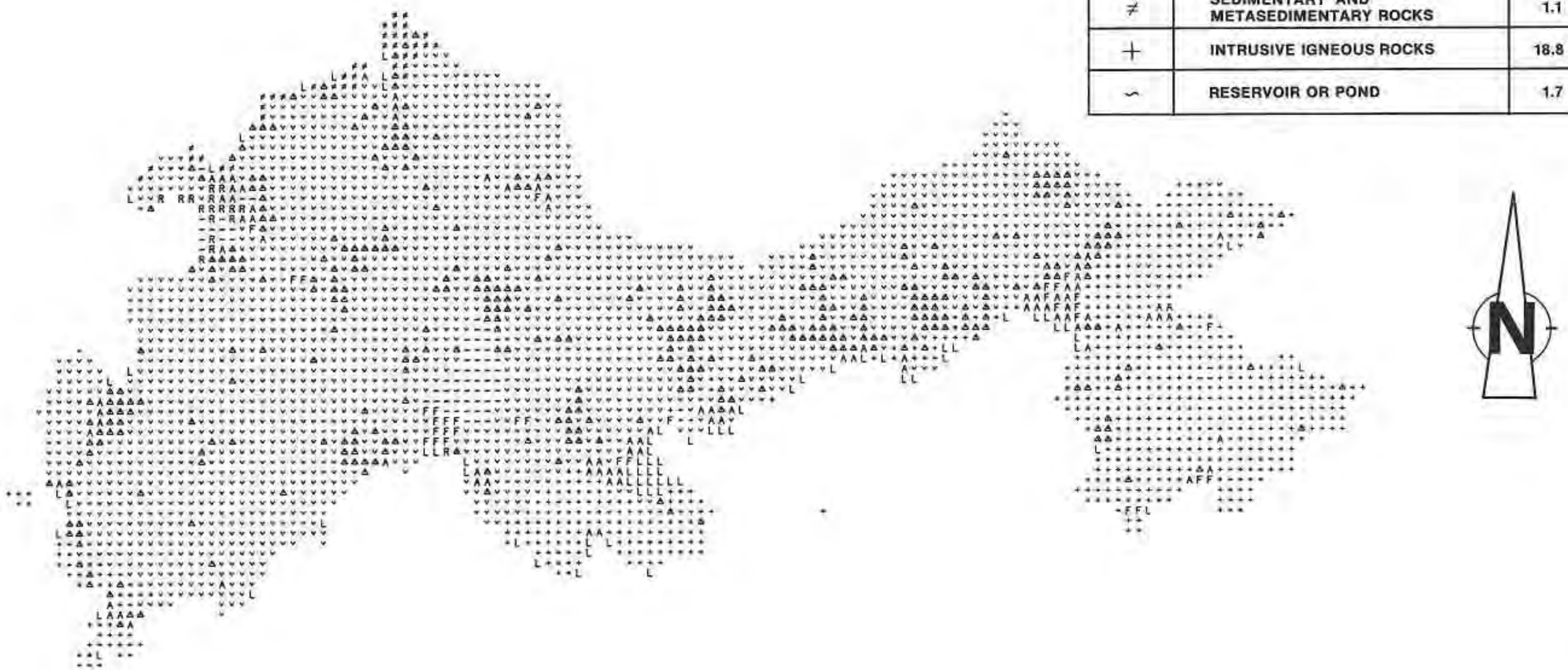


Scale
1:100 000

GEOTECS Plot - Slope Gradient

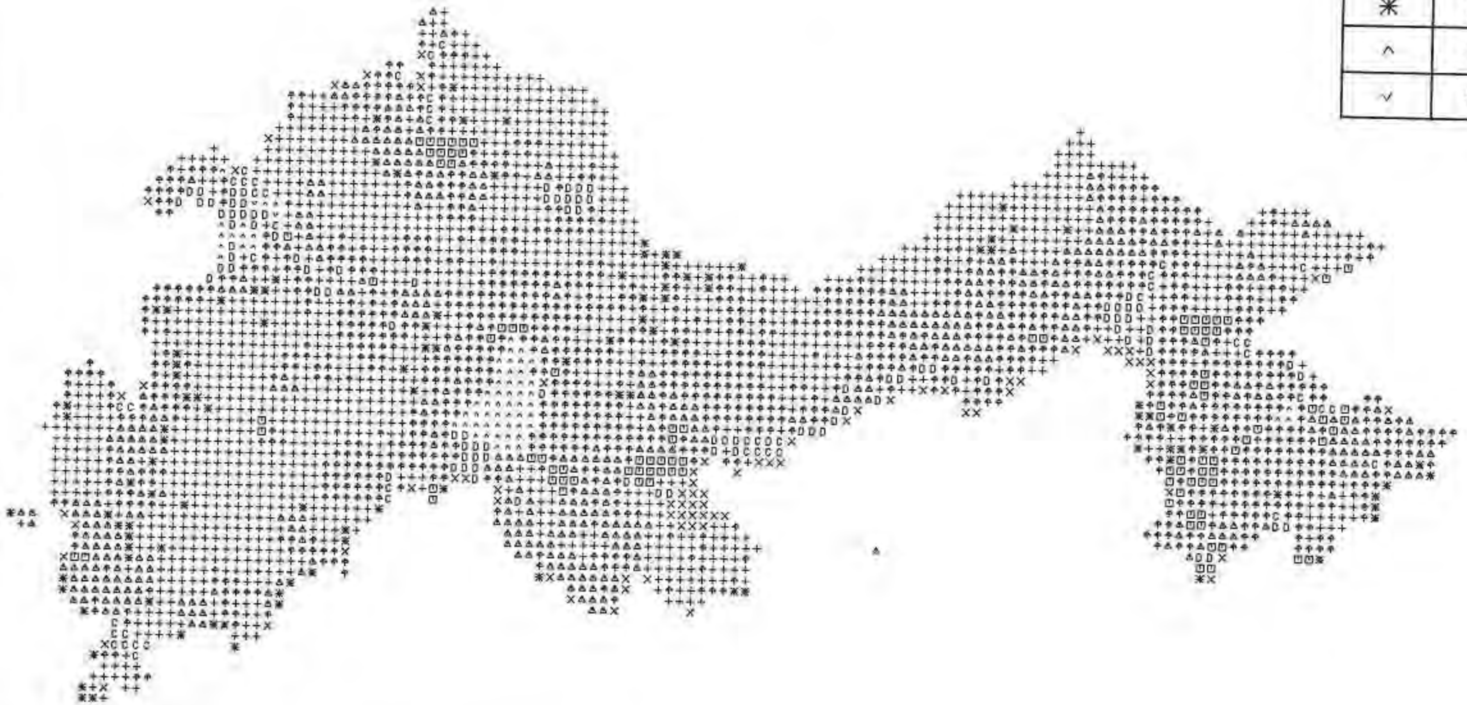
Fig. 5

SYMBOL	MEANING	%TOTAL
F	FILL	0.9
R	RECLAMATION	0.5
A	ALLUVIUM	2.4
⚠	COLLUVIUM	10.4
L	LITTORAL DEPOSITS	2.0
v	VOLCANIC ROCKS	62.2
≠	SEDIMENTARY AND METASEDIMENTARY ROCKS	1.1
+	INTRUSIVE IGNEOUS ROCKS	18.8
⌢	RESERVOIR OR POND	1.7



Scale 1:100 000	GEOTECS Plot - Geology	Fig. 6

SYMBOL	MEANING	%TOTAL
+	GRASSLAND	39.5
C	CULTIVATION	1.2
△	SHRUBLAND < 50% CANOPY COVER	13.8
☐	SHRUBLAND > 50% CANOPY COVER	2.7
♤	BROADLEAF WOODLAND	33.3
X	NO VEGETATION ON NATURAL TERRAIN	2.1
D	NO VEGETATION ON DISTURBED TERRAIN	2.6
✳	NO VEGETATION DUE TO ROCK OUTCROPS	3.0
^	RESERVOIR OR POND	1.7
v	STREAM OR CHANNEL	< 0.1



Scale
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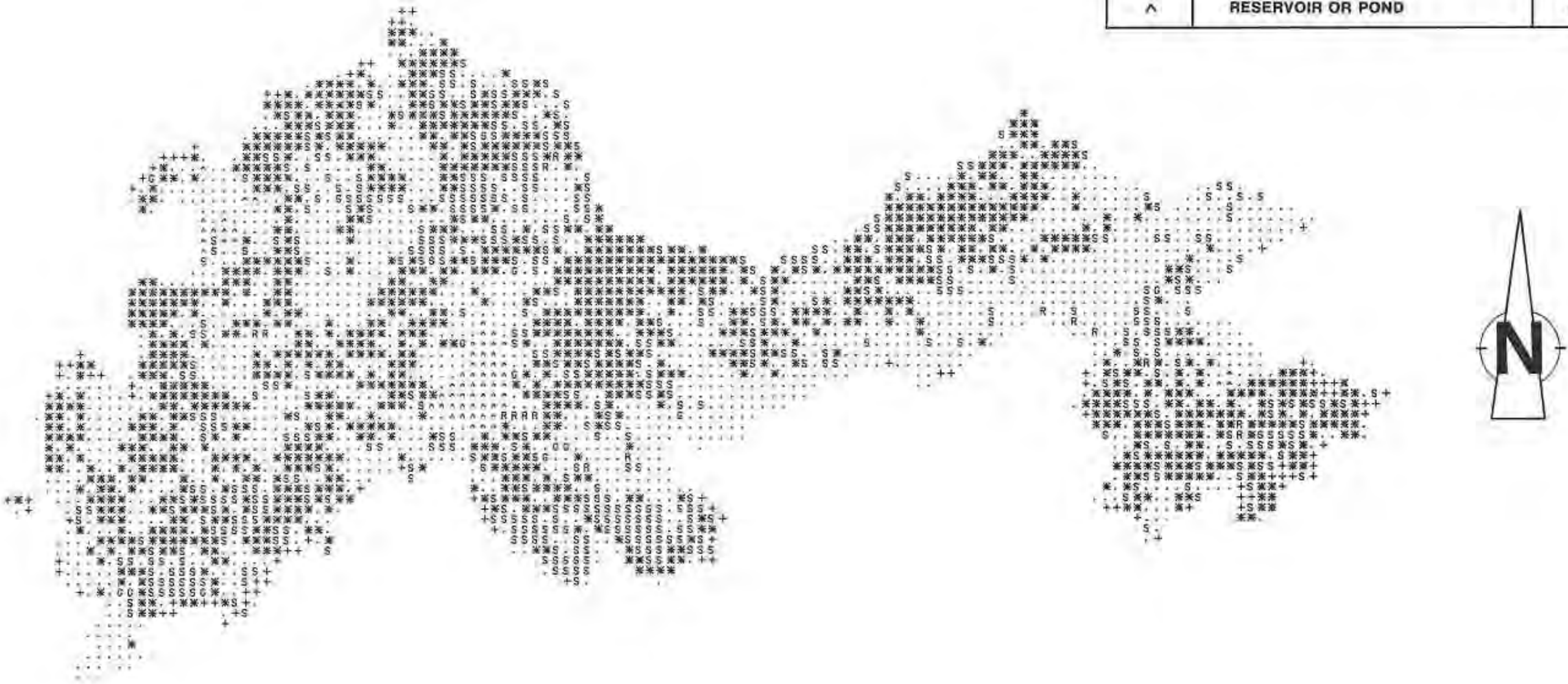
GEOTECS Plot - Vegetation

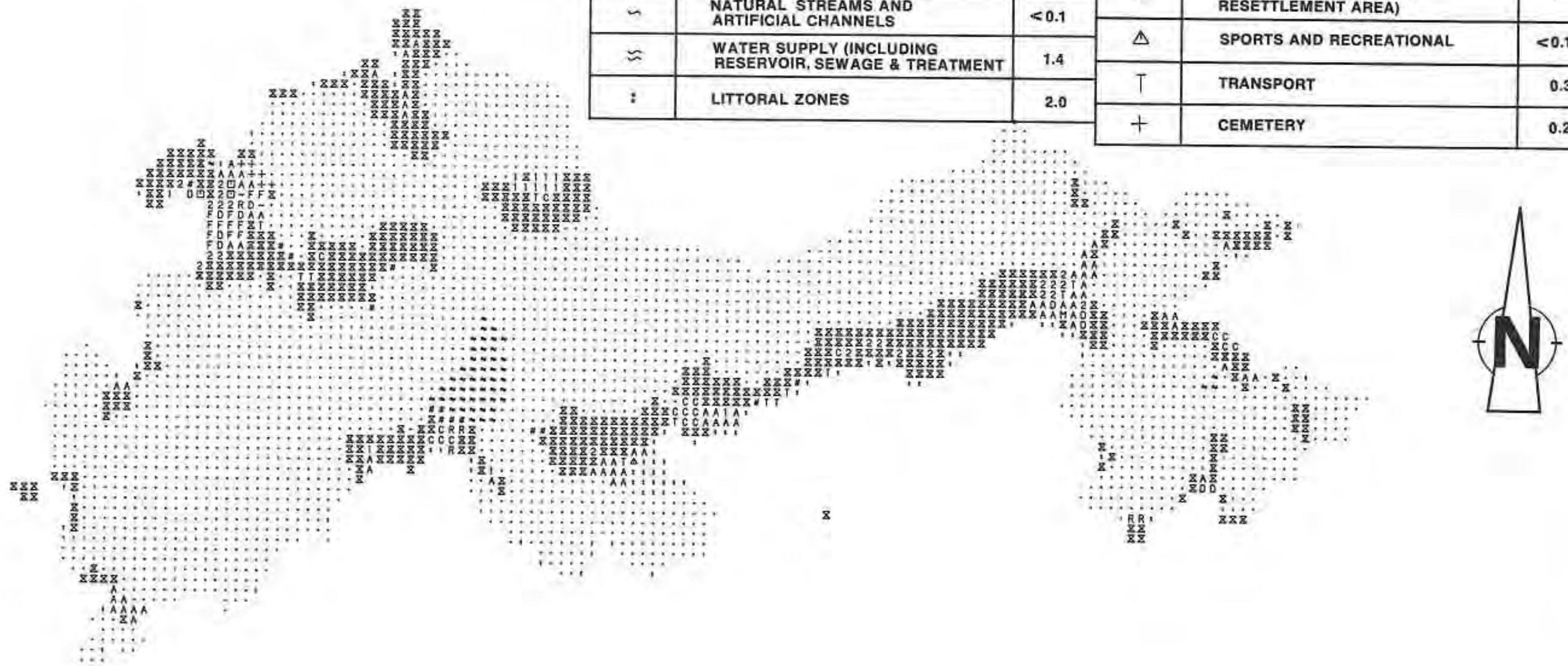
Fig. 7

SYMBOL	MEANING	%TOTAL
·	NO APPRECIABLE EROSION	44.0
S	SHEET EROSION	14.7
R	RILL EROSION	0.4
G	GULLY EROSION	0.3
+	COASTAL INSTABILITY	2.7
✳	GENERAL INSTABILITY	36.2
^	RESERVOIR OR POND	1.7



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

SYMBOL	MEANING	%TOTAL	SYMBOL	MEANING	%TOTAL
M	MILITARY (UNSPECIFIED)	<0.1	R	RESIDENTIAL (AND MIXED COMMERCIAL/RESIDENTIAL)	0.2
⊠	UNDISTURBED NATURAL TERRAIN	16.3	2	TWO STOREY HOUSING	0.6
·	COUNTRY PARK	75.2	1	SINGLE STOREY HOUSING	0.3
#	LARGE ARTIFICIAL SLOPES	0.4	⊡	SQUATTERS	0.1
A	AGRICULTURE (UNDEFINED)	1.9	C	COMMUNITY AND INSTITUTIONAL	0.5
F	FISH OR DUCK PONDS	0.3	D	INCOMPLETE DEVELOPMENT (INCLUDING TEMPORARY RESETTLEMENT AREA)	0.3
∽	NATURAL STREAMS AND ARTIFICIAL CHANNELS	<0.1	△	SPORTS AND RECREATIONAL	<0.1
≈	WATER SUPPLY (INCLUDING RESERVOIR, SEWAGE & TREATMENT	1.4	T	TRANSPORT	0.3
⁝	LITTORAL ZONES	2.0	+	CEMETERY	0.2

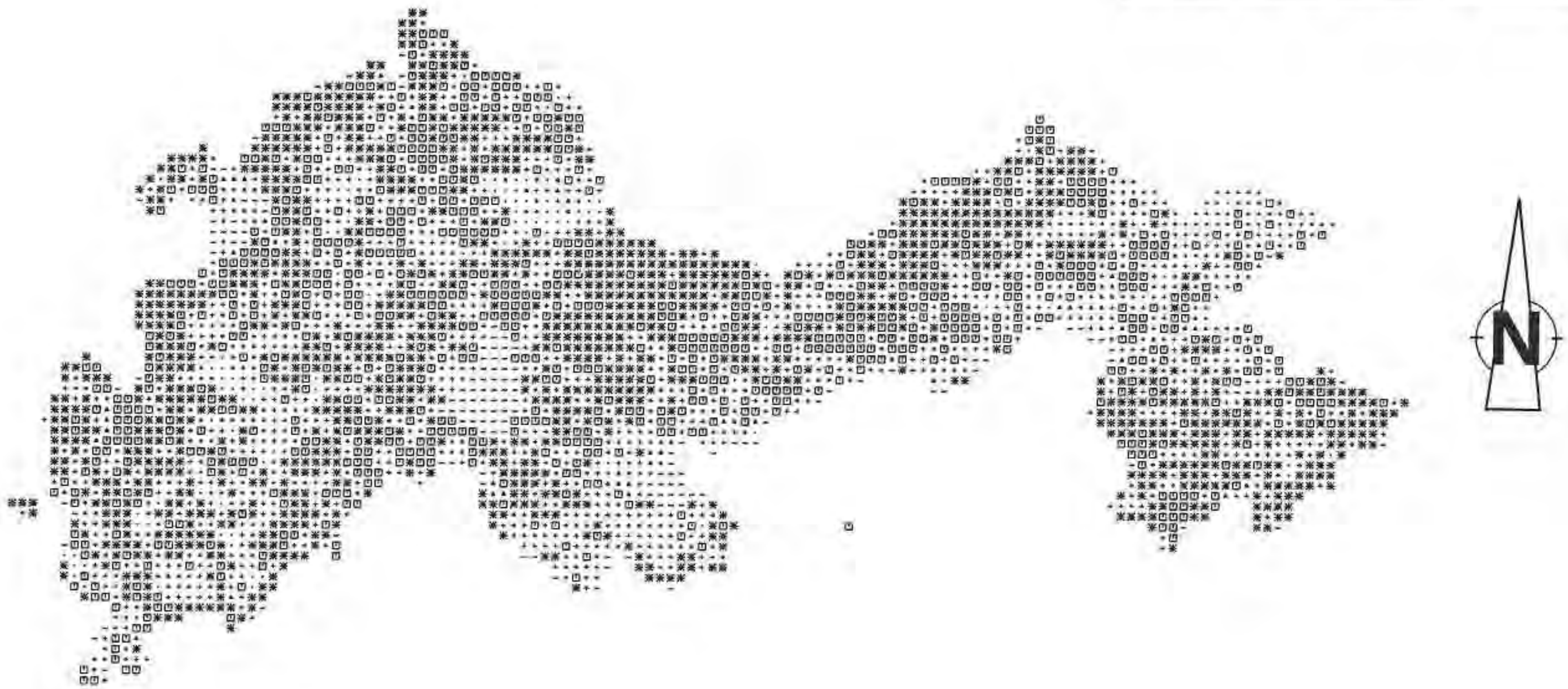


Scale 1:100 000

GEOTECS Plot - Land Use

Fig. 9

SYMBOL	MEANING	%TOTAL
·	GLUM CLASS I	2.7
+	GLUM CLASS II	32.6
△	GLUM CLASS IIs	1.9
☐	GLUM CLASS III	23.9
✳	GLUM CLASS IV	35.1
~	UNCLASSIFIED GLUM CLASS	3.8

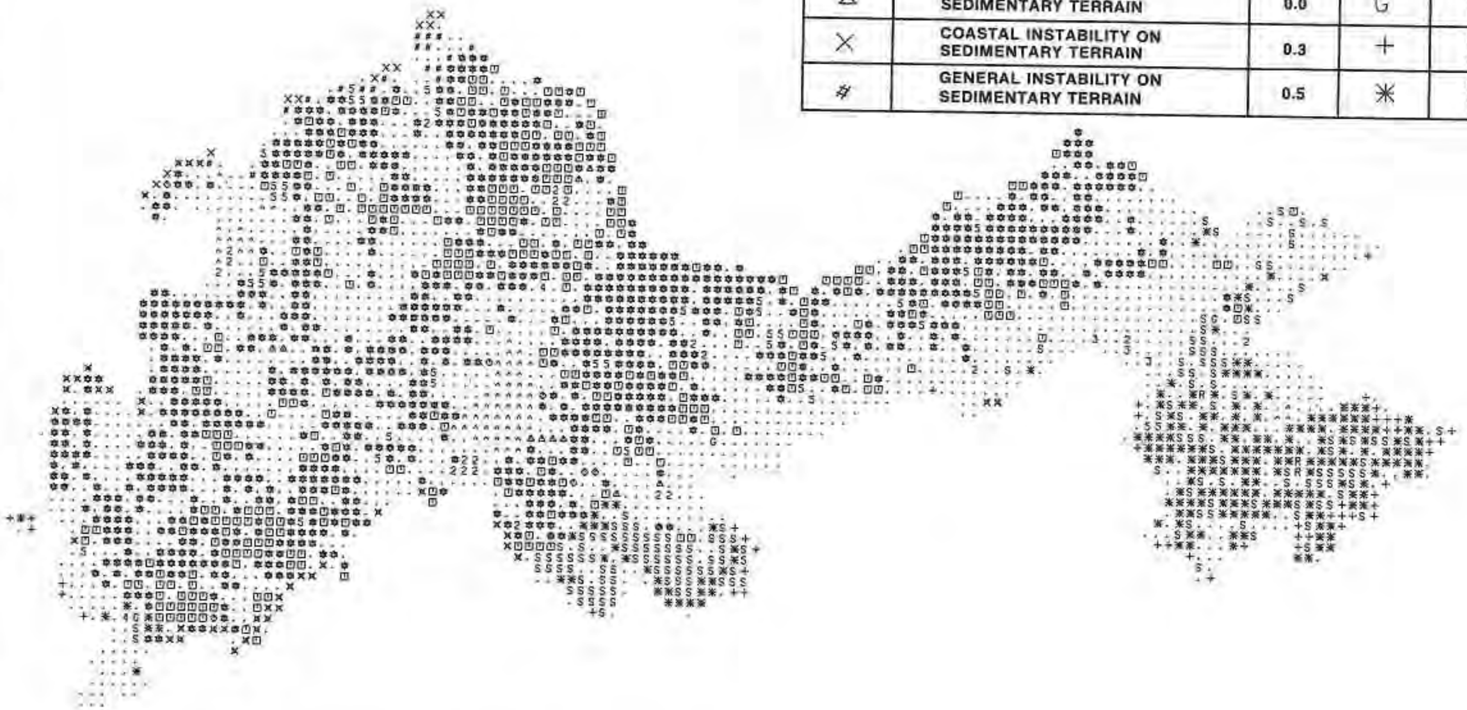


Scale 1:100 000

GEOTECS Plot - Geotechnical Land Use Map

Fig. 10

SYMBOL	MEANING	%TOTAL	SYMBOL	MEANING	%TOTAL	SYMBOL	MEANING	%TOTAL
^	RESERVOIR OR POND	1.7	2	SHEET EROSION ON SUPERFICIAL TERRAIN	0.5	⊡	SHEET EROSION ON VOLCANIC TERRAIN	9.9
•	NO APPRECIABLE EROSION	44.0	3	RILL EROSION ON SUPERFICIAL TERRAIN	< 0.1	△	RILL EROSION ON VOLCANIC TERRAIN	0.3
			4	GULLY EROSION ON SUPERFICIAL TERRAIN	< 0.1	◇	GULLY EROSION ON VOLCANIC TERRAIN	0.2
			5	COASTAL INSTABILITY ON SUPERFICIAL TERRAIN	0.0	⌘	COASTAL INSTABILITY ON VOLCANIC TERRAIN	1.1
			6	GENERAL INSTABILITY ON SUPERFICIAL TERRAIN	1.1	✡	GENERAL INSTABILITY ON VOLCANIC TERRAIN	28.8
			$	SHEET EROSION ON SEDIMENTARY TERRAIN	0.0	S	SHEET EROSION ON GRANITIC TERRAIN	4.3
			⧗	RILL EROSION ON SEDIMENTARY TERRAIN	0.0	R	RILL EROSION ON GRANITIC TERRAIN	<0.1
			⧖	GULLY EROSION ON SEDIMENTARY TERRAIN	0.0	G	GULLY EROSION ON GRANITIC TERRAIN	<0.1
			X	COASTAL INSTABILITY ON SEDIMENTARY TERRAIN	0.3	+	COASTAL INSTABILITY ON GRANITIC TERRAIN	1.3
			#	GENERAL INSTABILITY ON SEDIMENTARY TERRAIN	0.5	*	GENERAL INSTABILITY ON GRANITIC TERRAIN	5.8



Scale
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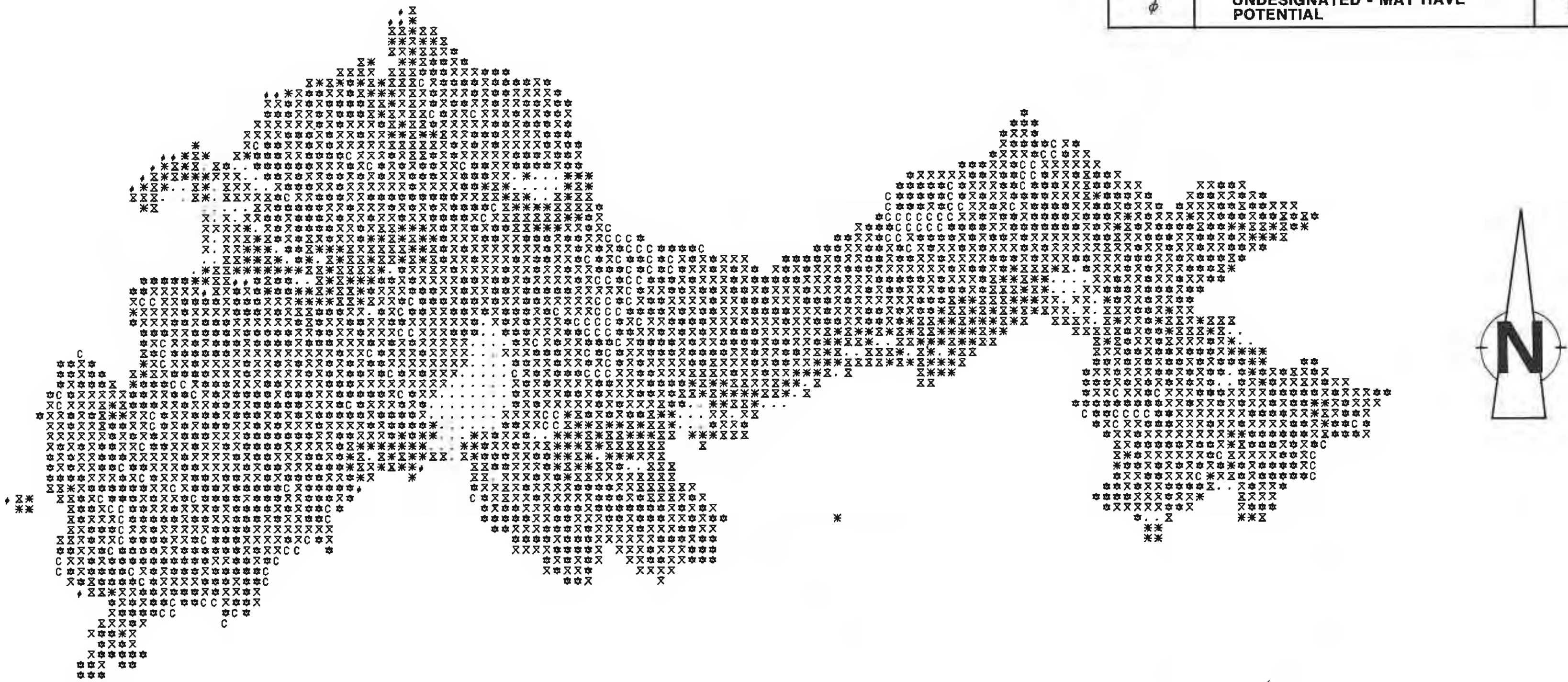
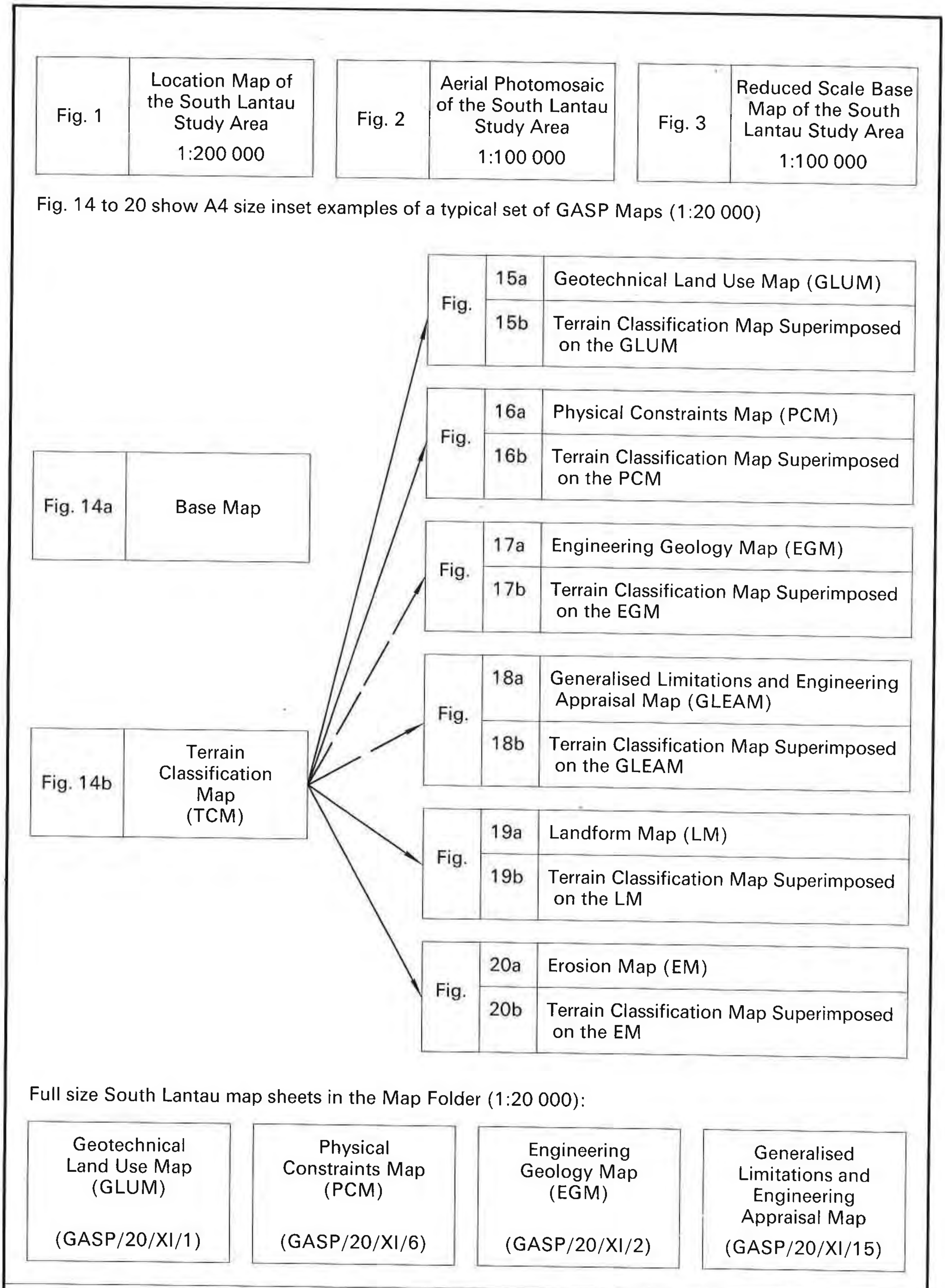
GEOTECS Plot - Geology, Erosion and Instability

Fig. 11

SYMBOL	MEANING	%TOTAL
✳	SUITABLE LANDFORMS - NO PRESENT USAGE	8.2
✡	SUITABLE LANDFORMS - COUNTRY PARK OR CULTIVATION	37.2
⧗	SLOPE < 40° - NO PRESENT USAGE	9.3
⧖	SLOPE < 40° - COUNTRY PARK OR CULTIVATION	36.4
·	EXISTING USAGE	4.2
C	OTHER TERRAIN - COUNTRY PARK	4.2
φ	UNDESIGNATED - MAY HAVE POTENTIAL	0.5



Scale 1:100 000	GEOTECS Plot - Potential Quarry Sites	Fig. 12



Presentation of Maps

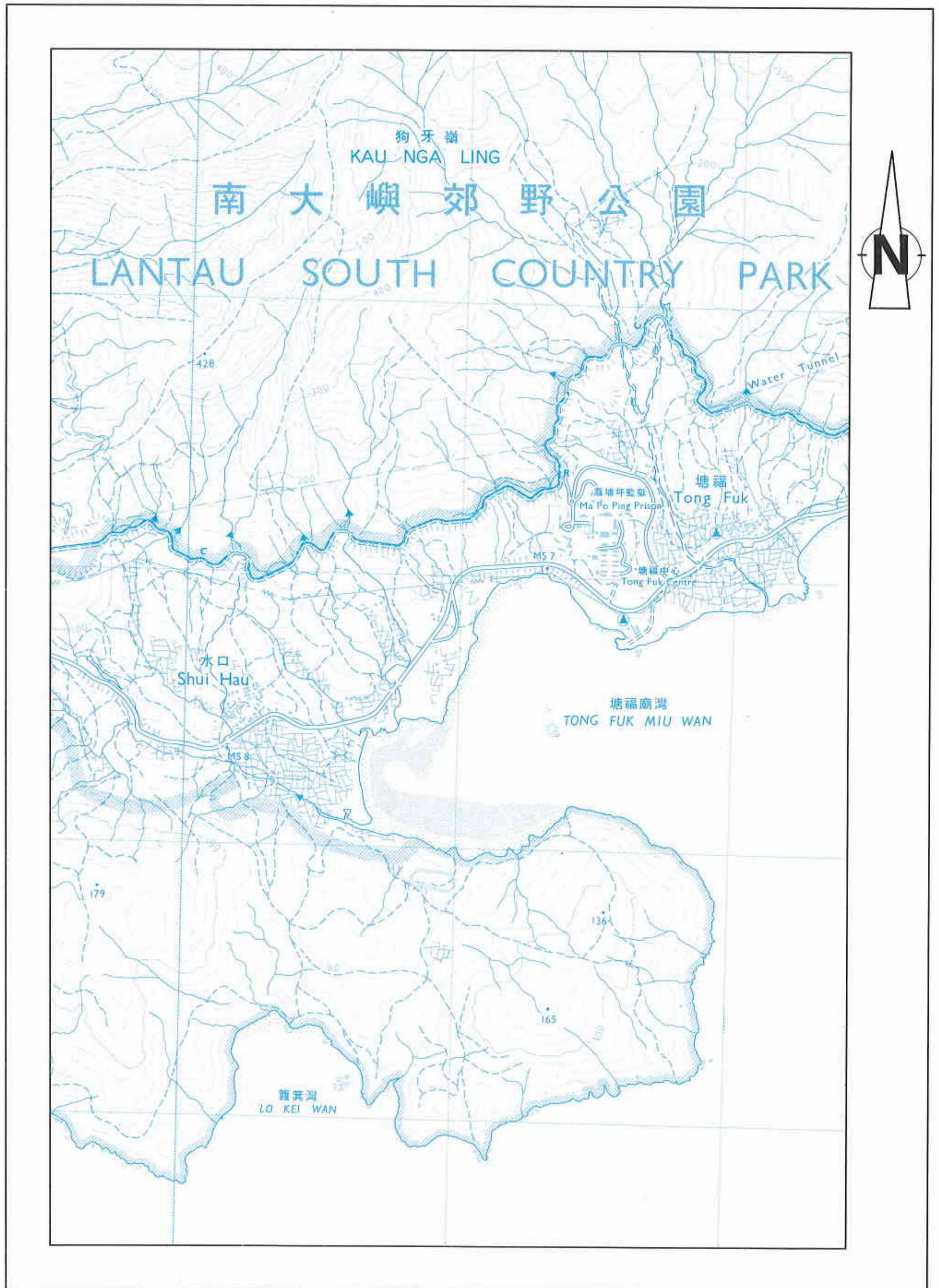
Fig. 13

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. 14b)

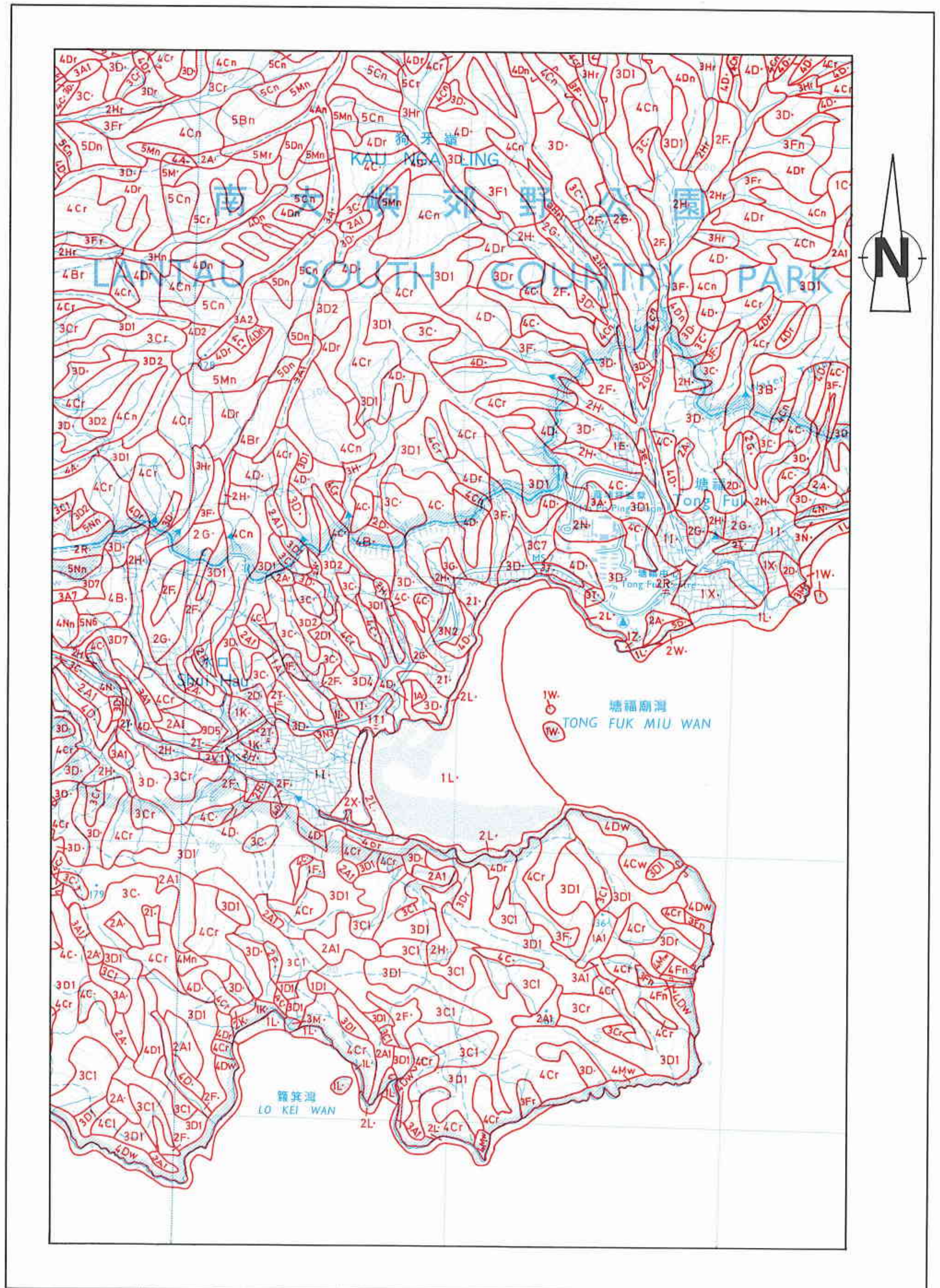
SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

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

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



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



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

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

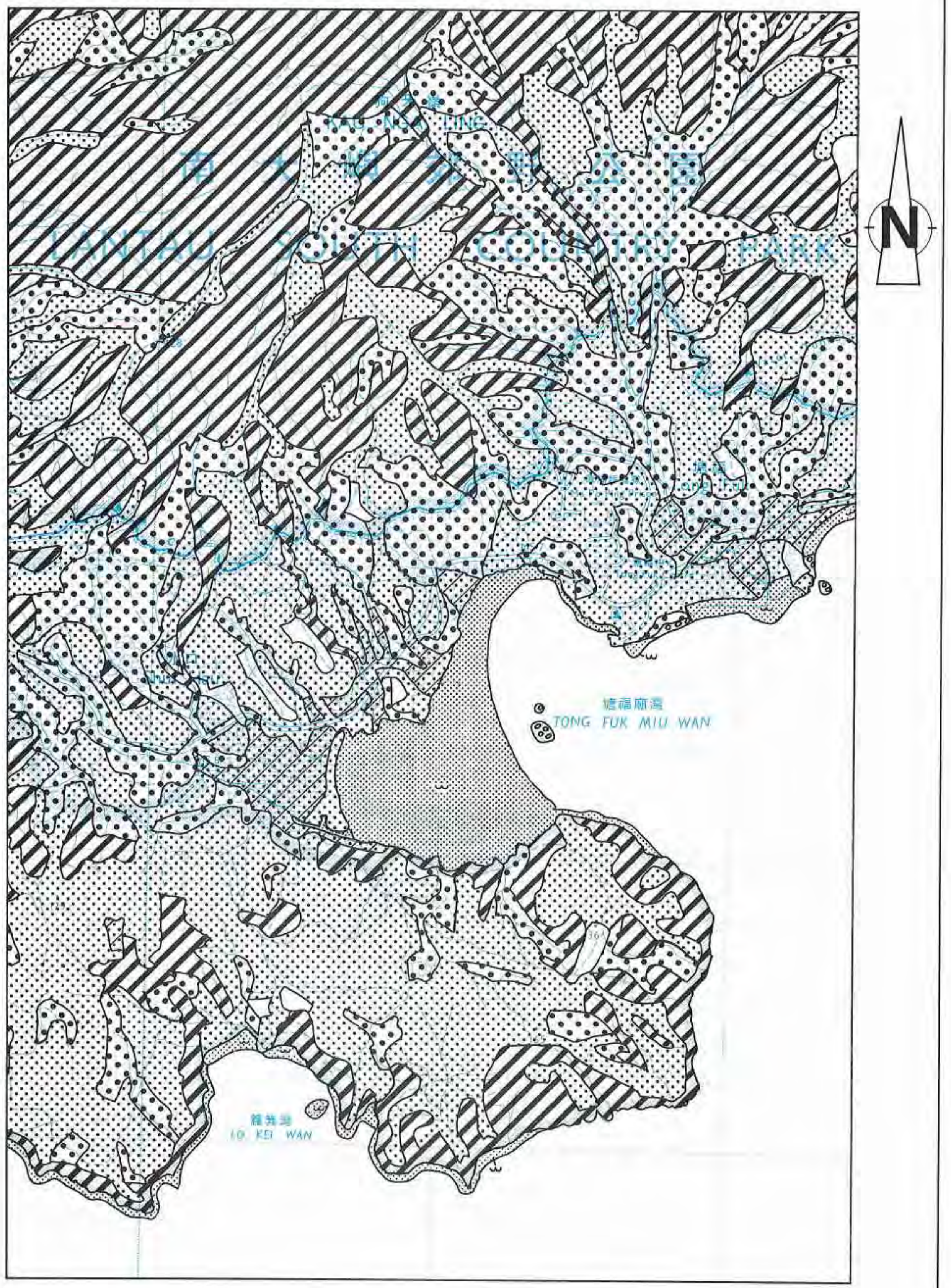
Class I	- Low Geotechnical Limitations
Class II	- Moderate Geotechnical Limitations
Class IIS	- Moderate Geotechnical Limitations (including flooding)
Class III	- High Geotechnical Limitations
Class IV	- Extreme Geotechnical Limitations
Waterbodies (streams, man-made channels, storage dams)	Unclassified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

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig.15b)

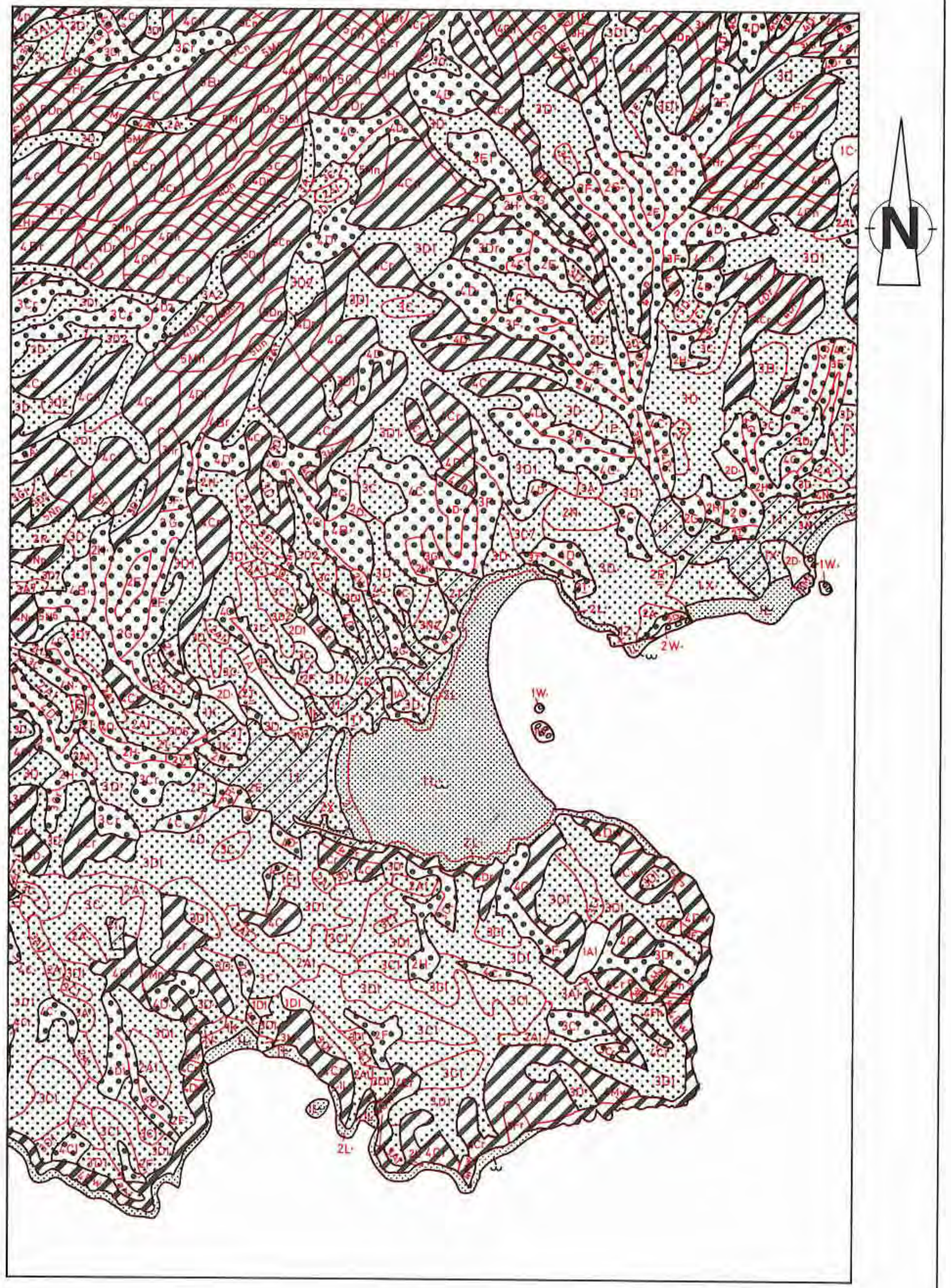
SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

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

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



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



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

LEGEND FOR PHYSICAL CONSTRAINTS MAP (Fig.16a)

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

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig 16b)

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

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

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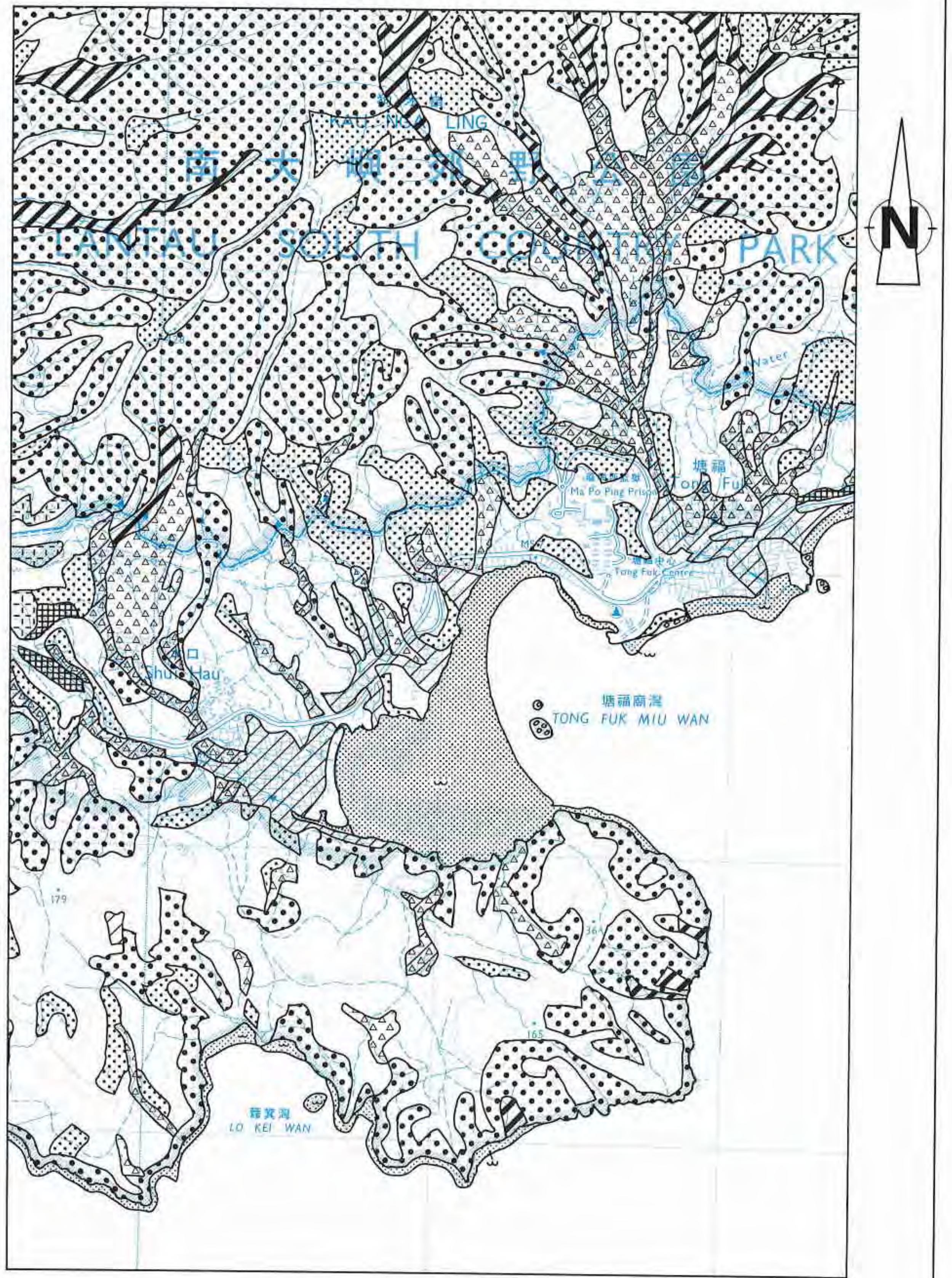
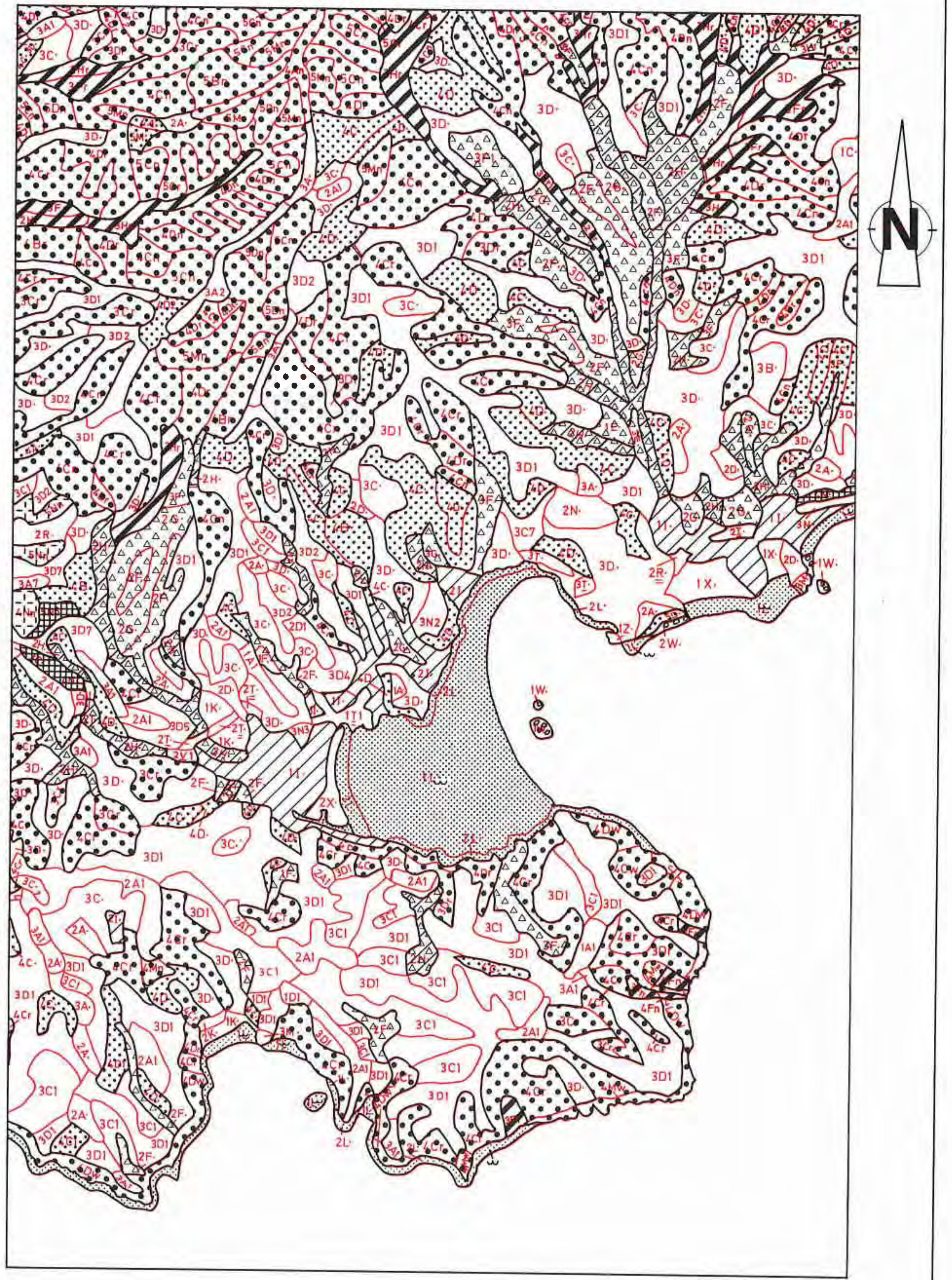
Rill erosion - minor	4
- moderate	5
- severe	6
Gully erosion-minor	7
-moderate	8
-severe	9
Well-defined landslip > 1ha in size	a
General instability) recent	n
General instability) relict	r
Coastal instability	w



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



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

LEGEND FOR ENGINEERING GEOLOGY MAP (Fig. 17a)

- Fill
- Reclamation
- Littoral deposits
- Alluvium (undifferentiated)
- Colluvium (undifferentiated)
- Feldspar porphyry dyke swarm
- Undifferentiated granitic rock
- Quartz monzonite
- Fan Lau Porphyritic Granite
- Ma On Shan Granite
- Cheung Chau Granite
- Sung Kong Granite
- Tai Po Granodiorite
- Repulse Bay Formation:
  - Sedimentary rocks and water-laid volcaniclastic rocks
  - Acid lavas
  - Agglomerate
  - Coarse tuffs
  - Dominantly pyroclastic rocks with some lavas
  - Undifferentiated volcanic rocks
- Tai O Formation
- General instability
- Depth in fathoms
- Wave cut platform

From Allen & Stephens (1971):

- Strike and dip of beds
- Strike and dip of bedding, way up known at this location
- Strike of bedding, dip unknown
- Vertical bedding
- Horizontal bedding
- Strike and dip of flow-banding in lavas
- Anticlinal axis; direction and amount of plunge shown
- Synclinal axis; direction and amount of plunge shown
- Minor fold axis showing direction and amount of plunge
- Horizontal minor fold axis
- Anticlinal axial plane trace
- Synclinal axial plane trace
- La Feldspar porphyry dyke
- Pq Quartz porphyry dyke
- D Dolerite dyke
- Fault
- Geological photolineament
- Geological boundary, position certain
- Geological boundary, position approximate

Other symbols:

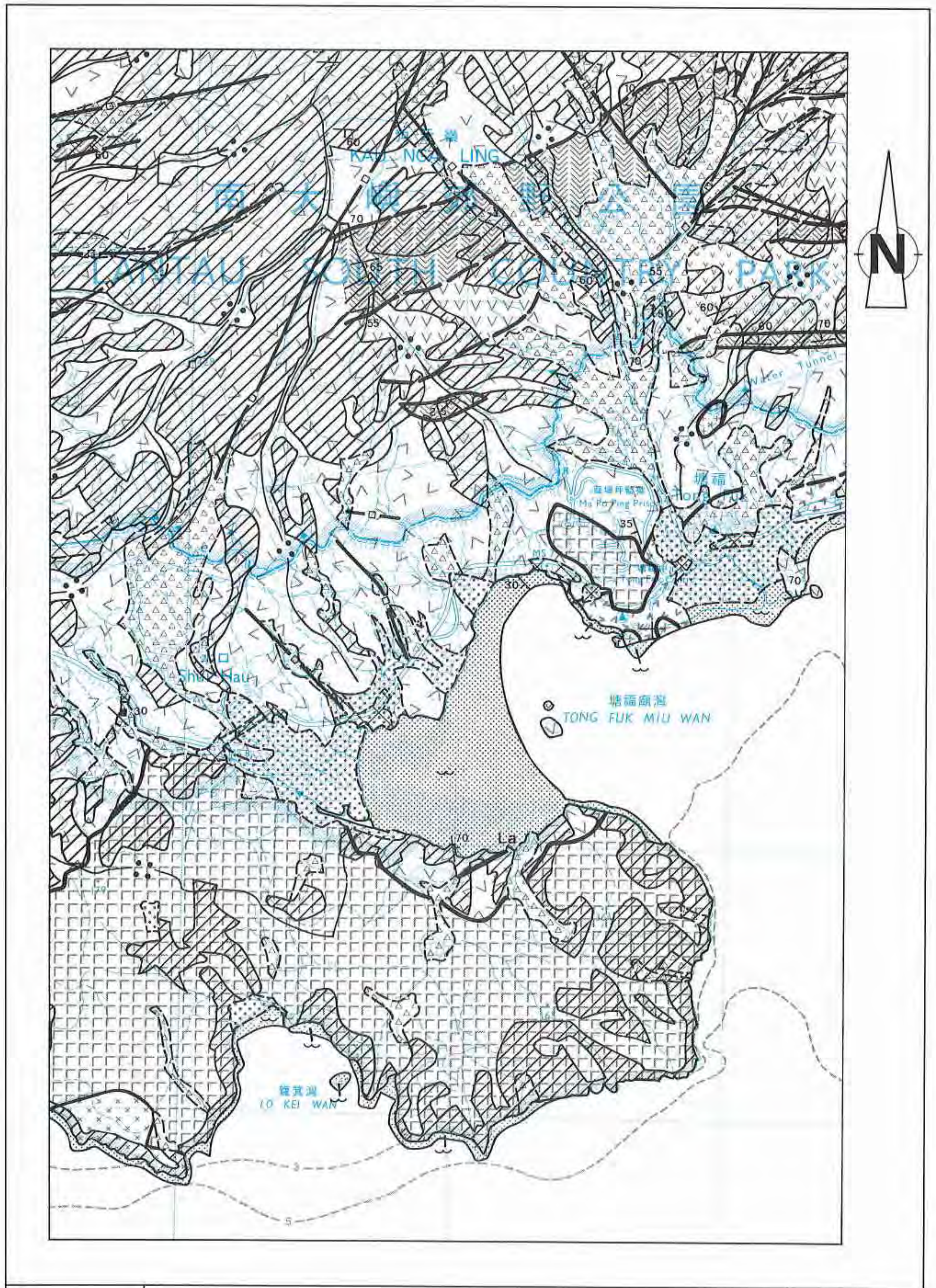
- Geological boundary (superficial)
- Geological photolineament (approximate)
- Fault (inferred)
- A A' Geological cross-section line
- Catchment boundary (order indicated by number of dots)

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig.17b)

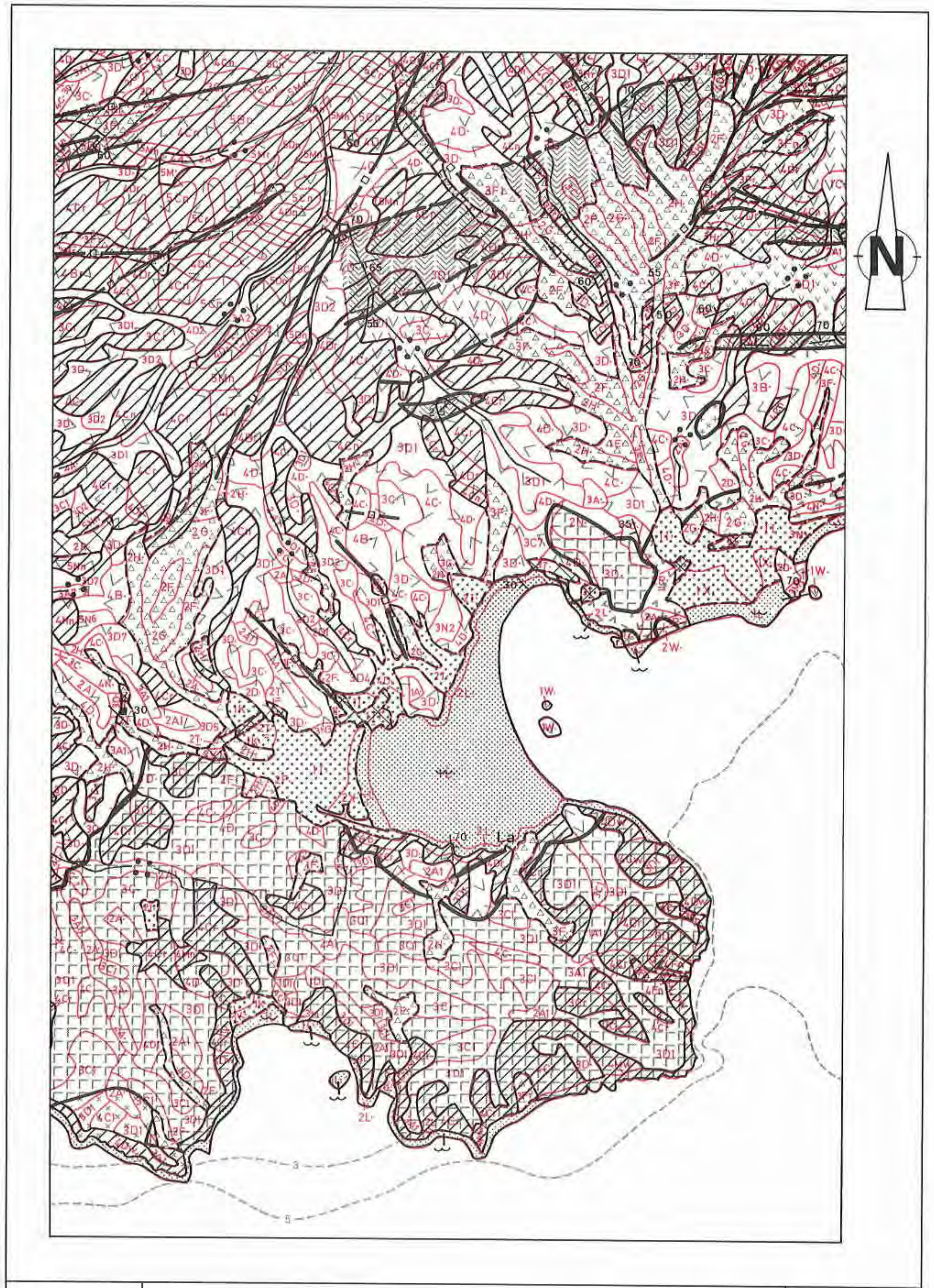
SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

TERRAIN COMPONENT	CODE
Crest or ridge	A
Sideslope-straight	B
-concave	C
-convex	D
Footslope-straight	E
-concave	F
-convex	G
Drainage plain	H
Floodplain	I
Coastal plain	K
Littoral zone	L
Rock outcrop	M
Cut - straight	N
- concave	O
- convex	P
Fill-straight	R
-concave	S
-convex	T
General disturbed terrain	V
Wave cut platform	W
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 Engineering Geology Map (EGM) | Fig. 17a



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

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

DEVELOPMENT PLANNING ZONES :

- Zone of potential for development (assessed in geotechnical terms)
- Zone of local geotechnical constraints (identified on PCM) within general PDA
- Zone of constraints for development (assessed principally in geotechnical terms)
- Zone of existing development (based on principal use of GEOTECS 2 ha unit)
- Country Park boundary
- Catchwater

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

ABBREVIATIONS :

Cont.	Control
Mod.	Moderate
Sh.	Shallow
Sl.	Slope(s)
St.	Steep
Str.	Structure (bedrock)
W.	Weathering
PDA	Potential development areas

FEATURES OF ENGINEERING SIGNIFICANCE :

- Geological photolineament or fault
- R Ridgeline
- D Di Drainage, incised drainage
- Coll. Colluvium (also in 'zone of local constraint', and PCM)
- Bs Boulders
- Instability influencing area
- Steep slopes influencing area (orientation of symbols indicates downslope direction)
- Potential for borrow or extensive cut and fill : opportunity to create site formation in 'constrained' area, or larger site formation in 'potential' area.

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

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

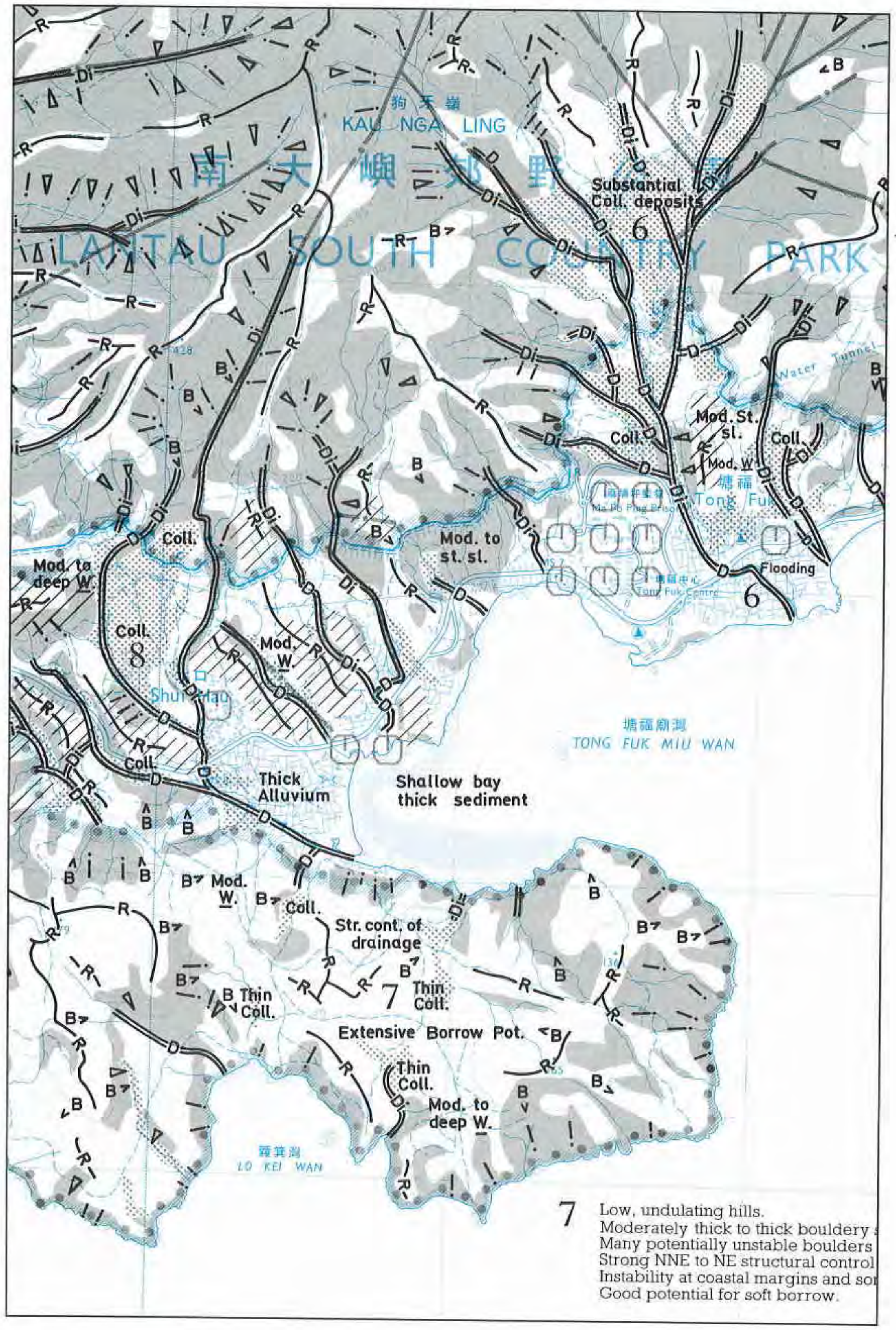
iii) Geological boundaries and photolineament are shown in full on the EGM. Those lineaments indicated represent the surface epxression of obvious structural discontinuities which affect the PDA's.

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. 18b)

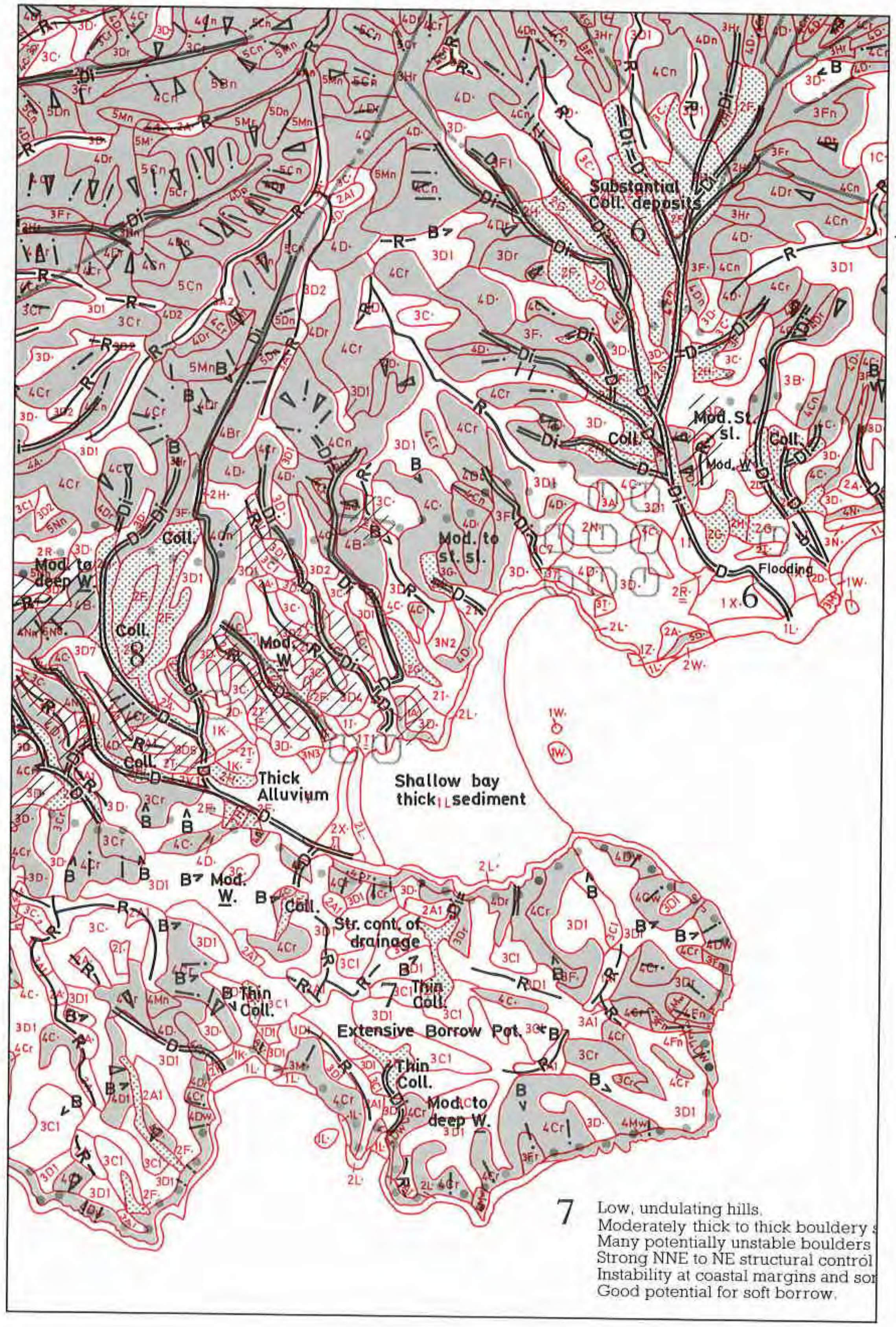
SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

TERRAIN COMPONENT	CODE
Crest or ridge	A
Sideslope-straight	B
-concave	C
-convex	D
Footslope-straight	E
-concave	F
-convex	G
Drainage plain	H
Floodplain	I
Coastal plain	K
Littoral zone	L
Rock outcrop	M
Cut - straight	N
- concave	O
- convex	P
Fill-straight	R
-concave	S
-convex	T
General disturbed terrain	V
Wave cut platform	W
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. 18a



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

LEGEND FOR LANDFORM MAP (Fig. 19a)

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

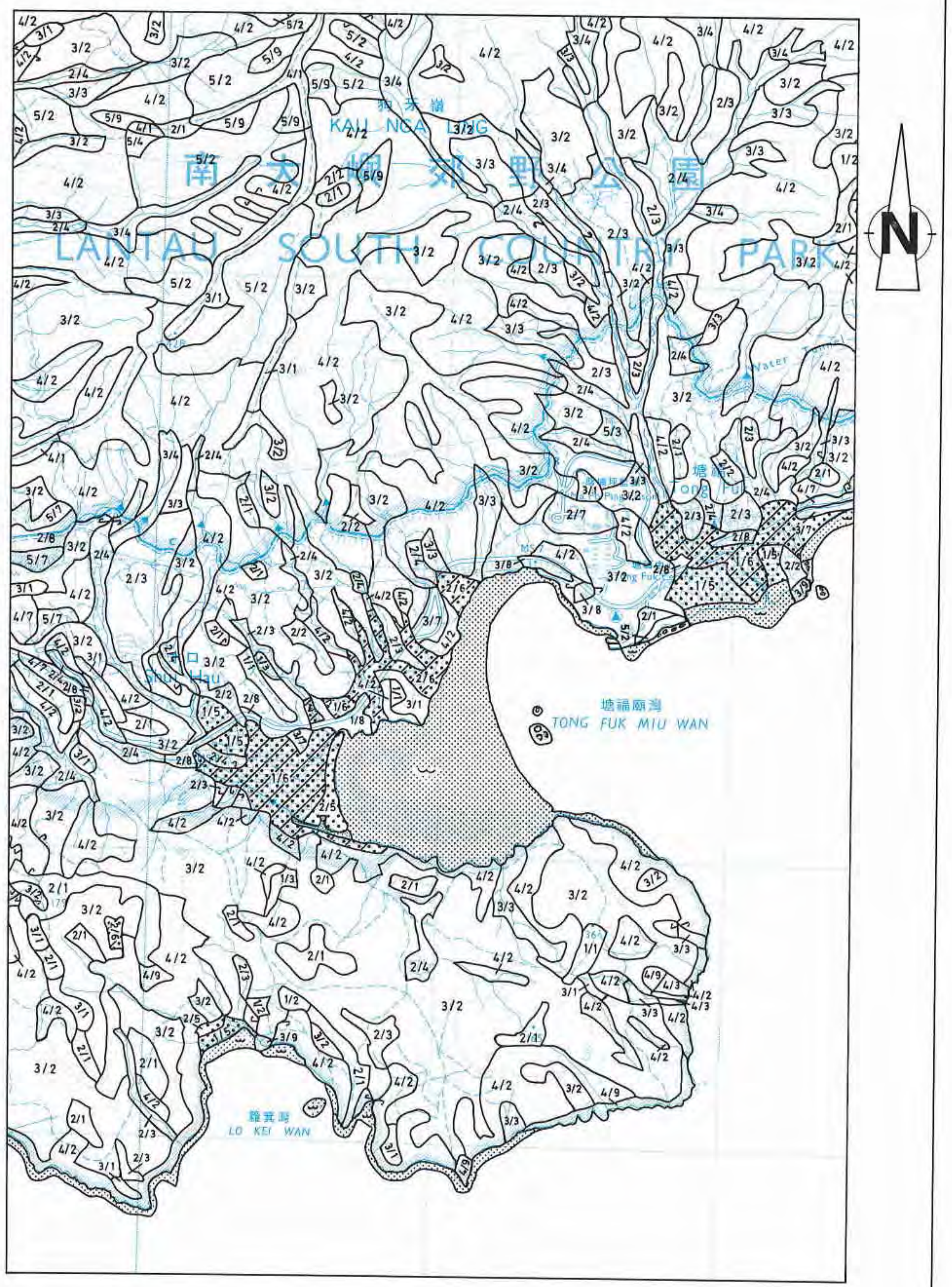
DESCRIPTION	CODE
Crest or ridge	1
Sideslope - insitu	2
Footslope - colluvium	3
Drainage plain - colluvium subject to overland flow and regular inundation. Unusual groundwater regime.	4
Alluvial plain - includes raised terraces.	5
Flood plain - portion of alluvial plain subject to overland flow and regular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

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. 19b)

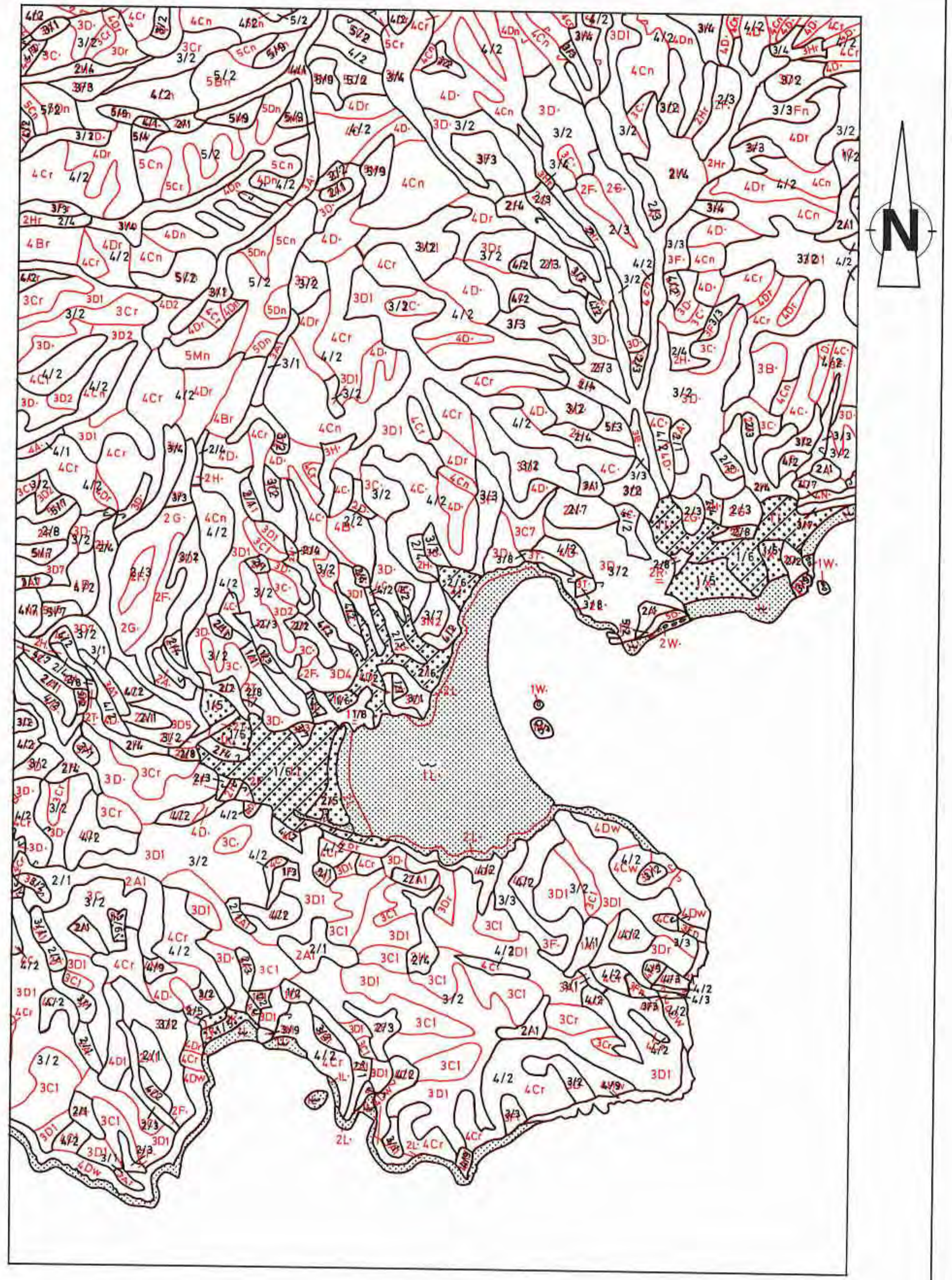
SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

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

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



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



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

LEGEND FOR EROSION MAP (Fig. 20a)

(blank)	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
(dotted)	Zones of general instability associated with predominantly insitu terrain
(hatched)	Zones of general instability associated with predominantly colluvial terrain
(stippled)	Waterbodies (streams, man-made channels, storage dams)
(dashed)	Ponds
(shaded)	Littoral zone (generally subject to tidal action)
(pebbled)	Wave cut platform

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. 20b)

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

TERRAIN COMPONENT	CODE
Crest or ridge	A
Sideslope-straight	B
-concave	C
-convex	D
Footslope-straight	E
-concave	F
-convex	G
Drainage plain	H
Floodplain	I
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Rock outcrop	M
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Fill-straight	R
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EROSION	CODE
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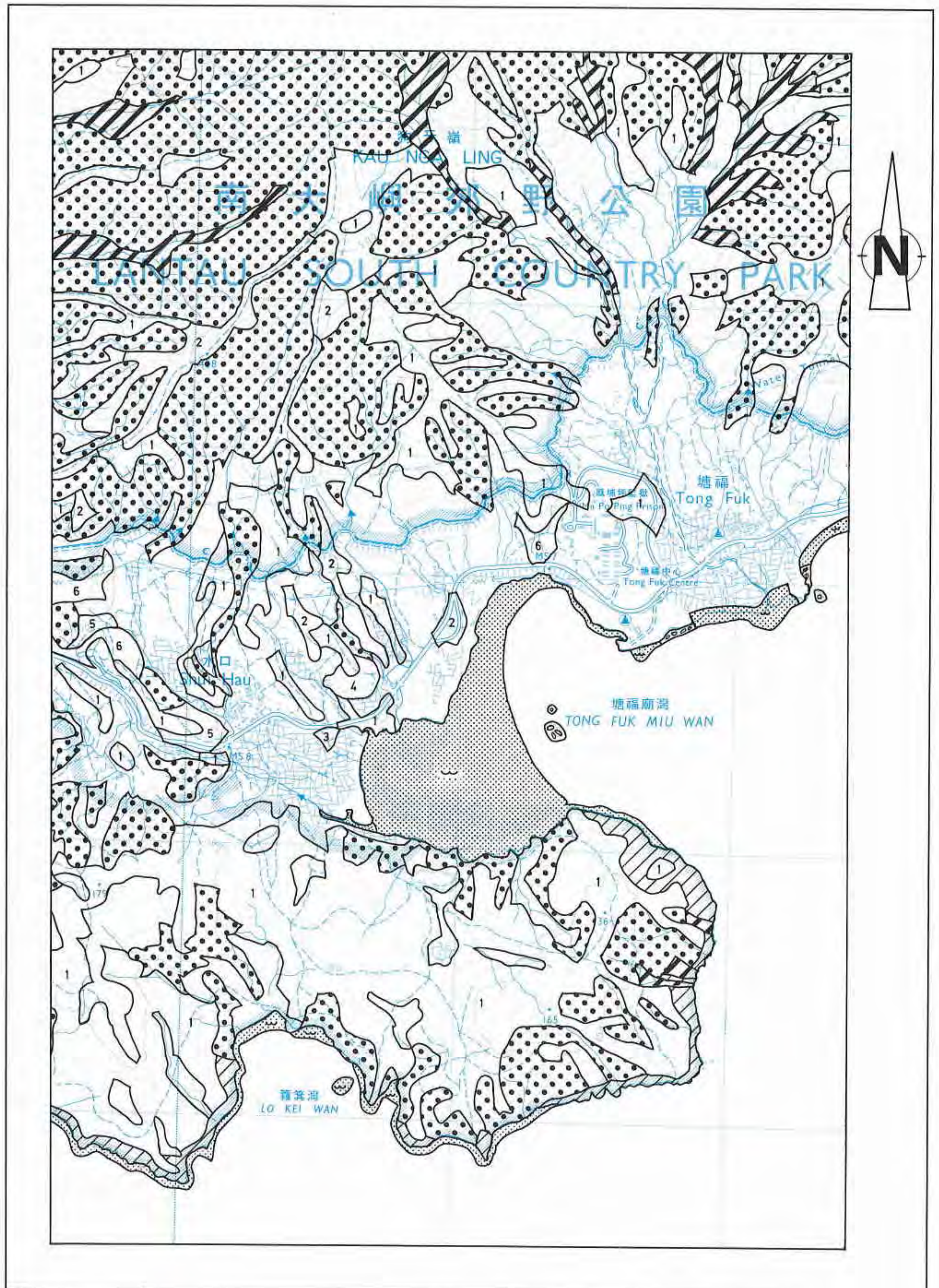
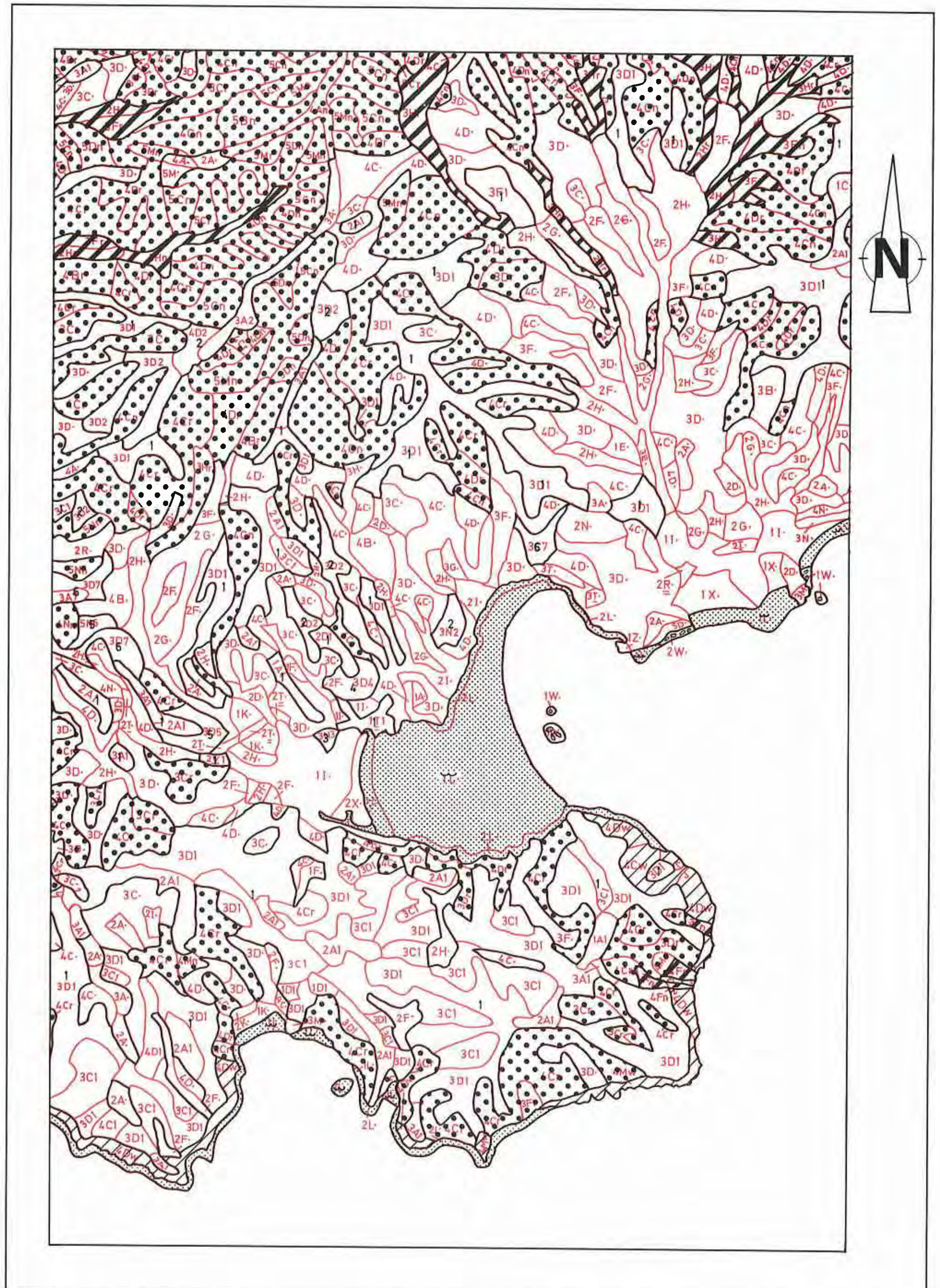
Gully erosion-minor	7
-moderate	8
-severe	9
Well-defined landslip > 1ha in size	a
General instability) recent	n
General instability) relict	r
Coastal instability	w



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



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

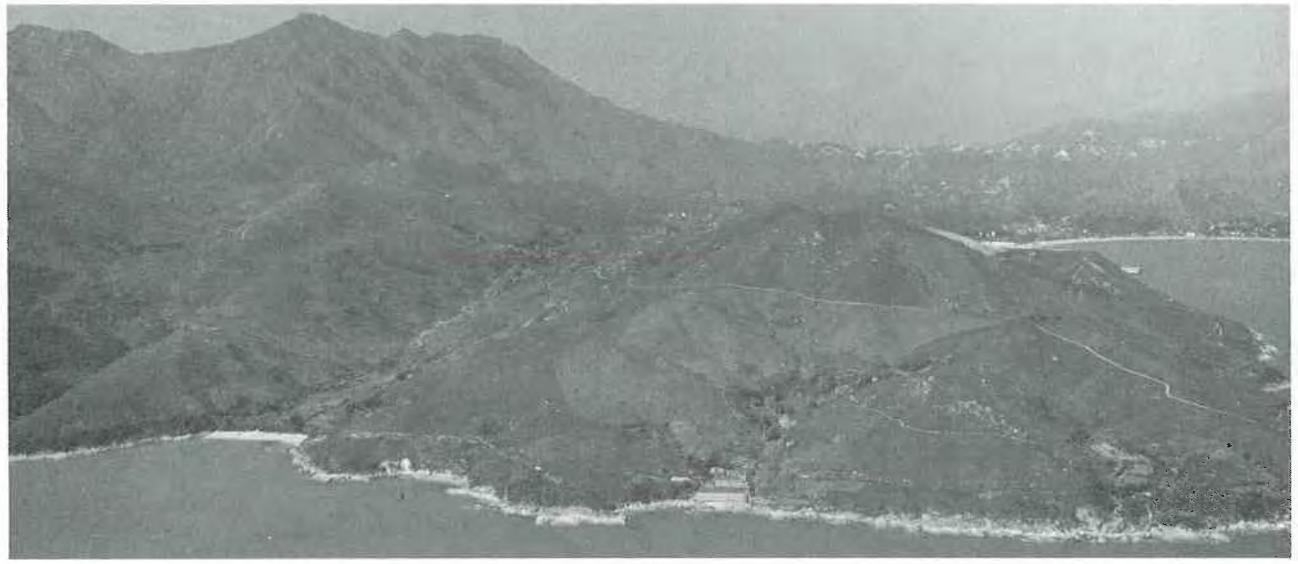


Plate 1. Oblique Aerial Photograph of Ngau Kwu Wan and Shu Tseng Wan. Narrow alluvial **floodplains** have been used for agriculture. (GCO/OAP 1984/11041).

Plate 2. Oblique Aerial Photograph of Wang Tong and the Shap Long San Tsuen to Ham Tin Lowlands. (GCO/OAP 1984/11040).

Plate 3. Oblique Aerial Photograph of Pui O and Ham Tin. The village of Pui O is located on colluvial footslopes above the flood-prone alluvial lowlands. (GCO/OAP 1984/11004).

Plate 4. Oblique Aerial Photograph of the Southern Chi Ma Wan Peninsula. Note that many boulders on the sideslopes may pose a hazard to development downslope. (GCO/OAP 1984/11013).

Plate 5. Oblique Aerial Photograph of Mong Tung Wan and the Mountainous Terrain of the Eastern Chi Ma Wan Peninsula. (GCO/OAP 1984/11010).

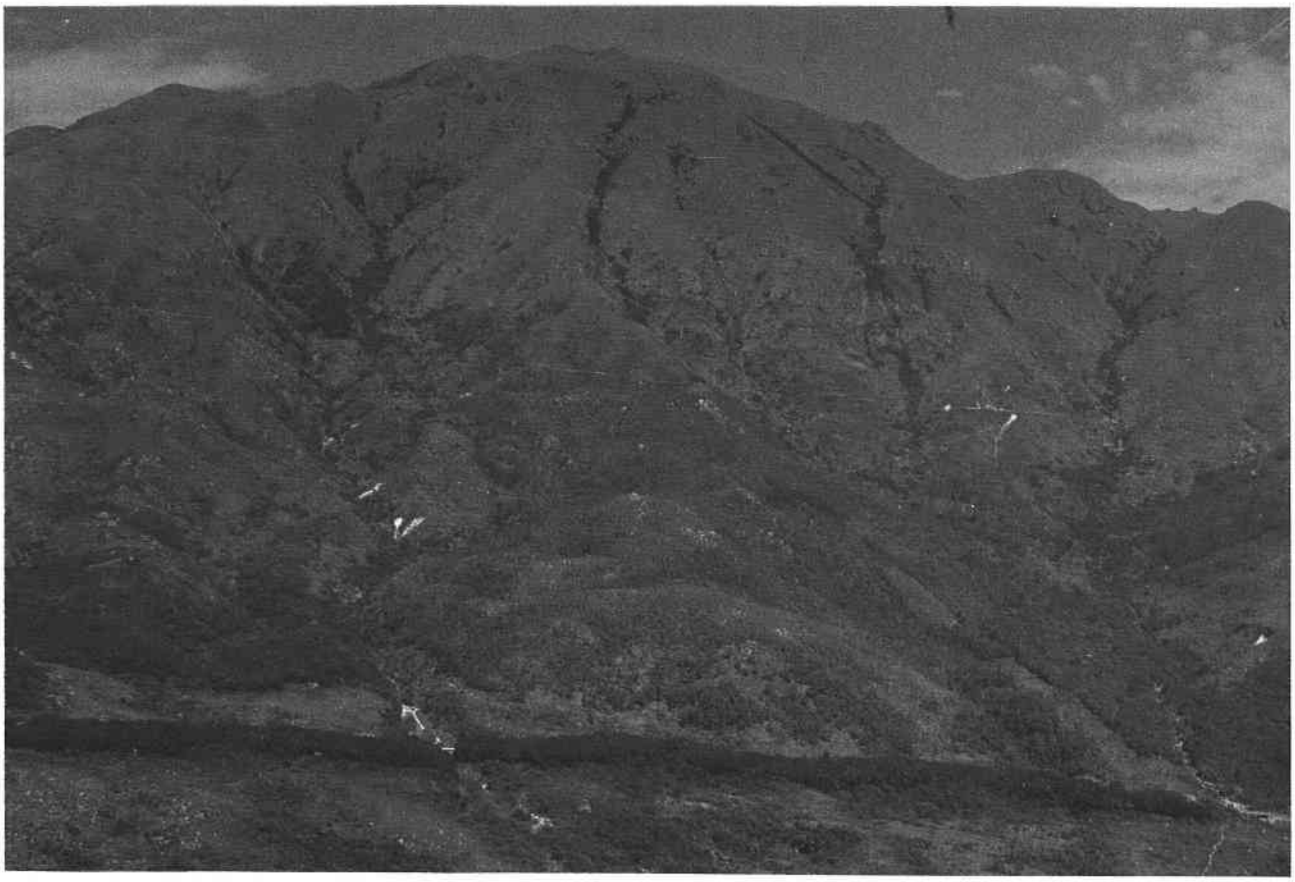


Plate 6. Oblique Aerial Photograph of the Southern Slopes of Sunset Peak. Note the small landslips adjacent to the drainage lines. (GCO/OAP 1979/2370).

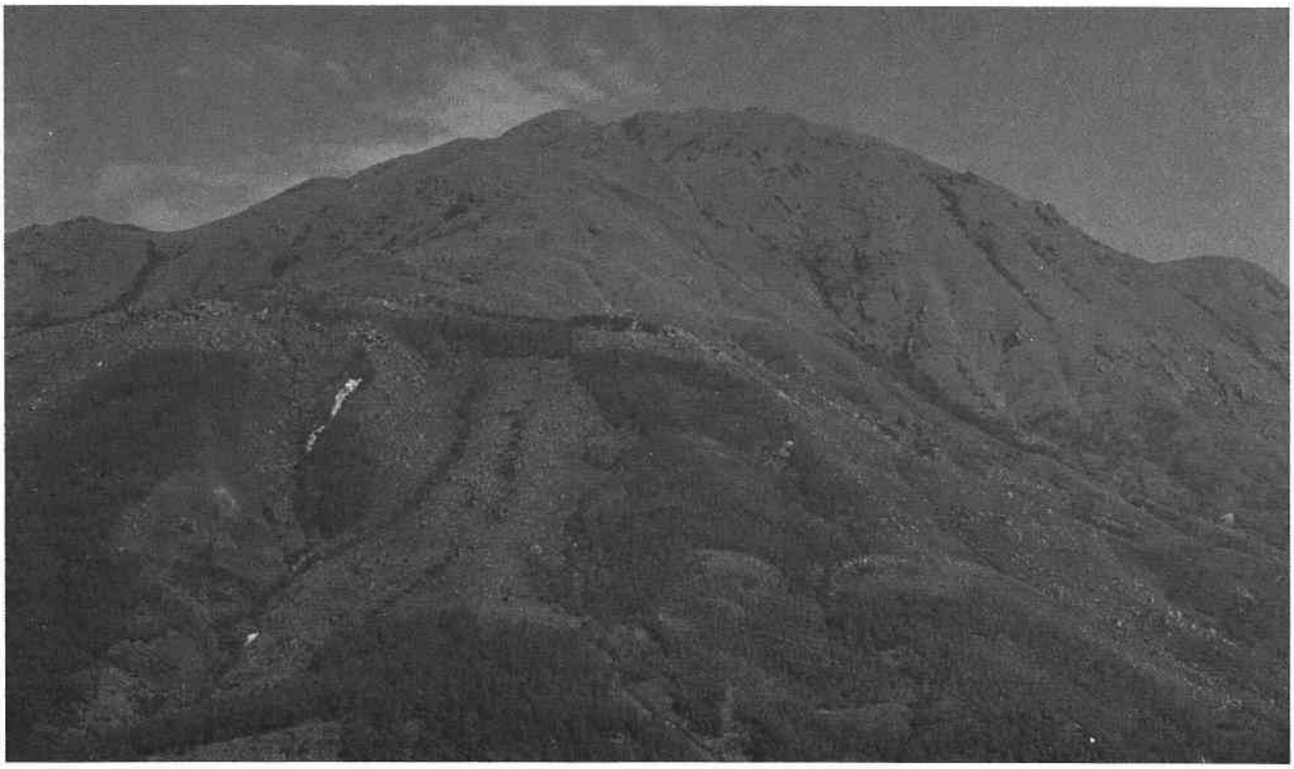


Plate 7. Oblique Aerial Photograph of the Southwestern Slopes of Sunset Peak. Note the number of boulders on the sideslopes. Landslips in this material transfer large quantities of debris to the footslopes where substantial deposits of colluvium have been formed. (GCO/OAP 1979/2357).

Plate 8. Oblique Aerial Photograph of Cheung Sha and the Southern Footslopes of Sunset Peak. (GCO/OAP 1984/11091).

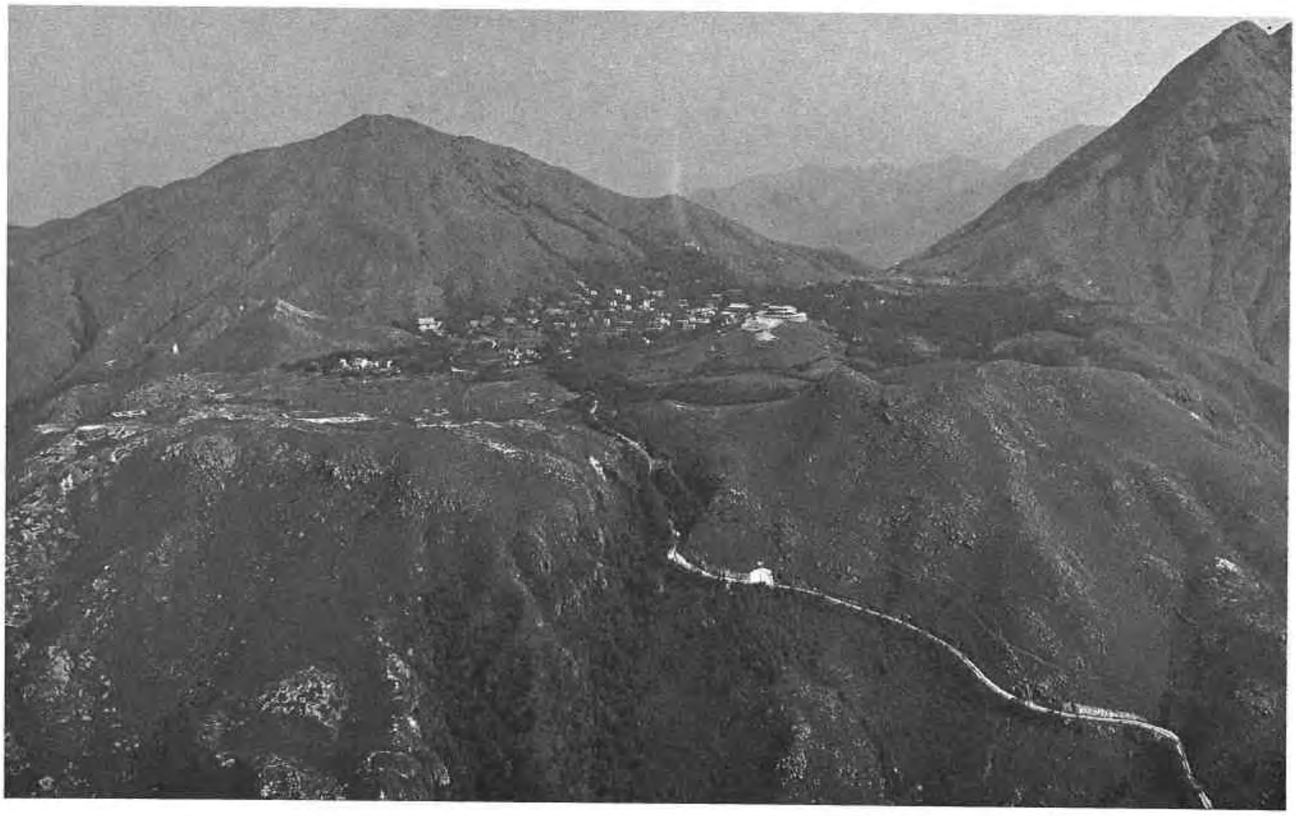


Plate 9. Oblique Aerial Photograph of the Ngong Ping Plateau. Note the steep access road and patches of bare soil due to incipient erosion. (GCO/OAP 1984/11020).

Plate 10. Oblique Aerial Photograph of Tong Fuk and the Valley below the Catchwater. (GCO/OAP 1984/11086).

Plate 11. Oblique Aerial Photograph of Tong Fuk and the Coastal Lowlands. (GCO/OAP 1986/11262).

Plate 12. Oblique Aerial Photograph of Tong Fuk Miu Wan and Shui Hau. (GCO/OAP 1984/11083).

Plate 13. Oblique Aerial Photograph of Lo Kei Wan and Shui Hau. Note the proliferation of boulders on the outcrop of the Quartz Monzonite of the Lo Kei Wan Peninsula. (GCO/OAP 1984/11081).

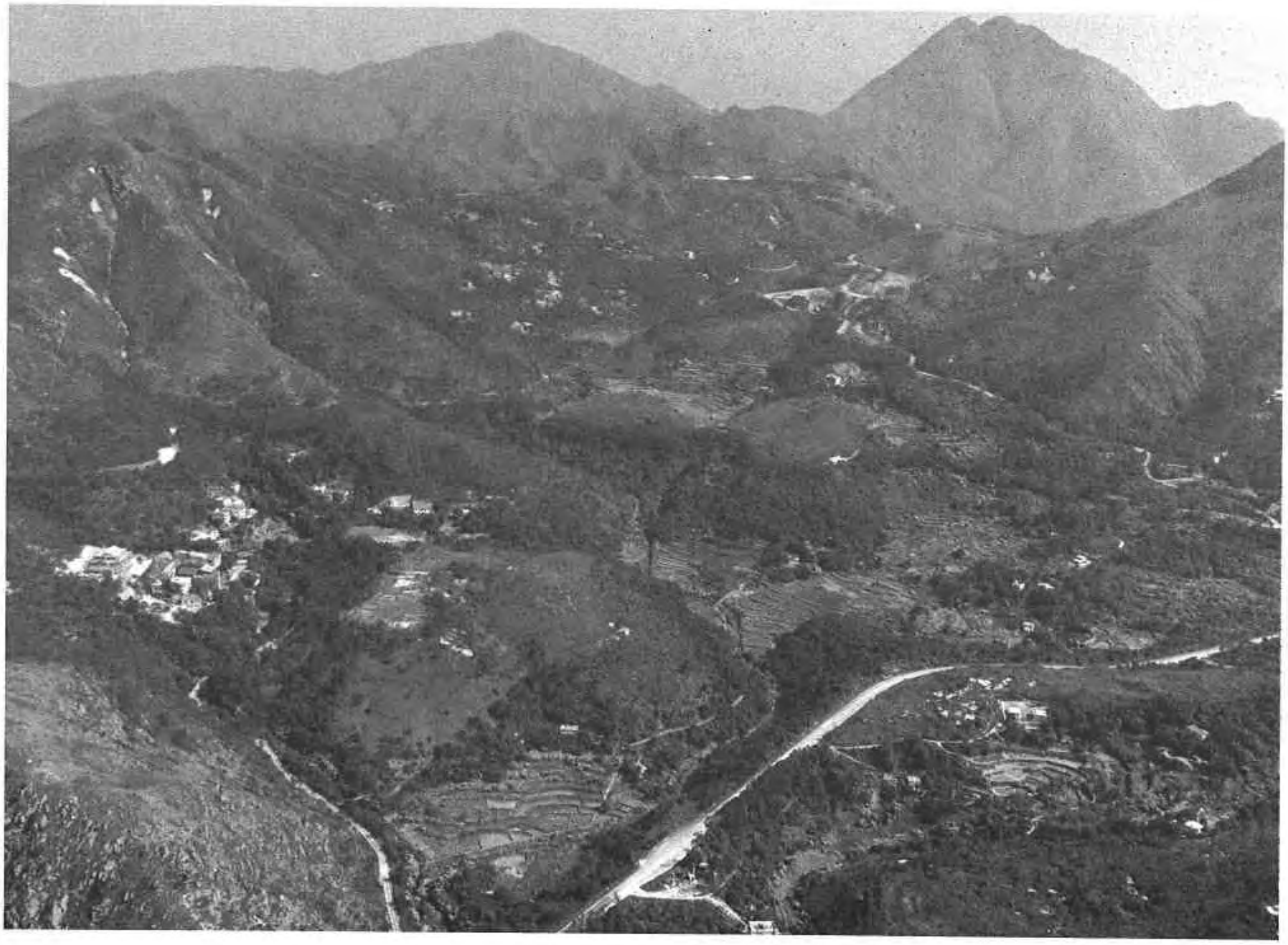


Plate 14. Oblique Aerial Photograph of the Keung Shan Valley. Note the landslips on the steep sideslopes in the upper left part of the Plate. (GCO/OAP 1984/11054).

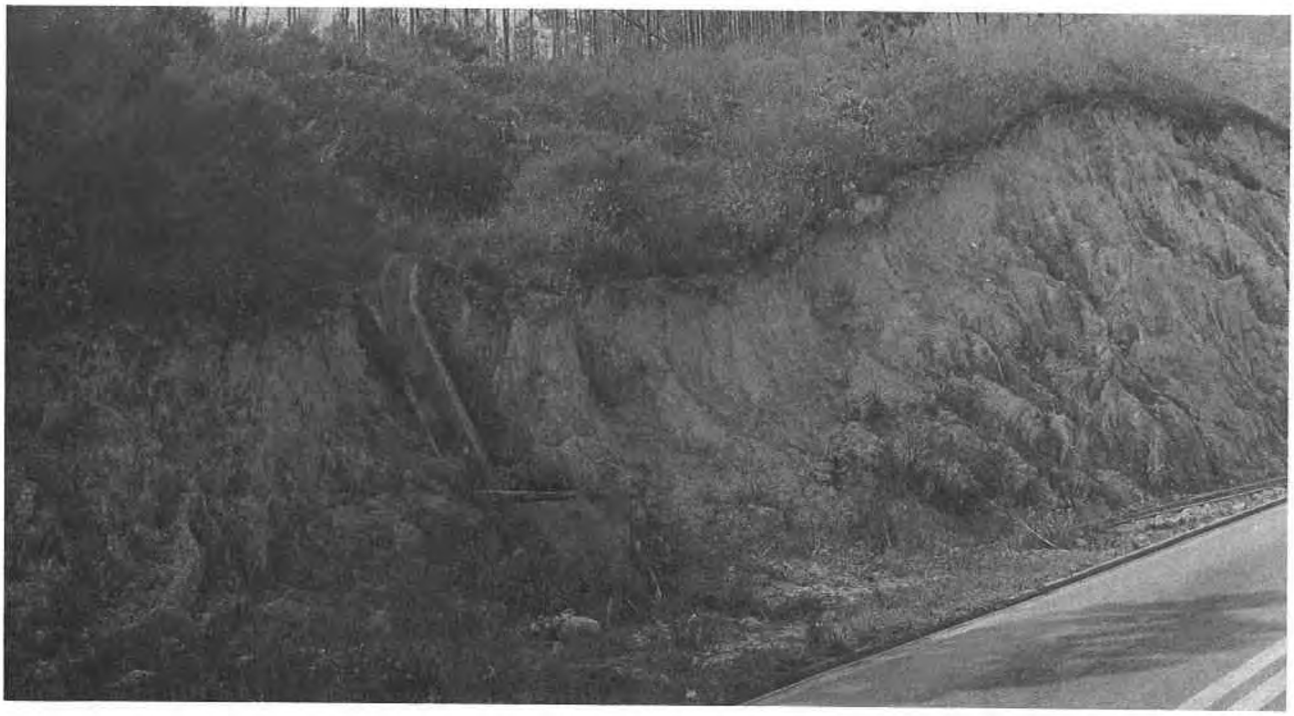


Plate 15. Eroded Cut Slopes in Completely Decomposed Volcanic Rock. The drainage channel has been partially undercut by the removal of the surrounding decomposed rock. Surface runoff cannot flow into the drain which has become ineffective. (GCO/OAP 1985/77–27).

Plate 16. Oblique Aerial Photograph of Shek Pik Reservoir and the Surrounding Terrain. Disused quarry slopes form areas of bare soil and rock around the margins of the reservoir. Many of the steep sideslopes are prone to landslips. (GCO/OAP 1984/11034).

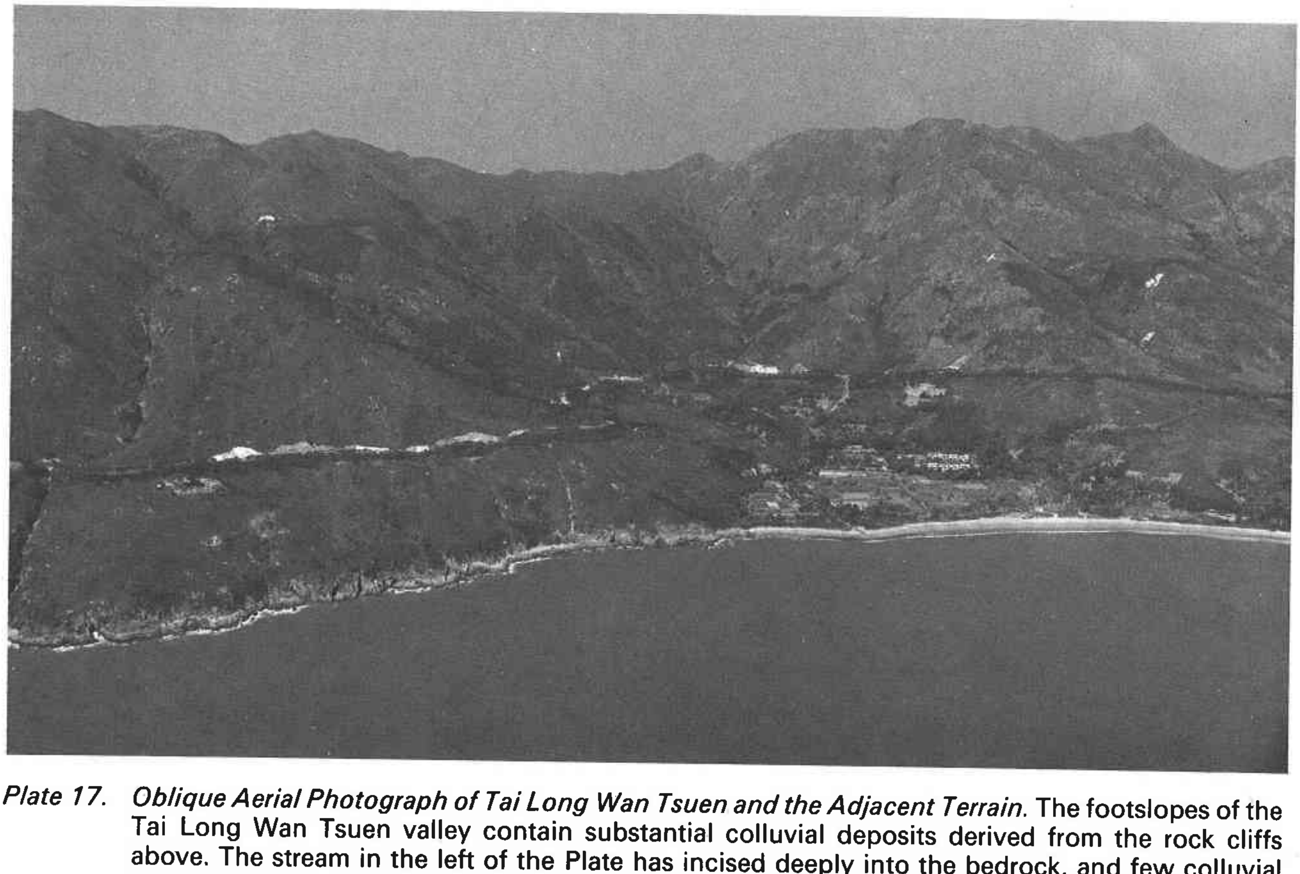


Plate 17. Oblique Aerial Photograph of Tai Long Wan Tsuen and the Adjacent Terrain. The footslopes of the Tai Long Wan Tsuen valley contain substantial colluvial deposits derived from the rock cliffs above. The stream in the left of the Plate has incised deeply into the bedrock, and few colluvial deposits remain. (GCO/OAP 1984/11032).

Plate 18. Oblique Aerial Photograph of the Southeastern Slopes of Ling Wui Shan. Landslips in the centre of this Plate are shown in greater detail in Plate 32. (GCO/OAP 1984/11031).

Plate 19. Oblique Aerial Photograph of the Southwestern Slopes of Ling Wui Shan and the Bay to the West of Kau Ling Chung. (GCO/OAP 1984/11026).

Plate 20. Oblique Aerial Photograph of Fan Lau. (GCO/OAP 1984/11025).

Plate 21. Oblique Aerial Photograph of Peaked Hill and Tsin Yue Wan. (GCO/OAP 1984/10721).

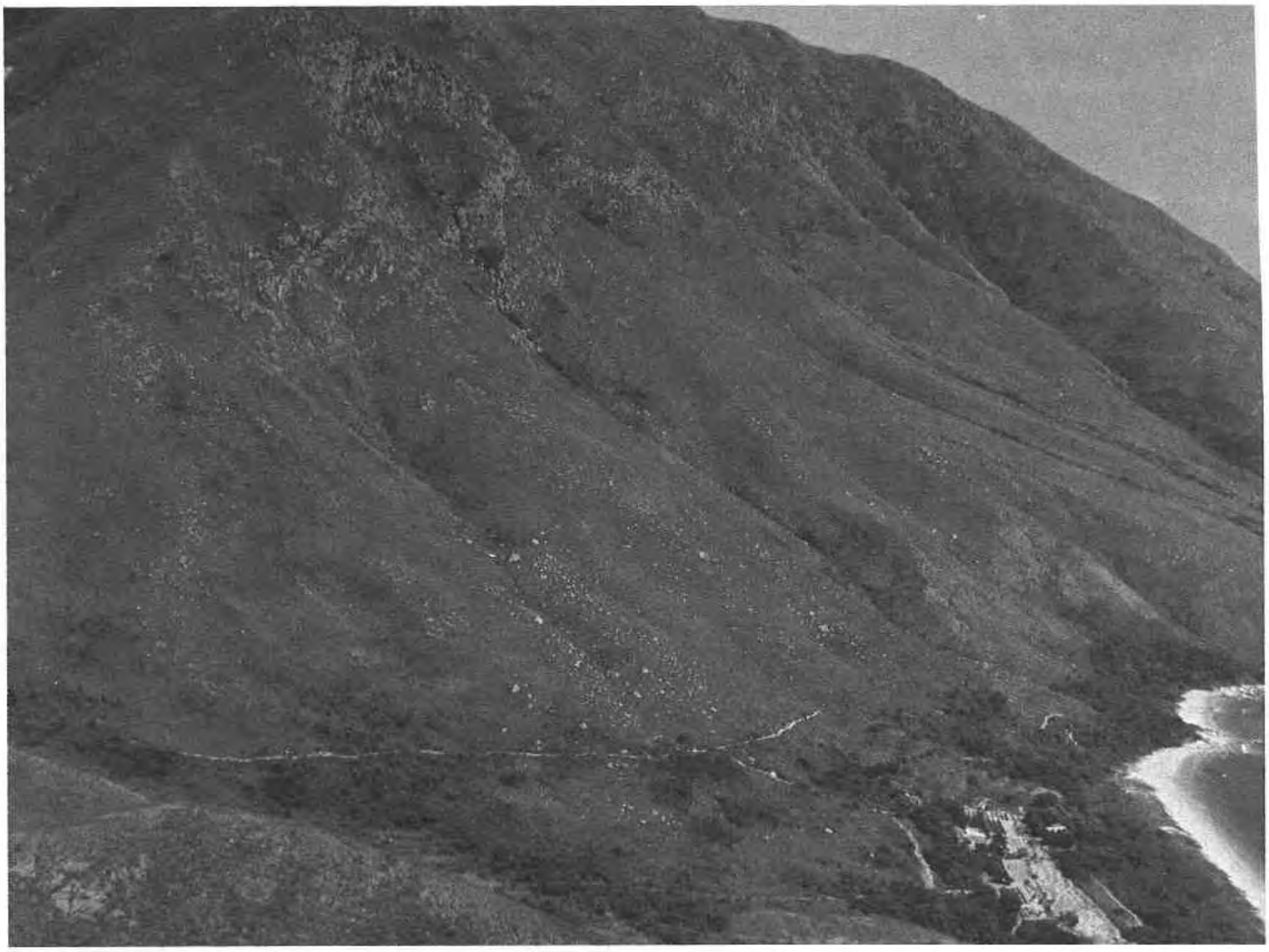


Plate 22. Oblique Aerial Photograph of the Cliffs and Colluvial Footslopes to the North of Tsin Yue Wan. (GCO/OAP 1986/12273).

Plate 23. Oblique Aerial Photograph of the Western Cliffs and Narrow Coastal Footslopes of Kai Kung Shan. (GCO/OAP 1986/12274).

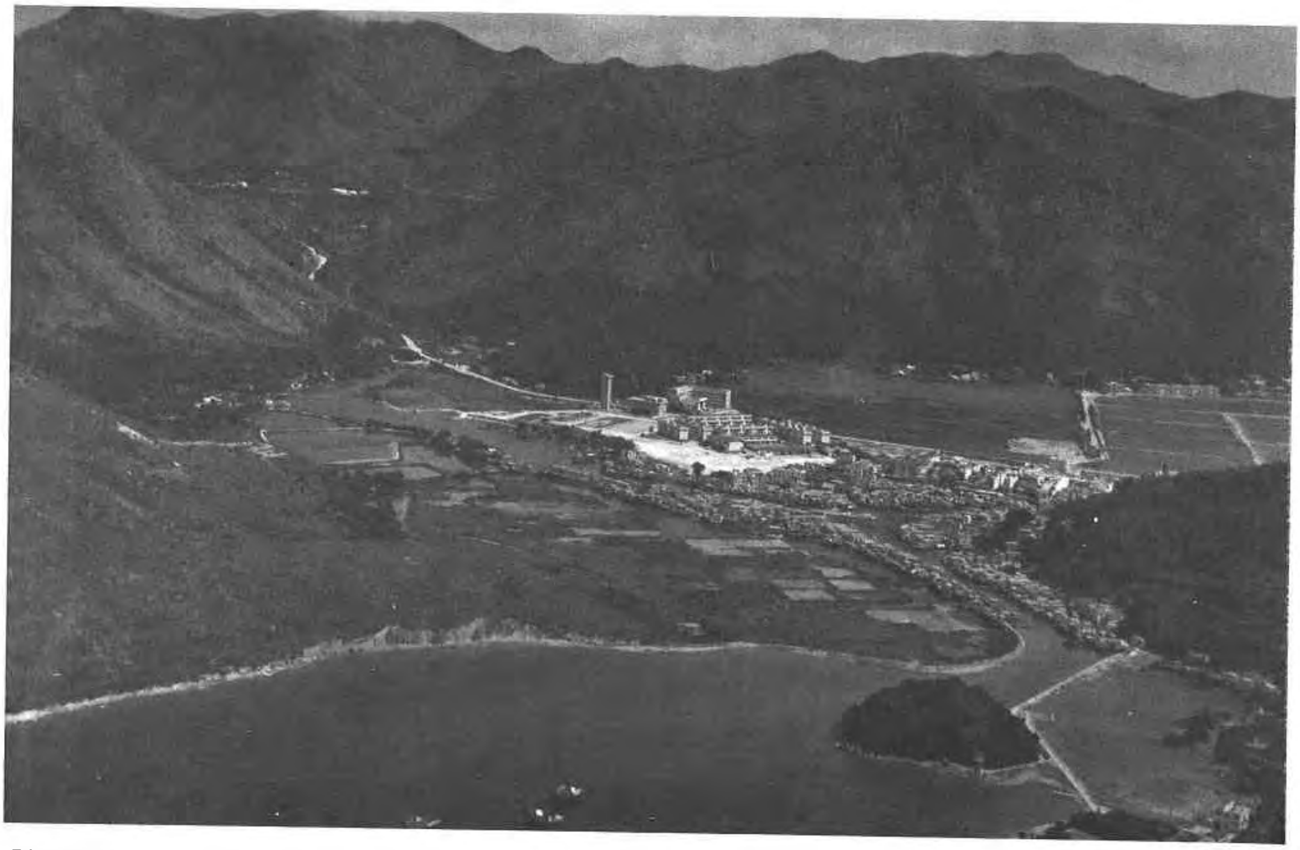


Plate 24. Oblique Aerial Photograph of Tai O and Yim Tin. (GCO/OAP 1986/12284).

Plate 25. Oblique Aerial Photograph of Tai O and Shek Tsai Po. Much of this development has been formed on reclamation. The walls of the salt pans in the upper right of the Plate were severely damaged during the typhoons of 1983. (GCO/OAP 1986/12277).

Plate 26. Oblique Aerial Photograph of the Terrain to the Northeast of Tai O. Landslips on the upper sideslopes have resulted in substantial colluvial footslopes. A large number of grave sites are scattered across the terrain. Note that the stream channels are less distinct upon reaching the colluvium because stream flows often disappear underground through the more permeable bouldery colluvium. (GCO/OAP 1984/11051).

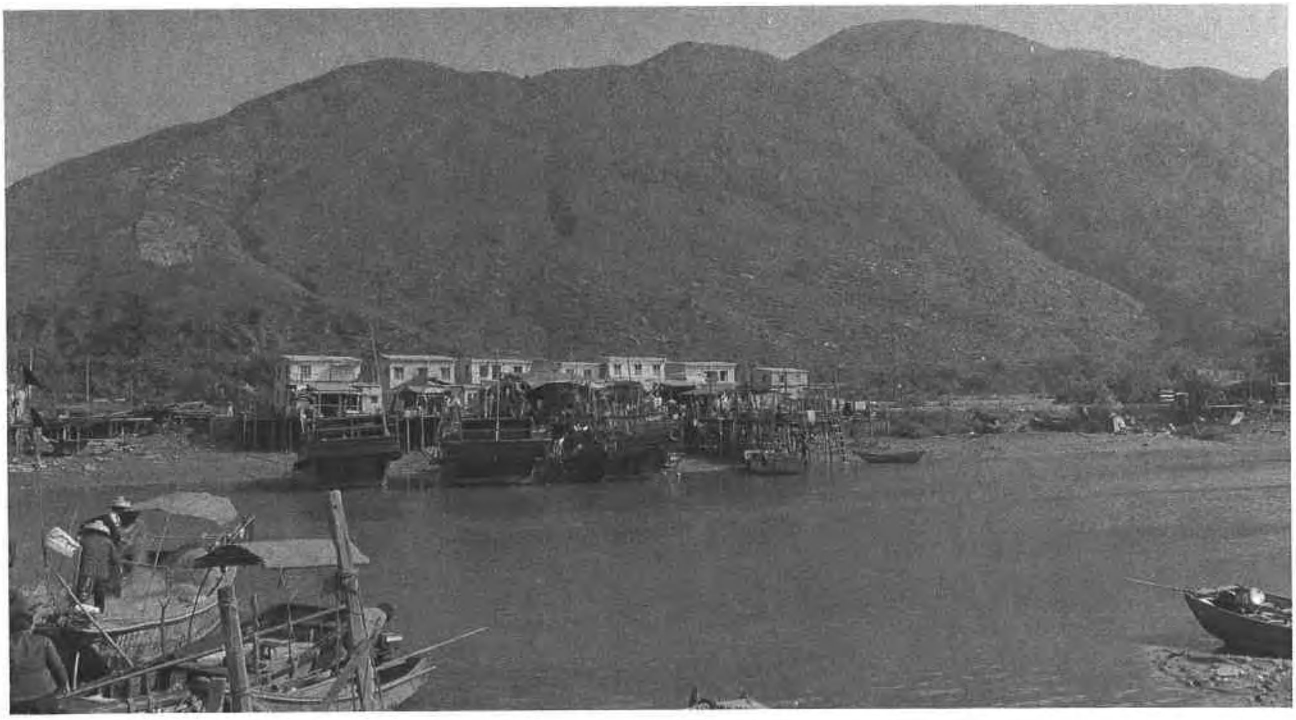


Plate 27. Stilted Riverbank Housing at Yim Tin. (GCO/TP 1985/77–7).

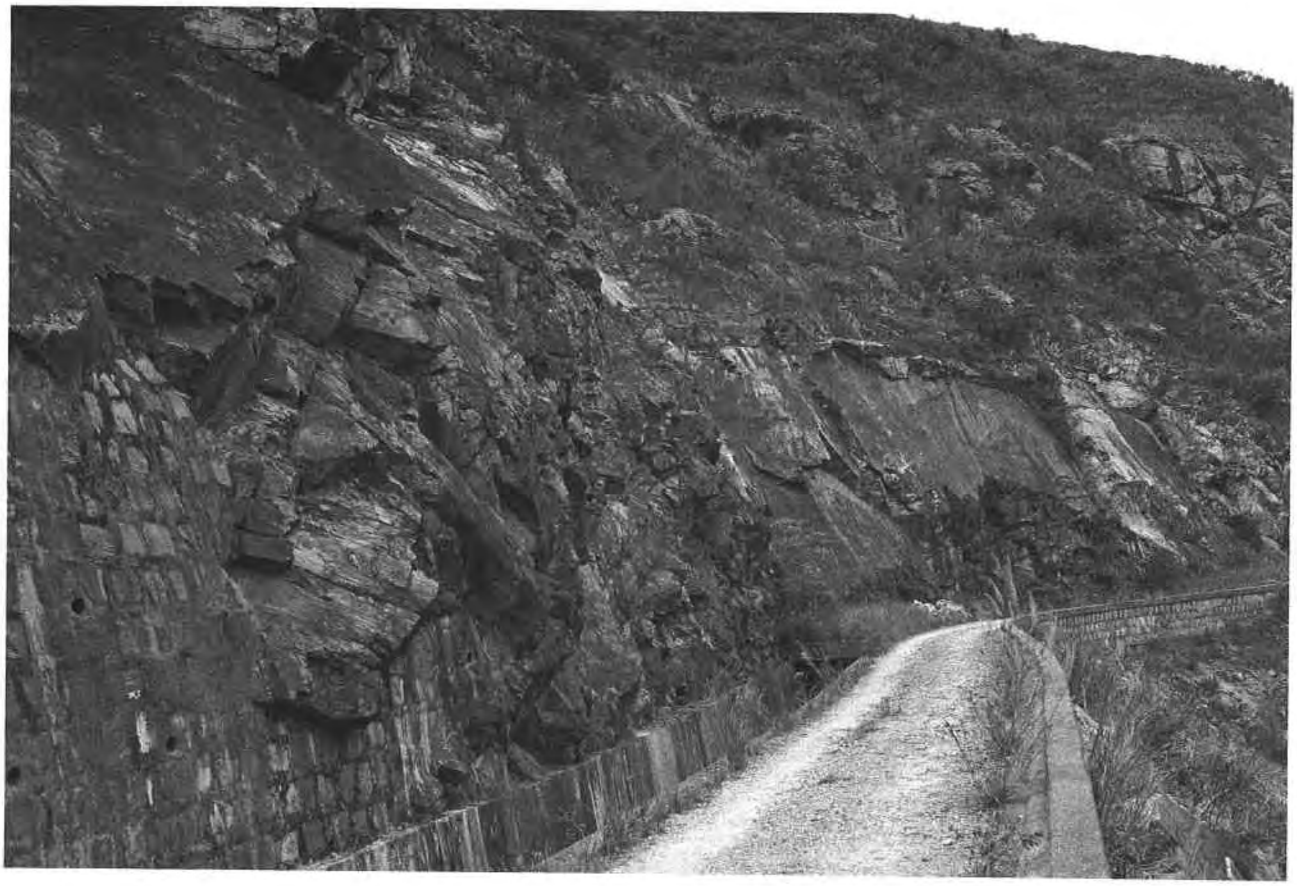


Plate 28. Adversely Jointed Volcanic Rocks in Cut Slopes Near the Western End of the Catchwater in the Keung Shan Valley. Steeply-dipping discontinuities in the bedrock have allowed blocks of rock to break away from the slope. (GCO/TP 1985/75–25).

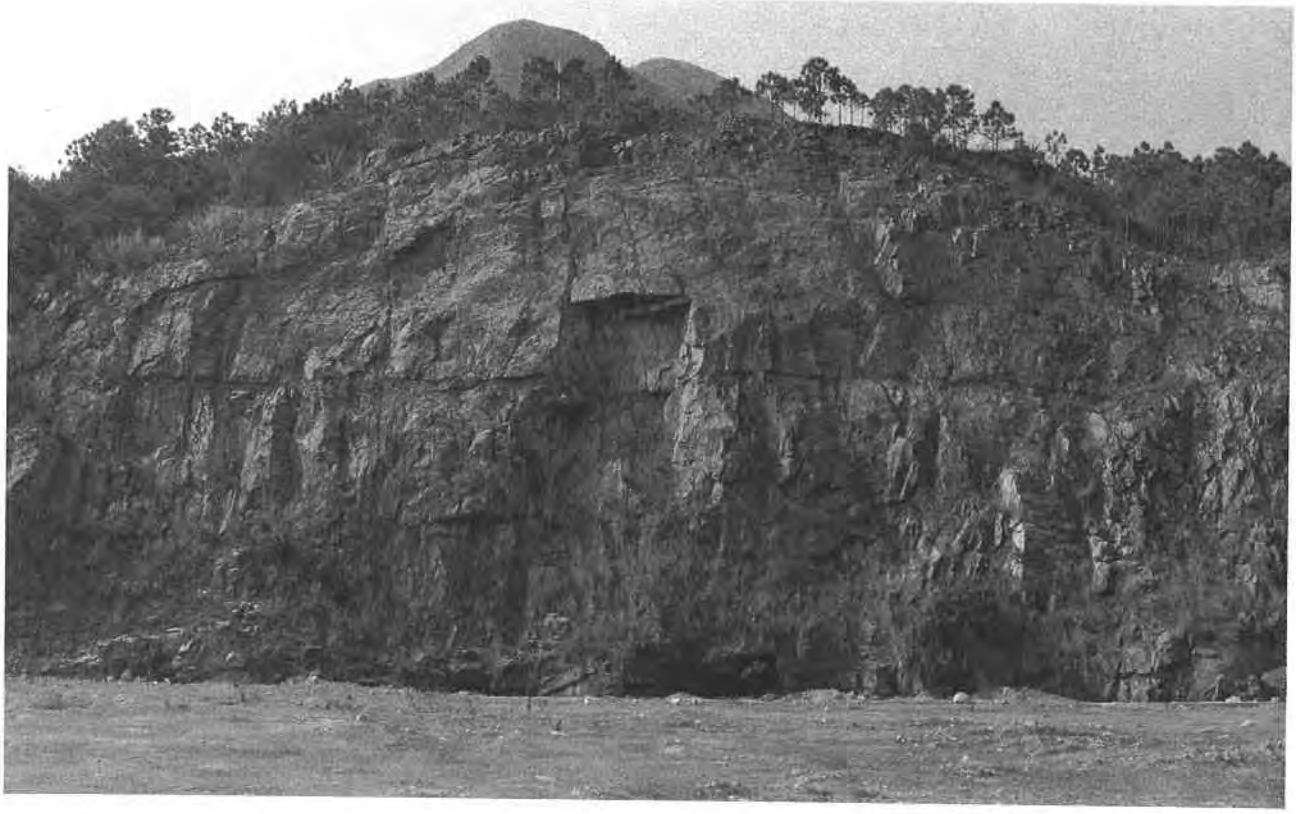


Plate 29. Near Vertical Rock Cut Slopes in a Disused Quarry to the West of Shek Pik Reservoir. Note the large rockfall from the oversteep quarry face in the centre of the Plate. (GCO/TP 1985/77–23).

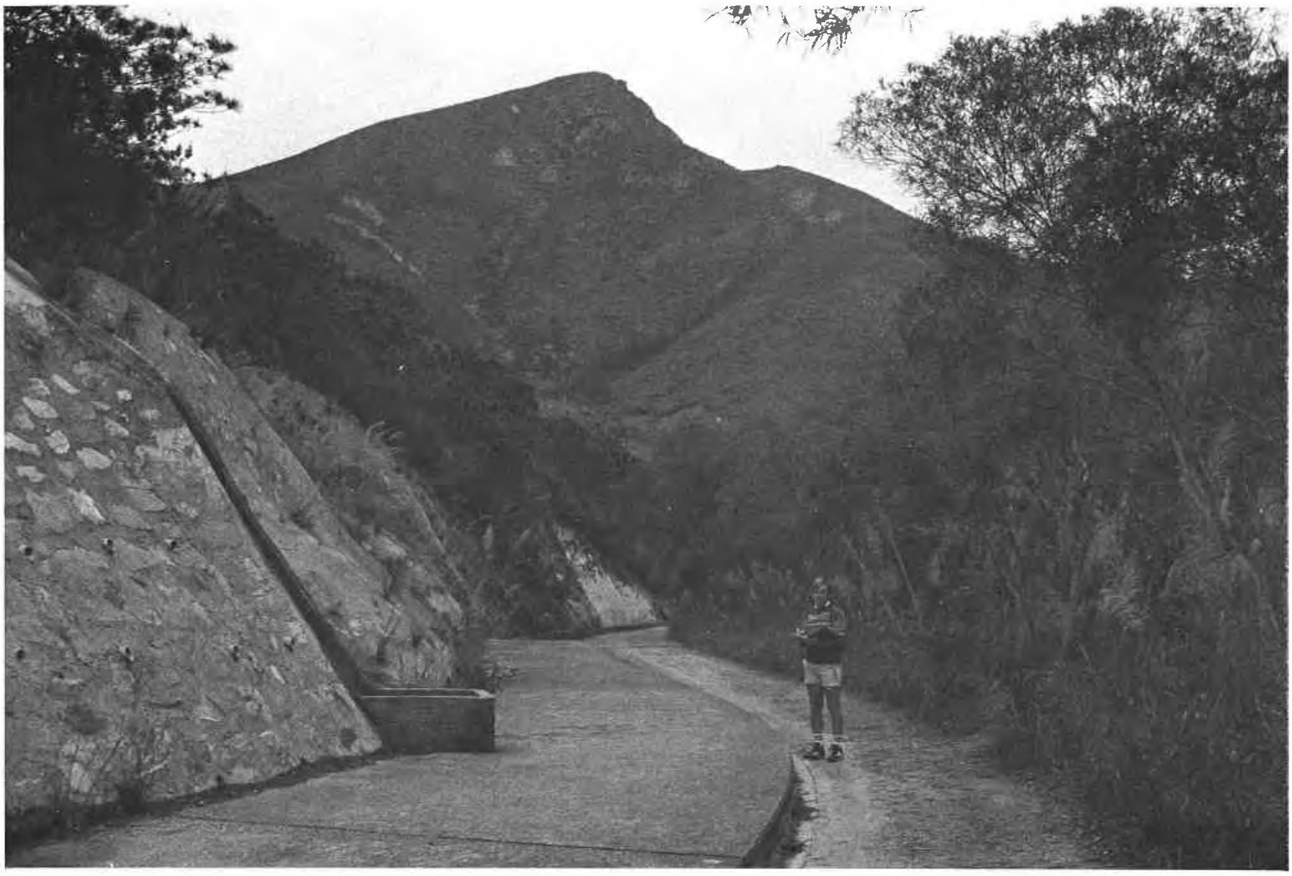


Plate 30. Random Rubble Masonry Wall Supporting a Cut Slope Adjacent to a Covered Section of the Catchwater in the Keung Shan Valley. Note the landslips on the upper sideslopes. (GCO/TP 1985/75-30).

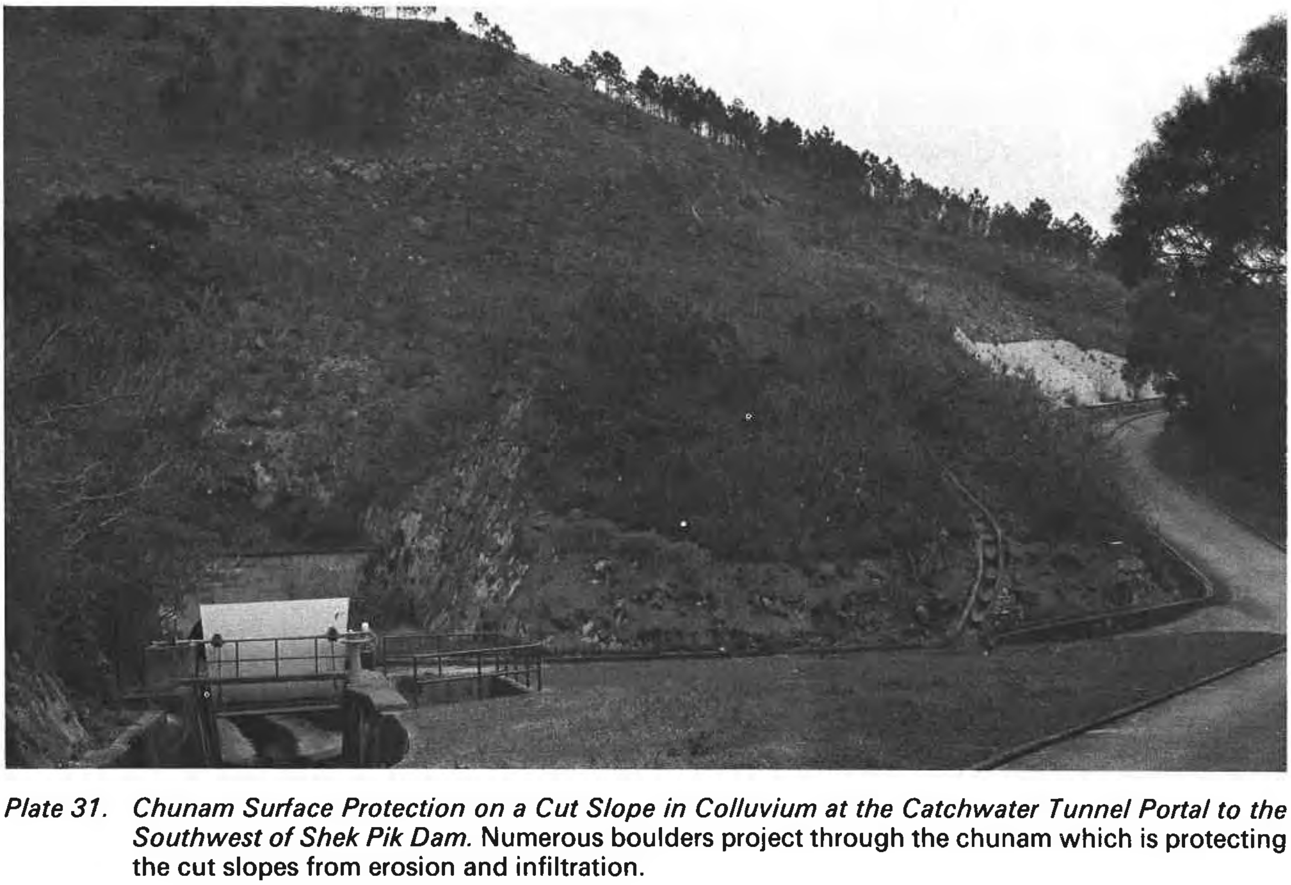


Plate 31. Chunam Surface Protection on a Cut Slope in Colluvium at the Catchwater Tunnel Portal to the Southwest of Shek Pik Dam. Numerous boulders project through the chunam which is protecting the cut slopes from erosion and infiltration.

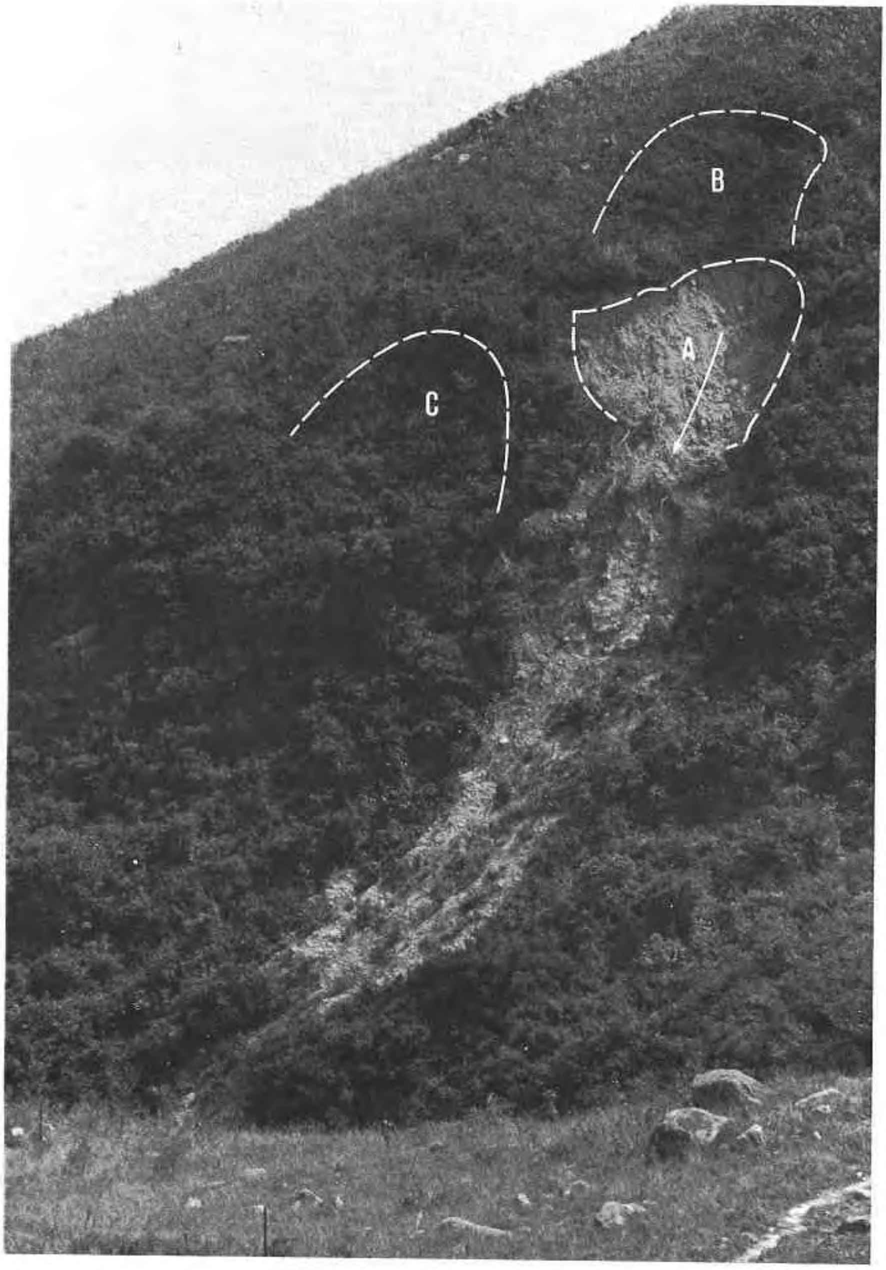


Plate 32. Landslips Adjacent to an Incised Valley to the West of Tai Long Wan. Note the recent landslip scar at A, and relict scars of ancient landslips at B and C. (GCO/TP 1985/74–15).

Plate 33. Fill on Estuarine Alluvium at Ham Tin. (GCO/TP 1985/76–30).

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 13.

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

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

(*b*) The basis for the user-oriented derivative maps, particularly the Geotechnical Land Use Map (GLUM), the Physical Constraints Map (PCM) and the Generalised Limitations and Engineering Appraisal Map (GLEAM). 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 14b. The three terrain attributes adopted for the analysis are:

(*a*) Slope gradient.

(*b*) Terrain component and morphology.

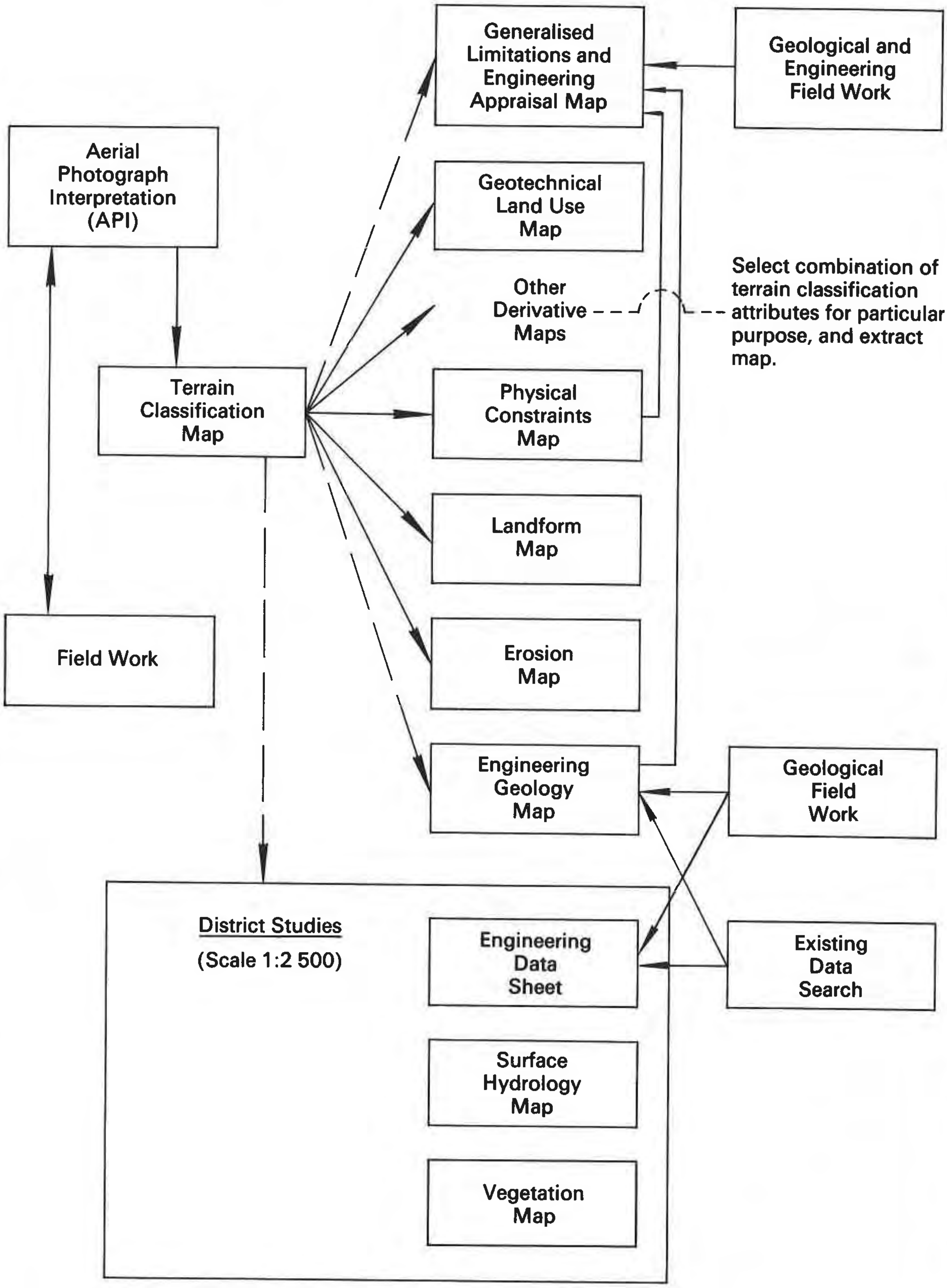
(*c*) Erosion and instability.

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

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

A.3 Terrain Classification Map

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



Technique of Data Acquisition and Derivation of Maps

Fig. A1

Table A1 Terrain Classification Attributes

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

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

A.3.1 *Slope Gradient*

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

A.3.2 *Terrain Component and Morphology*

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

There are the following 14 major terrain component classes:

(*a*) Hillcrest (Code A).

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

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

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

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

(*f*) Floodplain (Code I).

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

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

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

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

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

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

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

(*n*) Reclamation (Code Z).

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

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

A.3.3 *Erosion and Instability*

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

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

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

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

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

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

A.4 Landform Map

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

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

(*a*) Hillcrest or ridge.

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

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

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

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

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

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

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

(*i*) Cliff and rock outcrop.

(*j*) Wave cut platforms.

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

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

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

A.5 Erosion Map

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

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

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

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

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

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

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

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

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

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

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

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

(*k*) Wave and cut platforms.

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

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

A.6 Physical Constraints Map

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

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

The major constraints which are shown on the map are:

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

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

(*c*) Colluvium.

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

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

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

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

(*h*) Major waterbodies.

(*i*) Moderate and severe gully erosion.

(*j*) Instability on disturbed terrain.

A.7 Geotechnical Land Use Map

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

Table A2 GLUM Classification System

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

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

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

(i) *Class I—Low Geotechnical Limitations*
These areas are characterised by a low level of geotechnical limitation, and consequently have the highest suitability for development. Costs of site formation, foundation works and drainage works are expected to be low. Only normal geotechnical investigations will probably be required and investigation costs are expected to be low.

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

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

(iii) *Class III—High Geotechnical Limitations*
These areas are characterised by high geotechnical limitations, and consequently are of low suitability for development. Costs of site formation, foundation works and drainage works can be expected to be high. Intensive geotechnical investigations will be necessary, and investigation costs will be high.

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

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

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

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

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

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

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

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

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

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

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

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

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

A.8 Engineering Geology Map

A.8.1 *Background*

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

The comments made in this Report with regard to the engineering geology of the Central 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 geomorphology and material properties of the lithological units.

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

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

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

(*b*) Major photolineaments.

(*c*) Major topographic features.

(*d*) Isopachs of submarine superficial deposits.

(*e*) Boundaries of major catchments.

(*f*) Zones of general instability.

(*g*) Zones of reclamation.

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

A.8.3 *Colluvium Classification System*

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

(*a*) Essentially volcanic derived.

(*b*) Essentially granite derived.

(*c*) Essentially metasediment derived.

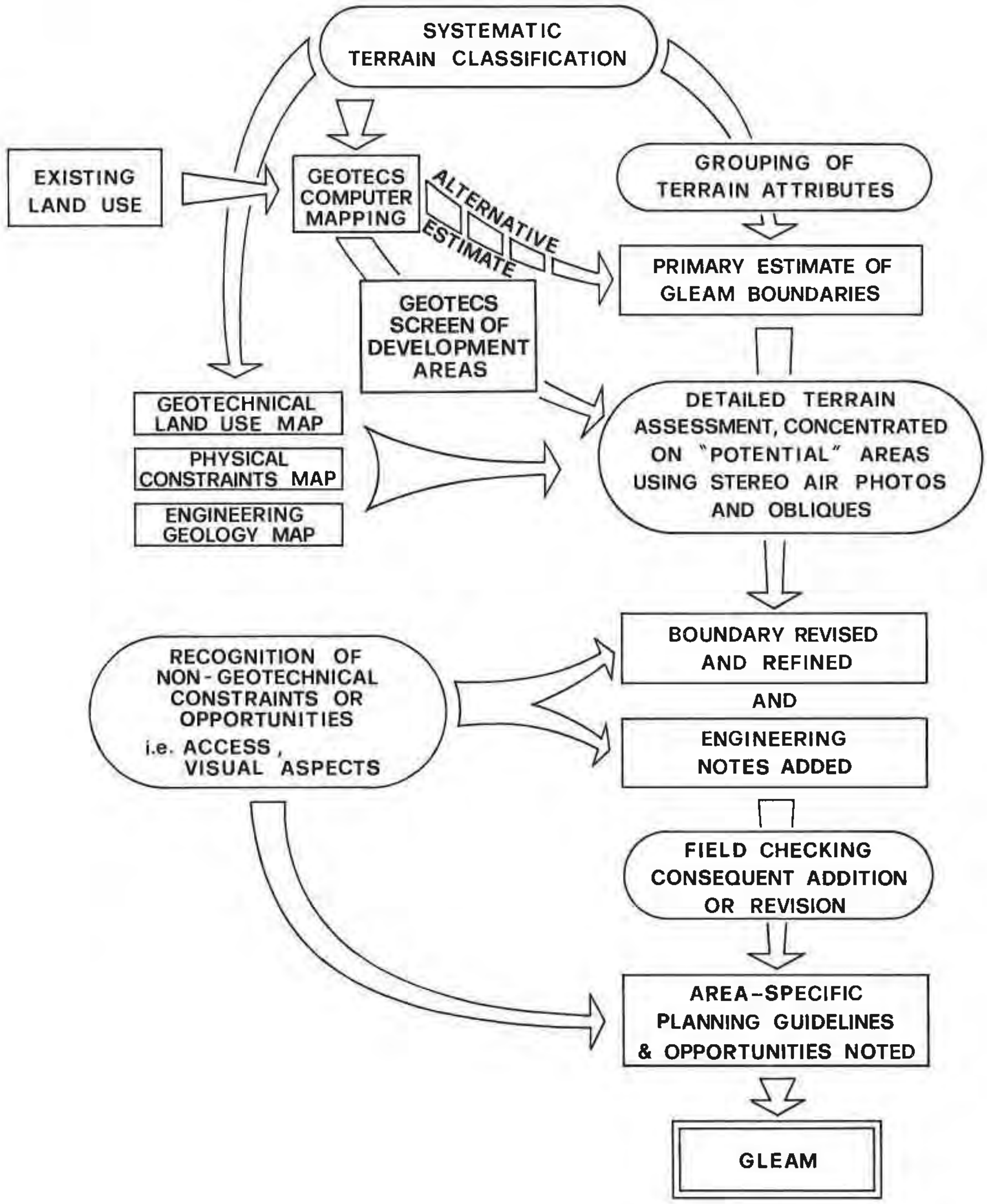
(*d*) Mixed origin.

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

A.8.4 *Data Collection*

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

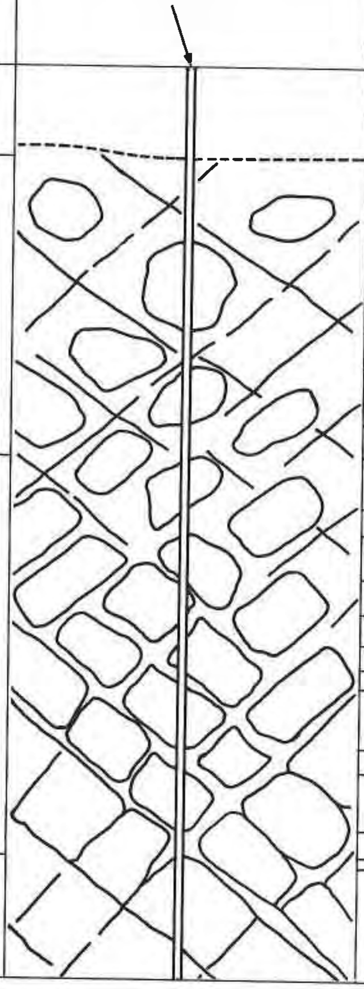
Details of the aerial photographs used for the terrain classification are given in Appendix C.3 and Table C.2.



Derivation of Generalised Limitations and Engineering Appraisal Map

Fig. A2

Table A3 Rock Weathering System

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

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

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

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

A.9 Generalised Limitations and Engineering Appraisal Map

A.9.1 *Introduction*

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

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.

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

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

Yes = Potential development   No = Constraint†

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

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

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

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

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.

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. Str. cont. = Structural Control (of drainage)
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 XI data bank consists of 3 720 grid cells, each of which covers approximately 2.04 hectares (49 cells per grid kilometre square) and is referenced to the Hong Kong Metric Grid. This programme, which is known within the Geotechnical Control Office as the Geotechnical Terrain Classification System (GEOTECS), is discussed briefly in Section 1.5.9. Nine natural resource attributes are recorded for each grid cell. The attributes are: slope gradient, terrain component, erosion and instability, aspect, relief, superficial and bedrock geology, existing land use, and vegetation.

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

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

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

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

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

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

APPENDIX B

DATA TABLES FOR THE SOUTH LANTAU GEOTECHNICAL AREA STUDY

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Table B1 Slope Gradient

Slope Gradient	% of Total Area	Area (ha)
0– 5°*	7.1	539
5–15°	12.3	936
15–30°	36.1	2 738
30–40°	39.7	3 013
40–60°	4.6	349
>60°	0.2	14
	100.0	7 589

* Approximately 131 ha of uncovered reservoirs and ponds are included in the 0–5° Class.

Table B2 Erosion and Instability

Erosion		% of Total Area	Area (ha)
Instability			
—coastal instability		2.7	202
—general instability		36.2	2 748
Appreciable Erosion	Sheet erosion—minor	11.9	906
	—moderate to severe	2.8	212
	Rill erosion —minor	0.3	23
	—moderate to severe	0.1	10
	Gully erosion —minor	0.2	18
	—moderate to severe	0.1	6
No Appreciable Erosion*		45.7	3 464
		100.0	7 589

* Approximately 131 ha of uncovered reservoirs and ponds are included within No Appreciable Erosion.

Table B3 Aspect

Aspect	% of Total Area	Area (ha)
North	4.2	318
Northeast	9.1	689
East	6.4	490
Southeast	24.1	1 828
South	10.0	763
Southwest	18.2	1 379
West	8.8	665
Northwest	12.1	918
Flat/Unclassified*	7.1	539
	100.0	7 589

* Approximately 131 ha of uncovered reservoirs and ponds are included in the Flat/Unclassified category.

Table B4 Aspect and Slope Gradient

Aspect	Slope Gradient					Total Area (ha)
	5–15°	15–30°	30–40°	40–60°	>60°	
North	41	120	147	10	0	318
Northeast	65	300	310	14	0	689
East	51	216	220	2	0	490
Southeast	288	690	741	108	2	1 828
South	118	271	326	43	4	763
Southwest	208	557	532	78	4	1 379
West	67	233	322	41	2	665
Northwest	98	351	414	53	2	918
0–5° (Flat/Unclassified)						539
						7 589

Table B5 Landform

Terrain (Landform)	Slope Gradient	% of Total Area	Area (ha)
Hillcrest		5.0	379
Sideslope	0– 5°	0.2	16
"	5–15°	2.1	161
"	15–30°	30.0	2 275
"	30–40°	38.6	2 930
"	>40°	2.1	161
Cliff/Rock outcrop	0–30°	<0.1	4
"	>30°	2.8	214
Footslope (colluvium)	0– 5°	0.4	29
"	5–15°	3.3	253
"	15–30°	2.6	200
"	>30°	0.3	20
Drainage plain (colluvium)	0– 5°	0.3	23
"	5–15°	2.9	222
"	15–30°	0.7	49
"	>30°	0	0
Alluvial plain	0– 5°	<0.2	16
"	>5°	0.2	18
Floodplain	0– 5°	1.7	129
"	>5°	0.2	14
Littoral zone	0–15°	2.0	149
Cut platforms : insitu	0– 5°	0	0
: colluvium	0– 5°	0	0
: alluvium	0– 5°	0	0
Cut slopes : insitu	>5°	1.1	82
: colluvium	>5°	0	0
: alluvium	>5°	0	0
Fill platforms : insitu	0– 5°	0	0
: colluvium	0– 5°	0	0
: alluvium	0– 5°	0.5	39
Fill slopes : insitu	>5°	0.1	10
: colluvium	>5°	0	0
: alluvium	>5°	0.2	12
Reclamation	0–5°	0.5	35
Wave cut platform		0.1	8
General disturbed terrain/platforms: insitu	0– 5°	<0.1	2
General disturbed terrain/slope: insitu	>5°	0	0
: colluvium	>5°	0.1	8
: alluvium	>5°	0	0
Natural stream		<0.1	4
Man-made channel		0	0
Water storage		1.4	106
Pond		0.3	25
		100.0	13 368

Table B6 Geology

Geological Unit	% of Total Area	Area (ha)
Alluvium: undifferentiated	4.0	304
: raised	0.1	8
Colluvium: volcanic	8.5	649
: granitic	1.1	84
: sedimentary	0.3	24
: mixed	0.5	39
Littoral deposits	2.0	149
Reclamation	0.5	35
Fill	0.9	67
Repulse Bay Formation: undifferentiated volcanics	17.7	1 342
: sedimentary rocks and waterlaid volcanics	10.4	788
: acid lavas	7.5	567
: mainly banded acid lavas, some welded tuffs	0	0
: coarse tuff	1.7	133
: agglomerate	0.1	10
: dominantly pyroclastics and some lavas	24.8	1 881
Tai O Formation	1.1	80
Quartz Monzonite	4.6	347
Feldspar Porphyry Dyke Swarm	2.4	182
Fan Lau Porphyritic Granite	0.2	18
Ma On Shan Granite	0.1	8
Cheung Chau Granite	8.8	667
Sung Kong Granite	2.3	173
Tai Po Granodiorite	0.3	24
Undifferentiated Granite	0.1	10
	100.0	7 589

Approximately 131 ha of reservoirs and ponds have been categorised as possessing alluvial deposits.

Table B7 Vegetation

Vegetation	% of Total Area	Area (ha)
Grassland	39.5	3 001
Cultivation	1.2	94
Mixed broadleaf woodland	33.3	2 524
Shrubland (<50%)	13.8	1 044
Shrubland (>50%)	2.7	208
No vegetation on natural terrain	2.1	161
No vegetation due to disturbance of terrain by man*	2.6	196
No vegetation due to rock outcrop	3.0	226
Waterbodies	1.8	135
	100.0	7 589

* Approximately 131 ha of uncovered reservoirs are included in this class.

Table B8 Geology and GLUM Class

Geological Unit	Area in GLUM Class (ha)				
	I	II	III	IV	Unclassified
Alluvium: undifferentiated	0	170	0	0	135
: raised	0	8	0	0	0
Colluvium: volcanic	0	16	525	108	0
: granitic	0	4	69	10	0
: sedimentary	0	6	18	0	0
: mixed	0	2	33	4	0
Littoral deposits	0	0	0	0	149
Reclamation	0	35	0	0	0
Fill	0	45	22	0	0
Repulse Bay Formation: undifferentiated volcanics	12	424	202	704	0
: sedimentary rocks and waterlaid volcanics	65	298	147	278	0
: acid lavas	43	267	116	141	0
: mainly banded acid lavas, some welded tuffs	0	0	0	0	0
: coarse tuffs	4	80	37	12	0
: agglomerate	0	0	0	10	0
: dominantly pyroclastics and some lavas	49	587	388	857	0
Tai O Formation	0	14	10	55	0
Quartz Monzonite	8	216	49	71	2
Feldspar Porphyry Dyke Swarm	8	104	31	39	0
Fan Lau Porphyritic Granite	10	2	2	4	0
Ma On Shan Granite	0	4	0	4	0
Cheung Chau Granite	2	206	108	347	4
Sung Kong Granite	0	106	55	10	2
Tai Po Granodiorite	2	16	2	4	0
Undifferentiated Granite	0	2	0	8	0

Table B9 GLUM Class

GLUM Class	Geotechnical Limitations	% of Total Area	Area (ha)
I	Low	2.7	204
II	Moderate	32.6	2 472
IIS	Moderate	1.9	141
III	High	23.9	1 814
IV	Extreme	35.1	2 666
Unclassified		3.8	292
		100.0	7 589

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	Coastal Instability	GI		
0–5°	Flat	V	23	14	0	0	0	0	37	0
		G	6	2	0	0	0	0	8	0
		S	0	0	0	0	0	0	0	0
		C	45	6	0	0	0	0	51	0
		A	282	2	0	0	0	0	284	0
		L	92	0	0	0	0	0	92	0
		F	51	16	0	0	0	0	67	0
5–15°	N	V	6	8	0	0	0	0	14	0
		G	0	2	0	0	0	0	2	0
		S	0	0	0	0	0	0	0	0
		C	14	0	0	0	0	0	14	0
		A	0	0	0	0	0	0	0	0
		L	6	0	0	0	0	0	6	0
		F	4	0	0	0	0	0	0	0
	NE	V	14	15	0	0	0	0	29	0
		G	6	0	0	0	0	0	6	0
		S	0	0	0	0	0	0	0	0
		C	27	2	0	0	0	0	29	0
		A	0	2	0	0	0	0	0	0
		L	0	0	0	0	0	0	0	0
		F	0	0	0	0	0	0	0	0
	E	V	8	6	0	0	0	0	14	0
		G	4	4	0	0	0	0	8	0
		S	0	0	0	0	0	0	0	0
		C	16	0	0	0	0	0	0	0
		A	4	0	0	0	0	0	0	0
		L	8	0	0	0	0	0	8	0
		F	0	0	0	0	0	0	0	0
	SE	V	41	29	0	0	0	0	70	0
		G	18	8	0	0	0	0	26	0
		S	0	0	0	0	0	0	0	0
		C	161	0	0	0	0	0	161	0
		A	14	0	0	0	0	0	14	0
		L	14	0	0	0	0	0	14	0
		F	2	0	0	0	0	0	2	0
	S	V	20	8	0	0	0	0	28	0
		G	4	0	0	0	0	0	4	0
		S	0	0	0	0	0	0	0	0
		C	74	2	0	0	0	0	76	0
		A	2	0	2	0	0	0	2	0
		L	6	0	0	0	0	0	6	0
		F	0	0	0	0	0	0	0	0
	SW	V	29	41	0	0	0	0	70	0
		G	10	8	0	2	0	0	20	0
		S	0	0	0	0	0	0	0	0
		C	94	0	0	0	0	2	96	0.02
		A	0	0	4	0	0	0	4	0
		L	16	0	0	0	0	0	16	0
		F	2	0	0	0	0	0	2	0
	W	V	8	16	0	0	0	0	24	0
		G	4	0	0	0	0	0	4	0
		S	0	0	0	0	0	0	0	0
		C	33	0	0	0	0	0	33	0
		A	0	0	0	0	0	0	0	0
		L	0	0	0	0	0	0	0	0
		F	2	4	0	0	0	0	6	0
	NW	V	17	12	0	2	0	0	31	0
		G	2	6	0	0	0	0	8	0
		S	0	0	0	0	0	0	0	0
		C	51	0	0	0	0	0	51	0
		A	0	0	0	0	0	0	0	0
		L	6	0	0	0	0	0	6	0
		F	2	0	0	0	0	0	2	0
15–30°	N	V	45	10	0	0	0	22	77	0.29
		G	15	12	0	0	0	8	35	0.23
		S	0	0	0	0	0	0	0	0
		C	6	0	0	0	0	2	8	0.25
		F	0	0	0	0	0	0	0	0
	NE	V	116	29	2	0	0	33	180	0.18
		G	61	29	2	0	0	4	96	0.04
		S	2	0	0	0	0	2	4	0.50
		C	18	0	0	0	0	2	20	0.10
		F	0	0	0	0	0	0	0	0
	E	V	82	43	2	2	0	16	145	0.11
		G	33	18	0	0	0	8	59	0.14
		S	2	0	0	0	0	0	2	0
		C	6	0	0	0	0	4	10	0.40
		F	0	0	0	0	0	0	0	0
	SE	V	259	157	4	2	0	59	481	0.12
		G	65	76	2	0	2	2	147	0.03
		S	0	0	0	0	0	2	2	1.00
		C	41	4	0	0	0	14	59	0.24
		F	0	0	0	0	0	0	0	0
	S	V	108	69	0	2	0	10	189	0.05
		G	27	22	2	0	0	0	51	0
		S	0	0	0	0	0	0	0	0
		C	18	0	0	0	0	6	24	0.25
		F	6	0	0	0	0	0	6	0
	SW	V	163	153	4	0	0	49	369	0.13
		G	59	59	0	2	0	8	128	0.06
		S	2	0	0	0	0	0	2	0
		C	31	0	0	4	0	12	47	0.26
		F	10	0	0	0	0	0	10	0
	W	V	59	39	0	0	0	39	137	0.28
		G	27	22	0	0	0	4	53	0.08
		S	4	0	0	0	0	0	4	0
		C	25	0	0	0	0	12	37	0.32
		F	2	0	0	0	0	0	0	0
	NW	V	139	27	0	0	0	47	213	0.22
		G	41	35	0	0	0	14	90	0.16
		S	4	0	0	0	0	2	6	0.67
		C	29	0	0	0	0	14	43	0.33
		F	0	0	0	0	0	0	0	0

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

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

Slope Gradient	Aspect	Surface* Geology	No Appreciable Erosion (ha)	Appreciable Erosion (ha)			Instability (ha)		Area (ha)	Area Instability Index
				Sheet	Rill	Gully	Coastal Instability	GI		
30–40°	N	V	16	0	0	0	2	82	100	0.84
		G	8	0	0	0	2	31	41	0.76
		S	0	0	0	0	2	2	4	1.00
		C	2	0	0	0	0	0	2	0
	NE	V	45	2	0	0	6	151	204	0.77
		G	16	2	0	0	10	67	95	0.81
		S	0	0	0	0	4	6	10	1.00
		C	0	0	0	0	0	0	0	0
	E	V	39	2	0	0	0	125	166	0.75
		G	14	2	0	0	10	27	53	0.70
		S	0	0	0	0	0	0	0	0
		C	0	0	0	0	0	2	2	1.00
	SE	V	141	20	0	4	10	398	573	0.69
		G	49	12	0	0	20	78	159	0.62
		S	0	0	0	0	0	4	4	1.00
		C	0	0	0	0	0	4	4	1.00
	S	V	78	8	4	0	6	165	261	0.66
		G	16	2	0	0	8	33	59	0.69
		S	0	0	0	0	0	0	0	0
		C	0	0	0	0	0	6	6	1.00
	SW	V	116	27	2	0	2	282	429	0.66
		G	29	2	0	2	10	55	98	0.66
		S	0	0	0	0	0	6	6	1.00
		C	0	0	0	0	0	0	0	1.00
	W	V	37	8	2	0	10	192	249	0.77
		G	16	2	0	0	10	37	65	0.72
		S	0	0	0	0	0	6	6	1.00
		C	0	0	0	0	0	2	2	1.00
	NW	V	53	6	0	0	6	259	324	0.81
		G	18	2	0	0	4	47	71	0.72
		S	4	0	0	0	4	6	14	0.71
		C	4	0	0	0	0	0	0	0
>40°	N	V	0	0	0	0	2	6	8	1.00
		G	0	0	0	0	0	0	0	0
		S	0	0	0	0	2	0	2	1.00
	NE	V	0	0	0	0	0	10	10	1.00
		G	2	0	0	0	2	0	4	0.50
		S	0	0	0	0	0	0	0	0
	E	V	0	0	0	0	0	2	2	1.00
		G	0	0	0	0	0	0	0	0
		S	0	0	0	0	0	0	0	0
	SE	V	4	0	0	0	16	78	98	0.96
		G	0	0	0	0	6	6	12	1.00
		S	0	0	0	0	0	0	0	0
	S	V	2	0	0	0	10	31	43	0.95
		G	0	0	0	0	0	4	4	1.00
		S	0	0	0	0	0	0	0	0
	SW	V	2	0	0	2	4	61	69	0.94
		G	0	0	0	0	6	6	12	1.00
		S	0	0	0	0	0	0	0	0
	W	V	2	0	0	0	2	37	41	0.95
		G	0	0	0	0	0	2	2	1.00
		S	0	0	0	0	0	0	0	0
	NW	V	0	0	0	0	4	35	39	1.00
		G	0	0	0	0	4	0	4	1.00
		S	0	0	0	0	12	0	12	1.00

Note: V=volcanic rocks; A=alluvium; GI=general instability; G=granitic rocks; L=littoral deposits; C=colluvium; F=fill and reclamation; S=sediments

Table B11 Geology, Erosion and Instability

Geological Unit	No Appreci-able Erosion (ha)	Appreciable Erosion (ha)			Instability (ha)		Total Area (ha)	Area Instability Index
		Sheet	Rill	Gully	Coastal Instability	General Instability		
Reclamation	29	6	0	0	0	0	29	0
Fill	51	0	0	0	0	0	51	0
Alluvium:								
—undifferentiated	294	4	6	0	0	0	304	0
—raised	8	0	0	0	0	0	8	0
Littoral Zone	149	0	0	0	0	0	149	0
Colluvium:								
—volcanic	565	8	0	2	0	73	648	0.11
—granitic	75	0	0	2	0	6	83	0.07
—sedimentary	18	6	0	0	0	0	24	0
—mixed	35	0	0	0	0	4	39	0.10
Repulse Bay Formation:								
—undifferentiated volcanics	398	169	12	8	14	741	1 334	0.57
—sedimentary rocks and waterlaid volcanics	288	175	4	0	12	306	785	0.41
—acid lavas	282	94	4	0	10	177	567	0.33
—coarse tuff	106	14	0	0	0	12	132	0.09
—agglomerate	0	0	0	0	0	10	10	1.00
—dominantly pyroclastic and some lavas	596	294	0	6	45	940	1 881	0.53
Tai O Formation	18	0	0	0	24	37	79	0.77
Quartz Monzonite	104	157	0	4	14	67	342	0.24
Feldspar Porphyry Dyke Swarm	123	18	0	0	8	33	172	0.24
Fan Lau Porphyritic Granite	14	0	0	0	4	0	18	0.22
Ma On Shan Granite	2	2	0	0	0	4	8	0.50
Cheung Chau Granite	177	103	6	0	57	322	665	0.57
Sung Kong Granite	112	45	0	2	4	10	173	0.08
Tai Po Granodiorite	18	2	0	0	2	2	24	0.17
Undifferentiated Granite	2	0	0	0	6	2	10	0.80

Table B12 Existing Land Use (From aerial photograph interpretation by the Geotechnical Control Office in 1982)

Existing Land Use	Area %	Area
Residential and private development	1.1	84
Squatters	<0.1	6
Institutional and community	1.0	75
Horticulture	1.1	86
Agriculture (undefined)	0.9	63
Undisturbed areas	17.8	1 355
Country park	75.6	5 732
Reclamation (unused)	0.1	10
Temporary land use	0.2	14
Artificial slopes	0.4	29
Water storage	1.4	106
Ponds	0.3	25
Natural streams	<0.1	4
	100.0	7 589

Table B13 Existing Land Use and GLUM Class

Existing Land Use	Area in GLUM Class (ha)				
	I	II	III	IV	Unclassified
Residential and private development:					
Private development	0	4	6	0	0
2 storey development	2	23	21	0	0
1 storey development	4	16	6	0	0
Government housing estate	0	2	0	0	0
Squatters	0	6	0	0	0
Institutional and community:					
Sports complex	0	2	0	0	0
Hospital	0	0	2	0	0
Temple or church	0	4	0	0	0
Cemetery	0	2	0	10	0
Prison	0	23	8	0	0
Roads	2	16	6	0	0
Horticulture	2	55	27	2	0
Agriculture (undefined)	0	57	6	0	0
Undisturbed areas	61	456	473	243	122
Country park	133	1 923	1 238	2 403	35
Reclamation	0	10	0	0	0
Temporary land use	0	14	4	0	0
Artificial slopes	0	0	21	8	0
Water storage	0	0	0	0	106
Ponds	0	0	0	0	25
Natural streams	0	0	0	0	4
Total 7 589	204	2 613	1 814	2 666	292

APPENDIX C

SUPPLEMENTARY INFORMATION

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APPENDIX C

SUPPLEMENTARY INFORMATION

C.1 Description of Geological Units

C.1.1 *Sedimentary Rocks – Tai O Formation*

Sedimentary rocks of the Middle to Lower Jurassic age Tai O Formation (Allen & Stephens, 1971) crop out along a coastal strip between 50 and 600 m wide, north and northeast of Tai O.

Two members occur within the study area. The lower member is dominated by thinly-bedded black and white siltstones, black silty shales, white or grey sandstones and some graphitic sandstones. The upper unit is formed mainly of sandstone. The strata are generally indurated as a result of low-grade metamorphism by the underlying granites, and they are locally intensely faulted.

There is a close lithological similarity between the Tai O Formation and sedimentary rocks within the Repulse Bay Formation. The characteristics and physical properties of these are likely be similar.

C.1.2 *Volcanic and Volcaniclastic Rocks – Repulse Bay Formation*

Volcanic, volcaniclastic and sedimentary rocks of the Repulse Bay Formation (Allen & Stephens, 1971) are widely exposed in the study area. The main rock types consist of a succession of water-laid sediments mainly of volcanic origin, coarse tuffs, welded tuffs, pyroclastics and lavas. These rocks were deposited during the regional volcanic activity of the Mid-Jurassic period, and are normally conformable with the Tai O Formation. The rocks of the Repulse Bay Formation are approximately 160 million years old and represent a period of intense volcanic activity interspersed with periods of quiescence. These latter periods are marked by sequences of sedimentary rocks deposited in lacustrine, fluviatile and possibly shallow marine environments. These sedimentary units are irregularly distributed throughout the main sequence of volcanic rocks. The Repulse Bay Formation is faulted, folded and subjected to local metamorphism. The rocks of the Repulse Bay Formation in the study area are divided into five mappable units by Allen & Stephens (1971). Undifferentiated volcanic rocks occur to the east of Shek Pik Reservoir where the cover of boulders and vegetation prevented detailed mapping by Allen & Stephens (1971).

(i) *Sedimentary Rocks and Water-laid Volcaniclastic Rocks (RBs)*
Numerous intercalations of sedimentary rocks exist within the volcanic sequence, and they represent both fluviatile and lacustrine deposits. Within the South Lantau study area, two sedimentary regimes are present, producing thin horizons to the east of Shek Pik Reservoir, while thicker sequences of sedimentary horizons crop out further west.

The southern flanks of the Sunset Peak ridgeline contain several units, up to 100 m in thickness, of hard, thinly banded black and grey siltstones, mudstones and volcanic sandstones with occasional conglomerates.

Sedimentary units north and west of Shek Pik Reservoir occur in two stratigraphic horizons separated by a thick unit of lava flow and tuffs. Extending from near Fan Lau to Sham Wat, the thickness of the lower unit generally decreases in a northerly direction. This lower unit consists mostly of mudstones, siltstones and sandstones with bands of coarser volcanic debris. The upper sedimentary sequence crops out in the upper slopes and plateaux to the north and west of the Shek Pik Reservoir. These latter sediments are thin and impersistent to the north, and are dominated by volcanic sandstones to the south.

(ii) *Acid Lavas (RBv)*
Two thick rhyolite flows occur to the west and north of Shek Pik Reservoir, and a flow of dacite outcrops to the north of Tong Fuk.

These distinctively banded rocks are green, grey or bluish grey and contain abundant phenocrysts of feldspar which are generally up to 5 mm long, and a few as large as 15 mm. Smaller phenocrysts of quartz, rare hornblende and biotite are also present. The flows often contain recognisable basal breccias, and may be associated with massive units of tuff.

(iii) *Coarse Tuff (RBc)*
A unit of coarse tuff crops out between Pui O and Tong Fuk, aligned approximately parallel to the coastline, dipping steeply to the north. The rock generally consists of a coarse-grained crystal tuff and forms thick unstratified beds. The grain size varies from coarse tuff to lapillistone and is dark grey, greenish-grey or bluish-grey. The main minerals consist of quartz and feldspar with subsidiary biotite and hornblende. Coarse tuff is characterised by features which indicate explosive and subaerial origins. These include the presence of volcanic bombs, lack of internal stratification and a wide range of fragment sizes. Abundant bombs of porphyritic lava are characteristic of this unit in South Lantau. Coarse tuffs are generally very thick deposits, exceeding 400 m in places. Pyroclasts

show features of explosive strain, especially in thin section where quartz grains are fragmented and often show bottle-shaped embayments. Mineral grains vary in shape from euhedral to blade-like slivers. The coarseness of the grain size may be linked to the partly crystallised state of the parent magma during its eruption. The grain size of the coarse tuffs may be related to the size and abundance of the phenocrysts in the enclosed volcanic bombs.

(iv) *Agglomerate (RBag)*
Impersistent beds of agglomerate occur on the southern flanks of Sunset Peak and on the northern flanks of Lantau Peak. The former consist of angular blocks of porphyritic lava, whilst the latter consist of angular blocks of tuff in a lapillistone matrix which form a prominent escarpment.

(v) *Pyroclastic Rocks with Some Lavas (RBp)*
These rocks outcrop extensively in the study area, forming mappable units north and west of Shek Pik Reservoir. To the east of the reservoir, Allen & Stephens (1971) were not able to identify this unit consistently because of the abundant cover of boulders and vegetation.

The pyroclastic rocks mainly consist of explosively erupted fine-grained tuffs. Blocky and lapilli tuffs often show almond-shaped explosive ejecta, streamlined by rapid cooling during passage through the air.

The dominant lithology within this unit in the study area is fine tuff. Locally however, lapilli of porphyritic rock may become sufficiently abundant to be classified as a lapilli fine tuff.

A massive fine tuff about 1 000 m thick occurs in the area to the southwest of Sham Wat. Impersistent horizons of coarse tuff may also be found. An upper unit, dominated by both fine and coarse pyroclastic rocks, crops out on the sideslopes to the west of Shek Pik Reservoir.

To the east of Sham Wat, the variety of rock types includes lavas, fine tuff, lapilli fine tuff with shreds of pumice and banded tuff.

C.1.3 *Intrusive Igneous Rocks*

Five phases of intrusive igneous activity in the Territory are identified by Allen & Stephens (1971). Representatives of the first three phases occur in the study area. The predominantly granitic rocks represent a complex multi-phase batholith, formed by successive magma injections, which intruded the pre-existing rocks. Table C1 lists the various phases of intrusion.

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 Ma On Shan Granite Cheung Chau Granite Sung Kong Granite	Yes Yes Yes Yes
3	Quartz Monzonite Feldspar Porphyry Dyke Swarm	Yes Yes
4	Granophyric Microgranite Needle Hill Granite Hong Kong Granite	No No No
5	Dolerite	Yes

In addition to the intrusive rocks described below, the island of Peaked Hill is formed by Undifferentiated Granitic Rocks (Allen & Stephens, 1971) and may require further study.

(i) *Tai Po Granodiorite (XT)*
Within the study area, granodiorite only crops out at Cheung Sha and along the catchwater to the north of Tong Fuk. The rock is coarse or medium-grained, mesocratic and porphyritic. The principal minerals are plagioclase, quartz, potassium feldspar, biotite and amphibole. The outcrops at Cheung Sha include xenoliths of coarse-grained granite in addition to the usual melanocratic xenoliths. Veins of epidote and quartz may also occur.

The rock weathers to a red brown clayey soil with large grains of sand and gravel, sometimes up to 5 mm in diameter. In several cut slope exposures, large central corestones of slightly decomposed rock with a thin mantle of highly and completely decomposed rock are present within residual soil. In other exposures, the saprolitic zone is more thickly developed. Weathering depth is variable, but exceeds 10 m in some places.

(ii) *Sung Kong Granite (SK)*
Outcrops of Sung Kong Granite occur at Fan Lau, Shek Lam Chau and to the north and east of Ham Tin. It consists of pale grey or pink (when fresh) coarse-grained porphyritic rock. The main minerals are potassium feldspar, plagioclase, quartz and biotite. Phenocrysts of potassium feldspar may reach 40 mm in length, and pools of quartz may exceed 10 mm diameter. These granites are difficult to distinguish from other granites, except in the weathered form, in which the coarse quartz grains are prominent. The rock exhibits widely spaced tectonic joints and shallow, open, irregular sheeting joints, in much the same fashion as the other coarse-grained granites of the Territory. The weathering is consequently deep, and large boulders develop on the surface after erosion of the surrounding, deeply weathered material.

(iii) *Cheung Chau Granite (CC)*
This rock type is widespread in the Territory and represents the main phase of intrusive activity. The rock is a medium-grained, sparingly porphyritic pink granite whose main constituents are potassium feldspar, quartz, plagioclase and biotite. Phenocrysts are of potassium feldspar. Quartz forms 35–40% of the rock and may occur in large pools of intergrown crystals. This granite is usually cut by dykes of feldspar porphyry and by veins of microgranite or quartz.

This granite weathers easily to produce thick residual sandy soils.

(iv) *Ma On Shan Granite (MS)*
Minor outcrops of the Ma On Shan Granite occur in the study area near Pui O. The rock is pale pink or grey, fine-grained with a porphyritic texture. The phenocrysts of feldspar are up to 8 mm in length. Dark minerals, such as biotite, are evident only in thin section because they form part of the fine-grained matrix. The granite is cut by dykes of feldspar porphyry.

Weathering of the Ma On Shan Granite results in a fine sandy clay soil which may be susceptible to erosion. Jointing is similar to that in other granites.

(v) *Fan Lau Porphyritic Granite (FL)*
With the known outcrop limited to the Fan Lau Peninsula, this rock type is a pale pink, fine-grained porphyritic granite. Phenocrysts of the feldspar and quartz comprise about 50% of the rock. The groundmass is formed of microperthite, albite, quartz and mica. The dominant mica is muscovite. The unit is often cut by veins of the Quartz Monzonite.

(vi) *Quartz Monzonite (MO)*
Large intrusions of quartz monzonite exist on the Fan Lau Peninsula, on the Lo Kei Wan Peninsula, near Tong Fuk, and to the north and east of Ham Tin. Numerous small dykes and veins are also present, particularly within the limits of the swarm of feldspar porphyry dykes.

Quartz monzonite is grey or pinkish grey, fine to medium-grained and porphyritic. This rock differs from the granites in that it generally has a lower quartz content (less than 15%), although at the margins of intrusions, concentrations of euhedral quartz phenocrysts may raise the quartz content to over 30%. Within the main body of the intrusions, the large phenocrysts are more usually pink or white feldspar, normally with a distinctive flow alignment and occasional quartz. Many samples contain dark minerals only in their groundmass. Mafic xenoliths are common.

Outcrops of this unit are generally more resistant to weathering and erosion than the granites, but under a favourable environment weathering may be quite deep, reaching over 10 m on the Lok Kei Wan Peninsula. Areas of outcrop are often strewn with many boulders. On weathering, these rocks form a clay with high plasticity.

(vii) *Feldspar Porphyry Dyke Swarm (La)*
Three types of feldspar porphyry are readily distinguishable in the study area:

(*a*) A granodiorite porphyry which contains large (up to 40 mm long) euhedral phenocrysts of white plagioclase set in a grey or black aphanitic groundmass.

(*b*) A granite porphyry which contains pink feldspar phenocrysts in a pinkish-brown, grey or purple, fine-grained phaneritic groundmass.

(*c*) An additional granite porphyry with small phenocrysts was recognised by Allen and Stephens (1971). The difference between this rock and the common granite porphyry is solely the small size of the phenocrysts (less than 10 mm) in the former.

The majority of dykes trend northeast or east northeast, and are generally less than 30 m wide. Although they can be very long, individual dykes may be difficult to trace for any great distance if a number of dykes are present within a small area. Allen & Stephens (1971) report that no contacts between volcanic rocks and dykes were found above an elevation of 300 m on Lantau Island. This indicates that the dykes were not able to penetate very far into the roof pendants of volcanic rock that remain above the granitic batholith. In South Lantau, individual dykes and swarms of dykes are intruded into volcanic and igneous rocks along the coast from Tong Fuk Miu Wan eastwards, on the headlands near Milestone 6 on the South Lantau Road, at Cheung Sha and more generally within the igneous intrusions to the east of Pui O.

C.1.4 *Superficial Deposits*

Overlying bedrock and its residual mantle, unconsolidated or weakly consolidated, 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 (C)*
Colluvium results from the concentration of material transported downslope through the influence of gravity. Deposits may be formed by soil creep, slope failure, boulder fall and local slopewash. Collvium may occur as broad, fan-shaped deposits on footslopes of steep mountainous terrain, and as lenticular deposits along drainage lines.

Colluvial deposits consist of a wide range of materials and grain sizes depending on the source rock, nature of deposition and age of the deposit. In the study area, there are four main source rock types. These are intrusive igneous, volcanic, volcaniclastic and clastic rocks. Granitic colluvium typically consists of sandy silt derived from slopewash, whilst volcanic colluvium contains many large boulders. Very coarse deposits of angular boulders, with only a small amount of interstitial soil, occur with marginal stability on the upper sideslopes of Lantau and Sunset Peaks. Young colluvium on the footslope terrain is normally coarser-grained and less weathered than the older deposits, which may be highly weathered, compacted and fine-grained with a few large fragments. In the colluvium, soil pipes or tunnels may develop, creating elongate voids which enable groundwater to be transmitted through the soil. Colluvium derived from volcanic sediments generally forms fine-grained deposits, but is of very limited extent in the study area.

Relict colluvium has generally undergone complete weathering, leaving very little structural or textural evidence as to its origins, other than the proximity of the likely source rocks.

(ii) *Alluvial Deposits (A)*
Alluvial deposits within the study area occur on the low-lying coastal plains and estuarine areas. Alluvial deposits may also occur upstream of the nickpoints produced by either the outcrop of a resistant band of rock or the headward extension of stream downcutting, such as results from changes of sea level.

Alluvium is generally composed of a range of grain sizes of material. Coastal alluvium is often finer-grained than upland alluvium, due to the greater distance of sediment transport and consequent increase in abrasion, attrition and sorting of the constituent particles. The major alluvial areas are at Tai O, Shek Pik, Tong Fuk, Cheung Sha, Pui O and Shap Long San Tsuen.

(iii) *Littoral Deposits (L)*
Littoral deposits are well developed in the west and south of the study area, with major beaches existing at Cheung Sha and Pui O. These deposits consist of a fine yellow to white sand. These sand deposits may be 15 m in thickness. Strand lines or shoals of coarser-grained (pebble size) material develop in the intertidal zone in some localities.

(iv) *Marine Deposits (M)*
Marine deposits tend to be either mud in areas of calm water or muddy sand to sandy mud in areas of current activity. Adjacent to the coast dark-coloured marine muds alternate with deposits of silty sand with shell fragments and occasional sandy gravels. The marine deposits are generally soft and unconsolidated. Marine deposits may interdigitate with alluvium and colluvium which were deposited subaerially during periods of lower sea level.

(v) *Reclamation*
Reclamation is generally restricted to the immediate vicinity of Tai O. Materials for reclamation are derived from a wide variety of sources and hence may represent any or all of the rocks and soils within the Territory, as well as demolition material or industrial and domestic refuse. The degree of compaction varies according to the age and nature of the reclaimed areas.

Table C2 Selection of Aerial Photographs

Year	Photograph Serial Number	Photograph Scale (Approx.)
1986	A04176–A04183	1:20 000
1985	A02633–A02637	1:30 000
	A02568–A02591	1:30 000
	A01687–A01690	1:20 000
	A01635–A01652	1:20 000
	67542–67548	1:20 000
	67485–67512	1:20 000
	67406–67409	1:20 000
1984	57304–57311	1:12 000
	57269–57276	1:12 000
	57207–57230	1:10 000
	57180–57198	1:10 000
	56136–56149	1:10 000
	55919–55935	1:12 000
	55889–55913	1:12 000
1983	51700–51720	1:40 000
	51356–51360	1:20 000
	51279–51313	1:20 000
	51240–51247	1:20 000
	47162–47172	1:40 000
1982	44822–44825	1:20 000
	44787–44814	1:20 000
	44487–44490	1:20 000
	44420–44438	1:20 000
	44376–44381	1:20 000
1981	39123–39124	1:20 000
	38980–39000	1:20 000
	38915–38939	1:20 000
	36774–36776	1:50 000
	36784–36758	1:50 000
	36699–36714	1:50 000
1980	33389–33405	1:20 000
	33237–33243	1:20 000
	33192–33194	1:20 000
	32896–32902	1:11 000
1979	27971–27989	1:20 000
	27745–27752	1:20 000
	27716–27721	1:20 000
	24634–24642	1:25 000
	24605–24609	1:25 000
1978	20924–20928	1:25 000
	20882–20893	1:25 000
	20830–20840	1:25 000
	20785–20786	1:25 000
1977	19145–19149	1:25 000
	19031–19033	1:25 000
	19015–19016	1:12 000
	18964–18966	1:12 000
1976	16594–16636	1:25 000
	15872–15879	1:25 000
1975	12015–12033	1:25 000
	11682–11691	1:25 000
1974	9560–9574	1:25 000
	9543–9551	1:25 000
	8221–8226	1:25 000
1973	8072–8092	1:25 000
	3929–3937	1:12 000
	3830–3865	1:12 000
	3760–3809	1:12 000
	3566–3571	1:12 000

Table C2 Selection of Aerial Photographs *(Continued)*

Year	Photograph Serial Number		Photograph Scale (Approx.)
1972	2300		1:26 000
1964	2883–2912		1:25 000
	2849–2852		1:25 000
	2561–2563		1:25 000
	2485–2470		1:25 000
1945	RAF: Run No. 681/6:	4168–4181	1:12 000
	RAF: Run No. 681/6:	4101–4120	1:12 000
	RAF: Run No. 681/6:	4001–4005	1:12 000
	RAF: Run No. 681/6:	3160–3162	1:12 000
	RAF: Run No. 681/6:	3086–3111	1:12 000
1924	RAF: Run No. H46:	2, 8, 11	
	RAF: Run No. H57:	26–34	

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

(vi) *Fill*

Areas of fill are relatively uncommon in the study area. Small areas of fill occur around Cheung Sha, Pui O, Ham Tin, Tong Fuk, Shek Pik and Tai O, and the materials have similar characteristics to those in reclamation. Cut and fill techniques generally involve the local soil and rock being used as a fill material. Filled areas associated with the Shek Pik Dam are of a specialised nature, the materials being derived from large quarries which are now partially submerged within the reservoir.

C.2 Site Investigation Data

A number of site investigations have been conducted by the public and private sectors. Many reports are held by the Geotechnical Information Unit (GIU) and some of these are available to the public in the Civil Engineering Library operated by the Geotechnical Control Office.

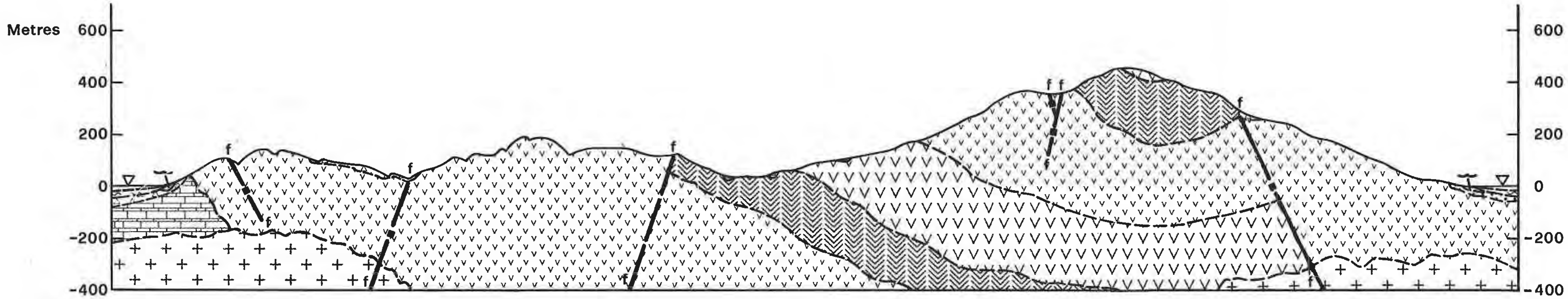
The Geotechnical Control Office GIU Report entry and retrieval system is based on a master grid marked on reference sheets. Each grid block is provided with an index card listing all the reports held within that individual grid block.

C.3 Aerial Photographs

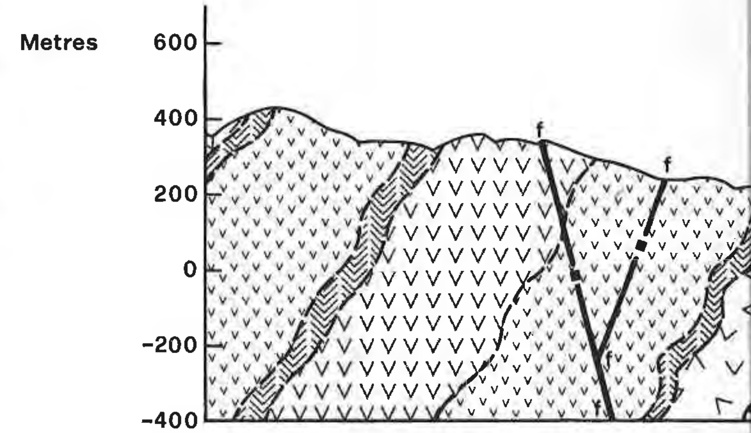
The study area has been extensively photographed from the air, and a very large number of vertical and oblique photographs are available from the Map Sales Office of the Survey & Mapping Office, Buildings & Lands Department. An abbreviated list of photographs is presented in Table C2.

C.4 Rainfall Data Relevant to the Study Area

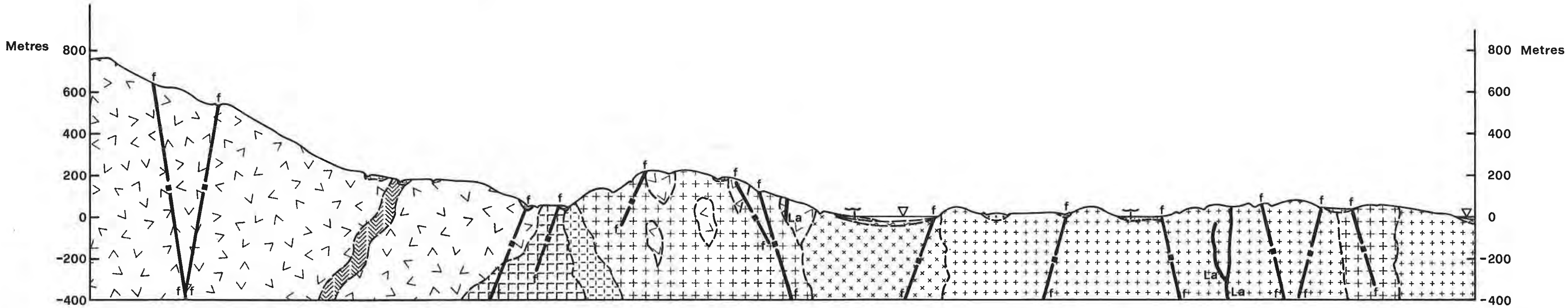
A general appreciation of the annual and monthly rainfall distributions for the study area can be obtained from Figures C2 and C3. Figure C2 is a reproduction of the mean annual rainfall isohyets for the years 1952 to 1976, published by the Royal Observatory. Figure C3 is a histogram of monthly rainfall for four selected Royal Observatory rainfall stations. Detailed monthly and annual rainfall information is available from the Royal Observatory.



Section A-A′

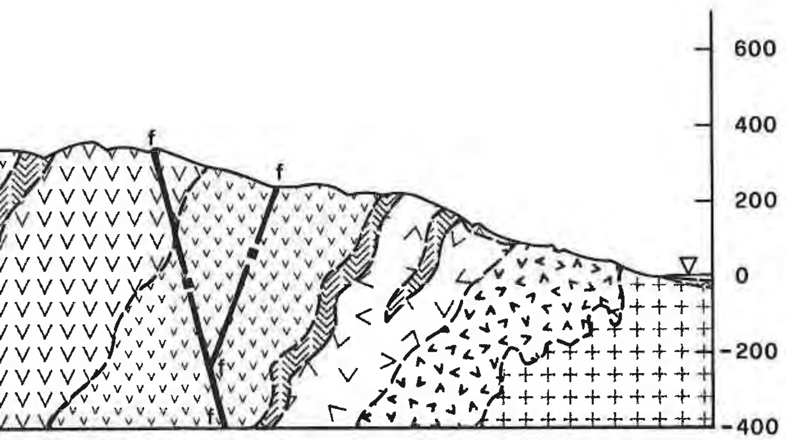


Section B-

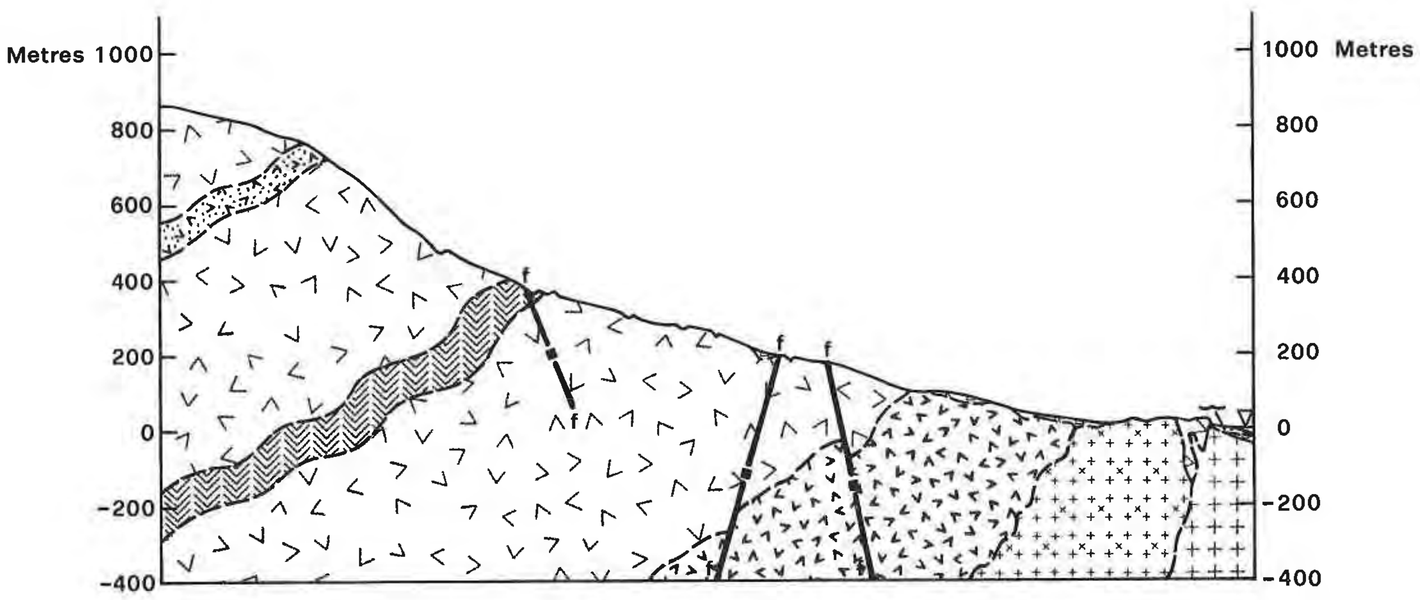


Section D-D′

Geological Cross-sections – South Lantau



Section B-B′



Section C-C′

LEGEND

- Alluvium
- Colluvium
- Littoral deposits
- Marine deposits
- Quartz monzonite and porphyritic adamellite
- Feldspar porphyry dyke swarm
- Ma On Shan Granite
- Cheung Chau Granite
- Sung Kong Granite
- Tai Po Granodiorite
- Sedimentary rocks and water- laid volcaniclastic rocks
- Acid lavas
- Agglomerate
- Coarse tuffs
- Dominantly pyroclastic rocks with some lavas
- Undifferentiated volcanic rocks
- Tai O Formation
- La — Feldspar Porphyry Dyke
- Geological boundary , position approximate
- f—f Fault (from Allen & Stephens , 1971)
- f—■—f Fault (inferred)

800 Metres
600
400
200
0
-200
-400

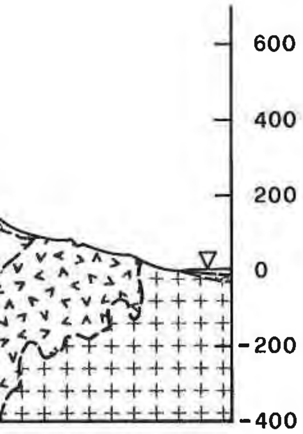
ATTENTION : USERS

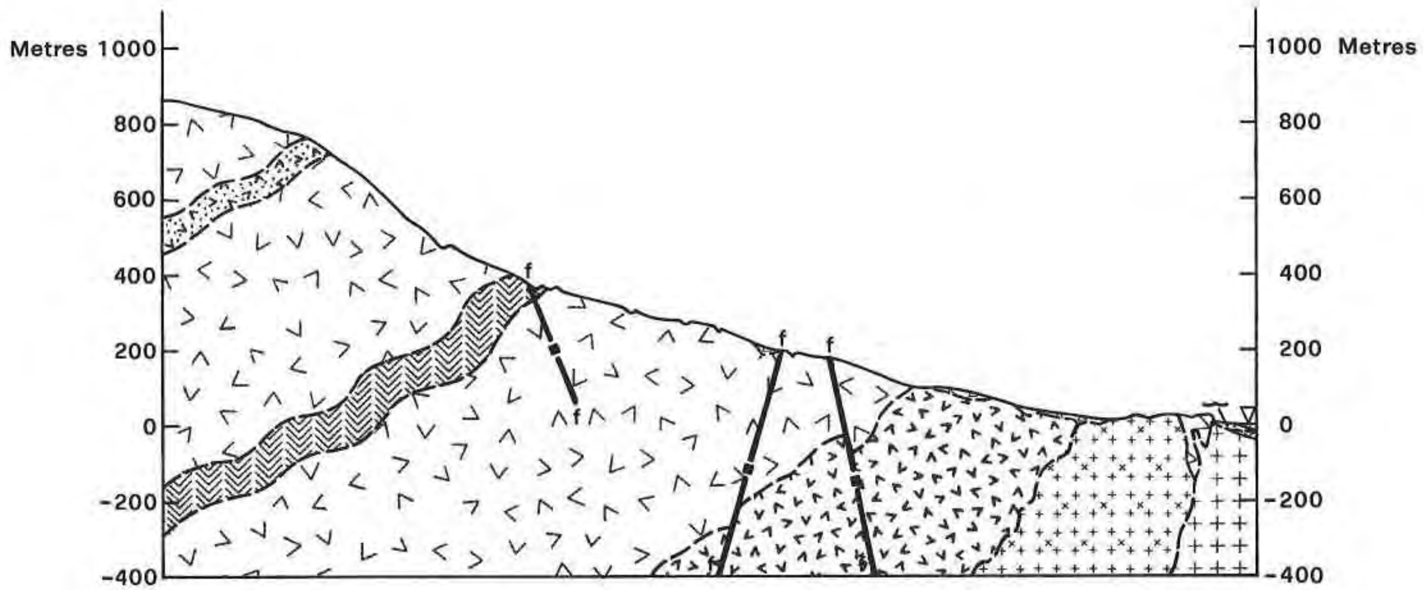
The bedrock geology shown on this sheet is that of Allen & Stephens (1971). Geological remapping of the Territory is currently underway and new geological maps at a scale of 1:20 000 and their accompanying memoirs should be consulted where available.

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

- For location of sections see Engineering Geology Map.
- 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 Principal Datum which is approximately 1.20m below Mean Sea Level.

uth Lantau	Compiled: A. Hansen	Drawn: C. P. Wan
	Scale: 1:20 000	Date: November, 1986





Section C-C'

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

- For location of sections see Engineering Geology Map.
- 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 Principal Datum which is approximately 1.20m below Mean Sea Level.

ATTENTION : USERS

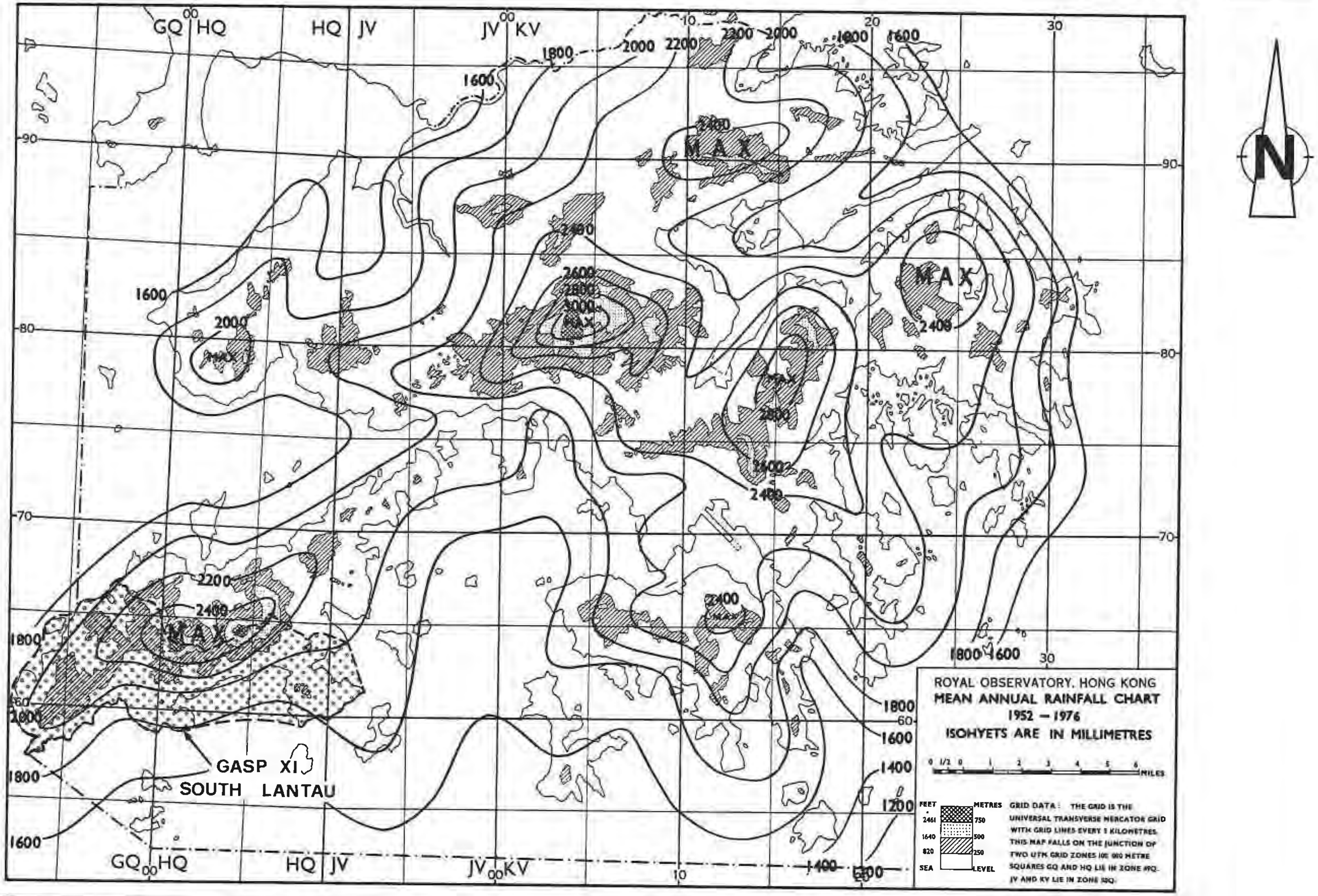
The bedrock geology shown on this sheet is that of Allen & Stephens (1971). Geological remapping of the Territory is currently underway and new geological maps at a scale of 1:20 000 and their accompanying memoirs should be consulted where available.

LEGEND

- Alluvium
- Colluvium
- Littoral deposits
- Marine deposits
- Quartz monzonite and porphyritic adamellite
- Feldspar porphyry dyke swarm
- Ma On Shan Granite
- Cheung Chau Granite
- Sung Kong Granite
- Tai Po Granodiorite
- Sedimentary rocks and water- laid volcaniclastic rocks
- Acid lavas
- Agglomerate
- Coarse tuffs
- Dominantly pyroclastic rocks with some lavas
- Undifferentiated volcanic rocks
- Tai O Formation
- La — Feldspar Porphyry Dyke
- Geological boundary, position approximate
- f—f Fault (from Allen & Stephens, 1971)
- f—f Fault (inferred)

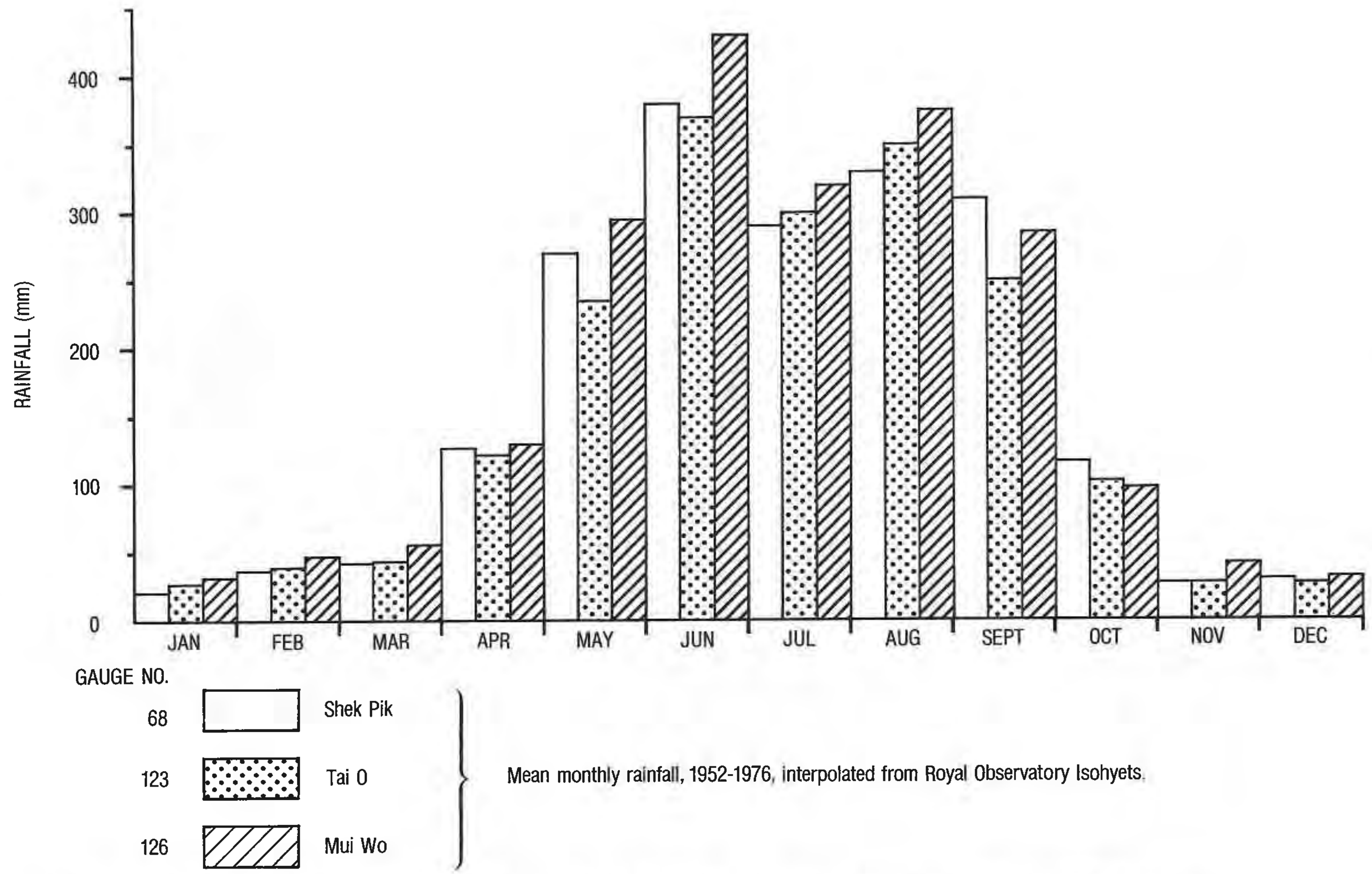
Repulse Bay Formation (Sedimentary rocks and water-laid volcaniclastic rocks; Acid lavas; Agglomerate; Coarse tuffs; Dominantly pyroclastic rocks with some lavas)

Compiled: A. Hansen	Drawn: C. P. Wan	Fig. C1
Scale: 1:20 000	Date: November, 1986	



Mean Annual Rainfall Isohyets (1952–1976)

Fig. C2



Note: Mui Wo has been used as an additional rainfall station to provide information for the eastern part of the South Lantau GASP XI study area

Summary of Mean Monthly Rainfall Data

Fig. C3

APPENDIX D

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

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APPENDIX D

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

D.1 Introduction

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

D.2 Rock Mass Characteristics

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

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

D.2.1 *Mode of Generation and Texture*

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

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

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

D.2.2 *Joints*

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

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

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

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

D.2.3 *Porosity and Permeability*

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

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

D.2.4 *Weathering and the Weathered Profile*

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

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

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

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

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

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

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

NATURAL LANDFORMING INFLUENCES :
SUBSURFACE & SURFACE VARIABLES.

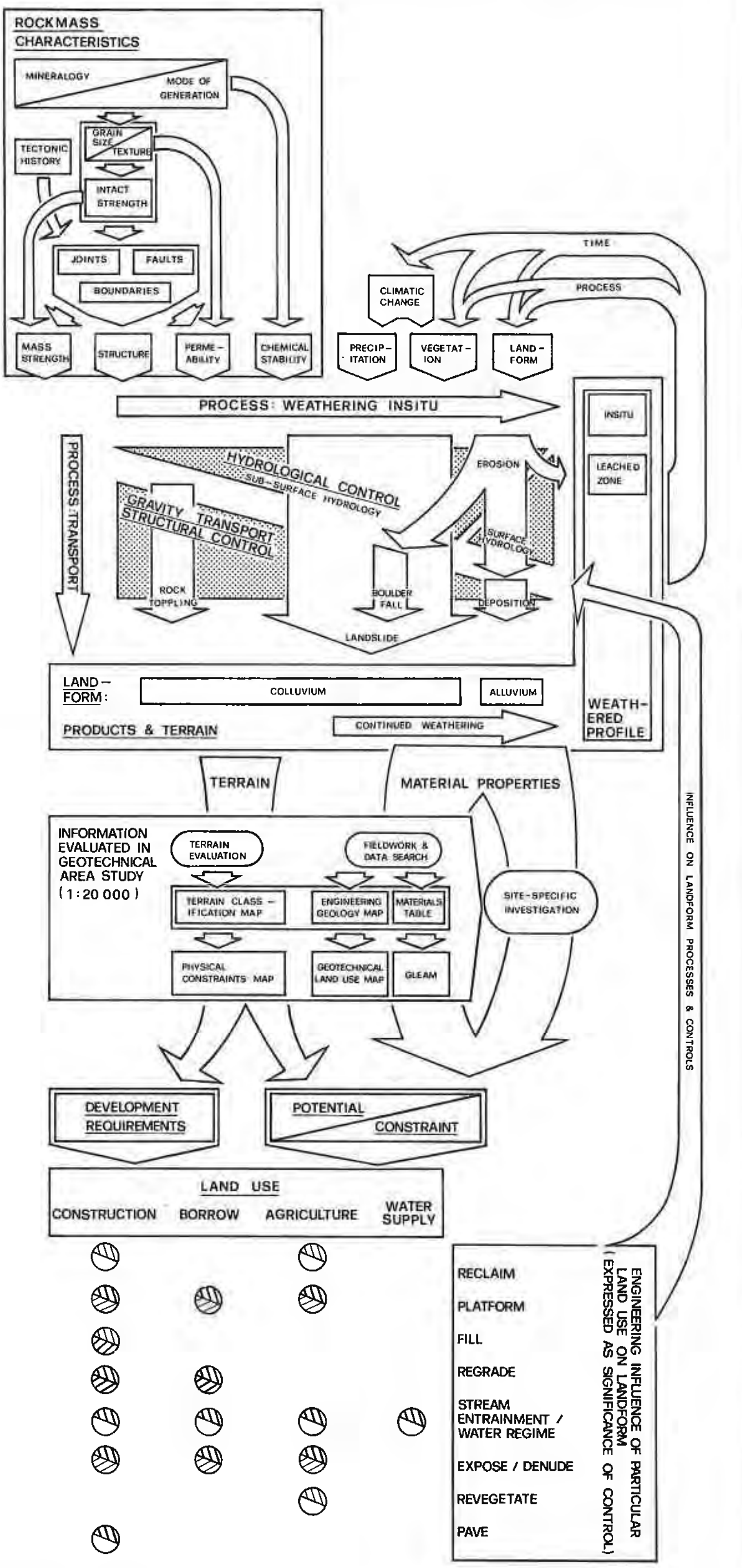
LANDFORMING PROCESSES :
RELATIVE INFLUENCE OF HYDROLOGY, STRUCTURE & WEATHERING ON TYPES OF TRANSPORT PROCESS. (BACKGROUND TRIANGLES SHOW PROPORTION OF INFLUENCE OF CONTROL).

LANDFORM :
INDICATED AS PRODUCTS OF VARIOUS LANDFORMING PROCESSES.

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

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

LAND USE CHART :
INTENSITY OF SHADING INDICATES ENGINEERING INFLUENCE OF PARTICULAR LAND USE ON
HYDROLOGICAL CONTROL / STRUCTURAL CONTROL THROUGH MODIFICATION OF LANDFORM :
SLIGHT
MODERATE
SIGNIFICANT



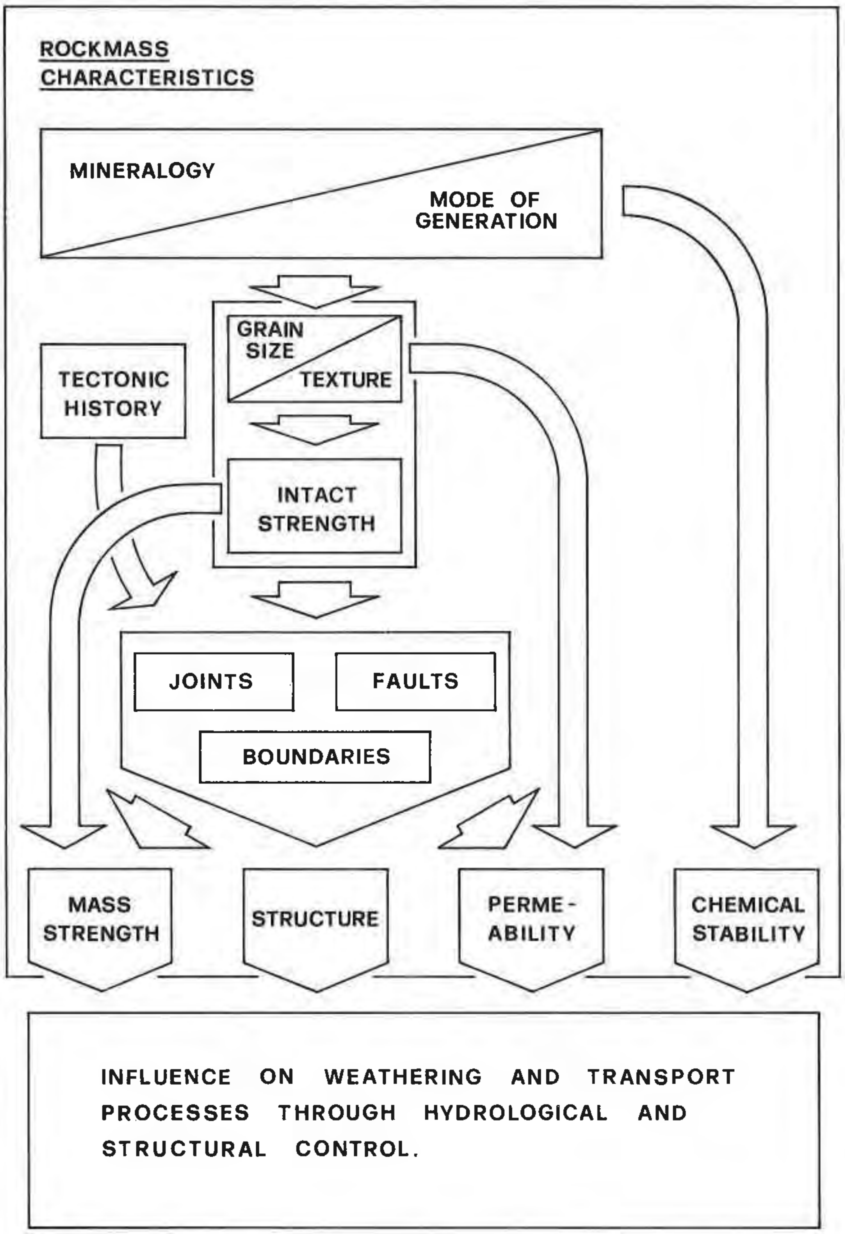
LEGEND :

BOXES INDICATE :
CAUSE OR PRODUCT

ARROWS INDICATE :
INFLUENCE, PROCESS, OR MECHANISM

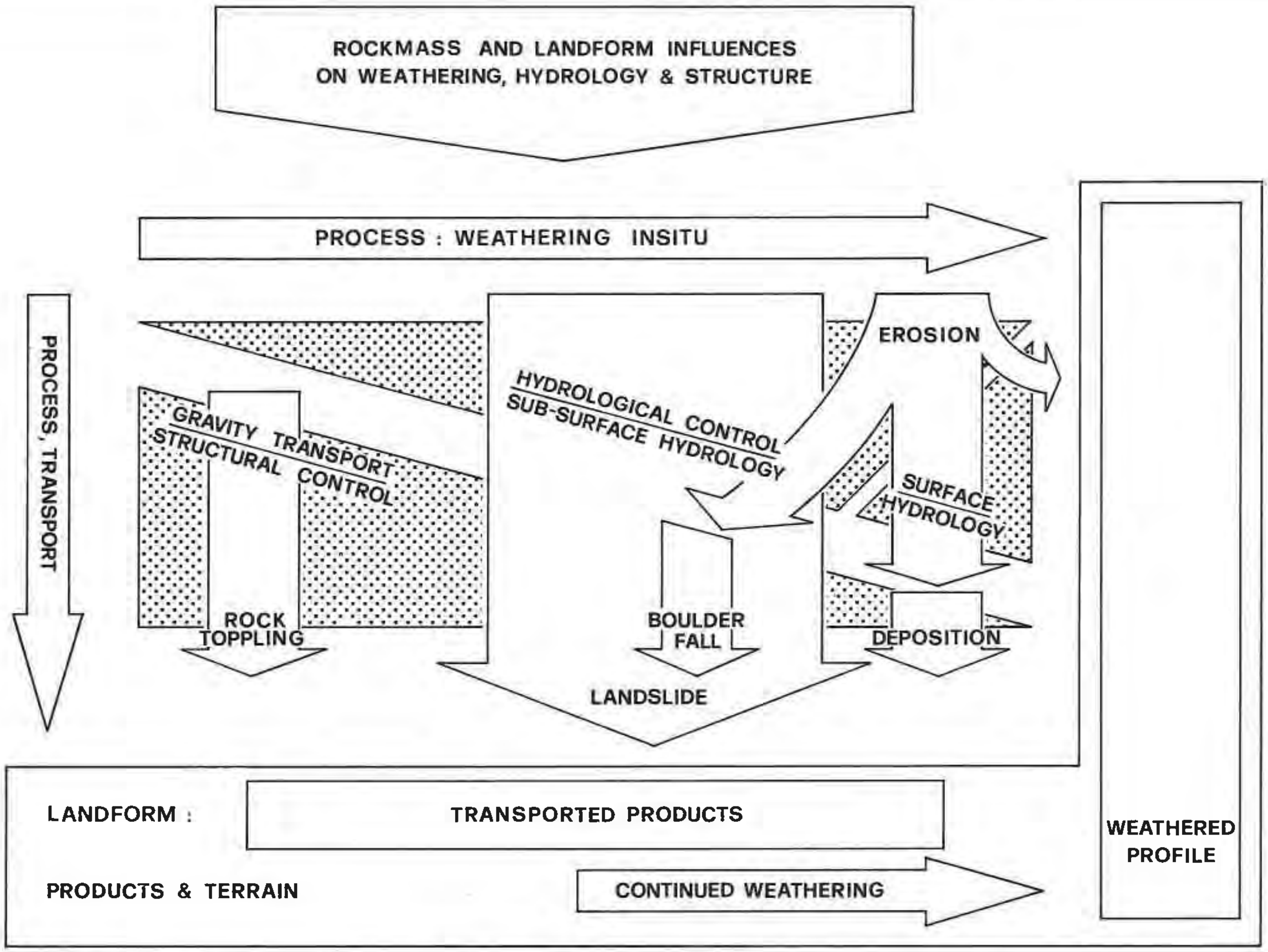
CIRCLES INDICATE :
HUMAN INVOLVEMENT

Influence of Landforming Processes **Fig. D1**



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

Rock Mass Characteristics	Fig. D2



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

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

Landforming Processes	Fig. D3

D.2.5 *Faults*

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

D.2.6 *Boundaries*

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

D.3 Engineering Considerations for Development Planning

D.3.1 *General*

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

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

D.3.2 *Geotechnical Constraints to Development*

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

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

Landslips in weathered material pose a considerable hazard, but they are often preceded by signs of distress. Although largely controlled by relict jointing in moderately weathered material, natural failure is often precipitated by the subsurface water regime in conjunction with landslip-prone topography. Leach (1982) and Leach & Herbert (1982) studied the question of groundwater flows on Hong Kong Island.

Whilst erosion alone does not pose as great a hazard as slope instability, it can cause severe problems for engineering work. In addition, changes to the terrain and hydrology through construction or earthworks may cause erosion which may create conditions conducive to mass movement. The loose structure of weathered granites make these more susceptible to erosion than the volcanics when vegetation is removed. Evidence of this occurs in the denuded, eroded and bouldery upper sideslopes of the granitic terrain, where landslips are common at the heads of drainage lines. The debris from such landslips may travel at high velocity for considerable distances, blocking drains and resulting in surface water infiltration.

Deep weathering may be present, particularly where it is accelerated by shattered rock structure or active subsurface groundwater. Although weathering is not a severe constraint, it may pose considerable difficulties during construction, especially if very localised. Localised problems associated with geological 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.

The locations of fill and reclamation are shown on the Engineering Geology Map and the Physical Contraints Map.

The nature and the engineering problems associated with fill can be categorised into the following:

(i) *Cut and Fill Platforms on Steep Terrain*
This technique is used in the Territory to provide level building platforms on otherwise steep terrain. Since the disastrous fill slope failures at Sau Mau Ping in 1972 and 1976 (Government of Hong Kong, 1972a & b, 1977), fill has been recognised as a potentially hazardous engineering material. Consequently, recent fill platforms and slopes are designed and constructed to stringent requirements. Common problems in older fills on steep terrain are due to the fact that many were 'end tipped'. This results in:

(*a*) Poor compaction – a generally loose structure makes the fills susceptible to liquification resulting from infiltration of rainwater, movement of groundwater, through flow or from fractured water mains. This leads to sudden loss of strength and failure of the slopes. Loose fill is also liable to settlement and possible lateral movement on loading.

(*b*) Stratification parallel to the natural slope – this enables the infiltration of water from the level platform into the fill and also creates inclined planes of potential weakness liable to preferential failure.

Old fill has often been tipped into unprepared natural drainage lines, and the natural groundwater regime may persist beneath the fill, leading to saturation and instability. The material behaviour is also subject to the variability of the source material. Completely weathered rock would result in a fairly uniform fill, whilst fill of less weathered rock may contain boulders and voids.

(ii) *Fill on Low-lying Terrain*
Few engineering problems are envisaged in these areas, with the exception of settlement. Large buildings are generally piled. Deep excavations may experience difficulties due to high groundwater tables in underlying alluvium.

(iii) *Land Reclaimed from the Sea*
Some of the coastal areas are modified by reclamation and considerable recent and proposed development is based on these areas.

Although most areas of reclamation are subject to current or proposed development, it is relevant to note that older reclamation materials may be very variable in quality. The following engineering problems should be anticipated during development in areas of reclamation:

(*a*) Lateral variability of materials—the extension of reclamation areas over a long time may result in material of differing sources and quality being present. Borehole samples should be examined and interpreted with this in mind.

(*b*) Variability of materials with depth—reclamation materials may vary with depth and cause local artificial aquifers and dense or loose zones. These should be anticipated in the choice of construction method and evaluated during site investigation. Boulders, timbers and other extraneous materials may be present in older areas. These may require localised measures during construction, such as hand-dug excavations. Better quality, more uniform material may allow driven piles for low structures such as warehouses, or larger diameter mechanically excavated sleeved caissons for heavier structures.

(*c*) Presence of old structures—within areas of reclamation, features such as old foundations and sea walls may occur. Consultation of archive sources may help avoid local difficulties or anticipate setbacks during the critical foundation construction period.

(*d*) Dewatering problems—the reclamation material, in its loose, permeable, saturated stage, is likely to have water problems which may cause heaving in deep excavations. Grouting or dewatering may therefore be necessary. Dewatering may cause settlement problems in adjacent slabs and unpiled structures. Permanent or temporary impermeable barriers to water flow, such as continuous walling, may also cause problems to adjacent buildings by interrupting groundwater flow and raising water levels.

(*e*) Basements—these require tanking or water resistant design. External drainage may be necessary to prevent an increase in water levels if drainage paths are blocked.

(*f*) Settlement—unpiled structures are subject to settlement and should be designed to redistribute loads or else to be flexible. Foundation stresses are subject to variation from fluctuating water levels in response to the tide. Piled structures may require design for negative friction in recent or deep reclamation.

(*g*) Underlying materials—the problems of construction on reclamation may be aggravated by considerable depths of marine or alluvial deposits and weathered bedrock. The depth of these will vary depending on the original ground profile. The general depth of underlying materials may be determined from site investigation, whilst local variation may be identifiable in the features of the old coastline and the onshore terrain.

(iv) *Sanitary Landfill*
Sanitary landfills are used for the disposal of domestic refuse. Typical engineering problems associated with the development of sanitary landfills include:

(*a*) Heterogeneous materials which are difficult to remove.

(*b*) Unpredictability of stability of landfill slopes and embankments.

(*c*) Unpredictable, large settlements.

(*d*) Fire hazard from methane gas emission.

(*e*) Erratic water flows within landfill.

(*f*) Noxious leachates, posing pollution problems and chemical attack of concrete and steel.

For these reasons, recently completed sanitary landfills and adjacent platforms are probably unsuitable for development other than as open space or recreation areas.

D.3.4 *Geological Photolineaments*

Major geological photolineaments are shown on the Engineering Geology Map for the study area. These features and some more minor lineaments are also shown on the GLEAM if they are significant in the engineering feasibility of potential development areas.

Lineaments are the surface expression of subsurface structural features and, hence should be carefully examined during planning and engineering feasibility. Differences in rock type, structure or strength are amplified by the landforming processes to produce contrasts in erosion or vegetation, or linear patterns in relief or drainage. Such contrasts are readily identified using API and are often apparent during site reconnaissance. It should be noted that structural features causing lineaments will probably continue beneath superficial deposits such as alluvium, colluvium or fill and their influence should be anticipated in foundation works through these materials.

In general terms, contrasts in the terrain are a reflection of the resistance or susceptibility of the underlying material to erosion. Surface features are often good indicators of local engineering characteristics.

Lineaments tend to be localised and therefore they may often be avoided during the layout and design stages of an engineering project.

Engineering factors which are often associated with lineaments may be classified into the following:

(i) *Deep Weathering*
Shatter and shear zones in the rock tend to concentrate water flow and result in deep weathering. Localised rock shattering may be due to faulting and is likely to appear as a major lineament. The GLEAM shows the influence of structure on drainage in this area; foundation difficulties may occur due to rapidly changing ground conditions.

Many of the photolineaments are major features which are continuous across the study area.

(ii) *Slickensiding*
Slickensiding is evidence of larger scale movements in rock and soil. Smoothing and striation on a fault plane render it more susceptible to failure if a cut slope were to intercept and release a slickensided joint. Whilst this problem may not be obvious prior to excavation, it should be anticipated where fault lineaments are indicated.

(iii) *Changes in Rock Mass Structure and Properties*
Smaller scale lineaments are often identified from preferential drainage caused by a weakness or strength of the adjacent rock mass. This may be due to variation in the rock itself or in its structure. Where the lineament is evidence of a structural weakness, problems may be encountered in the founding of caissons and in the construction of rock cut slopes.

Small scale, as well as major, photolineaments may be associated with anomalies in the general pattern of weathering depth which may cause differential settlements of raft foundations.

Regular patterns of lineaments are evidence of the regional pattern of structure present at smaller scale. Engineering works in the area may experience instability problems on cut slopes at particular orientations.

In areas of active coastal erosion, the local rock structure is often apparent from the pattern of erosion and instability.

Boundaries between rock types may or may not form photolineaments, partly depending on whether they are faulted or not. Identified rock boundaries are shown on the Engineering Geology Map. Changes in structure are likely at granite/volcanic boundaries, due to cooling stresses, and in strength and weathering due to contact metamorphism.

(iv) *Preferential Groundwater Flow*
The preceding engineering features of photolineaments are usually associated with preferential groundwater flow, both at and below the surface. This should be a consideration in the construction of fills in valleys where the subsurface hydrology may be largely unaffected inspite of surface water entrainment.

(v) *Seismic Influence*
Some photolineaments are identified on the Engineering Geology Map (after Allen & Stephens, 1971) as faults, and other major lineaments may also indicate faults. Faults may extend laterally for a short distance or many thousands of kilometres. The Government of the Peoples Republic of China has published a national seismic map which shows extensive fault-zones of NE or ENE trend in Guangdong Province and western Fujian Province. One of these fault-zones lies along the northern boundary of the Territory of Hong Kong, while others intersect the coast of Guangdong Province to the east of Hong Kong. Sources in China regard many of the faults of the region as active, the degree of activity being inferred from recent earthquake data, and that derived from the historical geological record.

Throughout the world, even in seismically 'quiet' areas, many major faults are active to some extent. For example, in the UK, which is classified as an area of low to moderate seismicity, a few hundred earthquakes occur every year, although they are rarely felt by individuals. Most of the earthquakes recorded by the Royal Observatory short-period seismograph network originated elsewhere in the Southeast Asian region. The few which actually have been felt by individuals in Hong Kong were mostly related to earthquakes in various parts of China. Nevertheless, minor seismic events originating within the Territory have also been recorded by the Royal Observatory, and these events may be attributed to minor movements on faults at depth giving rise to seismic waves but no apparent ground displacement. To date, no clear relationship is obvious between these local seismic events and known faults within the Territory.

On the basis of observations of the historical geological record and mapping work undertaken to date, it appears that, although minor crustal readjustments have been occurring in Hong Kong, the Territory is not characterised by local major fault movements or related severe seismic events.

D.3.5 *Colluvial Deposits*

Colluvium is a transported material, whose nature and engineering characteristics depend on the origin of the material, the conditions of its deposition and its subsequent history. Various types of colluvium exist within the study area, and their location, nature and material properties are discussed in Sections 2.3, 2.4 and 3.1.3. The extent of colluvium as identified by terrain classification is shown on the Engineering Geology Map.

Colluvium need not necessarily be regarded as a constraint for engineering. Relict colluvium in a completely weathered state may be strengthened by overconsolidation and be virtually indistinguishable in material behaviour from its weathered parent. However, colluvium is inherently variable and, as demonstrated by the Po Shan Road disaster in 1972, when a portion of a large colluvial slope failed, it is usually an extremely difficult material to assess in engineering terms (Government of Hong Kong, 1972 a & b).

Engineering factors which are often associated with colluvium may be classified into the following:

(i) *Physical Properties*
Colluvium is subject to local variations of structure, density, strength and water content, both horizontally and vertically. In particular, concentrations of subsurface water flow may result in voids and pipes caused by the removal of fines, and in local piezometric variation. Stratification of these deposits may cause perched water tables and variations in the strength profile. Settlements under load may be unpredictable. Hence, heavily loaded structures should be founded on caissons through to bedrock. In situations were loading of the colluvium could cause instability, measures should be taken to ensure that loads are not transferred to the colluvium. The variable nature of colluvium will often require the use of hand dug caissons. As discussed for boulder colluvium in Section 3.1.3, measures should be taken to avoid any adverse influence on the groundwater regime.

(ii) *Water Conditions*
The potential for localised flows and perched water tables should be anticipated if piezometers are to be installed. A single piezometer within the profile is seldom adequate to determine the groundwater regime, and the location of piezometers should be based on the observations of the site investigation. In particular, the water pressures should be monitored and interpreted, if significant to design, with respect to strata within the profile. Pressures in underlying weathered material are also important.

(iii) *Stability*

The stability of cut slopes is very susceptible to local variations in strength and water pressure. Since it may not be possible to define these fully from the site investigation, the progress of excavations should be closely monitored to accommodate local variation.

Particular attention should be paid to material boundaries, voids and seepage zones. These may render modelled design conditions doubtful. Many of the cuts in colluvium on footslope terrain show zones of water seepage. Local instability in natural oversteepened colluvial slopes results from emerging groundwater. In cuts in colluvium such conditions may lead to progressive collapse of a loose soil structure upslope with considerable debris flow.

(iv) *Site Investigation*

In heterogeneous deposits such as extensive recent colluvium and boulders, site investigation alone cannot reveal a comprehensive model of the ground, nor can appropriate strength values be accurately assessed. Carefully monitored trial caissons are often justified in colluvial deposits. Attention should be paid to variations in bedrock and its level in boreholes to ensure that foundations do not rest on boulders.

D.3.6 *Boulders and Rockfalls*

Boulder and rockfalls are a feature of the wet season in the Territory and have, on occasion, resulted in loss of life and considerable property damage.

Boulders are large blocks of rock which often result from wide joint spacing. They occur often in granitic rocks as the unweathered remnant corestones between completely weathered joints. If exposed on steep hillsides or in drainage lines, they may be liable to movement.

Adverse jointing and an exposed location may result in potential rockfalls in both granitic and volcanic terrain. In this case, weathering, except as a local weakening of the joints, is not a major contributing factor. In granitic rock, the presence of extensive sheeting joints also contributes to the rockfall potential.

Boulders, joint blocks and wedges may also be present in, or as exposed remnants of, both granitic and volcanic colluvium. Boulders may also exist in drainage lines where they are likely to be restrained and interlocked. However, high flows caused by torrential rain are liable to increase the likelihood of movement. Boulders in drainage lines may also trap detritus and torrential flows may cause mud or debris flows.

In areas with potential for development, boulders and rock outcrops are indicated on the GLEAM where they are obvious in aerial photographs. In many situations, boulders are hidden from view by dense vegetation.

Engineering solutions to the boulder and rockfall problem depend largely on the local situation, but may consist of one or a combination of the following:

(*a*) Removal—isolated boulders may be removed from the slope if the situation permits. This could be achieved by blasting or excavation.

(*b*) Restraint—it may be possible to restrain or support isolated boulders and rock wedges by buttressing, anchoring, or cable support.

(*c*) Protection—in areas with long slopes and many potentially unstable boulders or blocks of small to moderate size, identification and removal of critical boulders may not be warranted or may detrimentally affect stability. In such cases, general protection measures may be more appropriate, such as sterile zones, trap ditches or bunds, catch fences, protection nets or deflection barriers.

D.3.7 *Boulders below Ground*

In the granites and colluvium of the study area, boulders are often present within the weathered matrix. Site investigation and construction of load bearing foundations should examine these features. For deep foundations, hand excavation may be required. Blasting of boulders in caissons or cuttings may cause loosening or collapse of the surrounding matrix. Variations in the bedrock level and in the bedrock material may also indicate the presence of boulders.

In bouldery colluvium, voids are likely beneath boulders as a result of the nature of deposition or due to washing out of the matrix in underground drainage lines. This poses particular problems for the construction of deep foundations through these materials.

D.3.8 *Marine Deposits*

Marine deposits are not considered in detail from an engineeiing point of view in this Report, except in relation to reclamation. Their geological characteristics are discussed in Appendix C.

D.3.9 *Cut Slopes*

Cut slopes and/or slope support structures are an aspect of most large-scale developments in the Territory. Different considerations govern the use and design of slopes depending on the geological material, its state and structure. Hence, the overall form of a development should also relate to the engineering opportunities of the terrain.

The height and angle of a cut slope are a matter for design based on a model of the rock or soil strength and structure as determined by site investigation. Preliminary assessment of the size and form of slopes and retaining structures may be made on the basis of the engineering properties of the local rock type, as indicated on the Engineering Geology Map and in the Materials Table (Table 3.1). At the planning stage, flexibility of layout should be retained, especially where large cuts are involved, so that local variations in strength and structure can be accommodated in design. Lineaments and structural control are indicated on the GLEAM. Structural control may indicate shallow bedrock, and the structure will influence the stability of cuts in rock. Lineaments indicate a local structural feature which may influence the final slope design, probably requiring a shallower angle cut on the weaker rock zone.

In large developments on steep terrain, a more geotechnically economical use of the site can be made by providing a stepped site formation which follows the terrain, rather than a large level formation with very large cuts. The benefits of this approach occur in different ways, for each of the major geological materials occurring on steep terrain:

(i) *Volcanic Terrain*

Weathering depths of less than 15 m are generally noted for steep volcanic terrain in the study area, with rapid transition from weathered to fresh rock. In such terrain, structures can economically be founded at shallow depths and large fresh rock cuts avoided. Where fresh rock cuts are formed, the jointing of the rock may cause some surface ravelling, and net protection or a safety zone may be required to maximize slope angles. Locally persistent or unstable joints may require shallower angled cuts or support measures.

(ii) *Granite Terrain*

Considerable depths of various grades of weathering are encountered in the granitic areas. Large structures founded in this terrain will generally require caisson foundations to bedrock. If large flat site formations are to be created in steep granitic terrain, major cuttings and retaining structures should be provided through a range of weathered rock. The only advantage of this is that shallower caissons can be used, and that extensive flat areas can be created.

The design of cut slopes in less weathered granite (greater than Grade III) may require empirical approximations to model the strengthening influence of boulders. In cuts in fresh rock, sheeting joints are likely to be encountered which require additional support or the draining of water. These local measures enable steep cuts to be made in fresh granite, but the particular form of additional support cannot be determined in advance.

(iii) *Colluvial Terrain*

The creation of extensive cuts in colluvium should be avoided. Aspects of this material affecting stability are noted in Section 3.1.3. Colluvium overlies the insitu rocks in many of the potential development areas outlined in this Report. Colluvium has been associated with a number of serious slope failures in the Territory, and there are many instances where local failure has occurred on cuts formed for development platforms on steeper terrain.

D.3.10 *Maintenance of Natural Drainage*

In colluvial areas and in the vicinity of man-made fills, where stability of excavations and slopes is particularly sensitive to water pressure and localised erosion, the pattern of natural drainage should be maintained as far as is practicable.

Diversion of natural drainage, if poorly maintained or of inadequate capacity, may cause overtopping of channels with consequent erosion and infiltration on slopes during heavy rains when stability is most vulnerable. Many streams in the study area carry large amounts of silt from surface wash, which is often deposited on bends or flatter sections of entrainment schemes.

The pattern of subsurface flow beneath any superficial or partly weathered material is unlikely to be affected by most surface water entrainment schemes. Subsurface flows may enter fill in valleys from beneath, even though surface drainage reduces infiltration. It is possible that the fill slope failures at Sau Mau Ping (Government of Hong Kong, 1972 a & b, 1977) were the result of such subsurface flows.

Even in situations where the natural drainage pattern is not significantly altered, an impermeable surface cover such as a large paved area can considerably increase the quantity of surface runoff and reduce the time of concentration. Flooding and consequent infiltration of slopes may become a problem even though, in the natural terrain, it is not the case. Old nullahs located in developing areas are often subject to overtopping in intense rain for this reason.

The natural and post-development hydrology requires careful investigation and design due to their influence on slope stability.

D.3.11 *Site Investigation*

A 'desk study' is a necessary preliminary to any site investigation. The GASP report summarises, interprets and presents much of the information which would be reviewed in a desk study and, in addition, is reinforced by field reconnaissance.

The 1:20 000 GASP Report is designed for use at a strategic planning and engineering feasibility study stage. The GLUM indicates the general level of site investigation envisaged for each class of map unit and is summarised in Table A2. Information on the engineering geological characteristics, the local geological and terrain constraints, and the general suitability of an area is shown on the EGM, PCM and GLEAM. Only in determining the engineering feasibility of a large uninvestigated area should a preliminary site investigation be based only on a 1:20 000 GASP Report.

When interpreting the GLUM with regard to site investigation, the following points should be considered:

(*a*) In the study area, extensive site investigation for a range of engineering projects is available. Some of the reports are accessible in the GCO's Geotechnical Information Unit (GIU), and many provide a great deal of the background geotechnical information necessary for a new project. Figure C2 gives an indication of the distribution and intensity of site investigation records held in the GIU.

(*b*) A field reconnaissance of the site and the surrounding area is a necessary preliminary to planning a site investigation. On undisturbed sites, much can be inferred with regard to the strength of underlying materials, the pattern of superficial deposits, and local weaknesses in rock from site observations of the contrasts in landform and the pattern of drainage on and around the site.

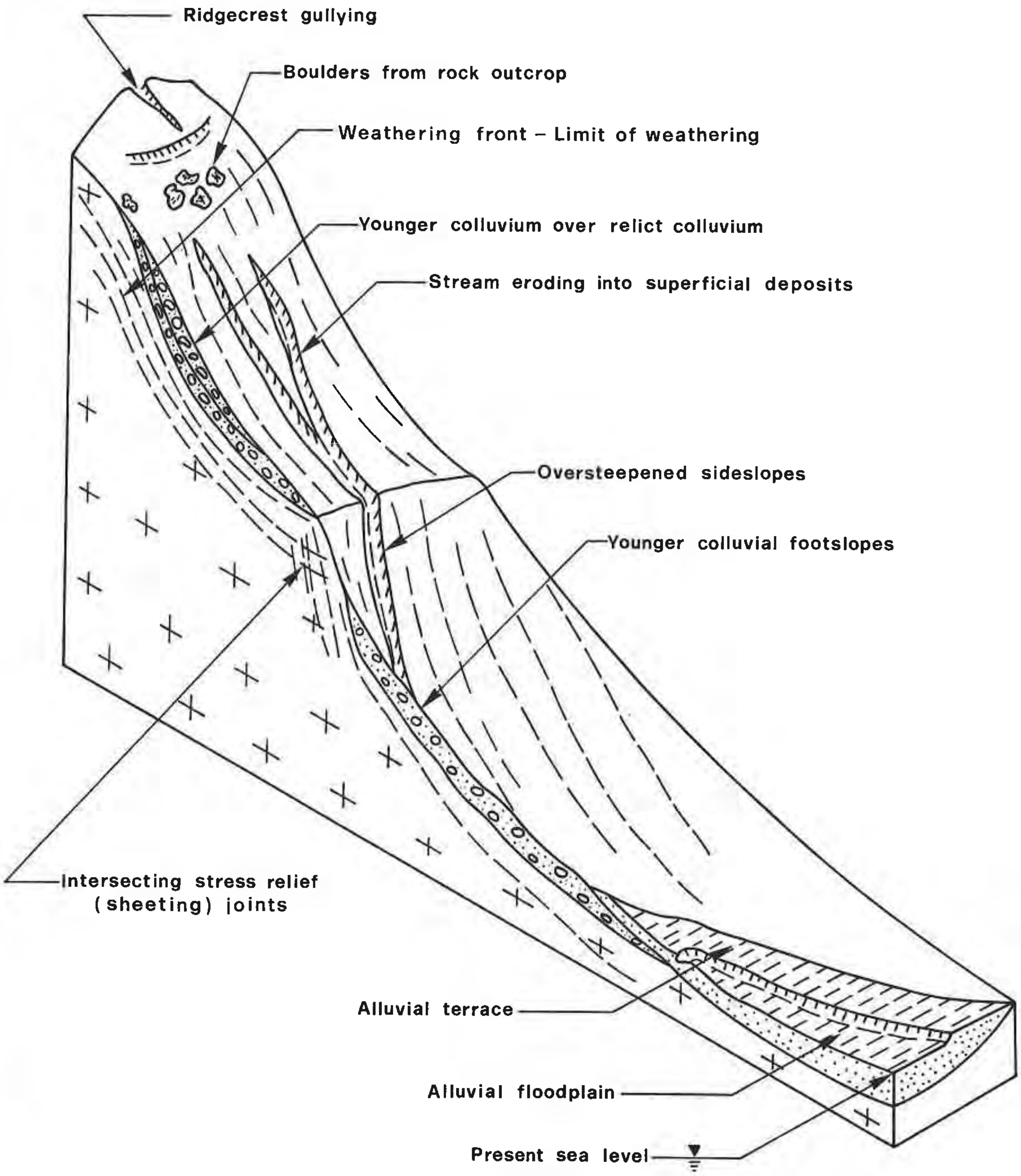
(*c*) The site investigation should be designed to highlight the scope of any available information, the anticipated material, its nature and variability, and the type and form of the engineering project.

D.4 Landform Model of the Terrain in Hong Kong

Landforms are the product of the local balance between weathering, erosion and deposition and are continually evolving. The mechanics of the system and its various components are shown in Figure D1 and described in Appendix D.3.1 (Hansen, 1984 a & b). This section discusses the significance of the sequence of landform evolution to the engineering properties of the materials within the study area. This is achieved in terms of their distribution and thickness. Many of the geomorphological processes act at rates that engineers consider insignificant. However an understanding of the evolutionary system will aid an engineering appreciation of the terrain, because the consequences of slope processes affect the materials with which an engineer constantly deals. Figure D4 provides a simplified hillslope model and relates to the following text.

Slopes that are too steep for the weathered material to remain stable are subject to periodic failure. The magnitude of failure may be isolated and small or catastrophic in nature. Therefore, the recognition of slope process is important in order to highlight the landslip hazard. The origin of many of the oversteepened inland slopes in the Territory lies in the consequences of the fall in sea level that resulted from the growth of the ice sheets during the Pleistocene. During this period, the sea level fluctuated dramatically; there is evidence in southern China that stream incision occurred and produced oversteepened slopes adjacent to the channels. Gradually, the incision progressed inland, taking advantage of structural weaknesses in the underlying geology, with the result that many valleys are narrow with steep sides. The increased rate of erosion removed much of the weathered mantle adjacent to the streams. This, in part, explains the occurrence of shallow weathering depths and slightly weathered bedrock along the floors of many incised valleys in the Territory.

Drainage courses are the main axes of erosion within a valley. The density of drainage pattern responds to and is influenced by the materials and structural control. Incision and removal of material creates oversteepened sideslopes adjacent to the drainage lines by erosion and slope failure. This process continues to induce oversteepening of the terrain, which causes lateral recession of the hillsides. Oversteepening progresses upslope through erosion by instability, as the depth of weathered mantle increases to a limiting value. The terrain on either side of the oversteepened slope section contains different associations of landforms (as shown in Figure D4) as each part of the slope is reacting to a different set of denudational conditions. Below the oversteepened sideslopes, the landforms are comparatively young. Boulders in the colluvium, deposited as a result of landslips and slopewash from the oversteepened slope, are generally unweathered. The oversteepened sideslopes contain many landslip scars, often as recent and relict features, as well as rock outcrops protruding through the thin soils. Above the level of slope oversteepening, the landforms are generally much older. Thus, the spurlines are more deeply weathered and may possess a relict colluvial cover with boulders that are decomposed insitu. In some situations in the study area, younger colluvium overlies older relict deposits. Stream incision occurs at a faster rate than the upslope migration of the oversteepened slopes. This promotes instability adjacent to the stream channels through undercutting. Erosion may result in the exhumation of corestones or boulders which are either distributed across the terrain or are concentrated within drainage lines.



Hillslope Model	Fig. D4

Irregularities in slope profile can also be the result of variations in the resistance to erosion of the underlying rock types. The existence of dykes, faults or more resistant strata are examples. However, these features usually result in a different spatial distribution of landforms and may can be distinguished through the careful use of aerial photograph interpretation and field mapping.

Provided that the debris resulting from the erosion of the oversteepened slope is continually transported away from the slope, instability will continue regardless of changes to the denudational system downslope. If the debris is not removed as fast as it is being deposited, colluvial fans form. If sediment supply decreases or base level is lowered, then incision of the fans results.

With the retreat of the ice sheets at the end of the Pleistocene, the sea level gradually rose. The deepened valleys became sediment traps for the material that was eroded from the sideslopes. Great thicknesses of alluvium (mainly sands and silts with occasional gravel lenses) accumulated, particularly in the lower reaches of the valleys in which there was an abundant sediment supply. Alluvium at the sides of these valleys is interlayered with colluvium deposited by landslips. As both alluvium and colluvium were deposited during the period of lower sea level, they may both exist beneath, as well as intercalating with marine sediments.

APPENDIX E

GLOSSARY OF TERMS

AERIAL PHOTOGRAPH INTERPRETATION

Technique of interpreting data from aerial photographs which are viewed stereoscopically. This method enables the evaluation of the terrain in three-dimensions.

AGGLOMERATE

Pyroclastic rock consisting mainly of fragments greater than 60 mm in diameter; rounded pyroclastics predominate.

ALLUVIAL FAN

Mass of sediments deposited at a point along a river or drainage line where there is a decrease in gradient. The fan is thickest at its point of origin and thins rapidly in a downstream direction.

ALLUVIUM

Sediment transported and deposited by a river or stream.

APHANITE

Rock with microcrystalline or cryptocrystalline texture that is too small to be seen with the naked eye.

AQUIFER

Water-transmitting rock or soil. Type aquifers are those which are normally associated with high transmissivity such as sandstone, limestone and chalk and are often used for water supply purposes.

AREA INSTABILITY INDEX

Proportion of a particular area of land which is affected by instability.

ASPECT

Direction in which a slope faces.

BATHOLITH

Large intrusive igneous rockmass.

BEDROCK (=SOLID GEOLOGY)

Insitu rock exposed at the surface or underlying any superficial material such as topsoil, residual soil, alluvium or colluvium.

BLOCKS

Solid pyroclastic fragments greater than 60 mm ejected from volcanoes by volcanic action.

BOMBS

Partially or wholly molten pyroclastic fragments greater than 60 mm ejected from volcanoes by volcanic action. These fragments often acquire distinctive shapes or surface textures during ejection and subsequent transport.

BRECCIA

Rock consisting of coarse grained (>60 mm) angular fragments implying minimal transport of material. Breccias are poorly sorted and commonly contain rock fragments derived from a restricted source. Also see FAULT BRECCIA.

CATCHMENT AREA

Area from which a river or stream collects surface runoff. Often used synonymously with DRAINAGE BASIN.

CHLORITISATION

Replacement by, conversion into, or introduction of chlorite into the rock substance.

CHUNAM

Cement-lime stabilised soil used as a plaster to protect the surfaces of excavations from erosion and infiltration. The recommended mix for chunam plaster, the proportions being measured by weight, is one part Portland cement, three parts hydrated lime and 20 parts clayey decomposed granite or volcanic soil.

COASTAL PLAIN

Terrain component defined as flat terrain lying between the littoral zone and mountain footslopes.

COLLUVIUM

Heterogeneous deposit of rock fragments and soil material transported downslope through the influence of gravity, including creep and local slopewash.

COUNTRY ROCK (=HOST ROCK)

General term applied to rocks penetrated by and surrounding an igneous intrusion.

CUT SLOPE AND CUT PLATFORM

Surface which remains after volume of soil and/or rock has been excavated. Within the terrain classification system, such units with gradients in excess of 5° are cut slopes, while those with gradients less than 5° are cut platforms.

DACITE

Extrusive equivalent of quartz diorite. The principal minerals are plagioclase, quartz, pyroxene and hornblende. The rock is glassy or fine grained with occasional phenocrysts.

DETRITAL

Term applied to any particles of minerals or, more commonly, rocks which are derived from pre-existing rocks by processes of weathering and/or erosion.

DIP (or TRUE DIP)

Angle of a plane to the horizontal, measured in a direction perpendicular to the strike of the plane.

DIP DIRECTION

Direction or azimuth of dip.

DISCONTINUITY

Interruption, usually of a planar nature, to the homogeneity of a rockmass (i.e. joints, faults). The description and classification of discontinuities is given in the 'Geotechnical Manual for Slopes' produced by the Geotechnical Control Office. (1984).

DISTURBED TERRAIN

Terrain component, defined as land permanently altered from its original state by man. Cut and fill slopes are usually designated as 'disturbed terrain'.

DOLOS

Interlocking precast concrete structures of regular geometric form normally used for protection against marine erosion.

DRAINAGE PLAIN

Terrain component, defined as an area subject to periodic overland flow of water, and within the GASP it is defined as colluvial in nature. It may be an area of spring activity. In some situations, drainage plains may include deeply incised drainage channels.

DURICRUST (=HARD PAN)

Near surface cemented layer occurring in soils or weathered rocks as a result of groundwater action. The cementing agent may be siliceous, calcareous, ferruginous or aluminous.

DYKE

Wall-like body of igneous rock which is discordant, i.e. cuts across bedding or structural planes of the host rock. Usually near vertical. A set of dykes in a parallel or radial pattern constitutes a DYKE SWARM.

EPHEMERAL STREAM

Stream which only flows for short periods of the year.

EROSION

Natural process which involves the wearing away and/or removal of the land surface by the action of a transporting medium or its entrained debris. The agents of transportation can be water, wind or gravity.

FABRIC

Overall appearance of a rock or soil exposure or hand specimen resulting from the combined features of texture and structure.

FAULT

Fracture in rock along which there has been an observable amount of displacement.

FAULT BRECCIA

Assembly of broken fragments formed by crushing or grinding along a fault plane.

FILL SLOPE AND FILL PLATFORM

Surface which is artificially constructed from soil or rubble transported by man. Within the terrain classification system, such units with gradients in excess of 5° are fill slopes, while those with gradients less than 5° are fill platforms.

FLOODPLAIN

Terrain component, defined as a flat area in alluvial terrain which is subject to periodic inundation.

FOOTSLOPE

Terrain component, which is essentially a zone of deposition and which usually occupies a basal position in the terrain. Within the Regional GASP, footslopes are defined as being colluvial in nature.

GENERAL INSTABILITY

Terrain attribute defined for use in 1:20 000 scale GASP mapping to describe areas where large numbers of small landslips or other instability occur.

GENERALISED LIMITATIONS AND ENGINEERING APPRAISAL MAP (GLEAM)

Map which delineates potential development areas in terms of geotechnical and other constraints.

GEOTECHNICAL AREA STUDIES PROGRAMME (GASP)

Geotechnical study of a specific area by the GCO on the basis of systematic terrain classification using aerial photograph interpretation, fieldwork and engineering assessment.

GEOTECHNICAL LAND USE MAP (GLUM)

Map which delineates the general geotechnical limitations of the terrain for planning purposes.

GRABEN

Downfaulted block between two or more parallel (or subparallel) faults.

GULLY EROSION

Terrain attribute, characterised by incised drainage channels formed by the removal of soil or decomposed rock by the surface flow of water.

HILLCREST

Terrain component, which is convex in shape. The terrain surrounding this component falls away in all directions.

HORNFELS

Fine grained non-schistose metamorphic rock, usually derived from fine grained sediments.

HYDROGRAPH

Graph showing the volume of stream (or channel) discharge against time. A 'flashy' hydrograph has a steep rising limb and indicates a very rapid increase of discharge following rainfall.

IGNIMBRITES (=WELDED TUFFS)

Chiefly a fine-grained rhyolitic tuff formed mainly of glass particles (shards), in which crystals of quartz, feldspar and sometimes other minerals are embedded. The glass shards are welded or bent around the crystals, having been viscous when deposited. The glass shards are often devitrified.

IMBRICATE STRUCTURE

Tabular or sheet structures that overlap each other in response to uni-directional forces.

INCISED DRAINAGE CHANNEL

Terrain component consisting of the channel and banks of a drainage line. Identification of this feature is largely dependent upon the scale of the survey and scale of the aerial photograph.

INDURATION

Process by which a soft soil or rock material becomes hard. Generally includes hardening by baking, pressure or cementation.

INSITU MATERIAL

Material in original position of formation as opposed to loose, disconnected, transported or derived material.

INTRUSION

Body of igneous rock which has forced itself into pre-existing rocks, either along some definite structural feature or by deformation and cross-cutting of the invaded rock.

LAND CAPABILITY

Capacity or potential of a parcel of land to sustain a particular use.

LANDFORM

General shape and characteristic morphology of the land surface.

LANDSLIP (=LANDSLIDE)

General name for downhill movements of soil or rock involving shear failure. Term is generally restricted to failures in soils. Rock failures are more commonly termed ROCKSLIDES or ROCKFALLS.

LAPILLI

Pyroclastic fragments measuring between 2 and 60 mm ejected from volcanoes by volcanic action.

LENTICULAR COLLUVIUM

Colluvial deposit which is essentially confined by valley sideslopes or is marginal to a natural drainage line. These deposits are usually ribbon shaped features.

LITHOLOGY

General physical character of a rock, including mineral constituents, texture and structure.

LITHOSTRATIGRAPHY

Stratigraphy based only on the physical and petrographic features of rocks (as opposed to a biological or age basis).

LITHOTYPE

Rock defined on the basis of certain selected physical characteristics.

LITTORAL ZONE

Terrain component, defined as the area between the highest and lowest levels of spring tides, i.e. beach.

MANTLE

Weathered rock material overlying fresh rock.

MASS WASTING

General term for the dislodgement and downslope movement of soil and rock material.

MATRIX

Finer grained fraction within a soil or rock containing large particles.

MAXIMUM DRY DENSITY

Density obtained using a specific amount of compaction at the optimum moisture content (British Standard Test: BS 1377).

NATURAL SLOPE

Area of sloping ground substantially unaltered by man.

NICK POINT

Point of interruption of a stream profile at the head of a second-cycle valley, usually as a result of a change in base level.

OUTCROP

Part of a geological formation or rock that appears at the ground surface. The exposure of bedrock or strata projecting through the overlying cover of detritus or soil.

PEGMATITE

Igneous rocks of very coarse texture found usually as dykes or veins associated with a large mass of plutonic rock of finer grain size (e.g. granite).

PERENNIAL STREAM

Stream that flows throughout the year.

PHYLLITE

Argillaceous rock of intermediate metamorphic grade.

PHYSICAL LAND RESOURCES

Physical characteristics of land.

PIPE (=SOIL PIPE)

Tubular conduit within the soil mantle, through which groundwater may flow.

POLYCYCLIC

Many cycles of development.

PYROCLASTIC ROCK

Volcanic rock composed of rock fragments (including molten material and fragments of country rock) explosively ejected from a volcano. TUFF is a general name for consolidated pyroclastic ash.

RECLAMATION

Area of land reclaimed from the sea or other waterbody.

RELICT

Term used to describe remnants of earlier landscapes or surface deposits. Also used to describe traces of lithological features in residual soil.

RESIDUAL SOIL

Soil resulting from the weathering of rock insitu.

RILL EROSION

Terrain attribute characterised by subparallel sets of small narrow channels formed by the concentration of surface runoff.

ROCK EXPOSURE (=ROCK OUTCROP as defined for Terrain Classification)

Discrete area of rock exposed at surface.

ROOF PENDANT

Mass of older country rock forming the roof of a major igneous intrusion (e.g. a granite batholith). On a map, a roof pendant is completely surrounded by the rock of the batholith.

SCREE (=TALUS)

Debris resulting from the mechanical weathering of rock which accumulates at the foot of a cliff or a steep slope.

SESQUIOXIDES

Oxides of iron and aluminium which are generally mobilized as ions in solution by groundwater and which, upon precipitation, often act as the cementing agent in the formation of duricrust.

SHEET EROSION

Terrain attribute, characterised by the removal of the surface layers of soil by wind or water.

SHEETING JOINT

Discontinuity produced by pressure release or exfoliation. Sheeting joints may separate large rock masses, e.g. of granite into tabular bodies or lenses, roughly parallel with the rock surface. Often persistent for large distances and generally following the shape of the landform.

SIDESLOPE

Terrain component, used to describe the terrain between footslope and hillcrest. This terrain unit is usually erosional.

SPHERULITE

Small radiating, and usually concentric arrangement of one or more minerals formed by radial growth of acicular crystals.

STRIKE

Azimuth of a horizontal line drawn on a bedding plane. Strike is at right angles to the direction of true dip.

STRUCTURE

Relationship between different features (and their causes) in a rock mass or soil, e.g. bedding, jointing, cleavage, faulting, contacts between different lithologies and, in a regional context, the geographical distribution of these features.

TECTONIC

Relating to a period of deformation or mountain building e.g. granite emplacement. Post-tectonic refers to events occurring after a particular deformation period. Syntectonic implies an event taking place coextensively with a definite period of deformation, intrusion, etc.

TERRAIN ATTRIBUTE

Characteristic of the terrain as defined within the terrain classification system. (Refer to Table A1).

TERRAIN CLASSIFICATION

Systematic terrain evaluation based on the use of terrain attributes for the production of a landscape model for engineering or other purposes.

TERRAIN COMPONENT

Geomorphological unit, e.g. hillcrest, floodplain. One of the attributes by which terrain is classified.

TERRAIN EVALUATION

Assessment of an area of ground for engineering or other purposes. The technique of aerial photograph interpretation is used to assess the landscape features.

TEXTURE

Relationship between the grains of minerals forming a rock, mainly in terms of size, shape and arrangement.

TOR

Landform characterised by an elevated pile of rock slabs or loose boulders formed by weathering and erosion of insitu materials.

TRANSMISSIVITY

The rate at which water is transmitted through a unit width of aquifer, under a unit hydraulic gradient.

TUFF

General rock name given to consolidated pyroclastic ash. Tuffs are classified as being essentially vitric (>50% glassy fragments), lithic (>50% rock fragments) or crystal (>50% crystal fragments) in composition, and fine (<0.06 mm), coarse (0.06–2 mm), lapilli (2–60 mm) and breccia (>60 mm) in size.

VOLCANICLASTIC

Clastic rock containing volcanic material in any proportion without regard to its origin or environment.

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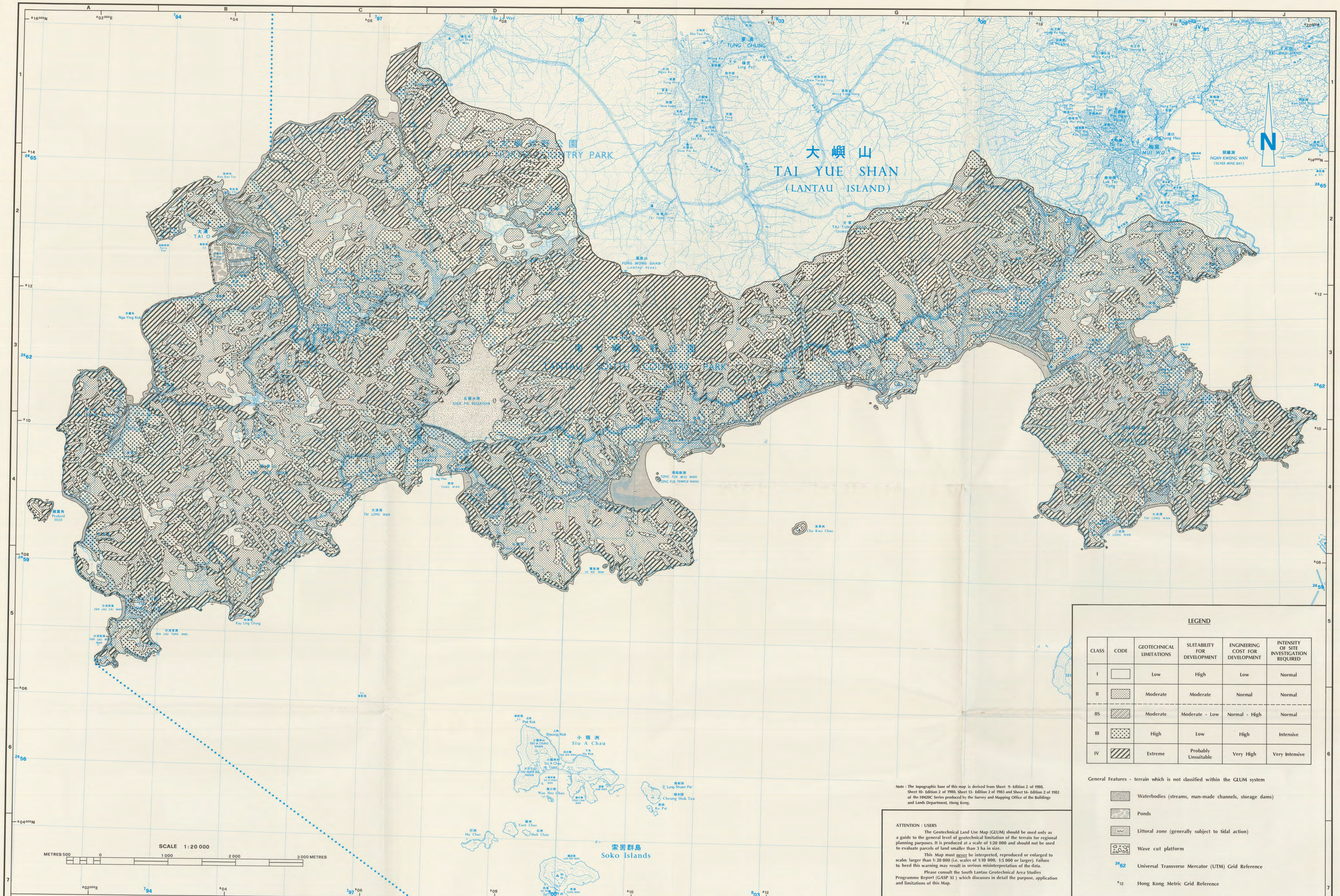

Note : The topographic base of this map is derived from Sheet 9- Edition 2 of 1980, Sheet 10- Edition 2 of 1980, Sheet 13- Edition 2 of 1983 and Sheet 14- Edition 2 of 1982 of the HM20C Series produced by the Survey and Mapping Office of the Buildings and Lands Department, Hong Kong.

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 South Lantau Geotechnical Area Studies Programme Report (GASP XI) which discusses in detail the purpose, application and limitations of this Map.

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 the GLUM system

- Waterbodies (streams, man-made channels, storage dams)
- Ponds
- Littoral zone (generally subject to tidal action)
- Wave cut platform
- 2462 Universal Transverse Mercator (UTM) Grid Reference
- 812 Hong Kong Metric Grid Reference

Geotechnical Control Office

Civil Engineering Services Department

GEOTECHNICAL AREA STUDIES PROGRAMME

GEOTECHNICAL LAND USE MAP – SOUTH LANTAU

Title: GEOTECHNICAL LAND USE MAP – SOUTH LANTAU	
Compiled: A . Hansen	Drawn: C.P. Wan
Scale: 1:20 000	Date: Original March, 1985 2nd Edition September, 1988
Map Ref. No: GASP / 20 / XI / 1 2nd Edition	Sheet:

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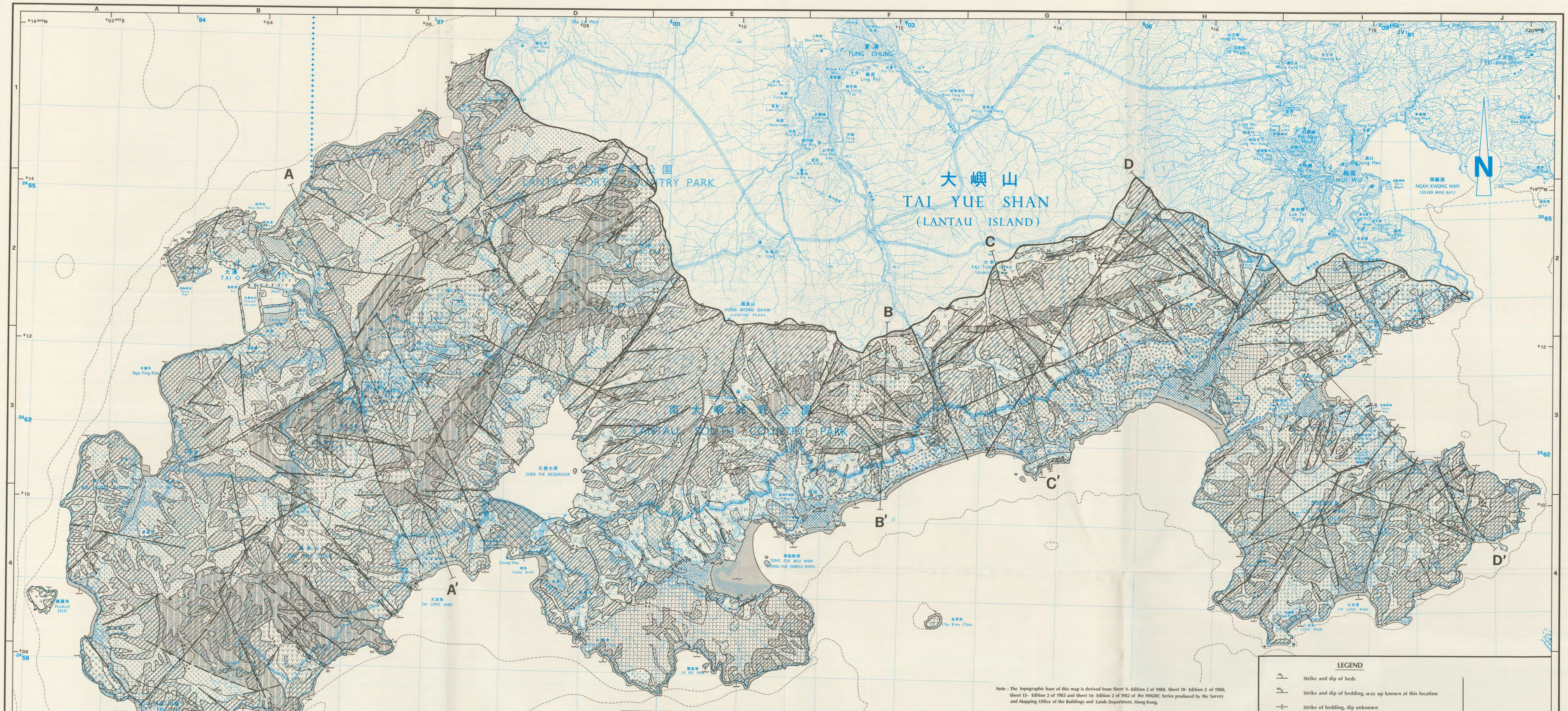

Note : The topographic base of this map is derived from Sheet 9- Edition 2 of 1980, Sheet 10- Edition 2 of 1980, Sheet 13- Edition 2 of 1983 and Sheet 14- Edition 2 of 1982 of the HM20C Series produced by the Survey and Mapping Office of the Buildings and Lands Department, Hong Kong.

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 1 000 2 000 3 000 METRES

Map Unit	Weathering and Soil Development	Engineering Comment (Stability, Foundation, Hydrogeology)	Material Uses and Excavation Characteristics
RECLAMATION; FILL	These materials placed by man have no soil (pedogenic) or weathering profile but may contain weathered rocks or be underlain by natural superficial deposits and/or a pre-existing weathered profile.	Few problems if properly compacted. Old fill slopes may be poorly compacted and subject to failure. Steep excavations require support. High groundwater requires special drainage. Low bearing pressures can be accepted directly, high loads need raft, spread or piled foundations. Settlement problems minor except in sanitary 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.
LITTORAL DEPOSITS	Nil	Materials are usually saturated and saline. Raised beaches may be leached by rainwater but may remain saline at depth. Groundwater extraction may induce incursion of saline water. Poor grading characteristics—low fines. Low bearing pressures can be accepted directly, moderate and high loads need raft, spread or piled foundations.	Main development potential is as beaches for recreational purposes. Excavation of these materials usually prohibited.
ALLUVIAL DEPOSITS	In subaerial locations, very minor development of soil horizon. Relict deposits may be more weathered. Very old deposits may contain completely weathered boulders.	Locally low-lying terrain may be subject to flooding. Materials are usually saturated and of a low density – clay layers are normally consolidated. Buried channels may pose local problems of high water flows into tunnels or excavations. Steep excavations require support. Groundwater may be saline if adjacent to coast. Incursion of saline groundwater following abstraction of fresh groundwater may occur. Low bearing pressures can be accepted directly, moderate and high loads need raft, spread or piled foundations.	Land deposits easily excavated. Marine deposits often form reasonable hydraulic fill. Excavation by cutter, suction or bucket dredger.
MARINE SEDIMENTS	Nil	Material is poor to unsatisfactory for hydraulic fill. It is also poor as a foundation because of settlement and bearing capacity problems. Will probably be susceptible to formation of mud waves if fill is end-tipped onto it. Consolidation may be aided by wick drains and/or surcharge loading.	Easily excavated using bucket or possibly suction dredger where necessary. Sandy deposits may be used in construction but silt and clay may pose problems of disposal.
COLLUVIUM: VOLCANIC DERIVED; GRANITIC DERIVED; MIXED	Colluvium can occur as independent deposits of a unique age such that one deposit overlies another. The older deposits may be subject to severe weathering and may be completely decomposed to a mottled, coloured sandy silt or clayey silt similar to the insitu residual deposits of their parent materials. The depth of such weathering may be in the order of 10 m or more.	This material has moved in its geologic past and is prone to reactivation if not carefully treated by such measures as low batter angles, drainage, and surface protection, especially when saturated. Has low to moderate bearing capacity characteristics but should always be carefully drained because it may be susceptible to failure when wet. Voids may cause settlement of roads, services and buildings. Tunnelling probably difficult. Site investigation is 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 bouldery stream deposits will be of limited use. Large boulders may require blasting or splitting.
INTRUSIVE IGNEOUS ROCKS – DYKE ROCKS: QUARTZ PORPHYRY Pq; FELDSPAR PORPHYRY La	Generally weathers faster than volcanic rocks but slower than granitic rocks. Develops a thick reddish soil. Weathering depths are generally in the range 7–15 m.	Surface hydrology can be affected by these rocks with drainage networks aligning with the strike of the dykes. Subsurface hydrology and foundation levels will be affected by the variable rockhead.	Restricted extend precludes deliberate borrow or quarry activities. May be suitable as aggregate when fresh. Excavation conditions may be difficult and expensive.
INTRUSIVE IGNEOUS ROCKS – PLUTONIC: QUARTZ MONZONITE	Shallow to deep residual soil over moderately weathered rock. Corestones extensive.	Relatively unknown rock type, comments as for granites but more care required with weathered materials because likely to be slightly more clayey. Several troublesome case histories noted.	Material can be scraped for borrow when weathered. Fresh rock must be blasted. Not often used for aggregate, but after testing to establish characteristics should be satisfactory. Should have good asphalt adhesion characteristics.
INTRUSIVE IGNEOUS ROCKS – PLUTONIC: UNDIFFERENTIATED GRANITIC ROCK	Generally moderately weathered rock in the order of 10 m thick. Upper weathered zone porous and permeable.	Stability of the weathered material can be suspect, i.e. Zones A & B, where soil type failures may occasionally occur. Insitu material is prone 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.
INTRUSIVE IGNEOUS ROCKS – PLUTONIC: FAN LAU PORPHYRITIC GRANITE	Moderate to deep weathering on ridgecrests and slopes protected from erosion. Shallow weathering on rocks exposed to wave erosion. Soils contain large percentage of coarse quartz sand.		
INTRUSIVE IGNEOUS ROCKS (PLUTONIC): MA ON SHAN GRANITE; CHEUNG CHAU GRANITE; SUNG KONG GRANITE	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.	Stability of the weathered material can be suspect, i.e. Zones A & B, where soil type failures may occassionally occur. Insitu material is prone 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.
INTRUSIVE IGNEOUS ROCKS (PLUTONIC): TAI PO GRANODIORITE	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.	Relatively unknown rock type in study area, comments as for granites but a little more care required with weathered materials because they are likely to be 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 asphaltic concrete.
SEDIMENTARY, VOLCANICLASTIC AND EXTRUSIVE IGNEOUS ROCKS – REPULSE BAY FORMATION: SEDIMENTARY AND WATER-LAID VOLCANICLASTIC ROCKS	Shallow to moderately deep, reddish to brown, fine, sandy to silty clay i.e. residual soil sometimes with ferruginous gravel and weathered rock fragments, overlying completely to highly weathered rock which grades into less weathered strongly jointed volcanic rock at depths from 5–20 m.	The sediments are bedded and fissile and weather relatively rapidly, when exposed, to a grey silt. Some stability problems may arise. Groundwater regime may be controlled by the bedded character of the rock.	Can be scraped and ripped when weathered. Fresh rock will need pneumatic machines or blasting. Due to highly variable properties and presence of chert bands, this material would not make a good source of aggregate but is well suited for filling. Scarn mineralisation with magnetite has been mined.
SEDIMENTARY, VOLCANICLASTIC AND EXTRUSIVE IGNEOUS ROCKS – REPULSE BAY FORMATION: ACID LAVAS; AGGLOMERATE	Rock usually develops a thin (< 1 m) soil horizon and a thin (< 10 m) weathered zone before passing rapidly into moderately to slightly weathered bedrock.	Stability of weathered material and also of highly jointed rock masses may be suspect, especially during or immediately after prolonged heavy rainfall. Failures are quite common, especially in over-steepened slopes. Rapid surface runoff is common. Stability of rock slopes controlled by relatively closely spaced discontinuities in moderately weathered to fresh rock mass. —Few opportunities for creation of platforms; usable sites may be small and fragmented, —Access route selection hampered by terrain, —Tunnelling probably easier than in granitoids. Deep weathering and close jointing should be anticipated near structural geological lineaments.	Very hard and abrasive when fresh, will require blasting which may result in brittle fracture. Inadvisable for aggregate unless tested for silica/cement reaction.
SEDIMENTARY, VOLCANICLASTIC AND EXTRUSIVE IGNEOUS ROCKS – REPULSE BAY FORMATION: COARSE TUFF; DOMINANTLY PYROCLASTIC ROCKS; UNDIFFERENTIATED VOLCANIC ROCKS	Rock usually produces a thin (< 1 m) soil horizon, followed downwards, especially on lower slopes, by yellowish brown sandy completely weathered material overlying less weathered, locally strongly jointed rock below an average depth of 11 m. On steep, high slopes considerable rock exposure with thin soil or weathered mantle occurs.		Material can be used for fill if it is weathered locally. It is possible to quarry, although very hard and not generally favoured. Coarse crystal tuff horizons may provide good aggregate.
SEDIMENTARY ROCKS: TAI O FORMATION	Generally moderately deep (5–10 m) uniform or gradational, red to red-brown residual clayey soil, overlying completely to highly weathered sediments.	Fresh material is generally stable and has good bearing capacity characteristics. Weathered material subject to creep and some instability, especially when saturated. May break down to silt if weathered material is over-compacted.	Restricted outcrop precludes extensive usage. 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.

LEGEND

- 30 — Strike and dip of beds
- 60 — Strike and dip of bedding, way up known at this location
- Strike of bedding, dip unknown
- Vertical bedding
- Horizontal bedding
- 40 — Strike and dip of flow - banding in lavas
- 10 — Anticlinal axis ; direction and amount of plunge shown
- 20 — Synclinal axis ; direction and amount of plunge shown
- 50 — Minor fold axis showing direction and amount of plunge
- Horizontal minor fold axis
- Anticlinal axial plane trace
- Synclinal axial plane trace
- D — Dolerite dyke
- f — f Fault
- Geological photolineament
- Geological boundary, position certain
- Geological boundary, position approximate

From Allen & Stephens (1971)

- Geological boundary, (superficial)
- Geological photolineament (approximate)
- f — f Fault (inferred)
- A — A' Geological cross-section line
- Catchment boundary (order indicated by number of dots)
- General instability
- 5 — Depth in fathoms
- 24 62 — Universal Transverse Mercator (UTM) Grid Reference
- 8 36 — Hong Kong Metric Grid Reference

Geotechnical Control Office

Civil Engineering Services Department

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ENGINEERING GEOLOGY MAP – SOUTH LANTAU

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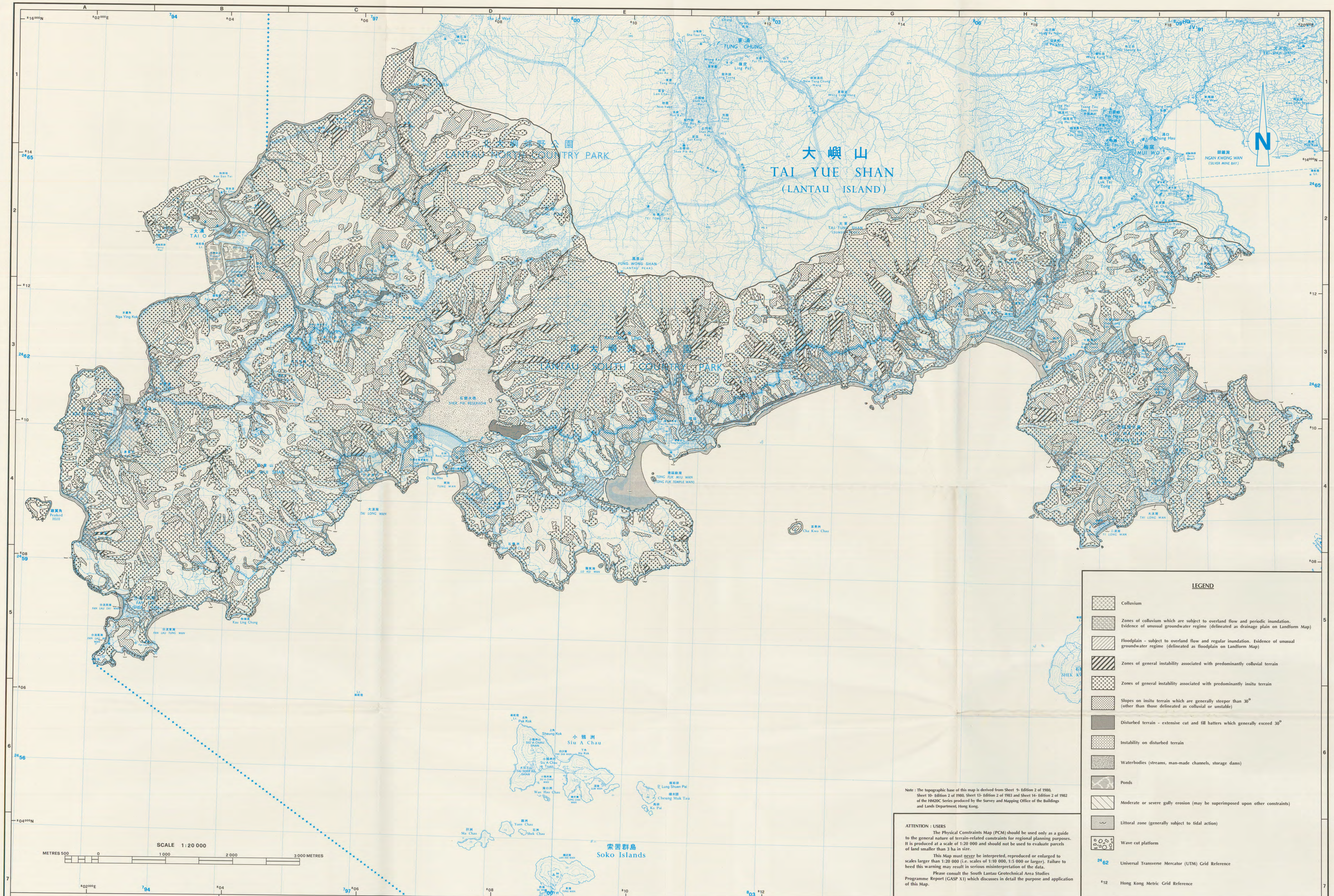

LEGEND

- 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° (other than those delineated as colluvial or unstable)
- Disturbed terrain - extensive cut and fill batters which generally exceed 30°
- Instability on disturbed terrain
- Waterbodies (streams, man-made channels, storage dams)
- Ponds
- Moderate or severe gully erosion (may be superimposed upon other constraints)
- Littoral zone (generally subject to tidal action)
- Wave cut platform
- $^{24}62$ Universal Transverse Mercator (UTM) Grid Reference
- $^{8}12$ Hong Kong Metric Grid Reference

Note : The topographic base of this map is derived from Sheet 9- Edition 2 of 1980, Sheet 10- Edition 2 of 1980, Sheet 13- Edition 2 of 1983 and Sheet 14- Edition 2 of 1982 of the HM20C Series produced by the Survey and Mapping Office of the Buildings and Lands Department, Hong Kong.

ATTENTION : USERS

The Physical Constraints Map (PCM) should be used only as a guide to the general nature of terrain-related constraints for regional planning purposes. It is produced at a scale of 1:20 000 and should not be used to evaluate parcels of land smaller than 3 ha in size.

This Map must never be interpreted, reproduced or enlarged to scales larger than 1:20 000 (i.e. scales of 1:10 000, 1:5 000 or larger). Failure to heed this warning may result in serious misinterpretation of the data.

Please consult the South Lantau Geotechnical Area Studies Programme Report (GASP XI) which discusses in detail the purpose and application of this Map.

Geotechnical Control Office
Civil Engineering Services Department

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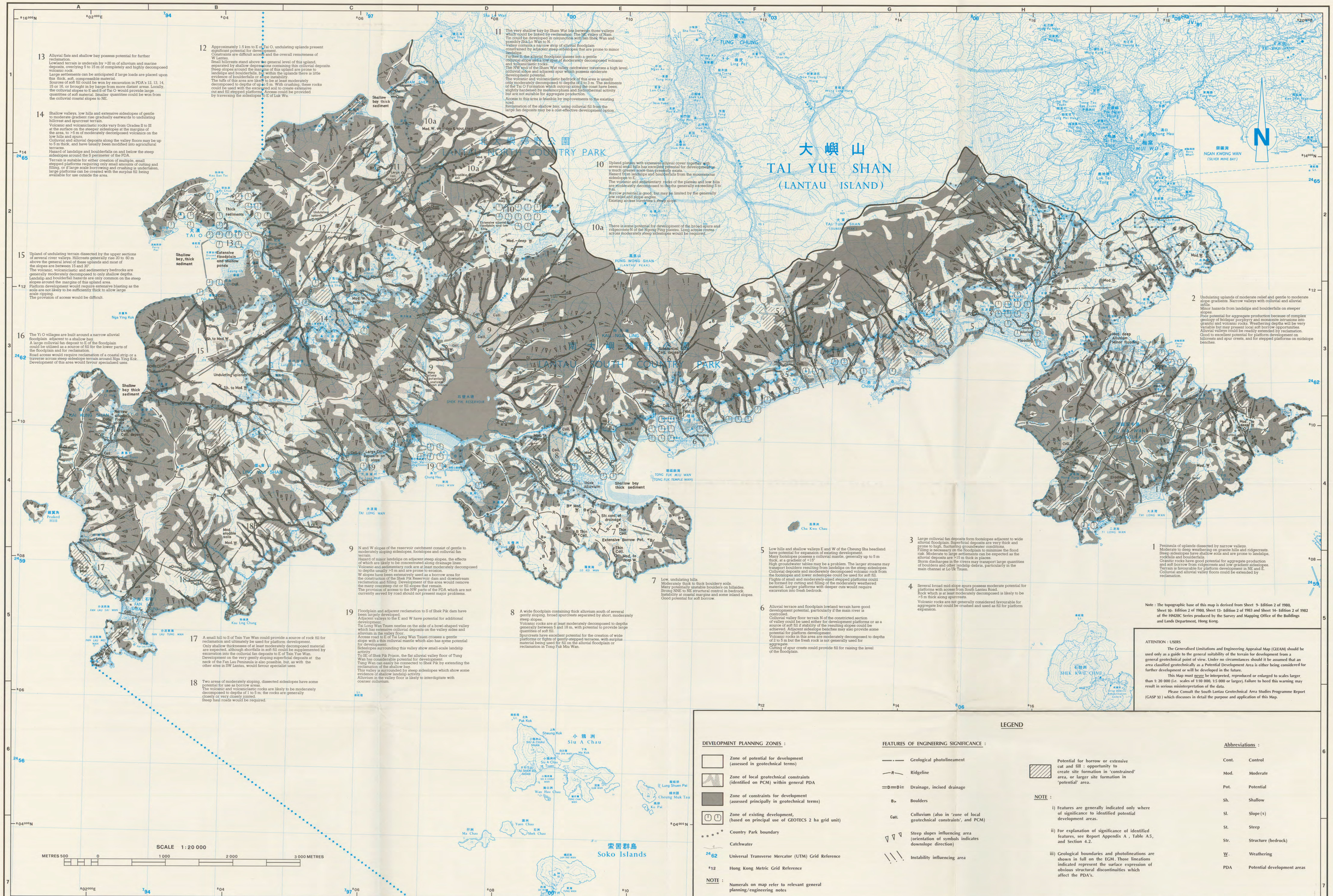

Geotechnical Control Office

Civil Engineering Services Department

GEOTECHNICAL AREA STUDIES PROGRAMME

GENERALISED LIMITATIONS AND ENGINEERING APPRAISAL MAP – SOUTH LANTAU

Title: GENERALISED LIMITATIONS AND ENGINEERING APPRAISAL MAP SOUTH LANTAU	
Compiled: A. Hansen	Drawn: S.P. Poon / C.P. Wan
Scale: 1:20 000	Date: Original March, 1985 2nd Edition September, 1988
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