Geotechnical Area Studies Programme

GASP Report VIII

North East New Territories

Geotechnical Control Office
Civil Engineering Services Department
Hong Kong

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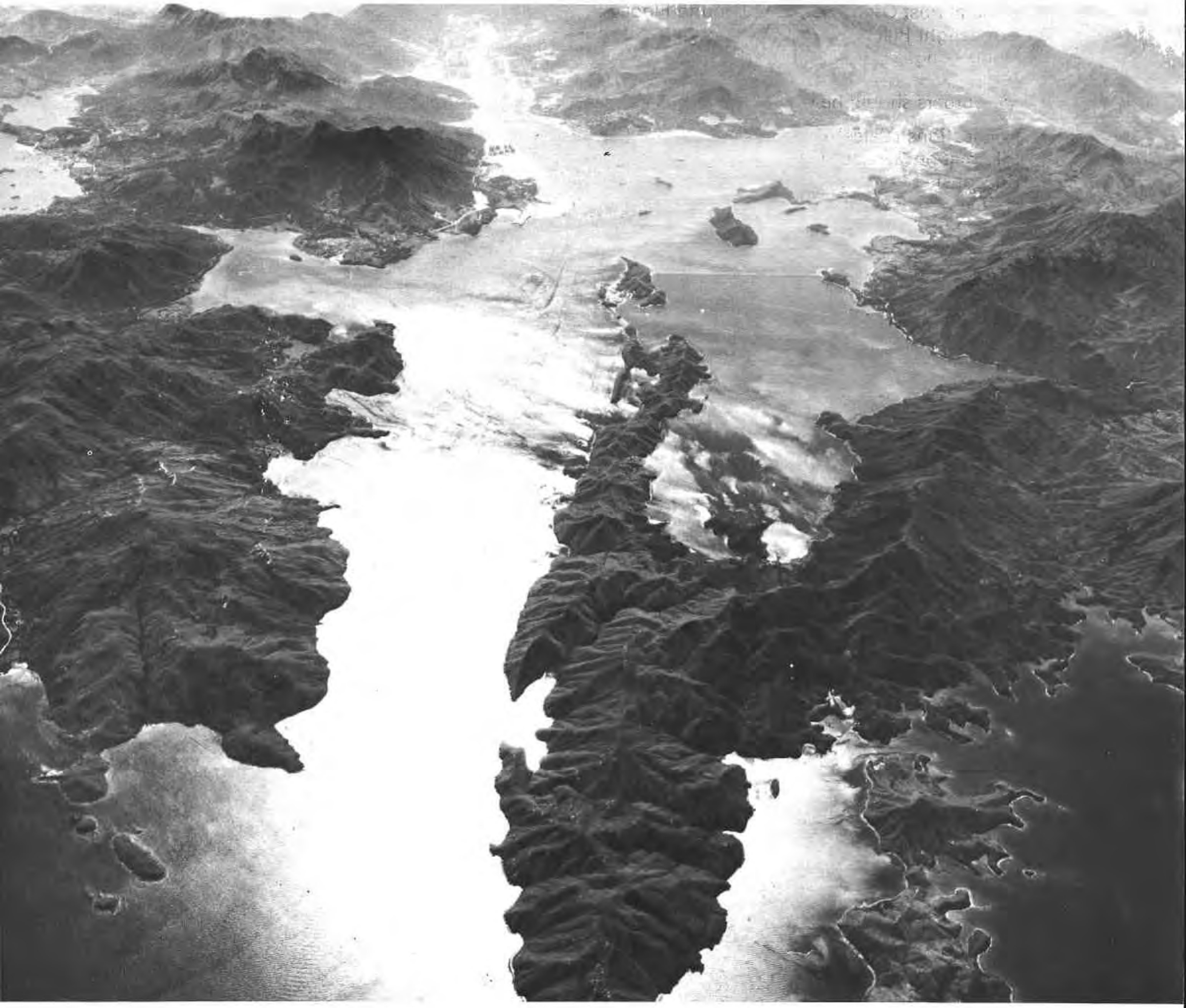

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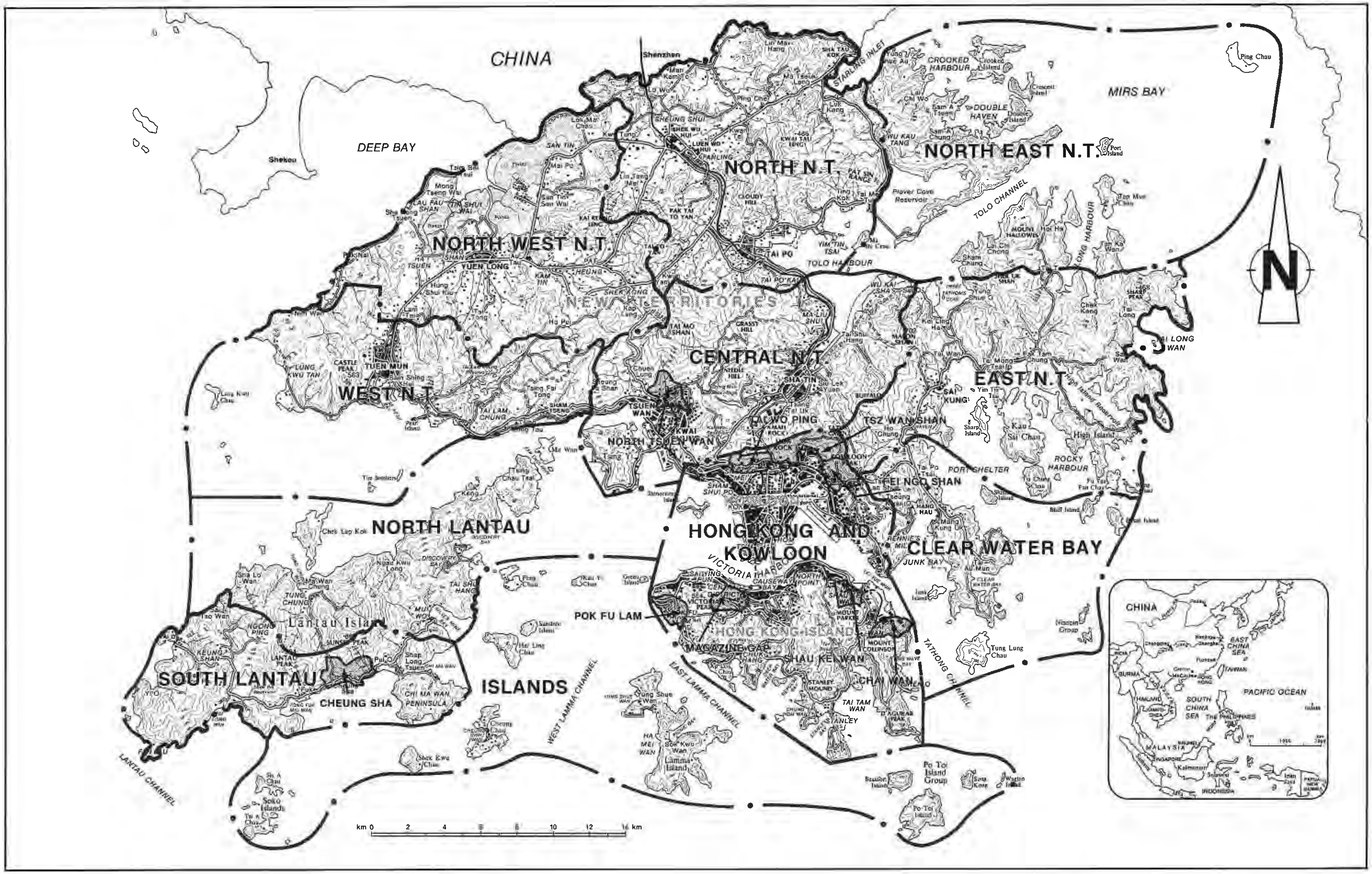

Map of the Territory of Hong Kong Showing the Locations of the Geotechnical Area Studies.
(Boundaries of the Regional Studies are shown by dashed lines and locations of District Studies are indicated by dark screens)

FOREWORD

This Report aims to provide an adequate geotechnical basis for the planning and land use management of the North East New Territories, mainly by way of information presented on a series of maps at a scale of 1:20 000. It is the eighth 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 North East New Territories, together with their accompanying Memoirs, are being published as they are completed, with full coverage anticipated by 1991.

This Report was originally produced in December 1985, for use within the Hong Kong Government, on the basis of information assembled during the period November 1983 to January 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 D. C. Cox, M. J. Dale, A. Hansen, J. M. Nash and K. A. Styles. The Planning & Terrain Evaluation Section is led by Mr K. A. Styles, and the Planning Division is under the direction of Dr A. D. Burnett.

Acknowledgements are due to the Survey & Mapping Office, Building & Lands Department of the Hong Kong Government, who provided most of the aerial photographs used in the study, a few of which are reproduced in this Report.

E. W. Brand
Principal Government Geotechnical Engineer
September 1988

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1. INTRODUCTION

1.1 The North East New Territories Geotechnical Area Study

This Report presents the results of a 1:20 000 scale Regional Geotechnical Area Study of the North East New Territories area. The study was carried out in the Geotechnical Control Office between November 1983 and January 1985. The area covered by the study, which is designated as GASP VIII, 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 and Memoir which cover much of the area dealt with in this GASP Report will be completed 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 future development. For this purpose, the study results are summarised on a series of maps.

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

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

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

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

Twelve Regional Studies have been completed, which cover the Territory of Hong Kong. This is the eighth of the Reports to be published; four more will follow in due course. 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 Section 1.7).

1.3 Aims of the Geotechnical Area Studies Programme

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

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

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

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

1.4 Organisation of the Report

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

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

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

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

The figures are designed to explain and demonstrate the system used for compiling the maps from the data. Figure 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 follow the example figures in the report, and these are presented as Plates 1 to 19. 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 North East New Territories study area. Appendix D discusses landform evolution and its relationship to engineering. A glossary of terms used in the Programme is presented in Appendix E.

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

1.5 Maps Produced within the Regional Study

1.5.1 *General*

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

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

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

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

1.5.2 *Terrain Classification Map (TCM)*

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

1.5.3 *Landform Map (LM)*

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

1.5.4 *Erosion Map (EM)*

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

1.5.5 *Geotechnical Land Use Map (GLUM)*

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

Table 1.1 GLUM Classification System

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

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

1.5.6 *Physical Constraints Map (PCM)*

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

1.5.7 *Engineering Geology Map (EGM)*

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

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

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

1.5.9 *Computer-generated Maps*

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

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

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

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

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

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

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

* Located in the Map Folder accompanying this Report.

1.7 Access to GASP Data

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

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

2. DESCRIPTION OF THE NORTH EAST NEW TERRITORIES STUDY AREA

2.1 Geographical Location

The study area occupies approximately 7 968 ha of upland terrain and indented coastal terrain to the north and south of Tolo Channel, numerous offshore islands and an archipelago formed by Double Island, Crescent Island and Crooked Island. Tolo Channel divides the study area into northern and southern sections (Figure 1). The former is mostly within the Plover Cove Country Park, whilst the latter lies within the northern part of the Sai Kung Country Park. To the east of the main study area, at the entrance to Tolo Channel, are Grass Island and Port Island. The indented coastline forms several anchorages such as Crooked Harbour and Long Harbour. Somewhat remote from the main study area is the island of Ping Chau, which is located in the eastern portion of Mirs Bay.

The western boundary of the study area crosses Tolo Channel north of Three Fathoms Cove. It then runs along the embankment of Plover Cove Reservoir, follows the coastline to Bride's Pool, and then passes northwards to Starling Inlet. The North East New Territories has common land boundaries with the North New Territories (GASP V) and the East New Territories (GASP IX). The southern boundary generally follows the drainage divide formed by Shek Uk Shan (482 mPD) and its associated ridgelines.

2.2 Topography

The North East New Territories study area is divided into three broad physiographic regions. To the north of Tolo Channel, an elongate ridgeline runs parallel to the coastline. The western section of this feature forms the southern perimeter of the Plover Cove Reservoir. The ridge is dissected by streams of very short reach, especially on the southern side. The highest elevation along this ridge is 295 mPD. Further north, a series of interlocking ridges are strongly dissected by streams of short reach. These ridges rise towards the highest point, northeast of Wu Kau Tang, of 416 mPD. Several broad valleys occupy the area between the high ground; these are located around the villages of Wu Kau Tang, Lai Chi Wo, So Lo Pun, Yung Shue Au and Kuk Po.

South of Tolo Channel, the highest elevations are formed by Shek Uk Shan which rises to 482 mPD, and by Mt Hallowes (372 mPD). The general relief south of Tolo Channel is more uniform, with less well-defined ridgelines and more rounded topography than the area north of Tolo Channel. Areas of low ground occur in the valleys of Sham Chung, east of Three Fathoms Cove, and Hoi Ha to the south of Hoi Ha Wan (Jone's Cove).

A feature of the terrain in the study area is the comparatively long coastline for the area of land enclosed. Lengthy headlands, long estuaries and channels and numerous islands are characteristic of an area of low, undulating topography which has been 'drowned' by the postglacial rise in sea-level. The islands are generally the remnants of steep-sided ridges. Ping Chau is an exception, being a relatively flat island with steep coastal cliffs. Ping Chau is, however, remote from the rest of the area.

Table B1 in Appendix B presents a summary of slope gradients within the study area and Table B5 highlights the distribution of landforms. The greater part of the study area is above 100 mPD in elevation and steep slopes are a common feature of the terrain.

2.3 Geology

2.3.1 *General*

In general terms, the regional geology of the study area consists of a sequence of Permian and Jurassic sediments overlain by a thick sequence of volcanically derived pyroclastics, tuffs, lavas and sediments of Upper Jurassic age. These are, in turn, stratigraphically overlain by metamorphosed sediments of Lower Cretaceous age. Traces of red breccias, possibly Upper Tertiary in age, occur in the north. The sediments are intruded by quartz monzonite of Upper Jurassic age, which has contributed to the alteration of some of the sediments through thermal metamorphism. The study area is traversed by numerous photolineaments, and, according to Allen & Stephens, (1971) there is evidence of a large thrust zone in the northeastern part of the area.

In the study area the stratigraphic succession from oldest to youngest is:

(i) *Tolo Harbour Formation*

(ii) *Tolo Channel Formation*

(iii) *Bluff Head Formation*

(iv) *Repulse Bay Formation*—Undifferentiated Volcanic Rocks
—Sedimentary and Water-laid Volcaniclastic Rocks
—Acid Lavas
—Coarse Tuffs
—Dominantly Pyroclastic Rocks with Some Lavas

(v) *Port Island Formation*

(vi) *Kat O Formation*

These relationships are illustrated in the geological cross-sections presented in Figure C1 in Appendix C.

The stratigraphy and ages of some of the above succession are uncertain. According to Allen & Stephens (1971), the Tolo Harbour Formation is considered to be of Permian age. This is based on the presence of the fossilised marine fauna. The occurrence of a bryozoan (Fenestella) indicates that the rocks are at least Permian in age and cannot, in biostratigraphic terms, be any younger. The Bluff Head Formation, however, is probably of Jurassic age, and is biostratigraphically dated as being younger than the Lower Lias. The Tolo Channel Formation is dated by ammonitic fossil evidence as Lower Lias (Heim, 1929).

Adjacent to the study area, two distinct groups of sediments with markedly different ages occur. These are the Tolo Harbour and Bluff Head Formations. These rocks are presumed to be separated by either a major unconformity or fault in order to account for the differences in rock type. Field evidence does not seem to support this conjecture, although it appears that whilst the Tolo Harbour Formation was probably subjected to two phases of deformation, the Bluff Head Formation possibly experienced only a single phase. The sediments of the Tolo Channel Formation are generally exposed as a linear outcrop beneath the Bluff Head Formation, at low tide along Tolo Channel. There is evidence that they outcrop underwater as thin quartzites and pyritous shales overlain by the coastal sediments of the Bluff Head Formation. The age relationships of the overlying volcanic sequence of the Repulse Bay Formation and subsequent sediments of the Port Island Formation, are relatively simple. These rocks are younger than those of the Repulse Bay Formation, and are believed to be younger than the intrusive igneous rock, the Tai Po Granodiorite, exposed on Centre Island.

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 of 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 maps and accompanying Memoir for the area will be completed 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 (1986) and Brand (1988). From an historical viewpoint Davis (1952) is still of considerable interest.

On the basis of this GASP study, the relative proportions of the geological materials are graphically illustrated in the pie chart at 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 *Metasedimentary Units*

(i) *Tolo Harbour Formation (TH)*
These rocks are among the oldest in the Territory and outcrop only on Centre Island. They consist of quartzites and marine mudstones with shales, and they are slightly metamorphosed in places. These rocks occupy less than 0.1% of the area.

(ii) *Tolo Channel Formation (TC)*
These rocks outcrop in a small area on the northern shore of Tolo Channel and consist of quartzites, and black shales with abundant pyrite. Lithologically similar to the Tolo Harbour Formation, they are distinguished only on biostratigraphical evidence. These rocks occupy less than 0.1% of the area.

(iii) *Bluff Head Formation (BH)*
These rocks outcrop along the northern side of Tolo Channel from Bluff Head to Harbour Island, and they form a sequence of shales, quartzites, sandstones, grits and conglomerates which represent a typical deltaic cyclothem of sediments. These rocks occupy 8% of the area.

2.3.3 *Volcanic and Volcaniclastic Units*

These occur in large tracts north and south of Tolo Channel, and outcrop on most of the outlying islands within the study area. They consist of a succession of tuffs, welded tuffs, lavas and pyroclastics which resulted from intense volcanic activity during the Middle Jurassic period. This Formation is classified by Allen & Stephens (1971), on the basis of major lithotypes.

(i) *Undifferentiated Volcanic Rocks (RB)*
These rocks consist of unassigned units of the Repulse Bay Formation and occupy 1.7% of the area.

(ii) *Sedimentary Rocks and Water-laid Volcaniclastic Rocks (RBs)*
These rocks consist of tuffaceous sandstones, sandstones and shales with volcanic conglomerate, and are found east of Three Fathoms Cove (Plate 1). There are also minor occurrences south and east of Starling Inlet and on Crescent Island. These rocks occupy 4.6% of the area.

(iii) *Acid Lavas (RBv)*
These rocks are generally rhyolitic or dacitic, and are exposed east of Three Fathoms Cove, on Kat O Chau and Crescent Island. The Acid Lavas occupy 2.2% of the area.

(iv) *Coarse Tuff (RBc)*
This subdivision is formed of thick deposits of coarse-grained crystal tuff, often containing volcanic bombs. These rocks outcrop mainly on the Sai Kung Peninsula east and west of Long Harbour. Small exposures are evident on Kat O Chau and Crescent Island. These rocks occupy 22.1% of the area.

(v) *Pyroclastic Rocks with Some Lavas (RBp)*
The pyroclastic units are formed by a sequence of varied rock types including fine tuffs, ash flows, lapilli tuffs and lavas. These rocks outcrop in a large area east of Three Fathoms Cove, and form most of the terrain between Starling Inlet and Crooked Harbour, as well as the northern shore of Plover Cove Reservoir. They occupy 23.1% of the area.

2.3.4 *Sedimentary Units*

(i) *Port Island Formation (PI)*
This unit consists of a sedimentary sequence of conglomerates, sandstones and shales. They outcrop over a large area between Bluff Head and Bride's Pool. The lower beds form a prominent escarpment. These rocks occupy 14.2% of the area.

(ii) *Kat O Formation (K)*
These rocks form a limited outcrop in the extreme north of the study area (Plate 2). They consist of red breccias and coarse grits, and are of fairly recent origin. The Kat O formation occupies 0.1% of the area.

2.3.5 *Intrusive Igneous Units*

(i) *Tai Po Granodiorite (XT)*
The intrusive igneous rocks are limited to a very small outcrop of Tai Po Granodiorite which occurs on Centre Island.

2.3.6 *Superficial Units*

In addition to the solid geology, natural and man-made superficial deposits cover approximately 1 860 ha (23.4%) of the area. The isolated nature and relatively low population density of this area result in little development, hence man-made superficials, such as fill and reclamation, are virtually absent.

(i) *Colluvium*
This material occurs on 359 ha (4.5%) 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, ranging from a mixture of clay, sand and gravel, to large boulder fans containing single units of several metres in thickness.

In the study area, three basic types of colluvium are encountered, these are subdivided on the basis of parent rock type.

(*a*) Volcanic colluvium (Cv)—This material occupies 263 ha and is most extensive on the Sai Kung Peninsula and southeast of Starling Inlet, where the corresponding source rocks outcrop. These deposits occur as fan-shaped lobes. The detrital material varies from large boulders to fine-grained material (Plate 3).

(*b*) Sedimentary colluvium (Cs)—This material occupies 96 ha and occurs downslope of the main areas of sedimentary rocks, mainly to the north of Tolo Channel. These deposits occur as large fans of often bouldery material, associated with rocks of the Port Island and Bluff Head Formations.

(*c*) Mixed colluvium (Cm)—This material is derived from source rock of both the above categories and occurs downslope of both volcanic and sedimentary units. Mixed colluvium is absent from the eastern half of the Sai Kung Peninsula area, around Long Harbour. Mixed colluvium occurs only as very isolated deposits.

(ii) *Alluvium (A)*
Several extensive areas of alluvium occur within the study area, mainly in coastal areas near Starling Inlet, Crooked Harbour and Double Haven, as well as on the eastern shore of Three Fathoms Cove. Alluvial deposits are also present upstream of nick points especially in the area north and east of

Bride's Pool. These reflect the change in base (sea) level which caused these features. These deposits occupy 1 438 ha, consist of poorly sorted sand and gravel with silt and clay, and are normally brown in colour. The upland representatives are normally coarser-grained than coastal alluvium.

(iii) *Marine Deposits (M)*
These deposits occur on the sea bed and consist of repetitive sequences of soft marine muds and shelly sands, with occasional lenses of coarser-grained material (conglomerate). Evidence of a four-fold sequence of marine deposits occurs in the Territory, and this is related to sea level changes.

(iv) *Littoral Deposits (L)*
These deposits, of medium-grained sands and gravels, are found on isolated beaches along the coastal fringes of the area (Plate 4). They occupy 33 ha of the area.

(v) *Fill*
Small areas of fill are associated with minor construction within the area, including works associated with Plover Cove Reservoir. This material varies according to the source of fill and its degree of compaction. Fill occupies only 32 ha of the area.

(vi) *Reclamation*
Small areas of reclamation are associated with the Plover Cove dam installations and occupy approximately 4 ha.

2.3.7 *Structural Geology*

The study area consists mainly of sediments and volcanic rocks and is unusual in that there are virtually no outcrops of intrusive igneous rocks. Some evidence exists that intrusive igneous rocks occur at depth. The only outcrop of granitoid rocks is on Centre Island, where there is a small intrusion of the Tai Po Granodiorite.

The rocks of the Tolo Harbour Formation display two sets of folds with different axial trends; however, these are relatively minor structures. Faulting is associated with the first set of folds, which are often isoclinal; fold limbs are often dragged into tear faults, and shear cleavage is evident. The second set of folds may be related to later episodes of folding.

The Tolo Channel Formation is younger than the Tolo Harbour Formation, but the evidence is biostratigraphic rather than structural. There is, similarly, no uncomformity between these beds and those of the overlying rocks of the Bluff Head Formation.

The Bluff Head Formation strikes parallel to the coast of the Tolo Channel (northeast to southwest) and dips steeply to the north. The rocks are closely jointed, especially on Harbour Island where the discontinuities are parallel, planar, filled with hematite and at right angles to the bedding planes. The rocks of the Bluff Head Formation are strongly folded, especially near Bluff Head, and are faulted against tuffs of the Repulse Bay Formation. Elsewhere, the relationship is apparently conformable. The units of the Bluff Head Formation are flexed into parasitic folds of small amplitude, which trend parallel to the strike. This evidence suggests that the whole outcrop of the Bluff Head Formation forms the northern limb of a major anticline whose axial plane strikes northeastwards through Tolo Channel. The southern limb of this anticline appears to be absent and may be downfaulted, causing the Bluff Head Formation to occur at depth below Tolo Channel. The axis of this major fold probably plunges northeastwards at 45°; some evidence for this trend exists at Bluff Head.

The overlying beds of the Repulse Bay Formation occur in a generally conformable succession, although localised unconformities are apparent at Bluff Head. The structure of the volcanic rocks of this Formation is complicated by their depositional nature which is often dependent on the disposition of the pre-depositional surface. Two main fold axial directions are evident in the Repulse Bay Formation; these trend northeast and northwest. The former is the most common within the study area, but is generally restricted to rocks east of Three Fathoms Cove.

The rocks of the Port Island Formation were deposited unconformably on those of the Repulse Bay Formation and have a consistent regional dip of about 16° to the north. The strike of these beds is roughly east to west. The outcrop of the Port Island Formation is bounded to the north by a large thrust fault which has abutted rocks of the Repulse Bay Formation from the north against the sediments of the Port Island Formation. The sediments are generally intensely cleaved and sheared (Plate 5), especially the finer-grained representatives, so that bedding is often masked. Shear cleavage is dominant, but a secondary cleavage produces a foliated, schistose appearance. Zones of intense shearing within the Port Island Formation may represent thrust zones. The thrust plane angle is close to the dip of the beds and is not easily recognised. The best example of a probable thrust zone occurs between Double Haven (including Double Island) and Starling Inlet where the rocks of the Repulse Bay Formation overlie those of the Port Island Formation.

Numerous photolineaments are evident on aerial photographs of the study area, and these generally trend in three major directions: east to west, northeast to southwest and north to south. Many of these photolineaments are probably normal faults, some of which are mapped by Allen & Stephens (1971). Evidence for a sinistral tear fault occurs on the northern coast of Centre Island. The distribution of photolineaments and faults is shown on the Engineering Geology Map (EGM).

2.4 Geomorphology

2.4.1 *General*

The geomorphology of the North East New Territories 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.

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.

The North East New Territories area is classified for the purposes of the study into three physiographic units: one north and one south of Tolo Channel and a group of larger islands.

2.4.2 *Terrain to the North of Tolo Channel*

The coastline north of Tolo Channel is clearly affected by submergence, with the ria coastline made up of many embayments formed by the drowning of river valleys and steep coastal slopes. The slopes, especially on the sedimentary rocks, often form subparallel spurlines joining a central ridge (Plate 6). Two main ridgelines dominate the topography. The southern ridgeline is probably the faulted extension of the Pat Sin Range, the fault subsequently running northwest through Bride's Pool. This ridgeline, which strikes approximately east to west, closely approximates to the boundary between the Repulse Bay Formation and the Port Island Formation. The northern ridgeline also approximates to the lithological boundary along a thrust fault zone. The strata of the Port Island Formation are exposed between the two ridgelines and dip to the north, with many of the beds forming dip slopes. The scarp slopes, on terrain formed by the Port Island Formation, are often moderately sheet-eroded. Sheet erosion is also visible on many of the ridgecrests and spurlines where the development of footpaths has removed much of the vegetation.

The drainage system, especially on the Port Island Formation, tends to form a 'trellised' pattern. Some possible stream capture and drainage superimposition at Bride's Pool and east of Wu Kau Tang are apparent. Many of the profiles of the more significant V-shaped valleys have been modified by fluvial action, with extensive alluvial flats being deposited in the valley floors. These are probably the product of the infilling of drowned valleys. Some minor sedimentary infills are evident at higher elevations. Other evidence of sedimentation is the infilling of some coastal embayments in the vicinity of Kuk Po, Yung Shue Au, So Lo Pun, Lai Chi Wo and Sam A Chung. These areas have been intensively cultivated in the past but are not in current use.

2.4.3 *Terrain to the South of Tolo Channel*

South of Tolo Channel the terrain is dominated by Mt Hallows (Tai Lam Koi) and Peak A (Shek Uk Shan). Two relatively large alluvium-filled valleys, at Sham Chung and Pak Sha O, occur along a major east to west fault which separates the two peaks. The valley at Pak Sha O subsequently drains northwards into Jone's Cove at Hoi Ha.

Much of the terrain, including the drainage pattern, is influenced by numerous major faults and structural lineaments that traverse the area south of Tolo Channel.

Coarse tuff of the Repulse Bay Formation is the dominant rock type in this area. This rock tends to erode so that numerous boulders are exposed on the surface. These boulders are generally observed on ridgelines, in some colluvial deposits (Plate 7), and as bouldery deposits on the coastlines. Sheet erosion generally occurs on south-facing slopes and ridgelines. This type of erosion is often encouraged by the formation of footpaths. Instability is mostly confined to the headward extension of drainage lines and occurs on the steeper slopes. Coastal instability is also present on the more exposed slopes around Mirs Bay.

As with the area north of Tolo Channel, several coastal embayments are being infilled by fluvial sediments. These occur at Sham Chung, Lai Chi Chong and Hoi Ha. There are probably some marine and colluvial intercalations within these alluvial sediments. These deposits probably have high groundwater tables and may be subject to inundation in periods of intense rainfall.

2.4.4 *Island Terrain*

The ria coastline is typified by the islands in the North East New Territories study area, especially those north of Tolo Channel. They are formed of essentially short, steep, coastal slopes which are subject to coastal erosion and instability, with numerous drowned valleys forming embayments and inlets (Plate 8). Only on Wong Wan Chau is a well developed drainage pattern present, most other streams flow from the coastal slopes directly into the sea.

Tap Mun Chau and particularly Ping Chau have flatter, more rounded topography. Tap Mun Chau is composed of coarse tuff, and is similar to the steeper terrain south of Tolo Channel. The gentler terrain on Tap Mun Chau may be a consequence of possibly deeper weathering or prolonged erosion by the sea. Ping Chau is formed by subhorizontally bedded sedimentary rocks, defined by Allen & Stephens (1971) as Repulse Bay Formation sediments. These rocks have weathered and eroded to form a relatively flat island (Plate 9). Ping Chau is surrounded by some almost vertical sea cliffs (Plate 10) and a wide wave-cut rock platform.

2.5 Hydrology

2.5.1 *Surface Hydrology*

The surface hydrology of the North East New Territories study area is largely dominated by the general ria form of the coastline and the steeply sloping coast. Analysis of the drainage pattern reveals that most of the drainage networks are third or fourth order, (Strahler, 1952) and only a few reach fifth and sixth order. The recent submergence of the coastline has led to the truncation of the drainage system, so that many of the existing drainage lines are only undrowned remnants which were once part of a larger and well integrated network.

The fifth and sixth order stream systems form quite distinct catchments. To the north of Tolo Channel, fifth and sixth order catchments occur at Wu Kau Tang, Kuk Po, Lai Chai Wo, Sam A Chung, Wu Chau Tong, and at Tung Wan on Double Island. These generally form a dendritic drainage network, although some trellised networks occur on the sedimentary rocks. A similar situation exists to the south of Tolo Channel at Sham Chung, Lai Chi Chong, Hoi Ha, and in an incomplete catchment at Tai Tan. The boundaries of these catchments are shown on the Engineering Geology Map. Most of the fifth and sixth order streams flow through sediment-filled valleys and often flow into the sea across sediment-filled embayments.

The directions of the first, second, third and sometimes fourth order streams reflect stronger structural control than the higher order streams. The second and third order streams often form subparallel patterns between spurs, draining relatively short, steep slopes. Their response time to rainfall is usually very short. In addition, the flow in the first, second and third order streams is usually intermittent, the higher orders having perennial flow.

All streams, except those at Wu Kau Tang and the second and third order streams surrounding the Plover Cove Reservoir, flow into the sea. Plover Cove Reservoir has a capacity of some 23 million cubic metres. The stream at Bride's Pool and the fifth order stream at Wu Kau Tang closely follow a probable fault line, (Chiu & So, 1983) and flow against the dip of the strata.

2.5.2 *Groundwater Hydrology*

For the purposes of water supply, the rocks and soils within the North East New Territories study area are not generally regarded as constituting type aquifer units, with the possible exception of the Port Island Formation.

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 (except some sandstones and conglomerates) are probably a function of jointing, fissuring or piping rather than intergranular flow. Consequently, zones of groundwater flow and velocities are difficult to predict.

Groundwater flow in the bedrock depends largely on the degree of jointing, fissuring and bedding (in the case of sedimentary rocks). The flow will almost certainly be concentrated where these features are most pronounced e.g. fault and shear zones. Fault shatter zones and dykes will also act as water-transmitting conduits.

In the superficial material, groundwater movement probably will be by intergranular flow or conduit flow which develops as a result of tunnel erosion (Nash & Dale, 1983). The type of flow, velocity of flow and permeability depend largely on the grainsize of the deposit; boulder fields are the most permeable and overconsolidated colluvial clay the least permeable. Within the alluvial deposits, groundwater may flow along old buried stream courses or as intergranular flow. These deposits may have a high groundwater table.

2.6 Vegetation

The vegetation of the study area is generally unaffected by human activities. In this Report, a nine class classification system is used to distinguish broad categories of vegetation type. The spatial distribution of these groups is illustrated in the GEOTECS Plot, in Figure 7, whilst the pie charts in Figure 4 show their relative proportions. Only 90 ha (1.1%) of the study area is devoid of vegetation due to man's disturbance. The data is presented in Table B7 at Appendix B.

The vegetation classes are:

(i) *Grassland*
This class generally consists of indigenous or introduced grass species which occur naturally, or after the clearing of shrubland or woodland. Grassland occupies 1 716 ha (21.5%) of the study area and occurs as scattered patches, normally on terrain with fairly high relief.

(ii) *Cultivation*
This class occupies 271 ha (3.4%) of the area. Large areas of Country Park and abandoned terraces have resulted in the alienation of a large amount of agricultural land in the study area.

(iii) *Mixed Broadleaf Woodland*
This class occupies 1 477 ha (18.5%) of the study area and covers extensive tracts of valley and lower and middle slopes, especially in Country Park areas. This class of vegetation is probably the indigenous vegetation of this part of the South China coast.

(iv) *Shrubland (Less than 50% Ground Cover)*
Shrubland occurs as regrowth on areas of disturbed terrain or on grasslands which have been affected by hill fires. This class occupies almost 1 900 ha (23.5%) of the area and occurs in large tracts of the middle and upper slopes, especially in Country Park.

(v) *Shrubland (Greater than 50% Ground Cover)*
Similar to (iv) but with denser cover, indicating greater maturity and a longer period of colonisation. This class occupies 1 230 ha (15.4%) of the area and occupies middle and upper slopes and upland plateaux.

(vi) *No Vegetation on Natural Terrain*
This is usually the result of erosion, and affects 64 ha (0.8%) of the area.

(vii) *No Vegetation due to Man's Disturbance*
This class is normally associated with urbanisation, and consequently occupies some 90 ha (1.1%) of this relatively undeveloped study area.

(viii) *Rock Outcrop*
Areas of rock outcrop contain sparse vegetation associated with cracks and crevices. Rock outcrops occur on approximately 55 ha (0.7%) of the area.

(ix) *Waterbodies*
Approximately 18 ha is occupied by ponds, and a further 1 177 ha by the Plover Cove Reservoir, forming a total of 15% of the study area.

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

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

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

2.7 Erosion and Instability

2.7.1 *General*

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

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

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

Erosion and instability affect 48.4% (3 857 ha) of the study area. However, only some 1% (80 ha) of the study area is currently developed, within which erosion is restricted to unprotected platforms and slopes. In addition to this, approximately 1 754 ha of natural terrain is subject to various forms of appreciable erosion.

Table 2.1 Erosion and Instability

Erosion		% of Total Area	Area (ha)
Instability			
	—well-defined landslips	—	—
	—coastal instability	2.1	169
	—general instability	24.3	1 934
Appreciable Erosion	Sheet erosion	6.3	506
	Rill erosion	<0.1	2
	Gully erosion	15.6	1 246
No Appreciable Erosion*		51.6	4 111
		100.0	7 968

2.7.2 *Erosion*

(i) *Sheet Erosion*
This form of erosion produces extensive areas of bare ground devoid of vegetation. Within the study area, sheet erosion occurs on south facing slopes and ridgelines and is often encouraged by the development of footpaths. Sheet erosion is particularly prevalent on rocks of the Port Island Formation. A total of 506 ha (6.3%) of the area is affected.

(ii) *Rill Erosion*
This form of erosion is usually associated with cut and fill batters, but in the study area these features are notably absent. Rill erosion may also occur in natural areas, and is found on areas of the coarse tuffs of the Repulse Bay Formation. On this terrain it often develops into more severe gully erosion. It is characterised by numerous subparallel drainage rivulets, which produce a striated appearance and cause significant soil loss. Within this area, rill erosion is of minor importance affecting less than 0.1% of the terrain.

(iii) *Gully Erosion*
This form of erosion produced deep dissection of the surface with consequent disruption of drainage lines. It may result in tunnel erosion, soil piping and precipitate instability. Gully erosion affects 1 246 ha (15.6%) of the study area and occurs mainly on the coarse tuffs of the Repulse Bay Formation.

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

2.7.3 *Instability*

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

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

Slope instability of some form or other is relatively common within the study area. Approximately 2 103 ha of the terrain displays some form of instability, and this represents 26.4% of the study area.

(i) *Well-defined Landslips*
Within the study area, no 'well-defined landslips' are delineated. The landslips which occur are generally 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 along the coast of the study area, because of the drowned nature of the ria shoreline. The more exposed coastal sections of Mirs Bay (Plate 11) are most susceptible, especially in their steeper sections. Coastal instability occupies 169 ha of the study area.

(iii) *General Instability—Recent*
This form of instability relates to colluvial and insitu terrain where many small landslips, failures 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 is the major class of instability and occupies 16.6% (1 322 ha) of the study area. *General Instability—Recent* occurs over much of the steep terrain especially in areas around stream sections, and often occurs as the headward extension of drainage lines (Plate 12).

(iv) *General Instability—Relict*
This form of instability occupies 7.7% of the study area (612 ha) and occurs in the same areas as *'General Instability—Recent'.* The two classes are closely related. This class of instability is no less important in terms of constraints upon 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 North East New Territories study area, existing development is very limited. A few small and isolated villages occupy coastal locations at the mouths of river valleys, and a fishing community exists on the western side of Kat O Chau. Installations associated with the Plover Cover Reservoir also occur. The distribution of land use is tabulated in Table B12.

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) *Commercial and Trading*
The remote nature and dominantly rural and marine based economy of the study area result in an almost total absence of commercial and trading establishments.

(ii) *Residential*
Residential accommodation is restricted to rural village settlements, normally consisting of single or double-storey housing associated with the agricultural and fishing communities. The main villages are at Wu Kau Tang, east of Bride's Pool, Chek Kok Tau on Kat O Chau and Kau Lau Wan on the east side of Long Harbour. Residential development occupies only 1.0% (78 ha) of the study area and is mainly located on GLUM Classes I & II terrain.

(iii) *Quarrying*
There are no active quarries in the study area at the time of mapping. Some small areas have been excavated; for building materials around the village settlements, and during the construction of Plover Cove Reservoir.

(iv) *Reservoirs*
The Plover Cove Reservoir provides fresh water for Urban Kowloon and parts of the New Territories. The reservoir occupies an area of approximately 1 200 ha which was formerly a tidal marine cove. This arm of the sea is now barraged between Tai Mei Tuk, Harbour Island and the isthmus north of Tolo Channel. The water body impounded as the reservoir is not classified within the GLUM system but the surrounding area consists of mainly GLUM Classes III & IV terrain.

(v) *Country Park*
Plover Cove Country Park occupies a large tract of land adjacent to the reservoir and includes many of the offshore islands; Kat O Chau, Yeung Chau, Crescent Island and Double Island, as well as some smaller islands in Double Haven. Ping Chau in Mirs Bay is included in an extension to the Plover Cove Country Park. South of Tolo Channel, large tracts of the Sai Kung Peninsula are occupied by the Sai Kung Country Park East and West Sections.

Except for parts of a few islands and some areas on the mainland, the whole of the study area north of Tolo Channel is designated as Country Park. In addition, Country Park forms most of the study area on the Sai Kung Peninsula. Country Park occupies 73.6% (5 861 ha) of the study area consisting mainly of GLUM Classes III & IV terrain.

(vi) *Natural and Undeveloped Areas*
Undeveloped natural terrain constitutes the major part of the study area, and also includes much of the area forming the Country Parks. Some 545 ha of the study area outside the Country Parks is currently in a natural and essentially undeveloped state, some 42 ha is GLUM Class I, 255 ha is GLUM Class II, 165 ha is GLUM Class III and 67 ha is GLUM Class IV.

(vii) *Agriculture*
Certain tracts of land, notably in the alluvial coastal fringes and upland river valleys, are used for intensive agriculture. These areas are situated around Kok Po, Lai Chi Wo and Wu Kau Tang in the area north of Tolo Channel. South of the channel, agricultural activities are centred upon Shum Chung, Lai Chi Chong, Pak Sha O and Tau Ka Wan. Agricultural land forms 292 ha (3.7%) of the study area and normally consists of GLUM Classes II & III.

(viii) *Recreational Areas*
Sporting facilities and recreational areas other than Country Parks are normally located near the urban centres and are very limited in this area.

(ix) *Institutional and Community*
This group includes landuses such as schools and hospitals, and occupies only 2 ha of the study area. They are generally located within villages and are limited, due to the low population density of the area.

(x) *Squatters*
The rural nature and remoteness of the study area result in a very low concentration of squatters.

(xi) *Roads and Services*
These are generally small linear features, and are not normally mapped as discrete units at the 1:20 000 scale.

2.8.3 *Future Development*

Development principles for the North East New Territories 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 availability of land, suitability of terrain and local requirements allow.

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

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

3. ASSESSMENT OF MATERIAL CHARACTERISTICS

3.1 Description and Evaluation of Natural Materials

3.1.1 *General*

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

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

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

(i) *Weathering*

Within the regional context, it is important to appreciate the influence of local features on determining the actual depth of weathering at a particular location. The descriptions given in column 7 of Table 3.1 are for general guidance only.

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

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

Erosion removes the soft products of weathering and reduces the actual thickness of the weathered profile. Major stream courses, if not filled with colluvium or alluvium, generally have fresh rock exposed in their beds due to incision of the weathered profile. In areas of active coastal erosion, the weathering profile is usually absent but may be developed beneath the marine and/or offshore terrestrial deposits 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 Figure 4 and are tabulated in Appendix B, Table B11. The Area Instability Index presented in the table indicates the percentage of each rock type affected by instability.

Before interpreting these results, it must be remembered that factors other than geology influence erosion and instability. In the 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 in the GEOTECS Plot in Figure 12.

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

In terms of general engineering behaviour, the geological materials of the study area are broadly classified into seven 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*) Metasedimentary rocks.

(*g*) Sedimentary rocks.

The characteristics of these groups are discussed and in the case of sedimentary, metasedimentary, igneous and volcanic rocks, are described under the heading of their stratigraphic name.

3.1.2 *Characteristics of Fill, Reclamation, Alluvium 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-made fill and reclamation. The latter two materials are of limited extent in the relatively undeveloped North East New Territories study area, and are present as minor fill and reclamation works associated with the Plover Cove Reservoir and 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 slightly weathered cobbles, which may be derived from a previously weathered material.

Erosion of these deposits is generally not a major problem in their undisturbed state, due to their predominantly flat gradient. Littoral deposits are subject to continuous erosion and redeposition by the sea. The GEOTECS data presented in Table B11 indicates that these materials are not subject to any marked degree of erosion. Should hydraulic conditions be altered, for example by man's activities such as construction works, then erosion may be initiated.

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

There is a wide range of particle sizes between members of this group. Alluvial deposits contain a high proportion of gravel and cobble sized materials, for example in the alluvial terrace in the upper reaches of the river which enters the sea at Tai Tan (Plate 13). Littoral deposits generally consist of a fairly uniform medium to fine sand, such as those at Hoi Ha (Plate 14). Marine deposits can range from silt to coarse sand and conglomerate, depending on the nature and environment of deposition.

Steep-sided excavations require strutting as these superficial materials have little cohesion. There is little natural instability in these materials due mainly to their intrinsically low slope angle. These 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. The materials in this group are easily excavated by machine methods. 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 unpredictable where the materials are dewatered. Finely-graded marine sediments are an exception, and may require considerable time for settlement, depending 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 a soft fill. Development tends to occur on areas of alluvium hence negating their use as a fill resource. Similarly, littoral deposits tend to occur adjacent to areas of alluvium and may be developed, or conversely be located in zones used for recreation.

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.1.8.

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 North East New Territories study area is unusual in having no granitic colluvium, because the area is composed almost entirely of sediments and volcanic rocks. From an examination of Tables B10 and B11 it appears that colluvium has a higher incidence of erosion compared with insitu materials. This may reflect the mode of origin of these materials, and the fact that colluvial deposits frequently occur in drainage lines, where they are subject to erosion by streams, and are generally subject to a high water table. No appreciable differences are noticed in the susceptibility to erosion (other than that induced by streams) of the different types of colluvium in the study area, but older, more decomposed and generally finer-grained colluvium, seems to be more eroded than the younger colluvium.

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 and in Figure 4, volcanic colluvium appears to have a higher proportion of instability compared with other colluvial materials. This is possibly a result of the steeper slope angles associated with both the parent rock type and the volcanic colluvial terrain.

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

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

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

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 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. $\phi = 25$–$35°$. 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.
			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.
			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. $c' \cong C - 10$ kPa, $\phi' \cong 20$–$25°$.	Locally low-lying terrain may be subject to flooding. Materials are usually saturated and of a low density – clay layers are normally consolidated. Buried channels may pose local problems of high water flows into tunnels or excavations. Steep excavations require support. Groundwater may be saline if adjacent to coast. Incursion of saline groundwater following abstraction of fresh groundwater may occur. Low bearing pressures can be accepted directly moderate and high loads need raft, spread or piled foundations.	Land deposits easily excavated. Marine deposits often form reasonable hydraulic fill. Excavation by cutter, suction or bucket dredger.
		PLEISTOCENE?	M	MARINE SEDIMENTS	Usually dark grey silty sand or clay with traces of shell fragments, and some sand horizons, especially near shore. A mixed succession with alluvium and/or colluvium may be present.	Seabed sediments of variable thickness (0–10's of metres) below low tide mark.	Nil	Usually a soft to very soft normally consolidated soil with a high moisture content and high plasticity (LL > 50%), clay content ranges from 20–35%, silt content from 50–70%. Cu < 10 kPa, $c' \cong 0$–5 kPa, $\phi' \cong 25°$. SPT < 10 but increases with depth.	Material is poor to unsatisfactory for hydraulic fill. It is also poor as a foundation because of settlement and bearing capacity problems. Will probably be susceptible to mud wave if fill is end-tipped onto it. Consolidation may be aided by wick drains and/or surcharge loading.	Easily excavated using bucket or possibly suction dredger where necessary. Sandy deposits may be used in construction but silt and clay may pose problems of disposal.
			C	COLLUVIUM: VOLCANIC DERIVED; GRANITIC DERIVED; MIXED	Composed of a range of materials which vary from boulder colluvium, to gravelly colluvium with clay and sand, to finer textured gravelly sands and clay slopewash. The boulder colluvium with sand and gravel occurs on the higher sideslopes, while the gravelly sands, sandy silts and clays are to be found on the middle to lower sideslopes and on footslopes.	Mainly occupies the lower sideslope and footslope terrain and may underlie much of the alluvial floodplain. Generally gently to moderately steep, broad, low, rounded dissected outwash-fans and interfluves with undulating and hummocky surfaces; elsewhere irregular planar to shallow concave colluvial footslopes, leading upslope to gentle to moderately steep outwash slopes.	Colluvium can occur as independent deposits of a unique age such that one deposit overlies another. The older deposits may be subject to severe weathering and may be completely decomposed to a mottled, coloured sandy silt or clayey silt similar to the insitu residual deposits of their parent materials. The depth of such weathering may be in the order of 10 m or more.	Only very general guidelines can be given for the matrix or finer components of this variable material. MC's average 20–30%, DD varies from 1 300 to 1 700 kg/m³. Grading ranges from 2–40% clay, 10–60% silt, 40–80% sand and medium gravel. Plasticity varies from PL 22–28%, LL 28–40%. Typical shear strength values are $c' \cong 0$–5 kPa, $\phi' \cong 29$–$42°$. Standard compaction values: OMC ≅ 17–20%, MDD ≅ 1 630–1 750 kg/m³. CBR ≅ 3–8%.	Material that has moved in its geologic past and is prone to reactivation if not carefully treated by 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 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.
			K	KAT O FORMATION	Formation consists of beds of brecciated rocks which are pale grey-green when fresh. They contain angular fragments of volcanic rock, commonly 100 mm long and include some larger blocks and coarse grit beds.	Forms a small headland north of Sai O. Also forms the islands of Ap Chau and Sai Ap Chau.	Rock weathers to a weak red to red-brown poorly cemented breccia.	Very little data available. The degree of weathering would determine overall strength. Individual clasts may retain rock strength depending on original material even when the matrix is weathered.	Extremely minor distribution; very unlikely to be built upon.	Extremely hard and durable when fresh; blasting would be required. Possible local source of aggregate.
BEDROCK	LOWER CRETACEOUS		PI	PORT ISLAND FORMATION	Interbedded conglomerate, pebbly sandstone and mudstone. Usually red or pink in colour. Rocks are moderately well cemented, very thickly bedded.	Outcrop essentially forms the gently northward dipping cuesta extending from the Pat Sin Range to near Starling Inlet.	Rock generally decomposes to a reddish brown silty sand with pebble traces. Weathering depths are usually small, < 7 m.	Very few results available. Properties vary depending on parent material.	Material has seldom been worked hence its characteristics are virtually unknown. The soil profile should be similar to the RBp. The rock profile stability aspects will be controlled by the existing discontinuities. No bearing capacity problems anticipated.	Material could be scraped for borrow when weathered. Fresh rock must be blasted. Not recommended for aggregate until further studied.

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

MATERIAL DESCRIPTION								EVALUATION OF MATERIAL		
Type	Age	Symbol	Map Unit		General Lithological Description	Topographic Form	Weathering and Soil Development	Material Properties	Engineering Comment (Stability, Foundation, Hydrogeology)	Material Uses and Excavation Characteristics
BEDROCK	UPPER JURASSIC	XT	INTRUSIVE IGNEOUS	TAI PO GRANODIORITE	Grey to dark grey, coarse to medium-grained, porphyritic granitoid rock. Large well formed crystals of white feldspar up to 15 mm are present in coarse-grained matrix. Matrix minerals are potassium feldspar, plagioclase, biotite and minor quartz. Xenoliths are common. Jointing is similar to granites in that rough sheeting joints and widely spaced tectonic joints are present.	Forms only a small area of Centre Island.	On mainland, average depth to Zone C is approximately 15 m but can be over 40 m. On Centre Island, the thicknesses are likely to be less. Boulders and corestones are common in weathered zones. Weathering product is subangular silty sand.	Little test data available for study area but decomposed granodiorite from Tai Po has the following general properties: DD ≅ 1 300–1 400 kg/m³, clay content 2–8%, silt 30–55%, sand 40–60%. Plasticity varies from non plastic to PL 27–37%, LL 40–50%. c′ ≅ 0–14 kPa, Ø′ ≅ 33–42°. Standard compaction values: OMC 16–21%, MDD 1 690– 1 780 kg/m³, CBR ≅ 8–20%. Fresh granodiorite has an unconfined compressive strength of 125–175 MPa and a DD of 2 600–2 700 kg/m³. 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 slightly more clayey. Special care must be taken in establishing adequate surface protection on newly formed slopes.	Because of the low to moderate content of quartz in the clay, weathered zone could be used for making bricks. Weathered zone material may be used for fill. Fresh rock is suitable for aggregate. Lower quartz content makes this material suitable for asphaltic concrete.
MESOZOIC BEDROCK	MIDDLE AND LOWER JURASSIC	RBs	SEDIMENTARY VOLCANICLASTIC AND EXTRUSIVE IGNEOUS ROCKS — REPULSE BAY FORMATION	SEDIMENTARY AND WATER-LAID VOLCANICLASTIC ROCKS	Generally a hard, thinly banded black and grey siltstone and black shale, interbedded with volcanic sandstones and tuffs, sometimes cherty. Very closely spaced joints in some units.	Forms areas of moderate to low relief.	Shallow to moderately deep, reddish to brown, fine, sandy to silty clay i.e. residual soil sometimes with ferruginous gravel and weathered rock fragments, overlying completely to highly weathered rock which grades into less weathered strongly jointed volcanic rock at depths from 5–20 m.	No test data available but likely to be variable, dependent on individual stratigraphic unit.	The sediments are bedded and fissile and weather relatively rapidly 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		ACID LAVAS	Dark green or bluish grey, fine-grained with light phenocrysts, banded strong rhyolite. The rock often displays closely spaced smooth joints.	Forms steep narrow ridges with deep structurally controlled valleys. Rock outcrops common.	Rock usually develops a thin (< 1 m) soil horizon and a thin (< 10 m) weathered zone before passing rapidly into moderately to slightly weathered bedrock.	No laboratory results available but should be similar to other volcanics as below.	Stability of weathered material and also of highly jointed rock masses may be suspect, especially during or immediately after prolonged heavy rainfall. Failures are quite common, especially in over-steepened slopes. Rapid surface runoff is common. Stability of rock slopes controlled by relatively close 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.
		RBc		COARSE TUFF	Grey to dark grey, fine matrix with coarse well formed crystals of feldspars 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 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 thin weathering mantle occurs.	The near surface completely decomposed material has a DD ≅ 1:500 kg/m³ and a saturation greater than 70%. Gradings are variable but 20–40% silt, 10–20% clay and 40–60% fine sand is common. Plasticity varies from PL 22–32%, LL 35–60%. Typical shear strength values are: c′ ≅ 0–10 kPa, Ø′ ≅ 30–35° Fresh rock properties are approximately as follows: unconfined compressive strength ≅ 150–250 MPa. Joint strength parameters are c′ ≅ 0 kPa, Ø′ ≅ 30°, roughness angles 5–10°. DD ≅ 2 500–2 700 kg/m³. Point Load Is(50) ≅ 6–12 MPa. Tangent modulus ≅ 30 000–60 000 MPa		Material can be used for fill if it is weathered locally. It is possible to quarry, although very hard and not generally favoured. Coarse crystal tuff horizons may provide good aggregate.
		RBp		DOMINANTLY PYROCLASTIC ROCKS WITH SOME LAVAS	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 uncertain but probably similar to RBp unit (see above).					
		BH	METASEDIMENTARY ROCKS	BLUFF HEAD FORMATION	Variably indurated pale coloured fine sandstones, orthoquartzites, siltstones and mudstones with occasional conglomerate horizons.	Rock type forms the larger portion of Bluff Head Peninsula and shows rounded form as a dissected ridgeline with perpendicular spurlines.	Only a thin (1–2 m) pedogenic horizon develops but the rocks are otherwise moderately weathered to great depths (5–25 m) as shown by the red colouration.	Very little data is available for these steeply dipping, folded strata of alternating mudstones, siltstones and sandstones.	Caution is advised regarding slope stability. Metasediments may be prone to instability, especially along discontinuities when weathered and saturated. Bearing capacities are reasonable for low to moderate loads on metasediments.	Could be used as very localized source of fill. May break down to silt upon overcompaction. Only the sandstone members will require blasting otherwise machine digging may be possible.
		TC		TOLO CHANNEL FORMATION	The sediments are steeply dipping or vertical thin quartzites and black shales containing abundant pyrite. They are commonly flexed, locally contorted and contain marine fossils. Closely spaced smooth joints are common, locally schistose.	Forms only a very restricted intertidal rock platform on the north shore of Tolo Channel. Submarine outcrop has been postulated.	No soil development due to intertidal location.	Not known due to limited extent and intertidal location of outcrop.	Very restricted occurrence and intertidal location preclude detailed comments.	All exposures would require blasting. Not suitable for aggregate or fill due to schistosity and sulphide content.
PALAEOZOIC BEDROCK	PERMIAN	TH		TOLO HARBOUR FORMATION	The main rock types are black shales, thinly banded shale and mudstone. Low grade metamorphism has converted some rocks to quartzite. This unit is structurally complex with numerous closely spaced smooth tectonic joints. It is also folded and faulted.	Encountered beneath Tide Cove, and also forms part of the southern tip of Centre Island.	Palaeosol developed beneath old alluvium. Weathering may be up to 40 m thick extending to −90 mPD.	Little information available. SPT ≅ 20–100.	If encountered in foundations the weathered material will be of low strength and contain sulphur. Acid attack on steel piles may occur.	Location precludes borrow activities. Excavation by machine digging with some blasting.

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

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

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

Colluvium 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. 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 can be difficult if large boulders are encountered.

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

Within the study area, the effects of coastal drowning have meant that colluvial deposits are often absent due to the short length of drainage courses and lack of footslope terrain. These features are particularly evident in the eastern part of the study area. Colluvium also tends to accumulate above nick points in the drainage system on higher ground. No obvious areas of colluvium are evident as sources of soft borrow. Access difficulties and remoteness generally preclude the few areas which may have potential for borrow. Site formation works should not, however, preclude the excavation and use of colluvial materials provided adequate care is taken with the design of slopes. Excavation problems may occur in deposits with large boulders if machine methods are employed.

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

3.1.4 *Characteristics of the Tolo Harbour Formation*

The outcrop of the Tolo Harbour Formation is of such a limited extent in the study area (Centre Island) that its material characteristics would have little influence on development of any scale. Black shales and mudstones form the major rock types; these are weak and fissile, and have closely spaced tectonic jointing. Resistant quartzites are also present in thin bands, and are structurally stronger than the shale and mudstone. A thin weathered zone may form, especially over siltstone and mudstone, and could be removed by machine methods. Fresh rock may require blasting, especially when quartzites are present.

3.1.5 *Characteristics of the Tolo Channel Formation*

The outcrop of this Formation is restricted to a wave cut platform on the northern shore of Tolo Channel and, as such, is unlikely to form the founding material of any but the most minor structures. Lithologies and structure are similar to those of the Tolo Harbour Formation. However, no pedogenic zone has developed due to the erosive tidal action. Removal of material would require blasting, or ripping where weathering has occurred along joint planes.

3.1.6 *Characteristics of the Bluff Head Formation*

The distribution of the Bluff Head Formation has been described in Section 2.3.2. These sediments comprise conglomerates, sandstones, siltstones and shales which were laid down in cyclic sequences. Metamorphism has marginally altered these sediments, mainly by hardening. The extent of induration varies according to rock type, the fine-grained representatives being more thoroughly affected than the coarser-grained rocks. Very little testing data is available for these sediments; however, closely spaced jointing has been observed, and Standard Penetration Tests on conglomerates and sandstones have indicated N values increasing from N < 30 in the weathered horizons, to N > 150 in the fresher rock, at depth. Laminated siltstones reveal a range of N values between 15 and 100. Hematite and pyrite are present in the finer-grained rock types of the Bluff Head Formation. These materials may produce reactive groundwater charged with sulphides, which could adversely affect reinforced concrete or other foundation materials. Weathering of the Bluff Head Formation may produce deeply weathered profiles up to 10 m in thickness, especially in the finer-grained rock types. The bearing capacity of these rocks is reasonable for low to moderate loads, but stability depends on joint orientation, and discontinuities would have to be examined to determine stability characteristics.

When weathered, the finer-grained representatives may slake, and these may be machine excavated to considerable depth. Fresh rock, especially the coarser representatives, might provide a suitable fill material, but is probably unsuitable as a roadstone or concrete aggregate.

3.1.7 *Characteristics of the Repulse Bay Formation*

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.1.4. Excluding the minor sedimentary member, these rocks tend to have similar material characteristics.

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

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

In these rocks, weathering tends to be relatively shallow, with average depths in the order of 8 to 10 m. The volcaniclastic rocks are generally more deeply weathered, and up to 20 m of weathered material is common. As discussed in Section 3.1.1, the depth of weathering is largely dependent on the joint spacing. Along photolineaments (shown on the Engineering Geology Map), very close jointing may be encountered which locally depresses the weathering profile. This effect increases the erodibility of the material by streams. These streams tend to 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 contents of the weathered materials tend to reduce the incidence of erosion in these rocks even though they occur on steep slopes. The GEOTECS data in Tables B10 and B11 and Figure 4 indicate that, except for the more deeply weathered coarse tuffs, the Repulse Bay Formation rocks show a general trend of relatively low incidence of erosion. This is probably a good reflection of the erodibility of these materials, due to the large statistical sample and the relative lack of major urban development on these rocks. The incidence of instability, as measured by GEOTECS, is slightly above the average compared to the mean for the insitu terrain in the study area. The morphological forms associated with slope failure in volcanics are similar to those in colluvium, in that they are characterised by small landslip scars with extensive debris deposits. That is, they are characterised by large length to width ratios (4 or 5:1).

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

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

3.1.8 *Characteristics of the Port Island Formation*

The distribution of the Port Island Formation is described in Section 2.3.4. The Formation consists of sequences of conglomerates and pebbly sandstones with shales. The conglomerates and pebbly sandstones form up-standing strike ridges, whilst the finer-grained members form lower relief. All beds in this formation are cleaved and locally sheared. Weathering profiles vary according to rock type, but the coarser beds weather up to 7 m in depth, forming a coarse sandy soil, often with numerous pebbles.

Little data is available on the engineering characteristics of these rocks; however, jointing and shearing characteristics probably determine rock slope configurations. The conglomerates and sandstones forming harder beds of the Formation, should support moderate to high loads on bedrock. These rocks could be used as fill, but only the conglomerates should be considered as a potential source of aggregate. Weathered material could be removed by machine methods, and bedrock could be ripped due to close jointing and the large grain size in some of the beds.

3.1.9 *Characteristics of the Kat O Formation*

The limited and very remote occurrence of these rocks renders then of relatively minor engineering significance. The beds comprise a coarse-grained breccia with large angular fragments, and subordinate gritstones. The unweathered rock should support moderate loads, however the rock weathers to a weak, poorly cemented, clay with the larger fragments remaining unaltered. Foundations on the weathered rock could only be of a minor nature unless excavated to bedrock. Machine excavation would normally be possible, although it is unlikely that these rocks would be sought as a source of borrow, unless for use in minor projects in the immediate locality.

3.1.10 *Characteristics of the Intrusive Igneous Rocks*

The outcrop of these rocks is restricted to the small exposure of Tai Po Granodiorite on Centre Island. The outcrop is so minor that its material characteristics would have little significance in any but the most minor construction work. Details of the properties of this material are given in Table 3.1 and in the GASP Reports for neighbouring areas; North New Territories (GASP V) and Central New Territories (GASP II).

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 (329 ha) with low geotechnical limitations, and approximately 3 129 ha with moderate geotechnical limitations. Terrain with low to moderate limitations (GLUM Classes I & II) forms 43.3% of the study area. Some 5% of the GLUM Class I and 15% of the GLUM Class II terrain are developed, and 3 189 ha of the GLUM Classes I & II terrain is substantially undeveloped. Some 2 892 ha occur in Country Park.

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, foundations 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 of the developed parts of the North East New Territories study area are discussed in the description of potential development areas in Section 4.2.

4.1.3 *Land with High Geotechnical Limitations*

Approximately 27.8% (2 211 ha) of the study area has a high level of geotechnical limitation (GLUM Class III) and of this, some 0.6% 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 13.3% (1 063 ha) of the area is classified as GLUM Class IV. This terrain should not be developed if alternatives exist. Less than (1%) 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 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 study area, there are many natural areas with potential for development, but a significant proportion occur within the bounds of designated Country Park, Green Belt and Water Supply Catchment. These artificial constraints are noted, but are not used to exclude areas that have potential from a geotechnical point of view based on their natural terrain attributes.

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

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

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

The GLEAM identifies 18 areas within the study area which have potential for development from a geotechnical point of view. This represents approximately 1 670 ha or 21% of the total area. The areas range in size from about 30 ha up to 300 ha. They occur on different types of terrain, which are not necessarily suitable for the same type of development.

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

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

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

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

4.2.3 *Development Opportunities*

There are 18 areas within the study area which have potential for development from a geotechnical point of view. These areas constitute approximately 1 670 ha of land.

Area 1 *Kuk Po* (100 ha approx.) Access to this area could be achieved relatively easily from the Bride's Pool Road. The PDA consist of a large alluvial fan traversed by numerous drainage channels which are susceptible to flooding during heavy rainfall and adverse tides. Small areas of constraint associated with slope instability occur in the PDA. Areas flanking the PDA also have geotechnical constraints associated with steep slopes, which could create engineering problems. Colluvium is present within the PDA, both in the drainage lines and as footslope deposits. The area is adjacent to the Closed Area flanking the Border between the Territory and the People's Republic of China.

Area 2 *A Ma Wat* (80 ha approx.) Access is the major constraint to development of this PDA, whilst periodic flooding could be expected. Filling of low-lying areas and stream culverting may be required to reduce potential drainage problems. Colluvium is present in a number of drainage lines, and may present stability problems in addition to constraints associated with drainage. Areas flanking this PDA are unstable and will pose engineering problems. Small areas of instability and difficult ground, which are included within the boundary of the PDA, could remain undeveloped or improved and developed with necessary engineering input. The area occurs within the Plover Cove Country Park.

Area 3 *Wu Kau Tang* (50 ha approx.) A large alluvial valley, the Plover Cove Country Park, forms this PDA. The village of Wu Kau Tang is excluded. The PDA also occurs within the catchment of the Plover Cove Reservoir and is susceptible to flooding and other drainage problems (Plate 16). Areas flanking this PDA are prone to instability. Access to the area is relatively good with existing roads linking to Bride's Pool Road.

Area 4 *Shek Shiu Kan* (100 ha approx.) This PDA flanks an east to west trending ridgeline and consists of moderately steep sideslopes and numerous drainage lines. Suitable engineering prior to development would be required to maintain the stability of sideslope terrain and to ensure adequate drainage measures. Small areas of instability within the PDA could remain undeveloped. Access into the area is a major constraint, and the PDA also impinges on both the Plover Cove Country Park and the catchment of Plover Cove Reservoir.

Area 5 *Sham Chung* (30 ha approx.) PDA 5 is very remote, with difficult access other than by sea. The area also suffers from periodic inundation of drainage lines and contains small areas of unstable terrain. Both of these constraints would require suitable engineering if the PDA were to be developed. This area could be developed in conjunction with reclamation of the shallow waters around the margins of Three Fathoms Cove.

Area 6 *Lai Chi Chong* (60 ha approx.) This PDA is an alluvial valley with very difficult access except from the sea. The area is also subject to periodic flooding during heavy rainfall. Some colluvium is present in drainage lines and part of the PDA lies within the boundary of the Sai Kung Country Park (Plate 17).

Area 7 *Ngau Kwo Lo* (120 ha approx.) Remoteness and difficult access are major constraints to development of this PDA. Colluvium along drainage lines and flood potential are significant limitations associated with the area. Areas of instability associated with the drainage lines also occur and would require treatment prior to site formation. The PDA occurs within the boundary of the Sai Kung West Country Park.

Area 8 *Pak Sha O—Hoi Ha* (100 ha approx.) This PDA occupies the river valley between the villages of Pak Sha O and Hoi Ha (Plate 18). The area is remote but is served by the Hoi Ha Road. Drainage problems are likely, and part of the area is affected by a perennially high groundwater table. Areas of instability are included within the PDA, but these could be avoided for the purposes of site formation. Some potential for borrow exists in the eastern part of the PDA.

Area 9 *Ko Tong* (60 ha approx.) This PDA is accessible from the Hoi Ha Road but is flanked by steep to moderately steep slopes, many of which are unstable. Small areas of unstable ground are within the PDA. Culverting of drainage lines would be required due to anticipated high storm runoff.

Area 10 *Tai Tan* (50 ha approx.) This PDA has relatively good access but has numerous drainage lines which would require control measures to prevent serious flooding and erosion problems. Colluvium in drainage lines and associated instability are some of the geotechnical constraints affecting this PDA.

Area 11 *Boulder Point* (60 ha approx.) This PDA is a remote area with access problems. Constraints to development include localised instability on sideslope terrain and potential drainage problems. These would require treatment during site formation.

Area 12 *Tap Mun Chau* (100 ha approx.) The major part of this island forms a flat PDA with few geotechnical constraints to development, although drainage lines and moderately steep side-slopes would require attention. The main constraint to development is difficulty of access. The island occurs within Country Park and should be considered for specialised development only.

Area 13 *Wan Tsai* (50 ha approx.) This remote area suffers from the problem of access. Steep to moderately steep slopes, ridgelines and a potential boulder threat are additional constraints to development. The short length of streams on this peninsula creates rapid runoff, hence drainage and erosion problems pose further engineering difficulties. The area would be suitable for borrow. Should reclamation of Jone's Cove be considered, borrow from PDA No. 8 could be used as a supplementary source.

Area 14 *Ping Chau* (120 ha approx.) Geotechnically, this island PDA is suited to development, being relatively flat, with minimal weathered material or superficial deposits and few drainage problems. The island is extremely remote and would only be suitable as specialist use, cultural or leisure development. The island is within the Plover Cove (Extension) Country Park.

Area 15 *Ma Niu Shui* (300 ha approx.) Geotechnical problems in this PDA include moderately steep sideslopes, and potential flooding along drainage lines which would require entrainment or culverting. Minor areas of geotechnical constraint within the PDA arise from instability and gully erosion.

Area 16 *Sam A Tsuen* (140 ha approx.) This PDA is a remote peninsula with difficult access. Physical constraints are floodplains and colluvium in drainage lines, but these may be treated during design. Filling may be required to raise levels above flooding.

Area 17 *Kat O Chau* (75 ha approx.) This is a remote island with difficult access, but the PDA has few geotechnical problems. It has moderately steep sideslopes and ridgelines in places. The area would be suitable for development of a specialised nature. Part of the PDA is within Country Park.

Area 18 *Lai Chi Wo* (75 ha approx.) This is a remote PDA with difficult access (Plate 19). Geotechnical constraints include colluvial drainage lines and low-lying alluvial areas prone to flooding. Some colluvium is also present on the footslopes below steep sideslopes. Localised instability occurs on the sideslopes flanking the PDA.

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) *Erosion in Reservoir Catchment*
Areas of sheet, rill and gully erosion are grouped together as one unit in the GEOTECS Plot in Figure 11. Catchment boundaries for the Plover Cove Reservoir are delineated, and the areas affected by erosion are shown. An indication of the areas which are influenced by erosion is readily available. This information could be used by planners and reservoir engineers to evolve catchment management schemes. These could be used to produce an assessment of the preventive measures to curtail soil loss and subsequent sedimentation of the reservoir basins. Bedrock geology is not included in the GEOTECS Plot in Figure 11, but further computer Plots could be produced including this, or other data, depending on various user requirements. Alternative GEOTECS Plots could be used to delineate areas most severely affected by erosion so they could be dealt with on a priority basis.

(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 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 520 ha of undesignated natural terrain has potential for quarry sites. A further 6 000 ha with potential for quarrying occurs within existing Country Parks or is under cultivation. These figures indicate that many options exist, but these options would be reduced when rock type is specified.

5. CONCLUSIONS

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

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

5.1 Materials and Land Resource Distribution

(*a*) Slope instability of some form or other is relatively common within the study area. Approximately 2 103 ha of the terrain (26.4%) 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.

(*b*) The geology of the area is relatively complex, and several aspects require careful investigation. Weathering depths vary according to bedrock lithology. The area is unusual in that there are large areas of sedimentary rocks and only very small areas of intrusive igneous rocks. The competition from alternative land uses restricts the future excavation of borrow material. There are numerous photolineaments present, many of which are likely to be faults, shear zones, major joint zones or dykes.

(*c*) Approximately 359 ha of the footslope terrain is covered by extensive colluvial deposits; with only 4.5% of the colluvium affected by instability. Significant geotechnical limitations should be anticipated on zones of runoff and surface drainage across the colluvium, which together occupy some 60% (210 ha) of the generally low angle colluvial footslope terrain.

(*d*) The volcanic terrain has approximately the same proportion of GLUM Classes I & II (53.4%) as the sedimentary rocks (54.6%). All the 359 ha of colluvial terrain which occurs within the study area is subject to high to extreme geotechnical constraints (GLUM Classes III & IV).

(*e*) Approximately 27.1% of the study area is characterised by slopes which have gradients between 0 and 15°. A further 70.5% of the terrain has slope gradients between 15 and 40° and 2.4% is steeper than 40°.

(*f*) Surface erosion is more pronounced on the small area of weathered granitic rock than on terrain with colluvium or volcanic bedrock.

(*g*) Sedimentary rock may suitable as borrow, but it is probably unsuitable for use as aggregate. Volcanic rock should be considered as a source of aggregate.

(*h*) Reclamation and other developments are of a very minor nature in this study area. Only 1.0% of the study area is currently developed.

(*i*) There are no squatter settlements with the characteristics of those found nearer the large urban centres, recorded in GEOTECS for this area.

(*j*) Country Park occupies over 5 861 ha (73.6%) of the study area, and 19.6% is currently developed or has some type of defined usage other than Country Park. Only some 545 ha (6.8%) occurs as undisturbed and undeveloped natural terrain outside the 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 North East New Territories study area, the geotechnical constraints associated with the terrain are important factors for land management purposes and engineering feasibility.

(*b*) Opportunities do exist for urban expansion in the study area, although it is unrealistic to envisage that future development can avoid areas with geotechnical limitations. The Generalised Limitations and Engineering Appraisal Map (GLEAM) recognises this fact, and delineates 18 areas which have overall potential for development from a geotechnical point of view. These represent a total of 1 670 ha or 21% 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 approximately 545 ha of currently undisturbed natural terrain, which occurs outside of Country Park. Of this figure, GLUM Classes I & II occur on some 54% (312 ha) of the terrain, and 233 ha is associated with high to extreme geotechnical limitations (GLUM Classes III & IV). There is approximately 5 861 ha of land within the Country Parks and of this figure 2 892 ha is classified as either having low or moderate geotechnical limitation (GLUM Classes I & II).

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

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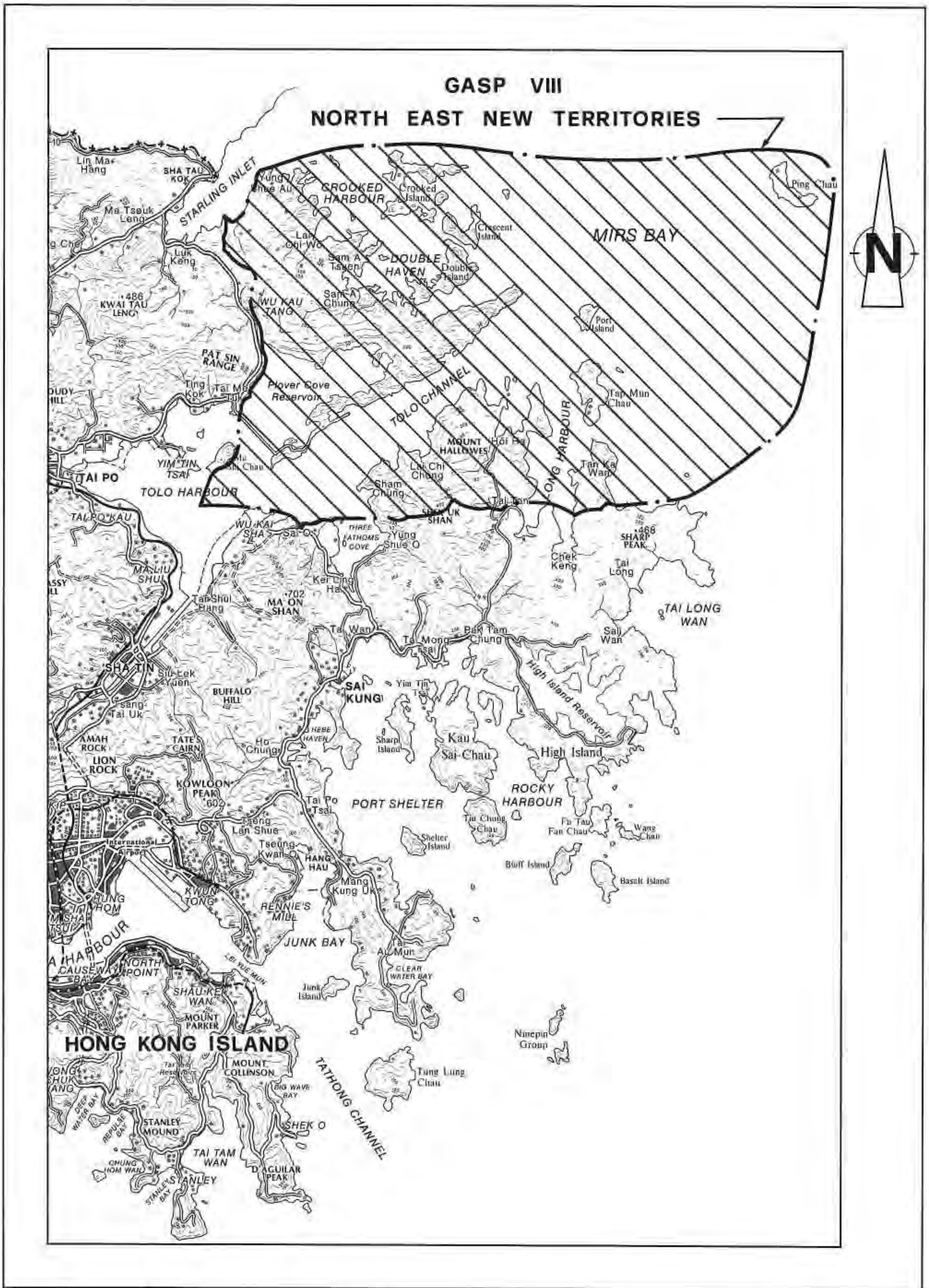
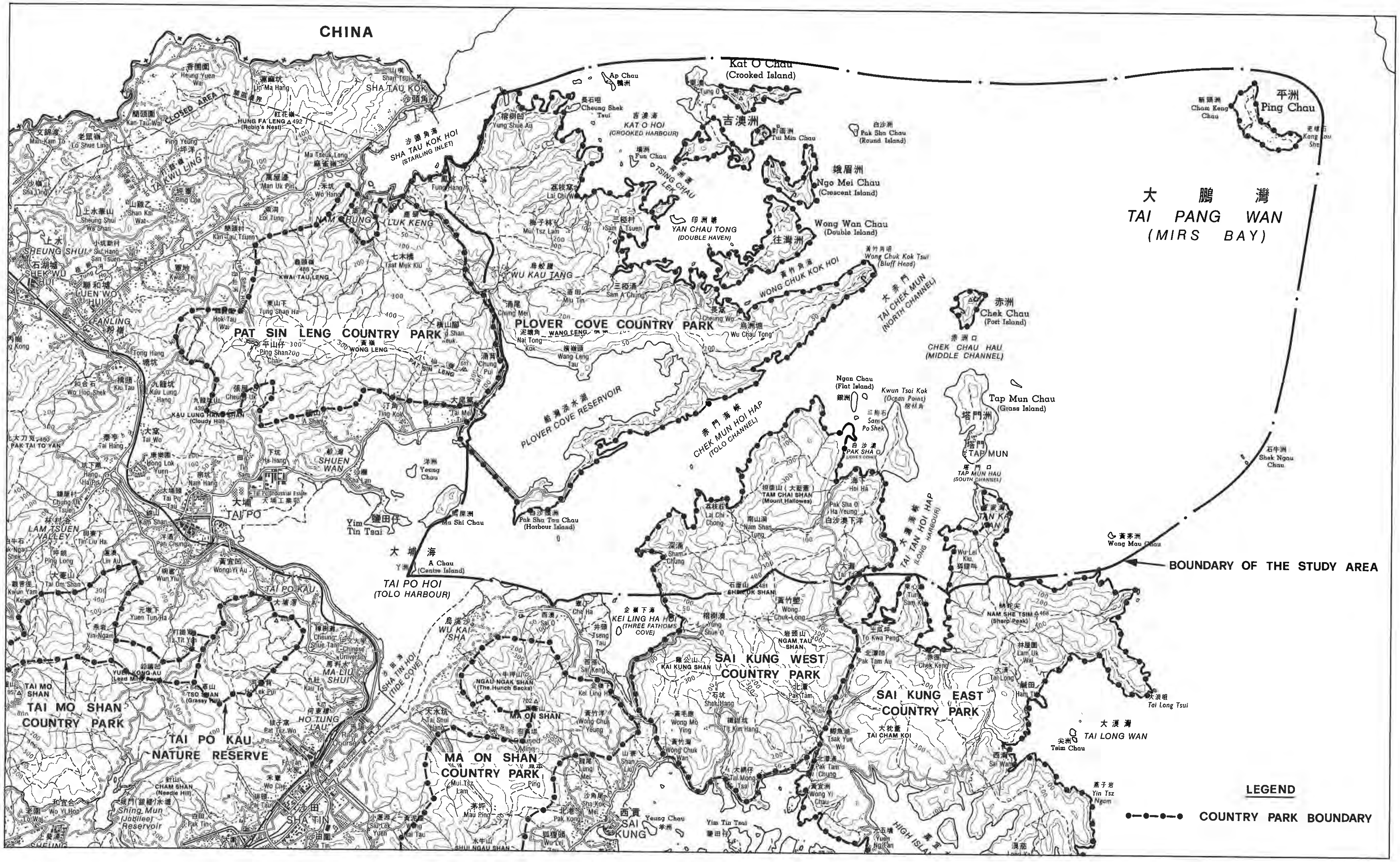
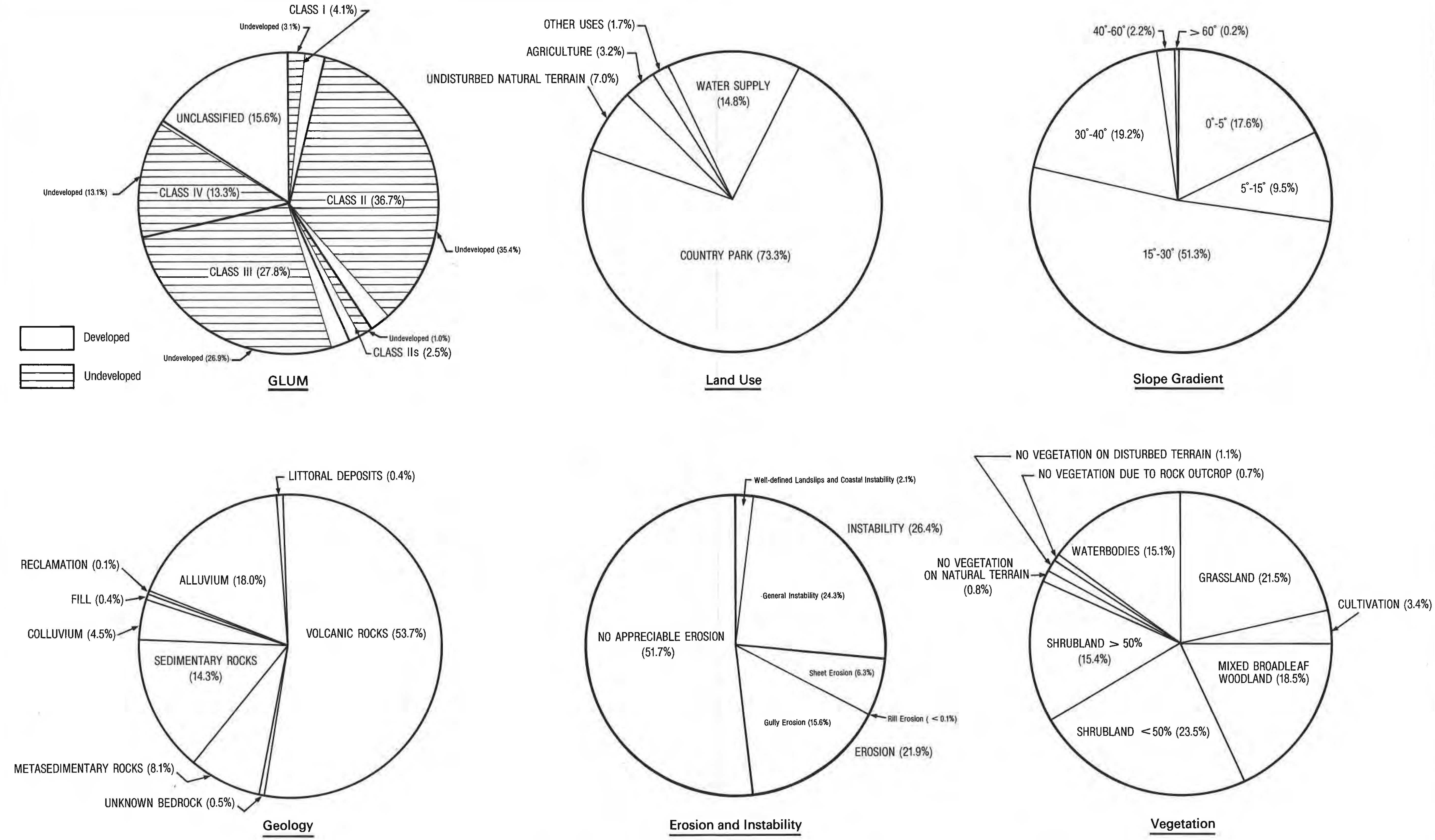


Scale 1:200 000	Location Map of the North East New Territories Study Area	Fig. 1

Scale 1:130 000	Aerial Photomosaic of the North East New Territories Study Area	Fig. 2

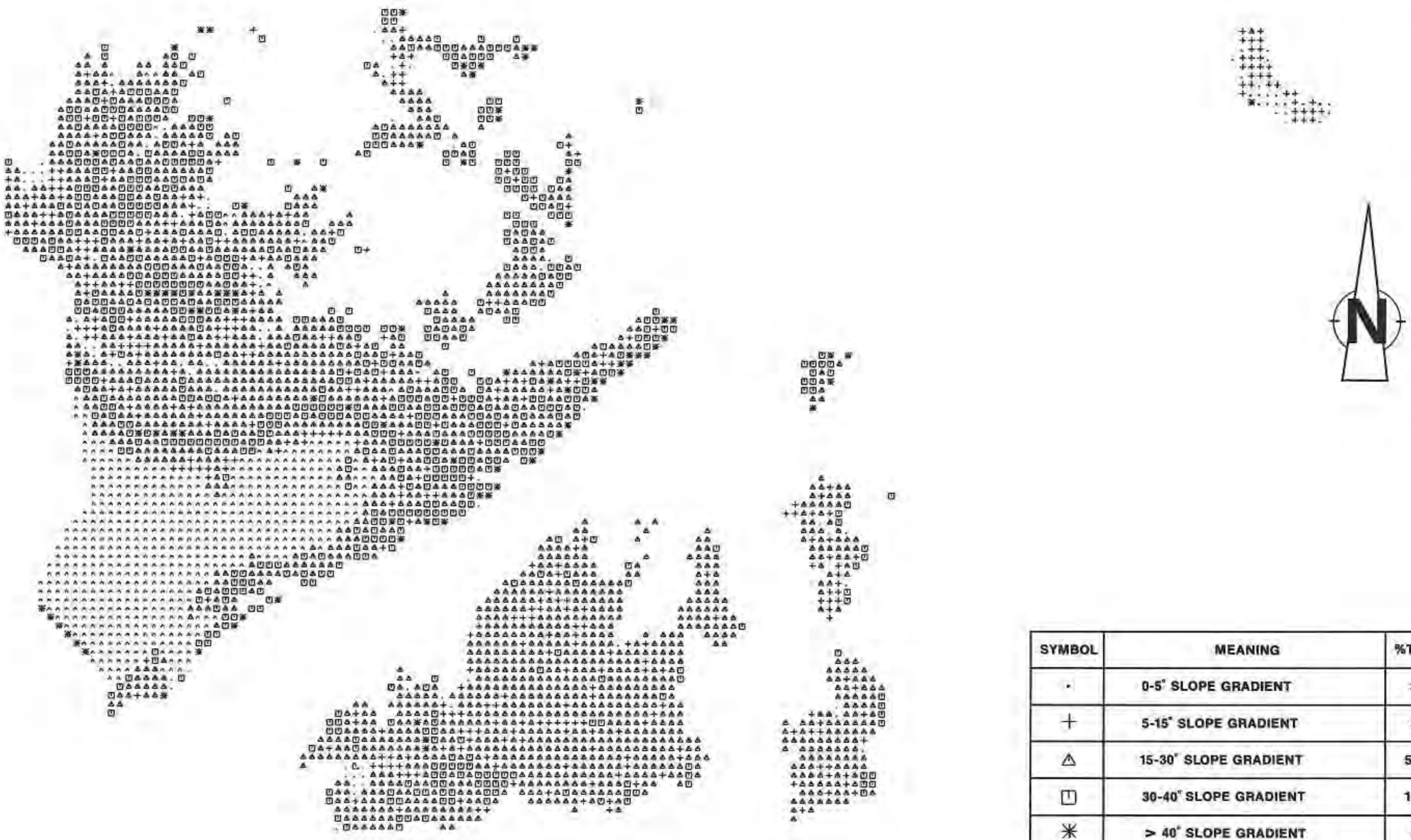


Scale 1:100 000	North East New Territories Study Area	Fig. 3



Pie Charts of Selected Attributes of the North East New Territories

Fig. 4

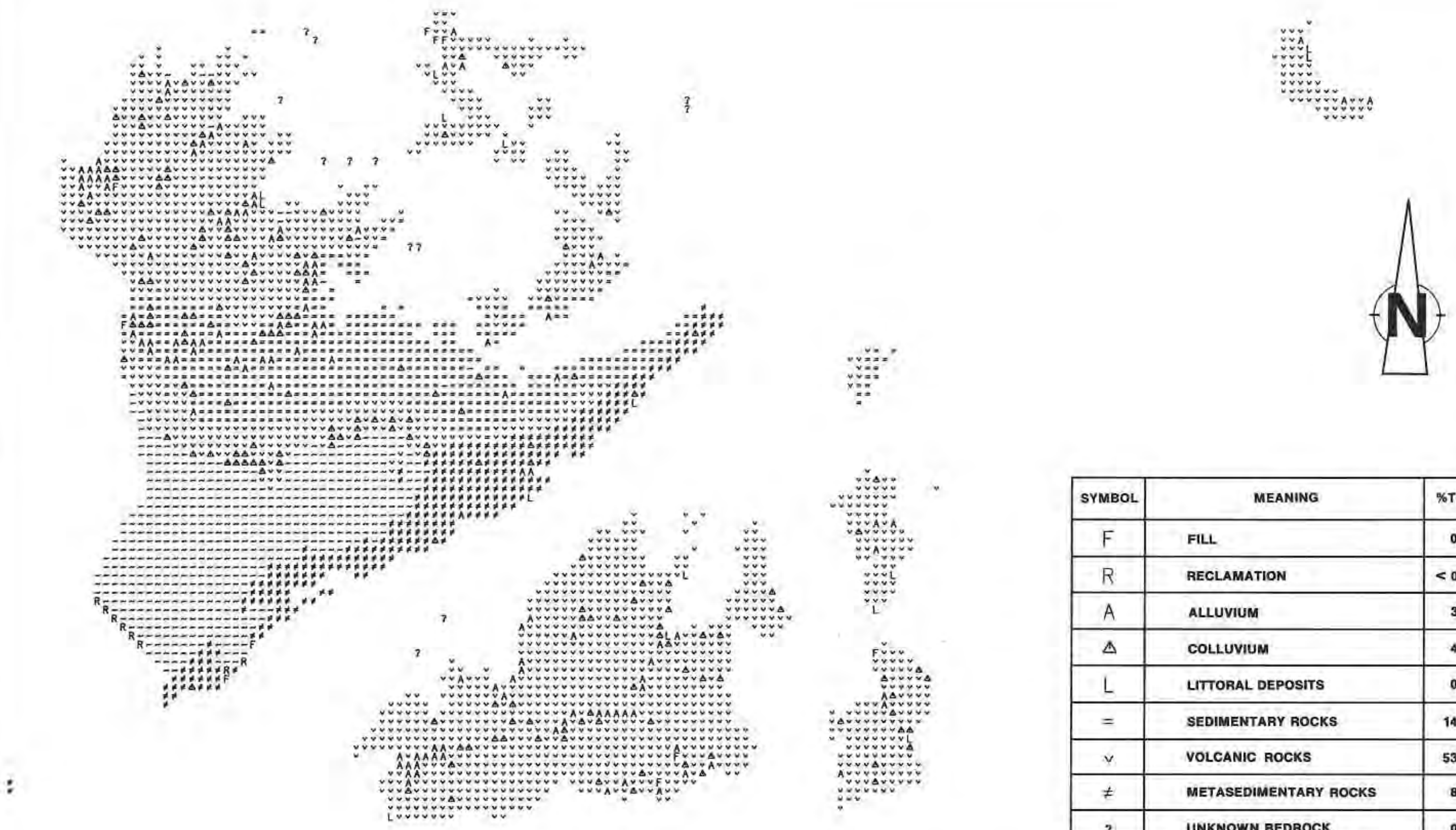


SYMBOL	MEANING	%TOTAL
·	0-5° SLOPE GRADIENT	3.0
+	5-15° SLOPE GRADIENT	9.5
△	15-30° SLOPE GRADIENT	51.3
⊡	30-40° SLOPE GRADIENT	19.2
✳	> 40° SLOPE GRADIENT	2.4
~	ARTIFICIAL CHANNEL, RESERVOIR OR POND	14.6

Scale 1:100 000

GEOTECS Plot - Slope Gradient

Fig. 5

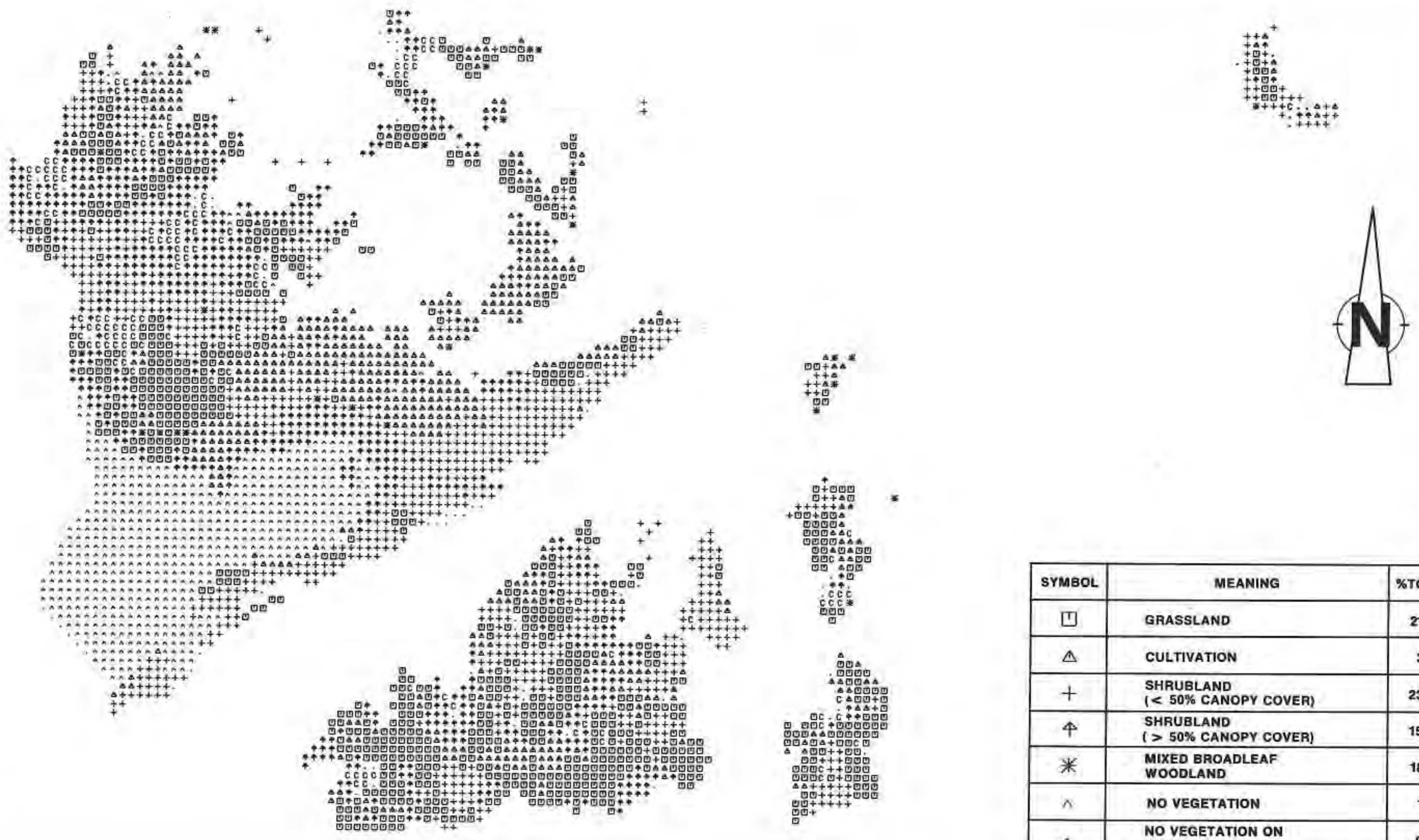


SYMBOL	MEANING	%TOTAL
F	FILL	0.4
R	RECLAMATION	< 0.1
A	ALLUVIUM	3.0
△	COLLUVIUM	4.5
L	LITTORAL DEPOSITS	0.4
=	SEDIMENTARY ROCKS	14.3
v	VOLCANIC ROCKS	53.7
≠	METASEDIMENTARY ROCKS	8.1
?	UNKNOWN BEDROCK	0.5
~	RESERVOIR OR POND	15.0

Scale 1:100 000

GEOTECS Plot - Geology

Fig. 6

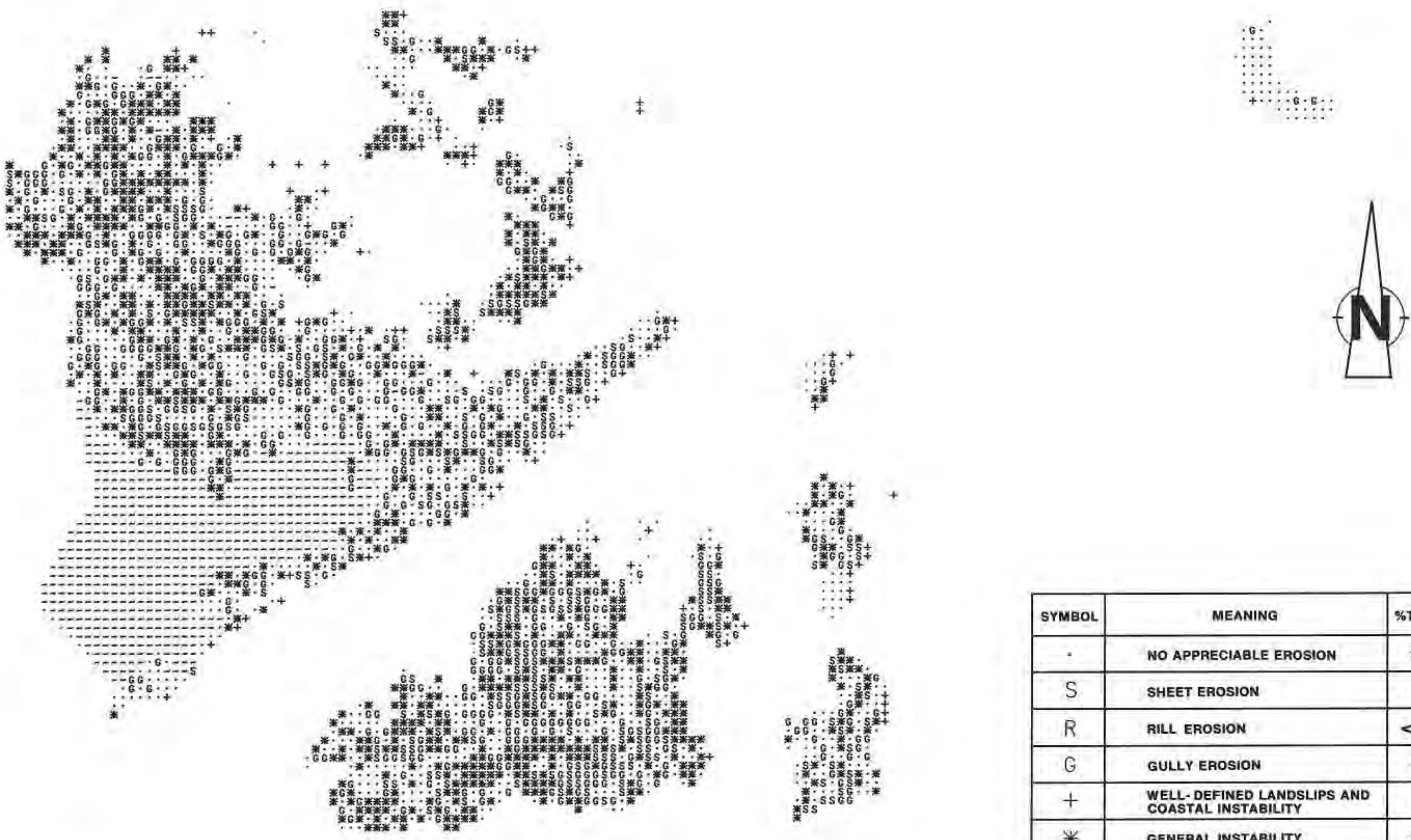


SYMBOL	MEANING	%TOTAL
⊡	GRASSLAND	21.5
△	CULTIVATION	3.4
+	SHRUBLAND (< 50% CANOPY COVER)	23.5
✢	SHRUBLAND (> 50% CANOPY COVER)	15.4
✳	MIXED BROADLEAF WOODLAND	18.5
^	NO VEGETATION	1.9
·	NO VEGETATION ON ROCK OUTCROPS	0.7
C	WATERBODIES (STREAM, CHANNEL, RESERVOIR, PONDS)	15.1

Scale
1:100 000

GEOTECS Plot - Vegetation

Fig. 7

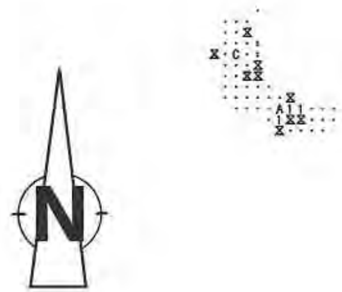


SYMBOL	MEANING	%TOTAL
·	NO APPRECIABLE EROSION	36.6
S	SHEET EROSION	6.3
R	RILL EROSION	< 0.1
G	GULLY EROSION	15.6
+	WELL-DEFINED LANDSLIPS AND COASTAL INSTABILITY	2.1
✳	GENERAL INSTABILITY	24.3
~	STREAM, CHANNEL, RESERVOIR OR POND	15.1

Scale 1:100 000

GEOTECS Plot - Erosion and Instability

Fig. 8

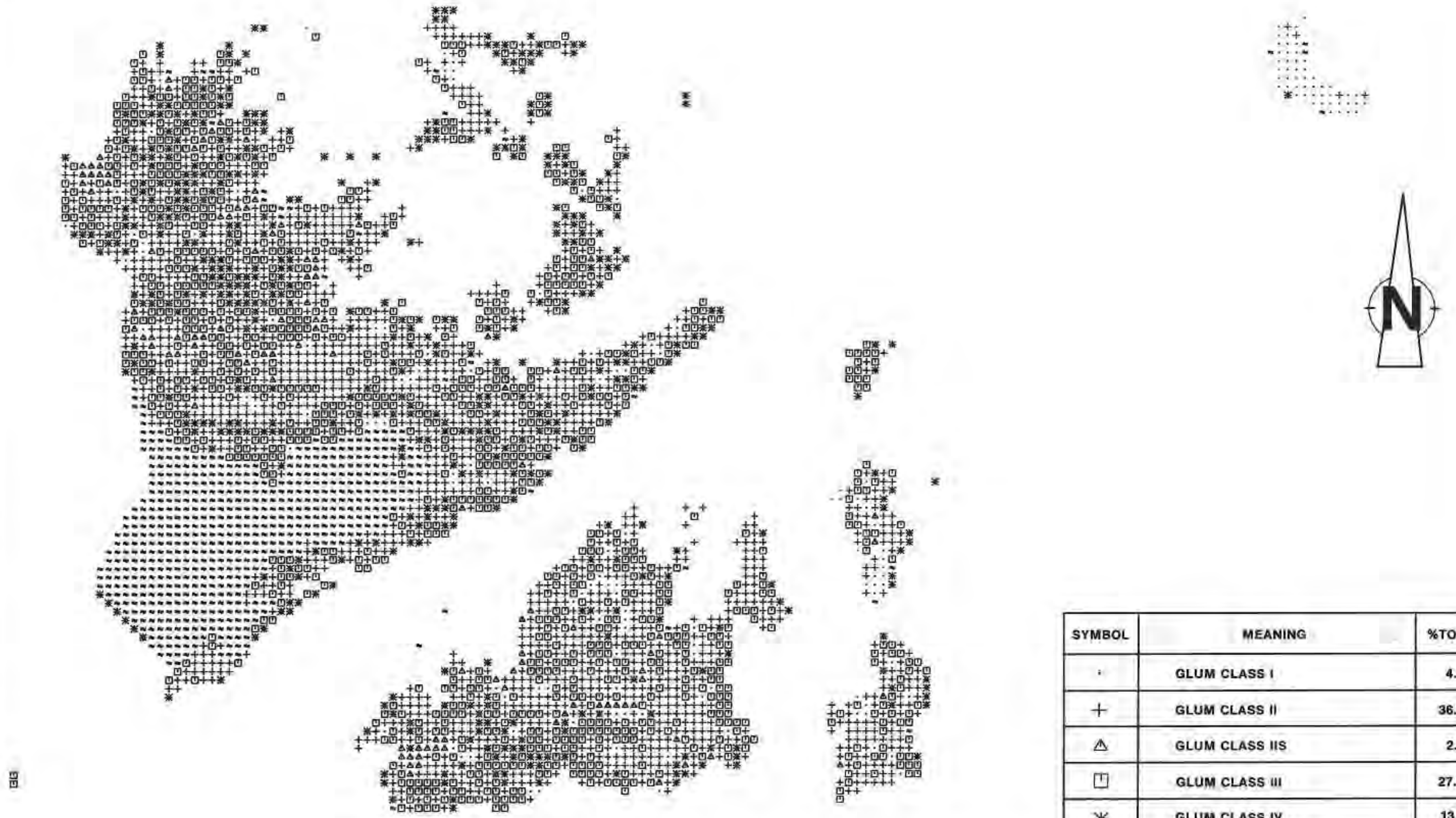


SYMBOL	MEANING	%TOTAL
R	RESIDENTIAL (AND MIXED COMMERCIAL /RESIDENTIAL)	< 0.1
1	SINGLE STOREY HOUSING	0.6
2	DOUBLE STOREY HOUSING	0.3
C	COMMUNITY AND INSTITUTIONAL	< 0.1
D	INCOMPLETE DEVELOPMENT (INCLUDING TEMPORARY RESETTLEMENT AREA)	< 0.1
⊿	SPORTS AND RECREATIONAL	< 0.1
~	WATER SUPPLY (INCLUDING RESERVOIR, SEWAGE & TREATMENT)	14.8
A	AGRICULTURE (UNDEFINED)	3.2
F	FISH OR DUCK FARMING	0.2
⧖	UNDISTURBED NATURAL TERRAIN	7.0
·	COUNTRY PARK	73.3
#	LARGE ARTIFICIAL SLOPES	0.2
:	LITTORAL ZONE	0.4

Scale 1:100 000

GEOTECS Plot - Land Use

Fig. 9

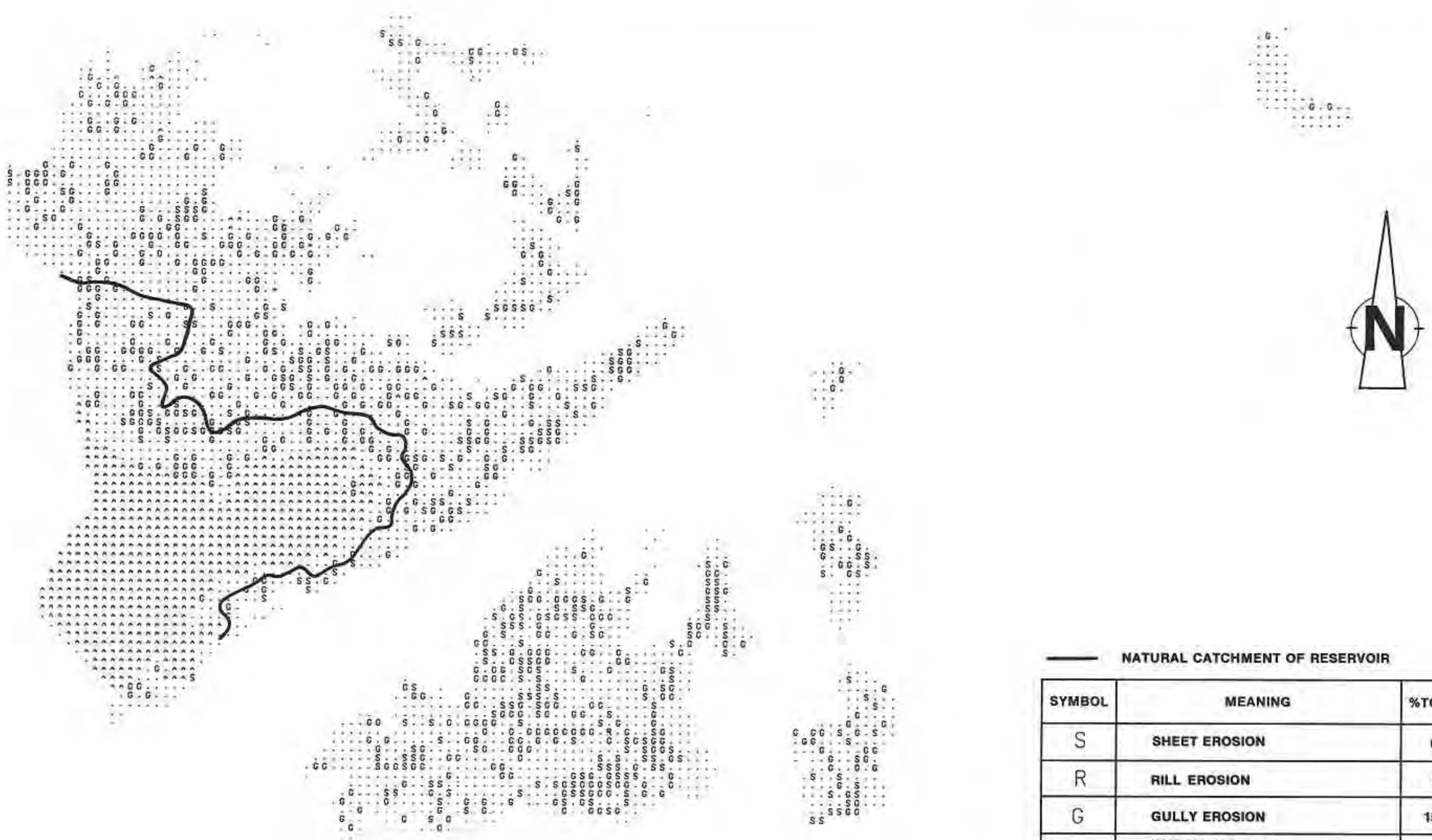


SYMBOL	MEANING	%TOTAL
·	GLUM CLASS I	4.1
+	GLUM CLASS II	36.7
△	GLUM CLASS IIS	2.5
◫	GLUM CLASS III	27.8
✳	GLUM CLASS IV	13.3
~	UNCLASSIFIED GLUM CLASS	15.6

Scale
1:100 000

GEOTECS Plot - Geotechnical Land Use Map

Fig. 10



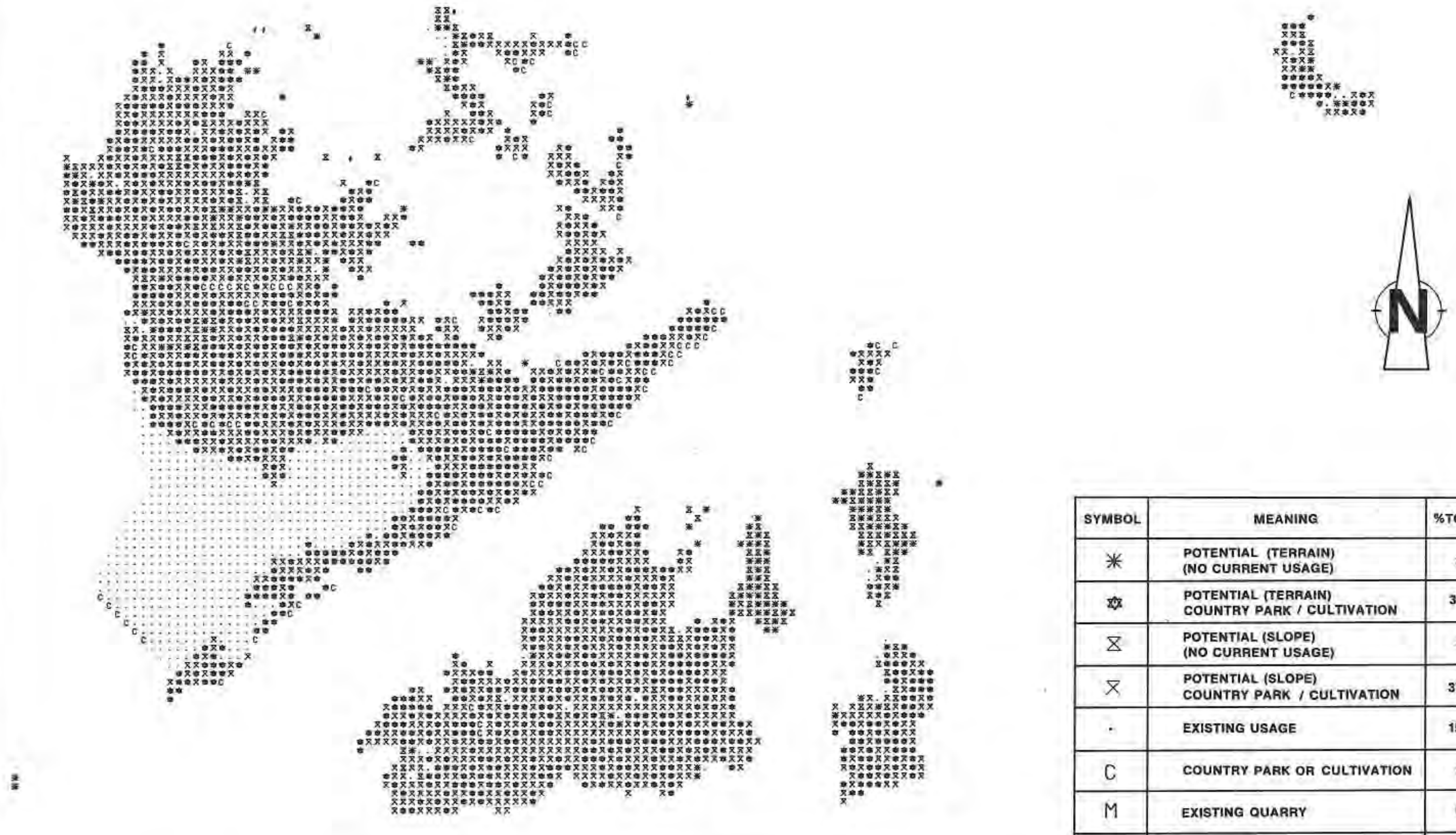
— NATURAL CATCHMENT OF RESERVOIR

SYMBOL	MEANING	%TOTAL
S	SHEET EROSION	6.3
R	RILL EROSION	0.0
G	GULLY EROSION	15.6
·	INSTABILITY AND NO APPRECIABLE EROSION	63.0
^	RESERVOIR OR POND	15.0

Scale 1:100 000

GEOTECS Plot - Erosion in Reservoir Catchments

Fig. 11

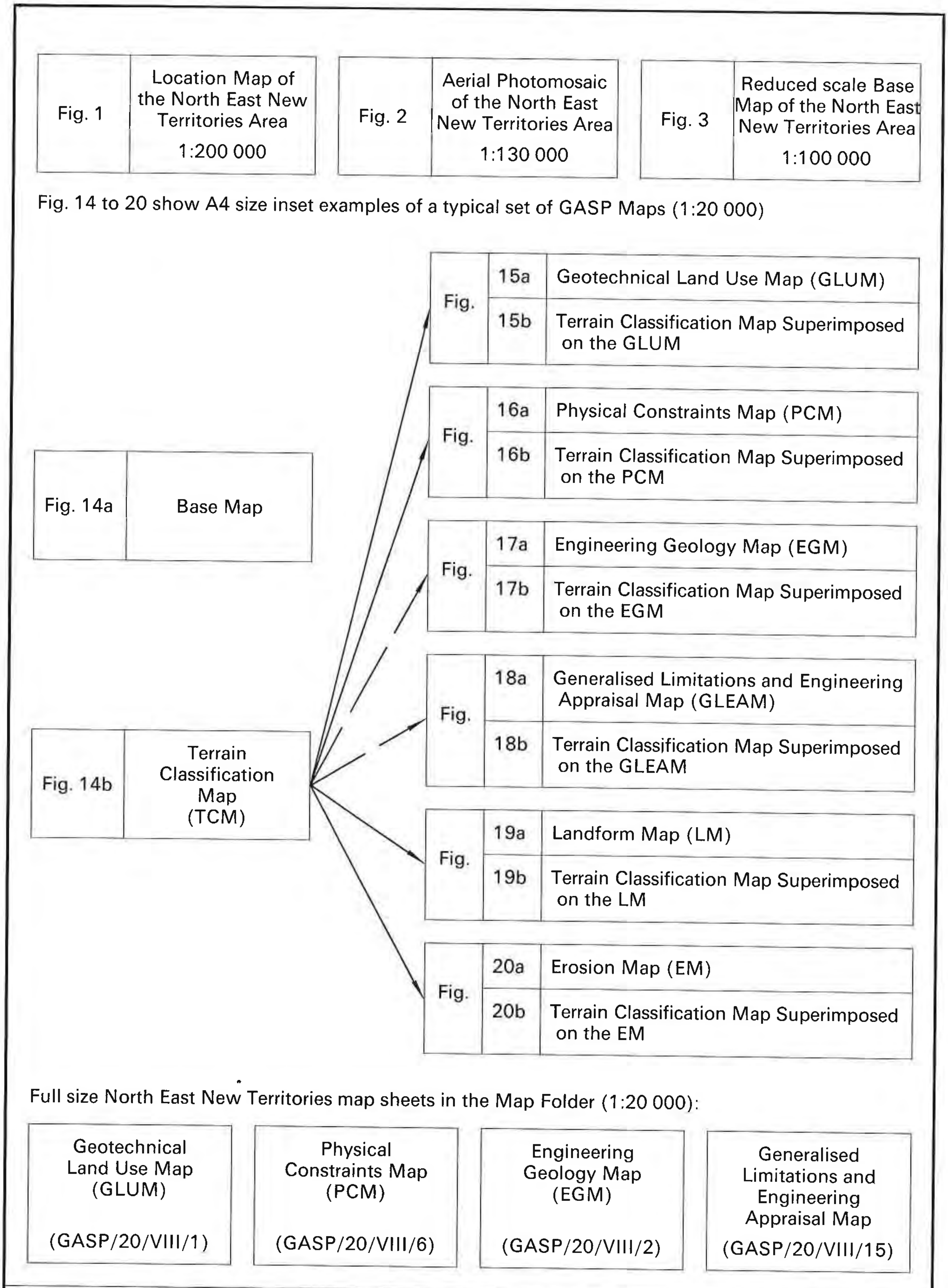


SYMBOL	MEANING	%TOTAL
✲	POTENTIAL (TERRAIN) (NO CURRENT USAGE)	3.5
✡	POTENTIAL (TERRAIN) COUNTRY PARK / CULTIVATION	38.1
⧖	POTENTIAL (SLOPE) (NO CURRENT USAGE)	3.2
⧗	POTENTIAL (SLOPE) COUNTRY PARK / CULTIVATION	37.0
·	EXISTING USAGE	15.8
C	COUNTRY PARK OR CULTIVATION	2.3
M	EXISTING QUARRY	0.0
ϕ	UNDESIGNATED (MAY HAVE POTENTIAL)	0.1

Scale 1:100 000

GEOTECS Plot - Potential Quarry Sites

Fig. 12



Presentation of Maps

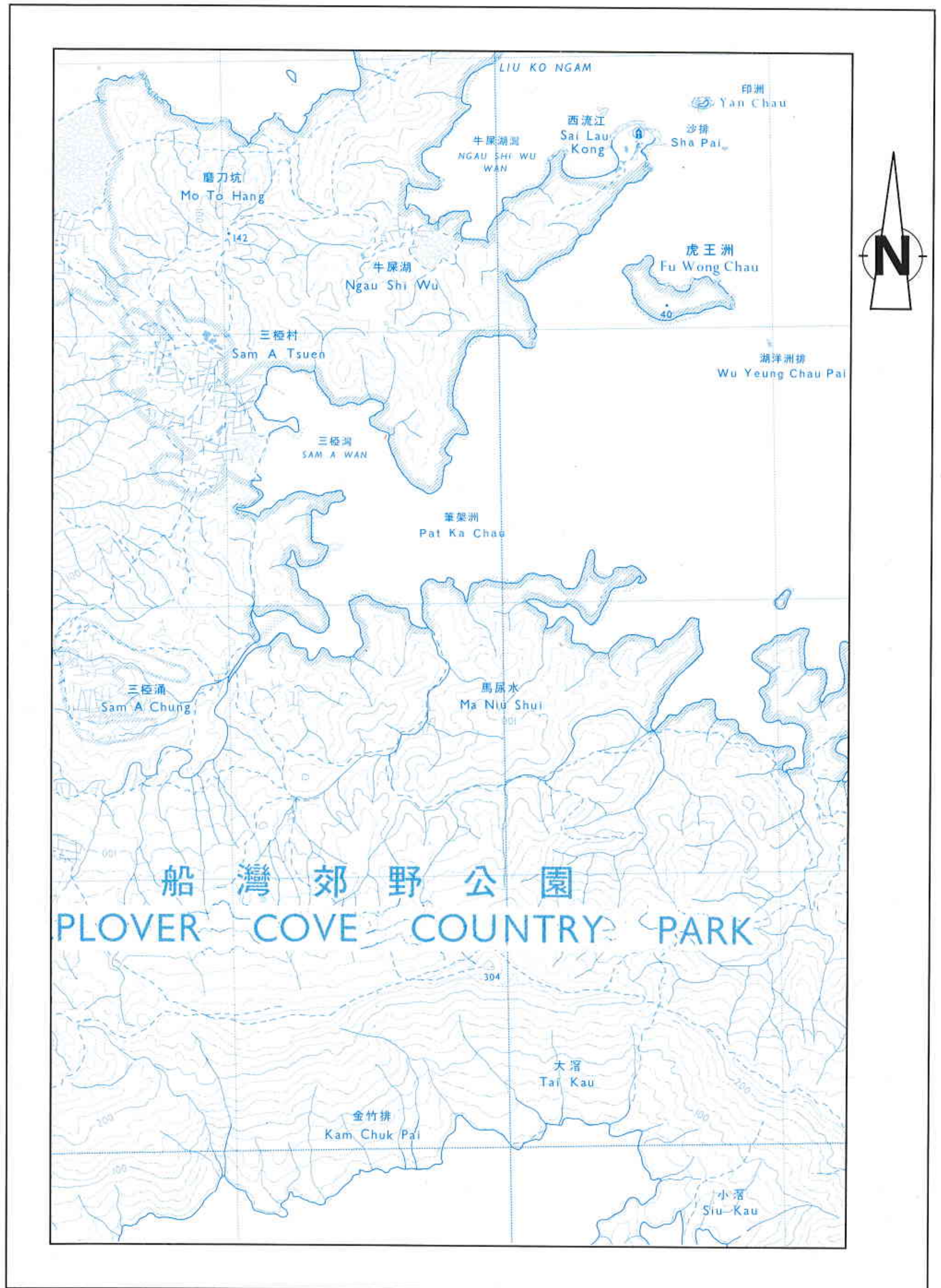
Fig. 13

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. 14b)

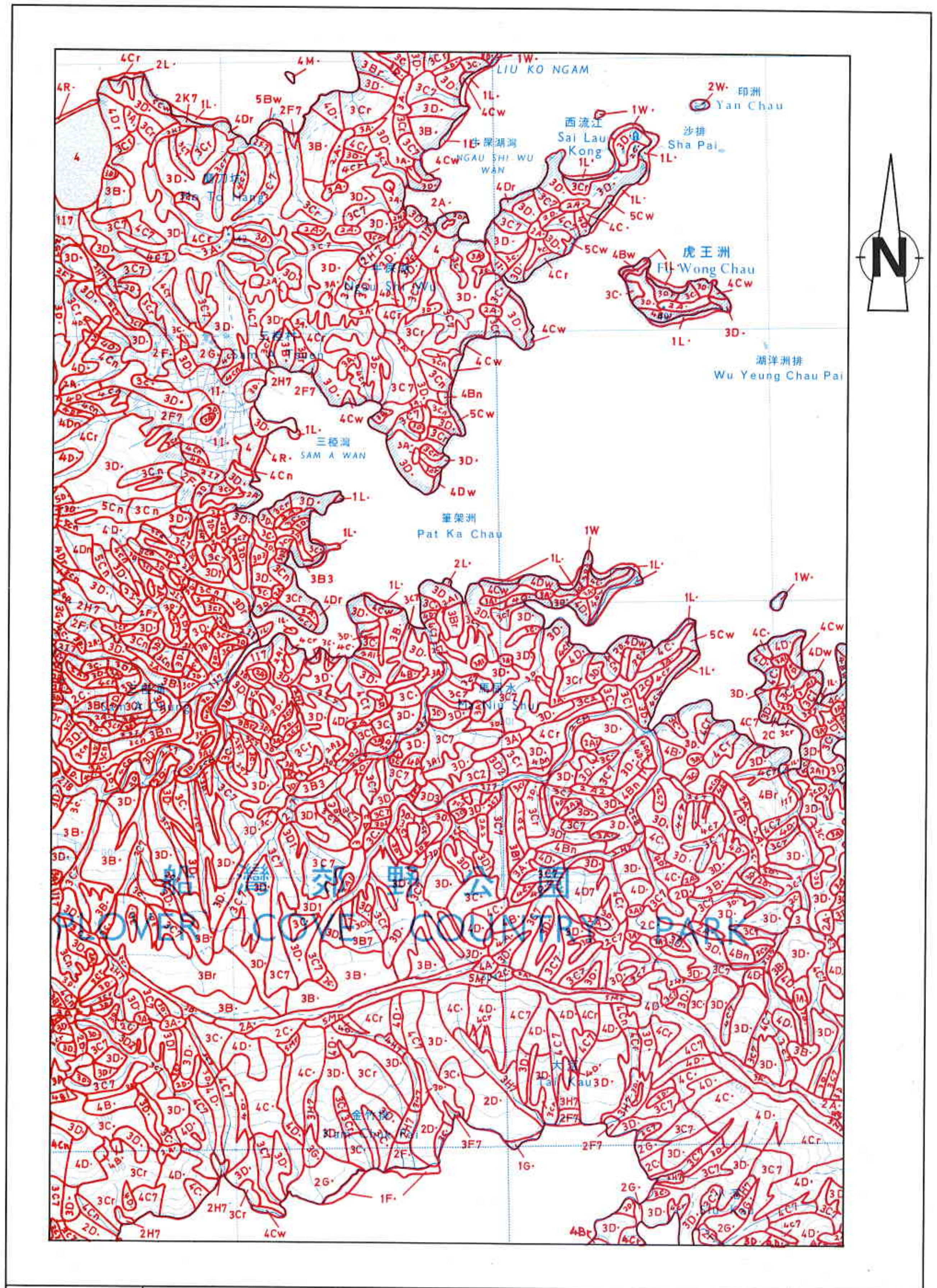
SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

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)

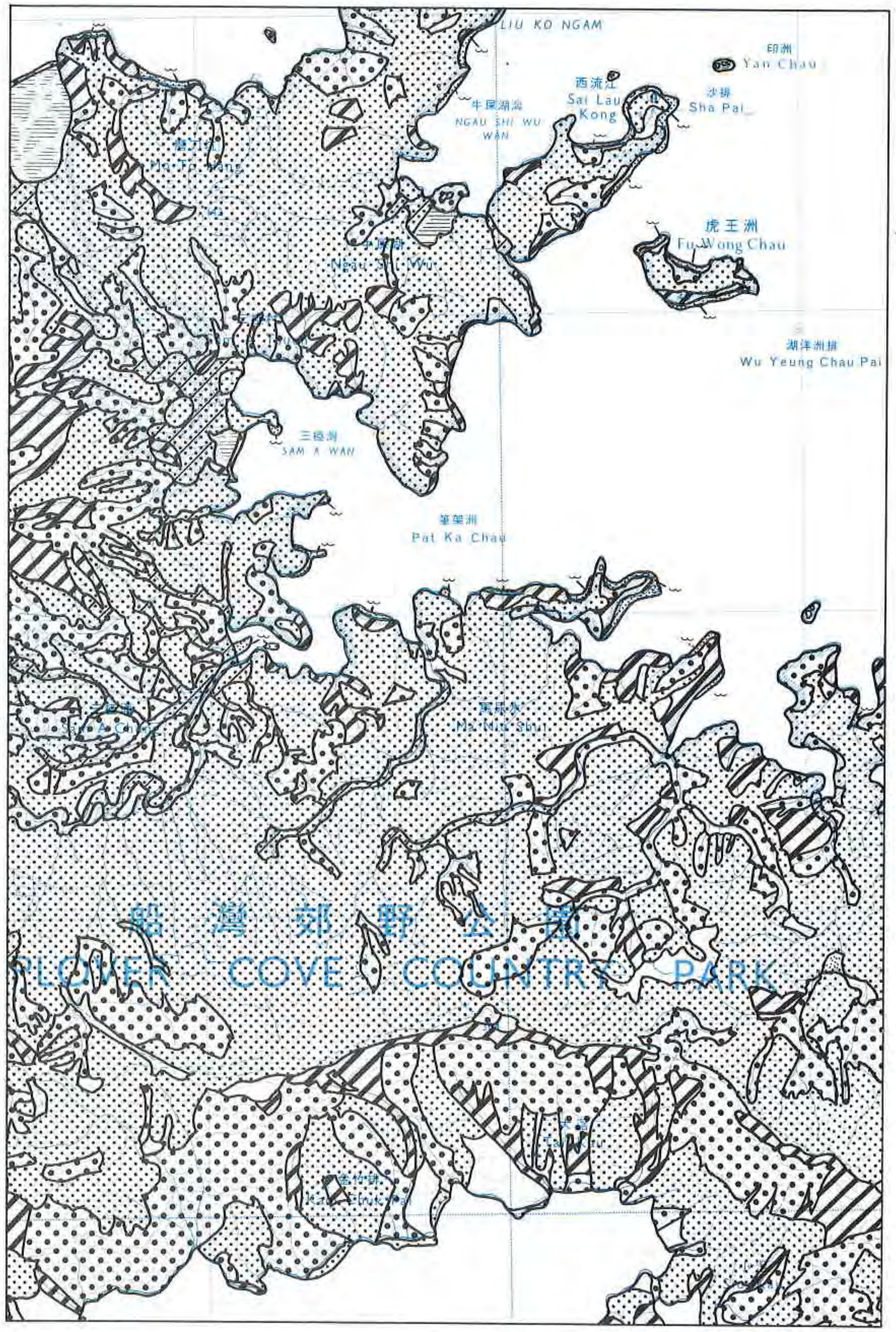
Class I	- Low Geotechnical Limitations	
Class II	- Moderate Geotechnical Limitations	
Class IIS	- Moderate Geotechnical Limitations (including flooding)	
Class III	- High Geotechnical Limitations	
Class IV	- Extreme Geotechnical Limitations	
Waterbodies (streams, man-made channels, storage dams)		Unclassified
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)

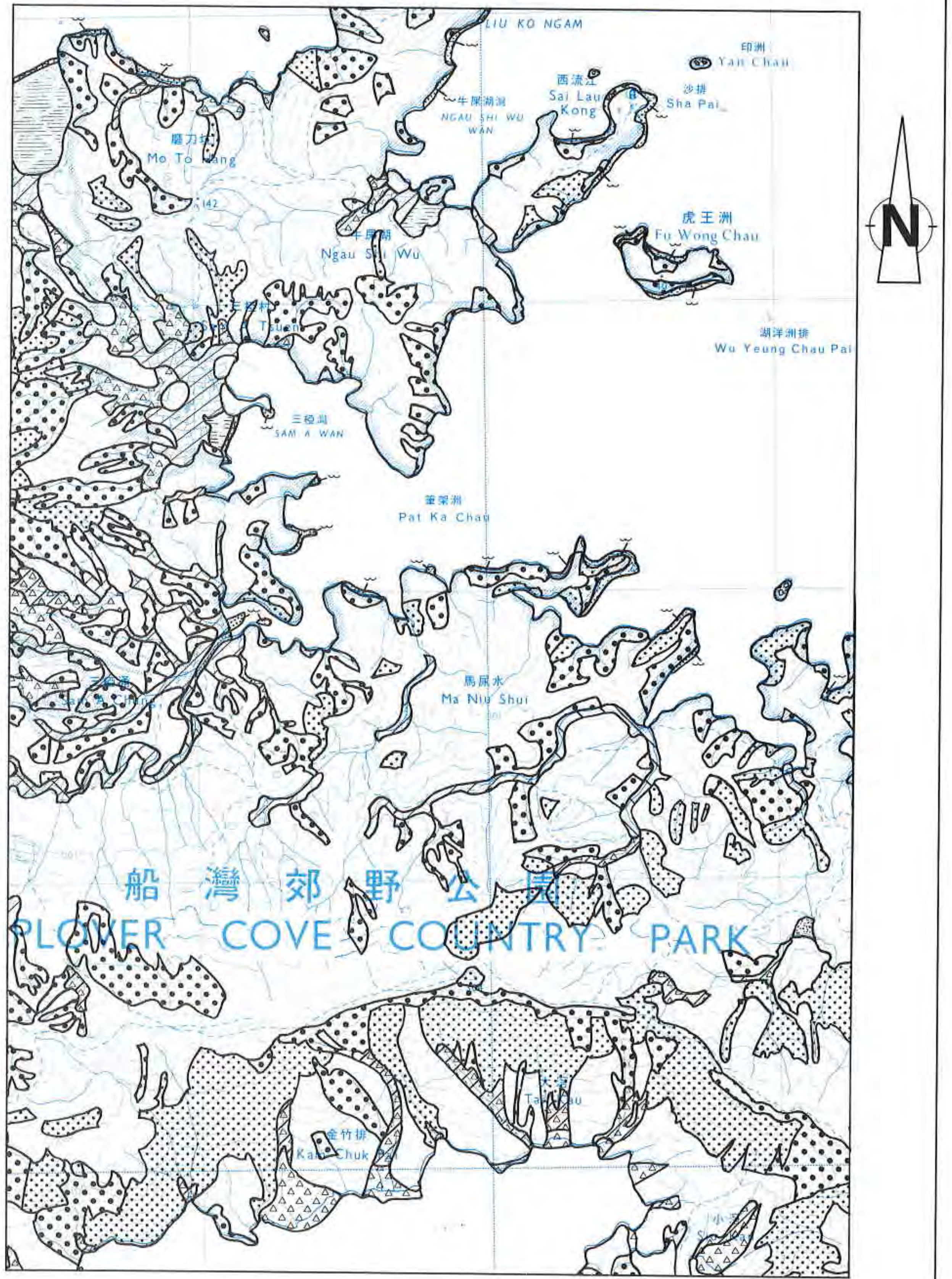
- Colluvium
- Zones of colluvium which are subject to overland flow and periodic inundation. Evidence of unusual groundwater regime (delineated as drainage plain on Landform Map)
- Floodplain - subject to overland flow and regular inundation. Evidence of unusual groundwater regime (delineated as floodplain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

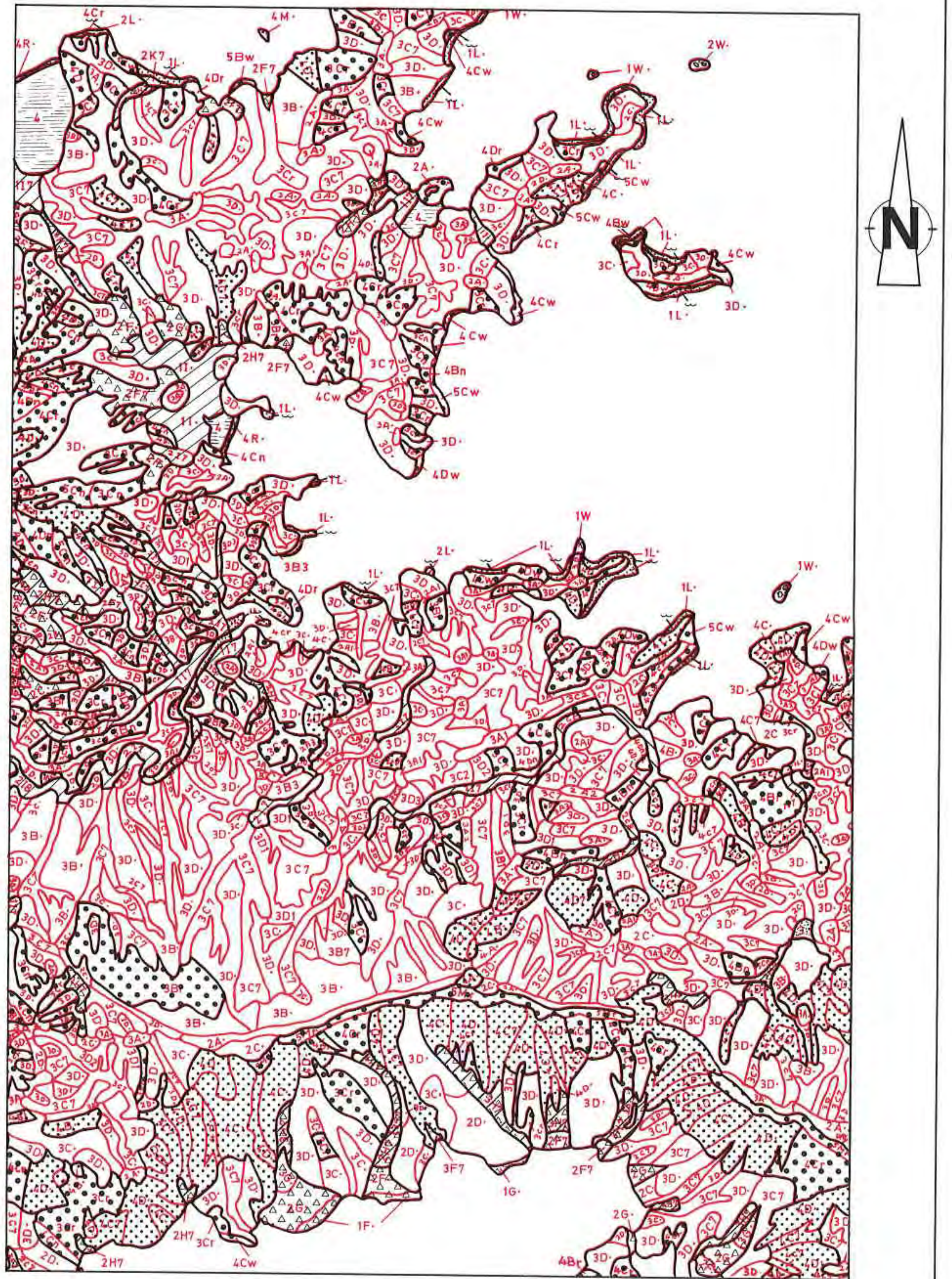
SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

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
Coastal plain	K
Littoral zone	L
Rock outcrop	M
Cut - straight	N
- concave	O
- convex	P
Fill-straight	R
-concave	S
-convex	T
General disturbed terrain	V
Wave cut platform	W
Alluvial plain	X
Reclamation	Z
Waterbodies - Natural stream	1
- Man-made channel	2
- Water storage dam	3
- Fish pond	4

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



Scale 1:20 000	Example of the 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)
Kat O Formation
Port Island Formation
Tai Po Granodiorite
Undifferentiated volcanic rocks)
Sedimentary rocks and water-laid volcaniclastic rocks)
Acid lavas) Repulse Bay Formation
Coarse tuff)
Dominantly pyroclastic rocks with some lavas)
Bluff Head Formation
Tolo Channel Formation
Tolo Harbour Formation
Wave cut platform

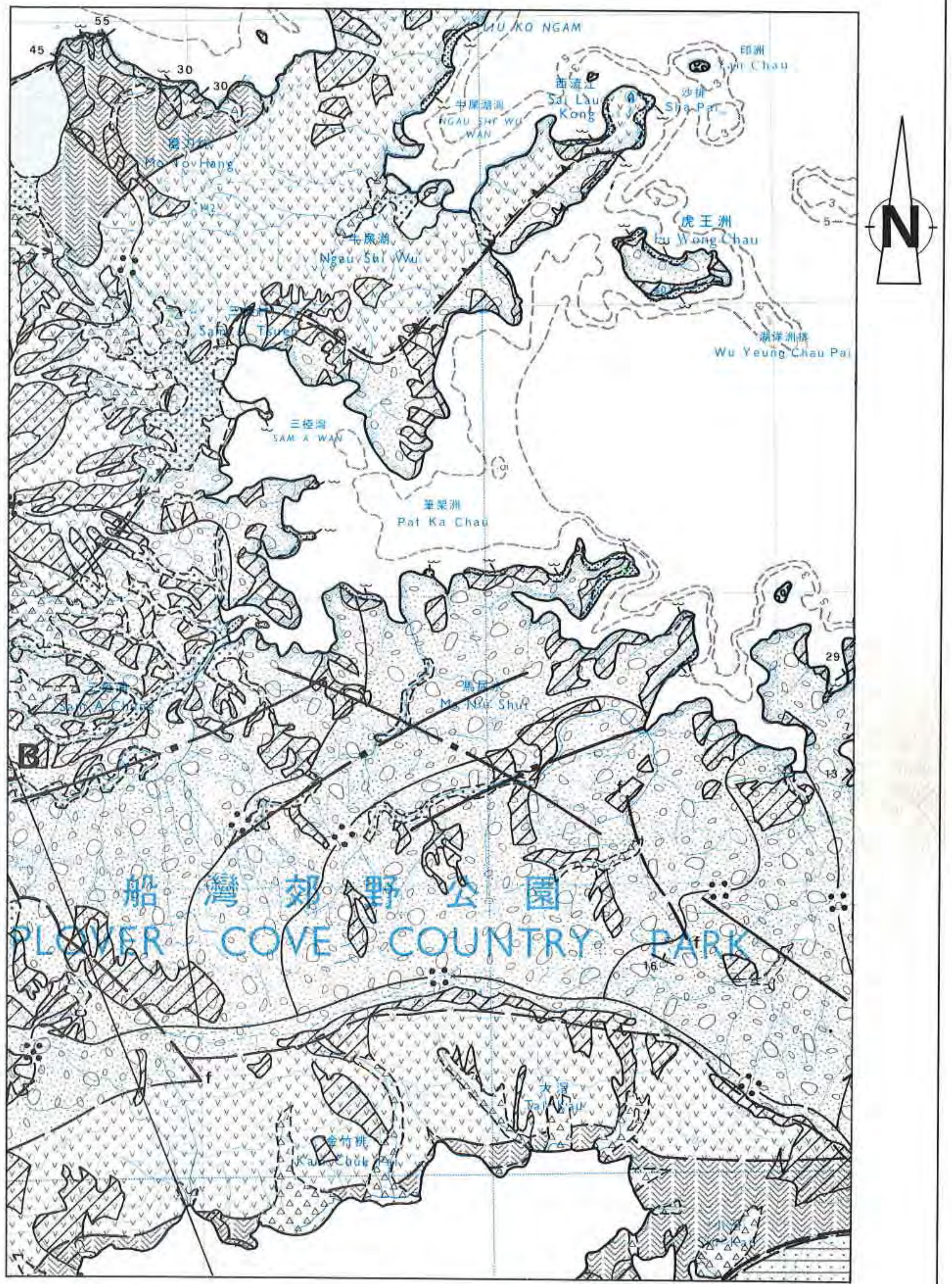
Geological boundary (solid)
Geological boundary (superficial)
Geological cross-section line (A–B)
Strike of bedding, amount and direction of dip known (30)
Vertical bedding
Strike and dip of flow-banding in lavas (80)
Anticlinal axis; direction and amount of plunge shown (10)
Minor fold axis showing direction and amount of plunge (60)
Thrust; teeth pointing to upper plate
Fault (from Allen & Stephens, 1971)
Reverse fault, tick on downthrow side
Geological photolineament (from Allen & Stephens, 1971)
Geological photolineament (approximate)
Possible (marine) block faulting
General instability
Catchment boundary (order indicated by number of dots)
Main drainage divide, low order catchments

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. 17b)

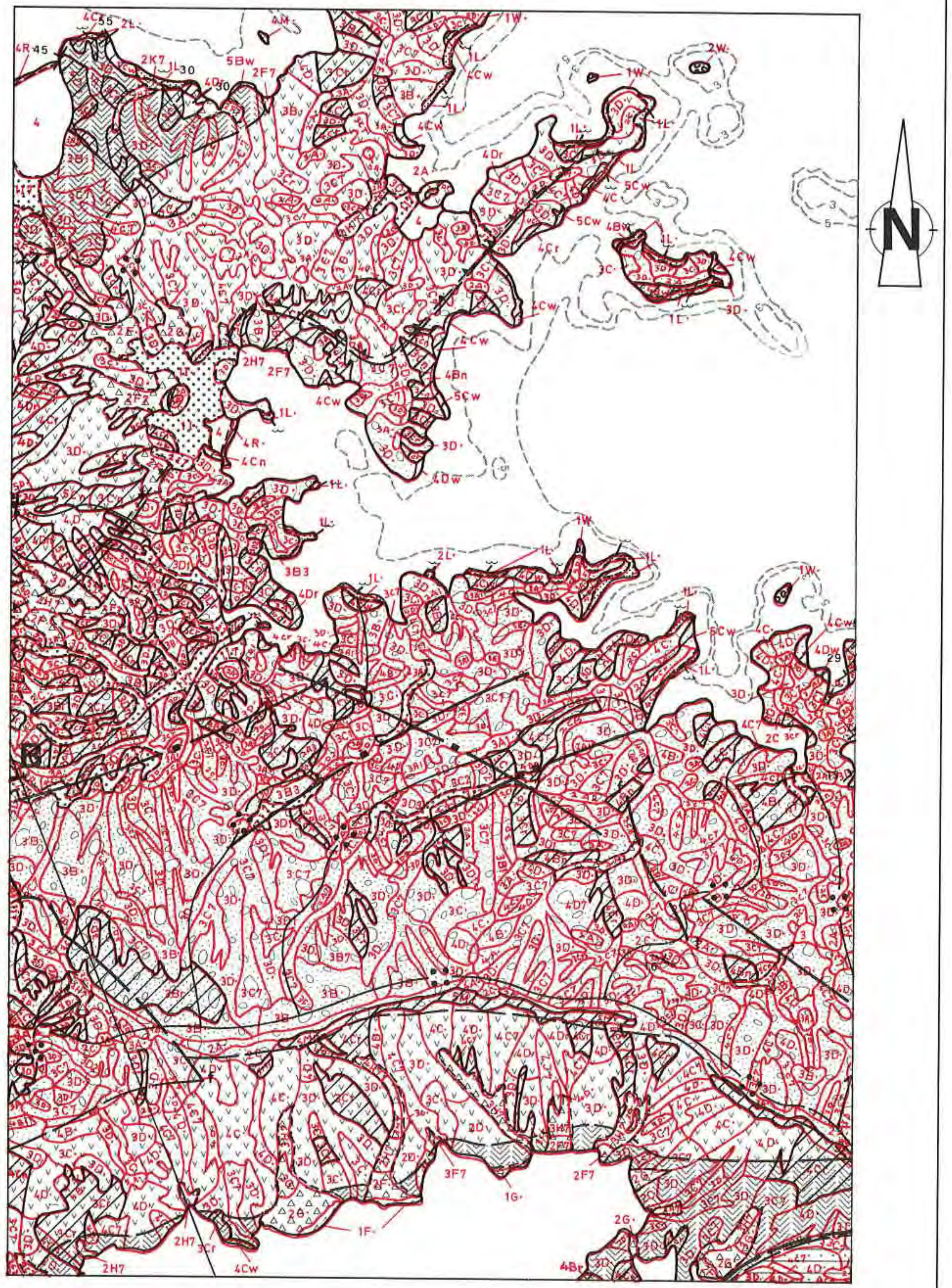
SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

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
General instability) relict	r
Coastal instability	w



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



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

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

DEVELOPMENT PLANNING ZONES :

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

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

ABBREVIATIONS :

cont.	control
devt.	development
gran.	granite
instab.	instability
mod.	moderate
pot.	potential
sed.	sedimentary
sh.	shallow
st.	steep
volc.	volcanic

FEATURES OF ENGINEERING SIGNIFICANCE :

- Geological photolineament (from Allen & Stephens, 1971)
- Geological photolineament (approximate)
- —R— Ridgeline
- =D=Di= Drainage, incised drainage
- Coll. Colluvium (also in 'zone of local constraint', and PCM)
- Str. Structure/sturctural
- W. Weathering
- f — — f Faults
- B. 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.

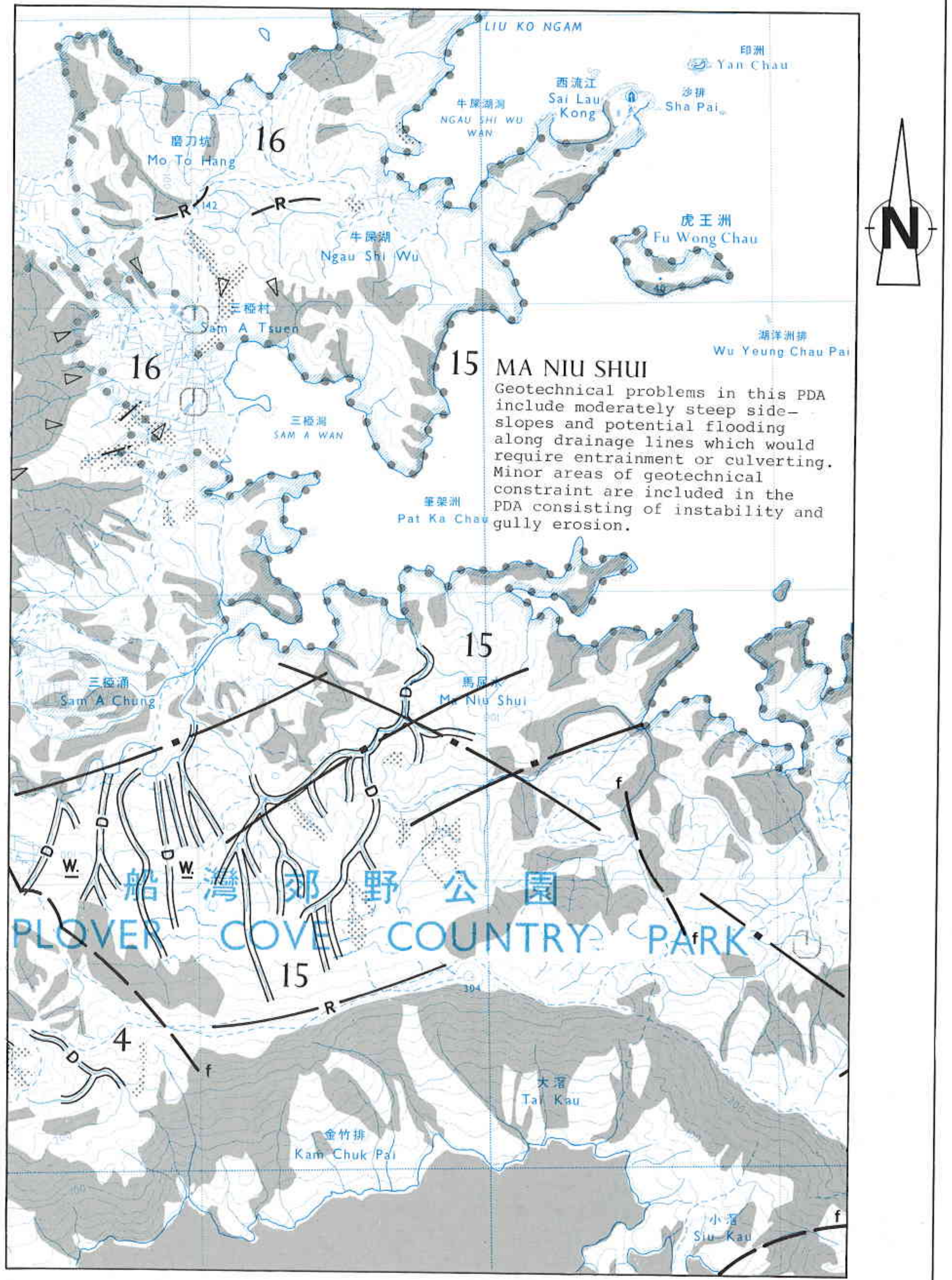
iii) Geological boundaries and photolineament are shown in full on the EGM. Those lineaments indicated represent the surface epxression of obvious structural discontinuities which affect the PDA's.

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. 18b)

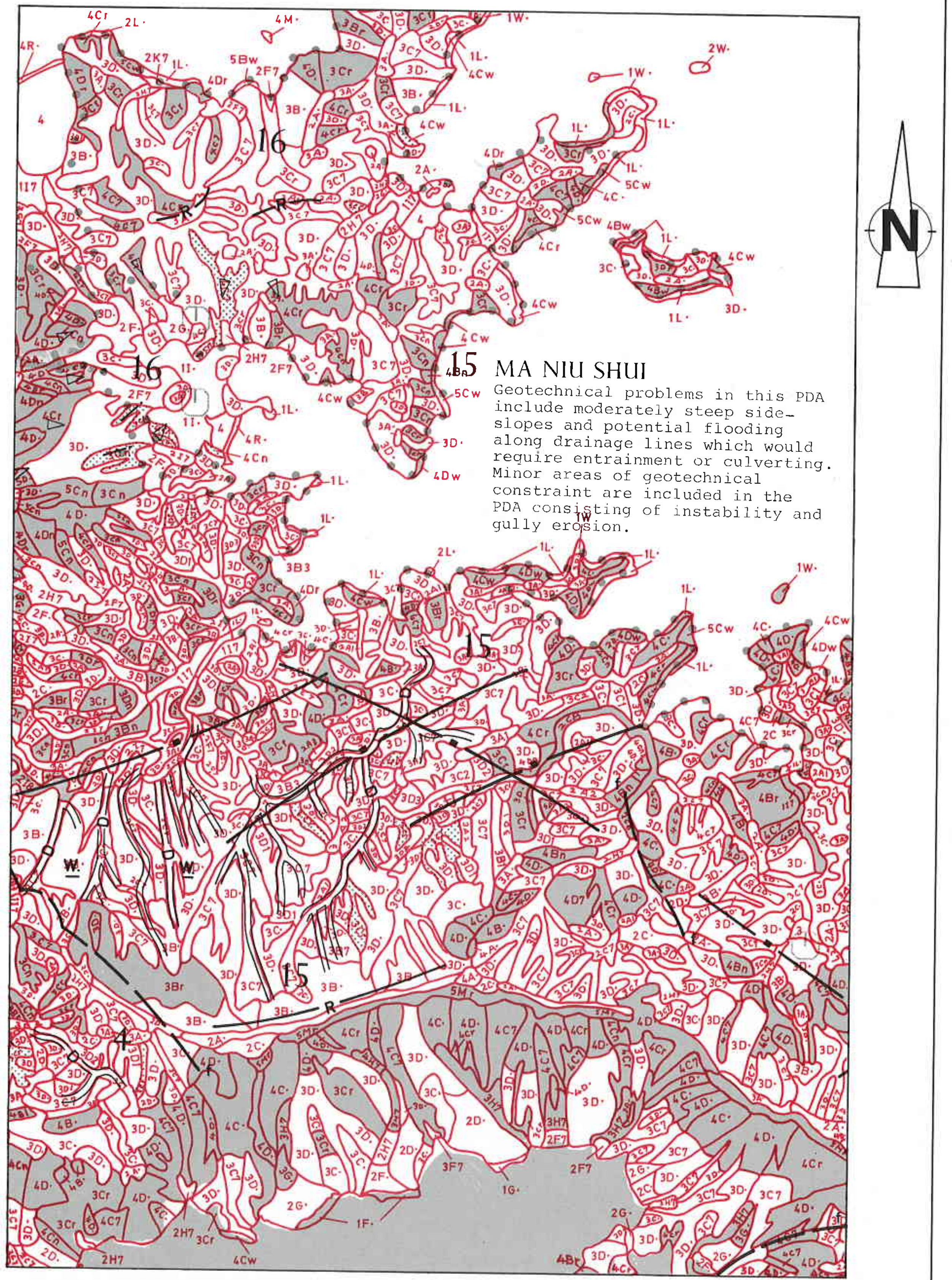
SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

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
- concace	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



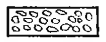
Scale 1:20 000	Example of the Generalised Limitations and Engineering Appraisal Map (GLEAM)	Fig. 18a



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

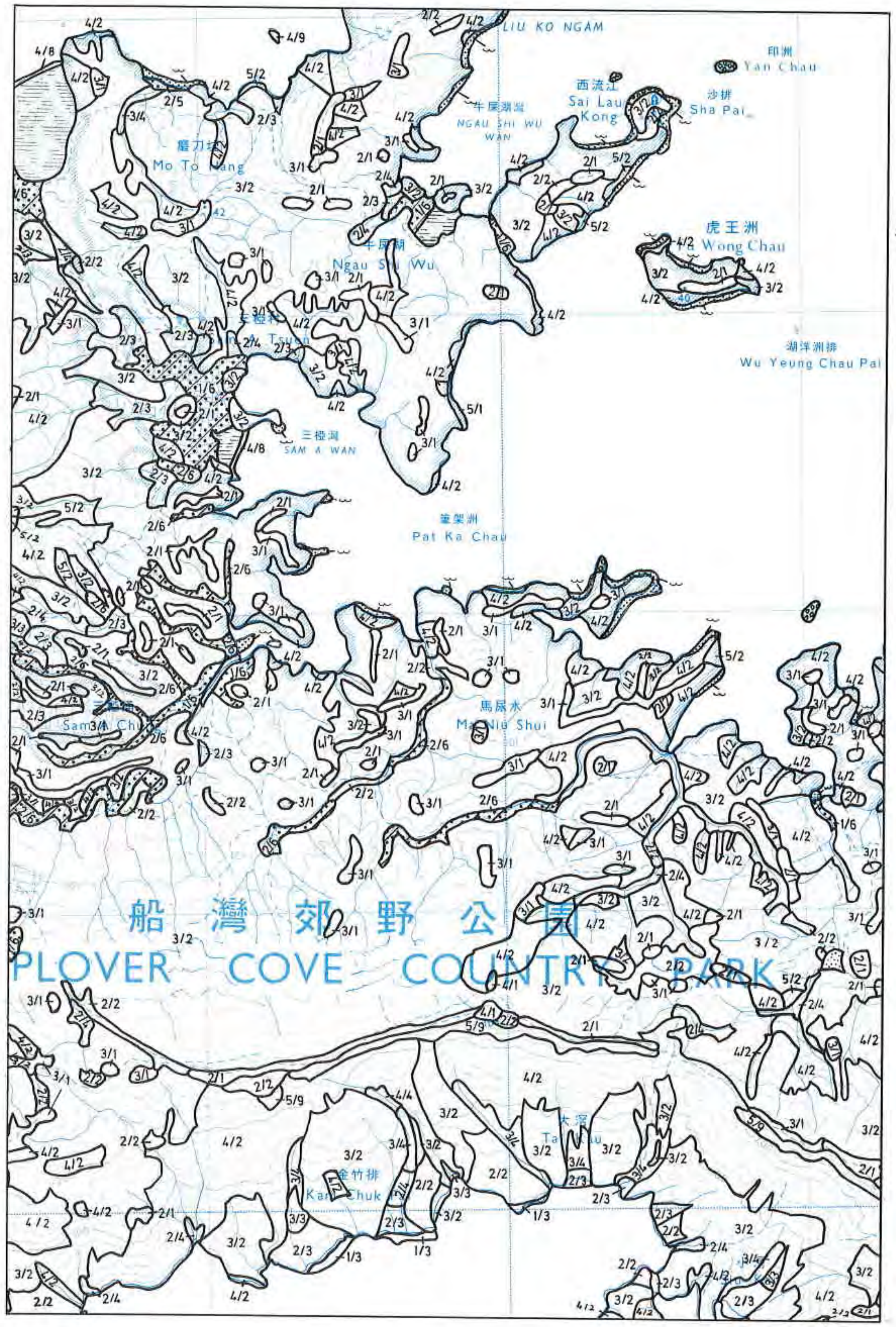
DESCRIPTION	CODE
Crest or ridge	1
Sideslope - insitu	2
Footslope - colluvium	3
Drainage plain - colluvium subject to overland flow and regular inundation. Unusual groundwater regime.	4
Alluvial plain - includes raised terraces.	 5
Flood plain - portion of alluvial plain subject to overland flow and regular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

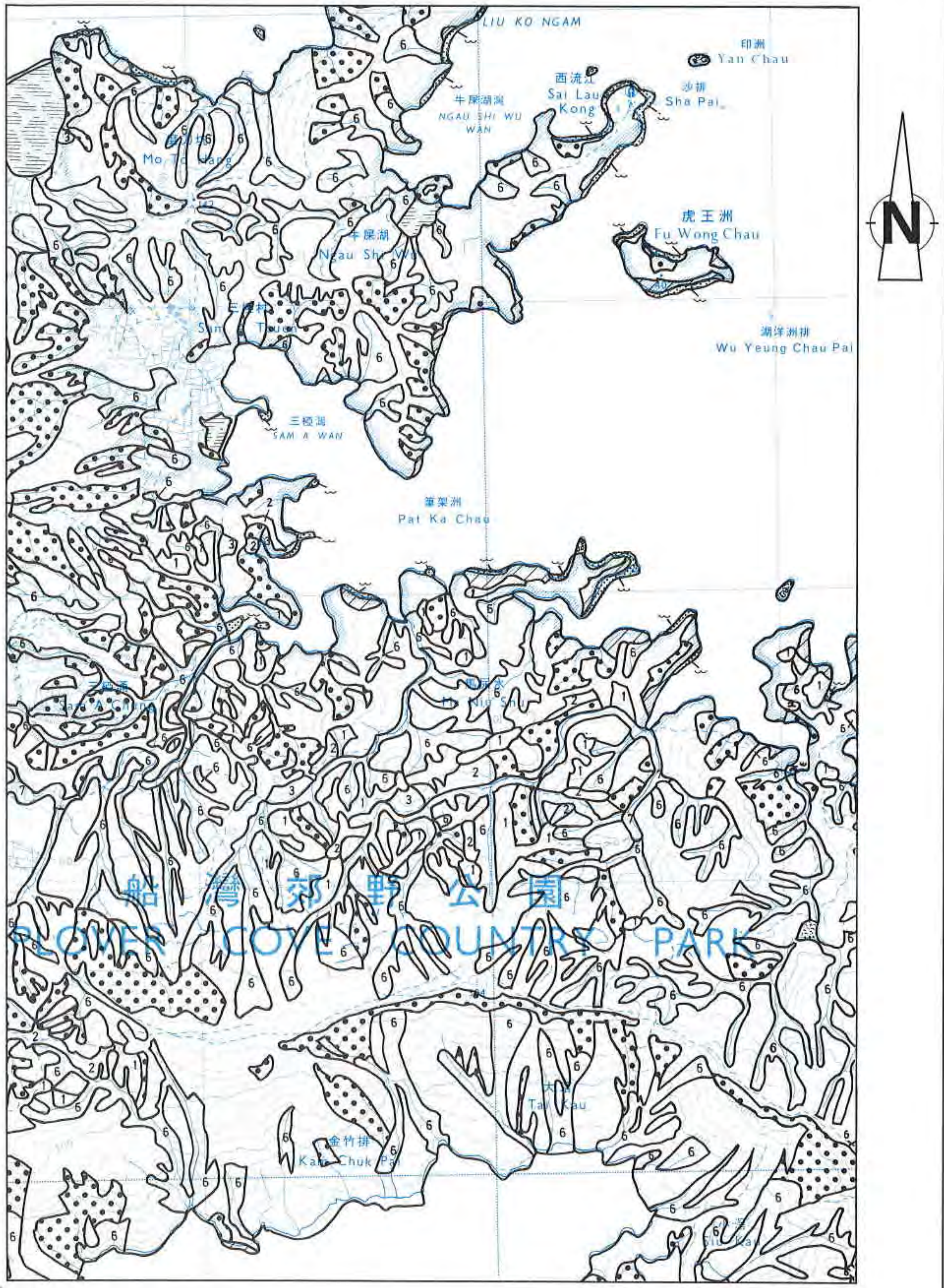
	No appreciable erosion
1	Minor sheet erosion
2	Moderate sheet erosion
3	Severe sheet erosion
4	Minor rill erosion
5	Moderate to severe rill erosion
6	Minor gully erosion
7	Moderate to severe gully erosion
	Zones of general instability associated with predominantly insitu terrain
	Zones of general instability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

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. 20b)

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

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

EROSION	CODE
No appreciable erosion	.
Sheet erosion-minor	1
-moderate	2
-severe	3
Rill erosion - minor	4
- moderate	5
- severe	6
Gully erosion-minor	7
-moderate	8
-severe	9
Well-defined landslip > 1ha in size	a
General) recent	n
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. Sedimentary Rocks of the Repulse Bay Formation. This outcrop at Lai Chi Chong shows sandstones, cherts and siltstones of volcanogenic origin forming a rhythmnic depositional sequence which has been folded and contorted. (GCO/YP 1984/38–19A).

Plate 2. Coarse-grained Sedimentary Breccias of the Kat O Formation. This outcrop is exposed on Ap Chau and shows large, angular fragments forming an imbricate structure aligned parallel to the pre-depositional topography. The matrix is deep red in colour. Wave action has preferentially eroded the base of the cliff, resulting in a natural sea arch. (GCO/TP 1984/39–14).

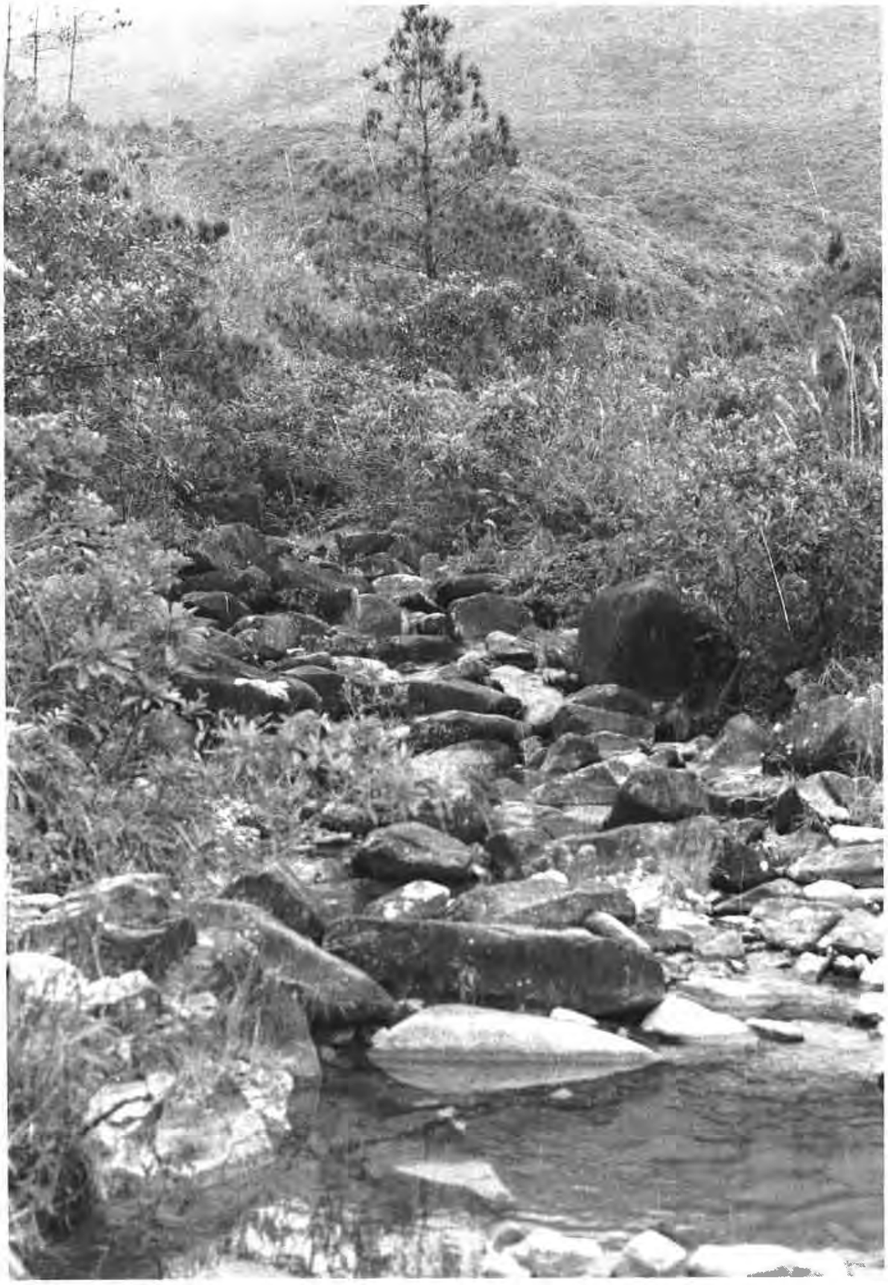


Plate 3. Volcanic Colluvium in Drainage Lines. Large boulders of volcanic origin form a linear deposit in this drainge line in the Lai Chi Chong valley. (GCO/TP 1984/38–30A)

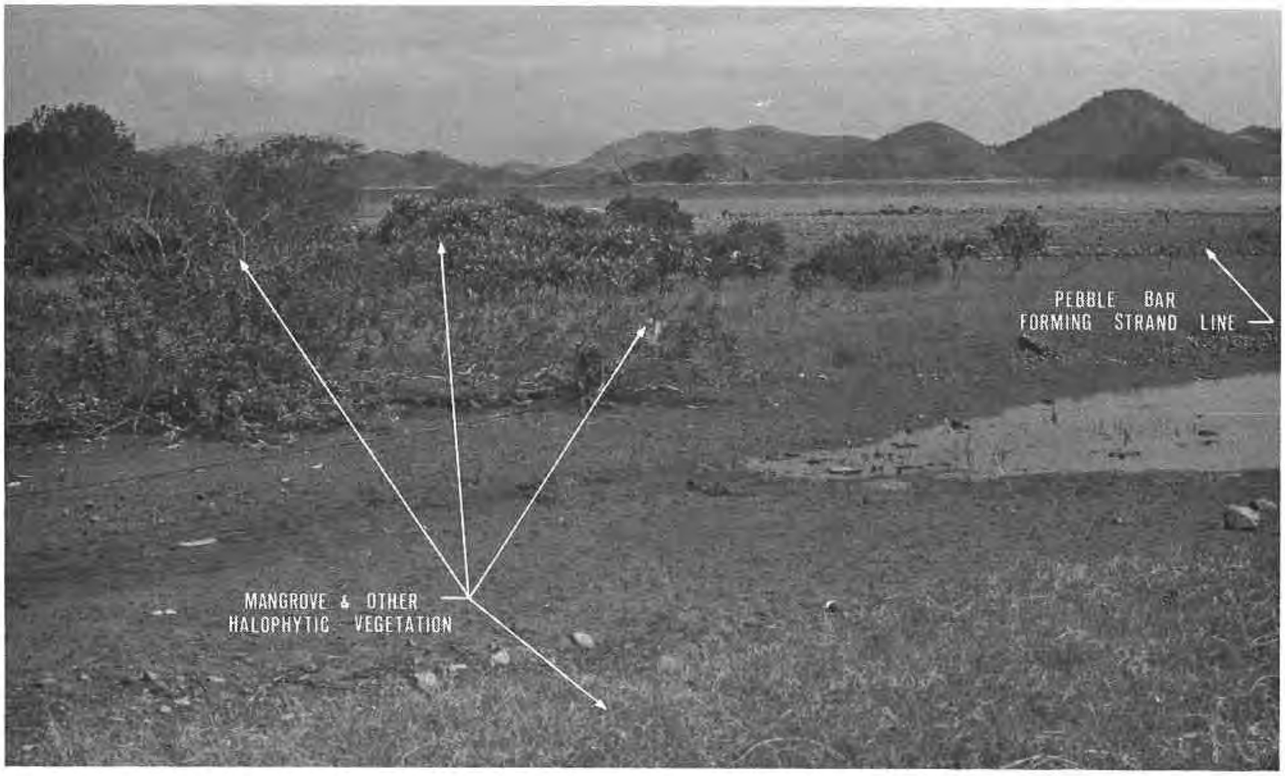


Plate 4. Littoral Deposits at Lai Chi Wo. These deposits vary from fine sand to gravels. The intertidal fringe of this sheltered coastal area is colonised by mangrove-type vegetation. The island of Kat O Chau is in the background. (GCO/TP 1984/37–3A).

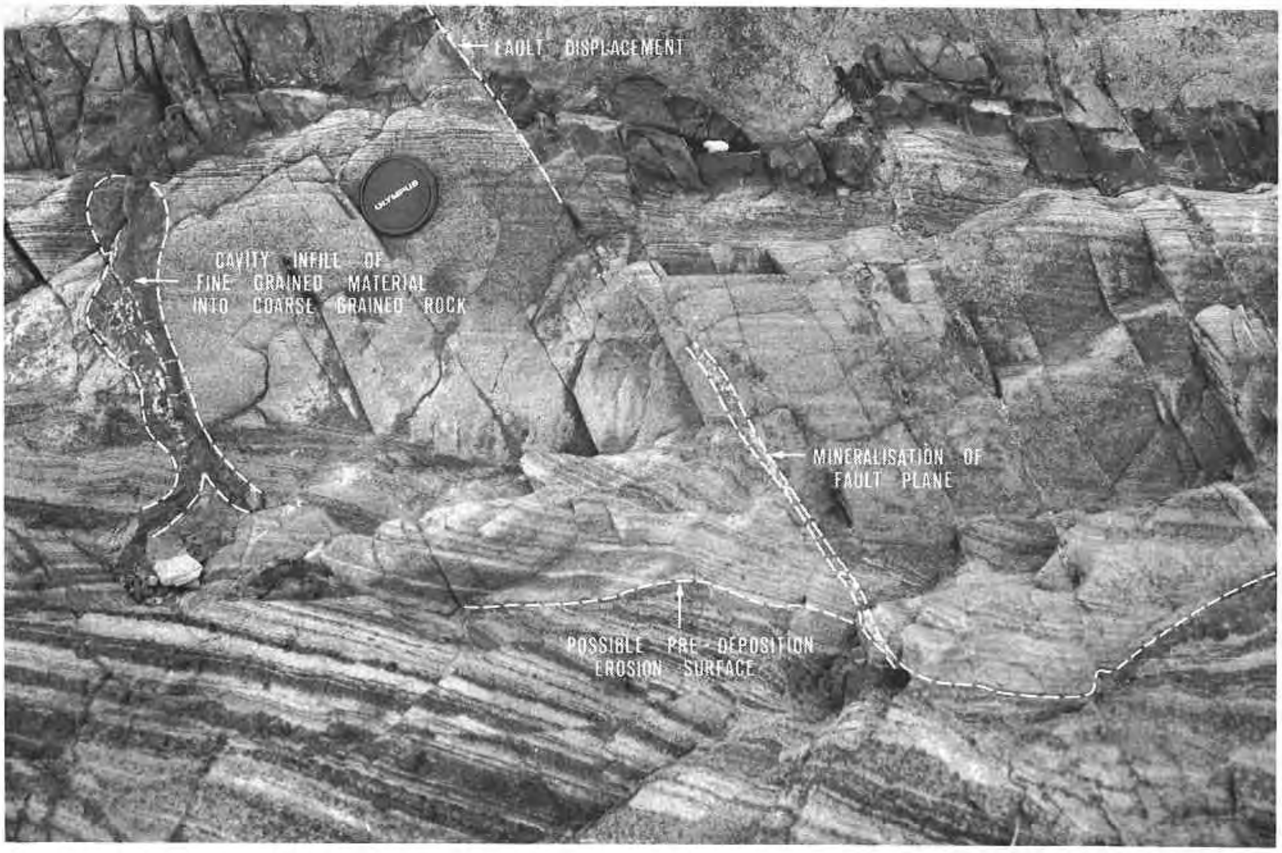


Plate 5. Intensely Cleaved and Sheared Rocks of the Repulse Bay Formation. The rocks in the lower centre part of the photograph are partially foliated in places. (GCO/TP 1984/38–15A).

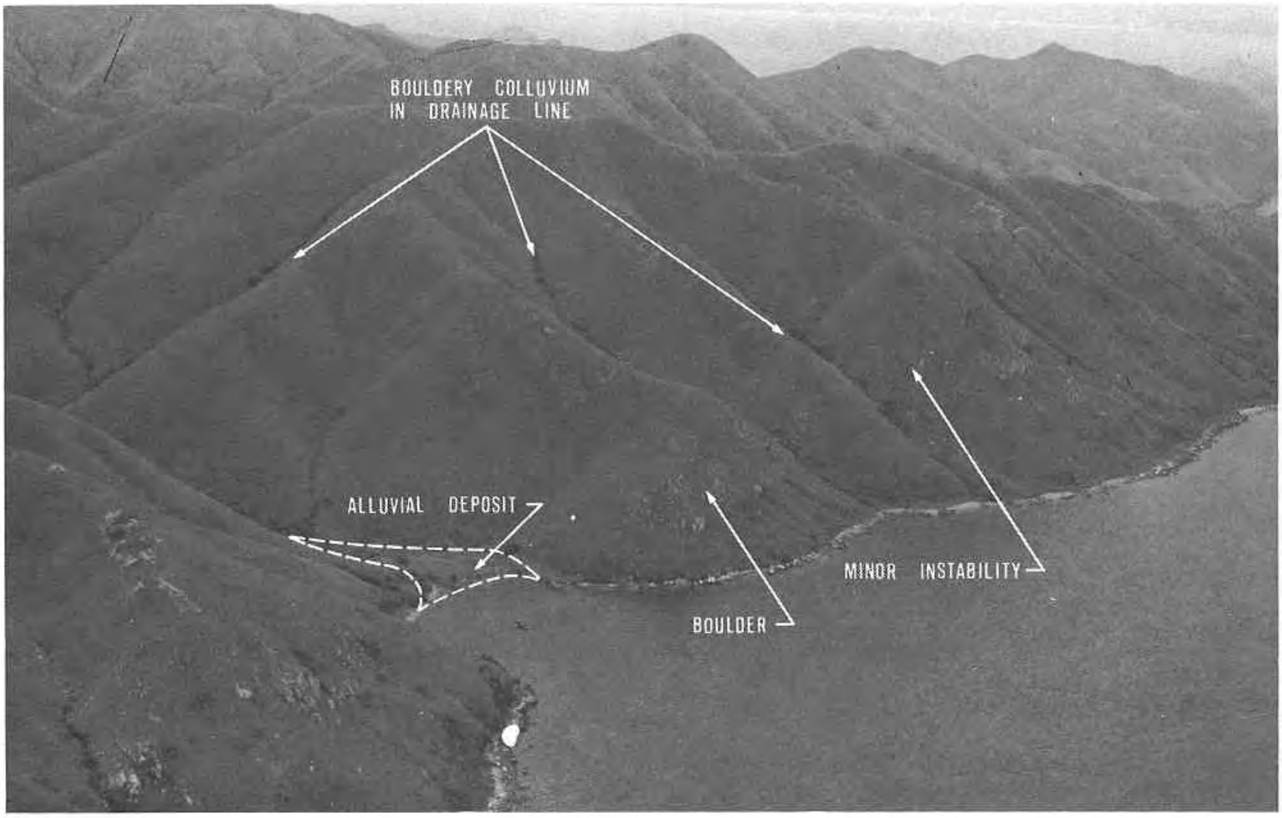


Plate 6. Sub-parallel Spurlines Joining a Central Ridge on the Northern Shore of the Bluff Head Peninsula. (GCO/OAP 1982/7875).

Plate 7. Repulse Bay Formation Coarse Tuffs Eroding to Form a Large Boulder Field. The boulders are perched on ridgelines or move downslope to form colluvial fans or deposits along the shoreline. (GCO/OAP 1982/7328).

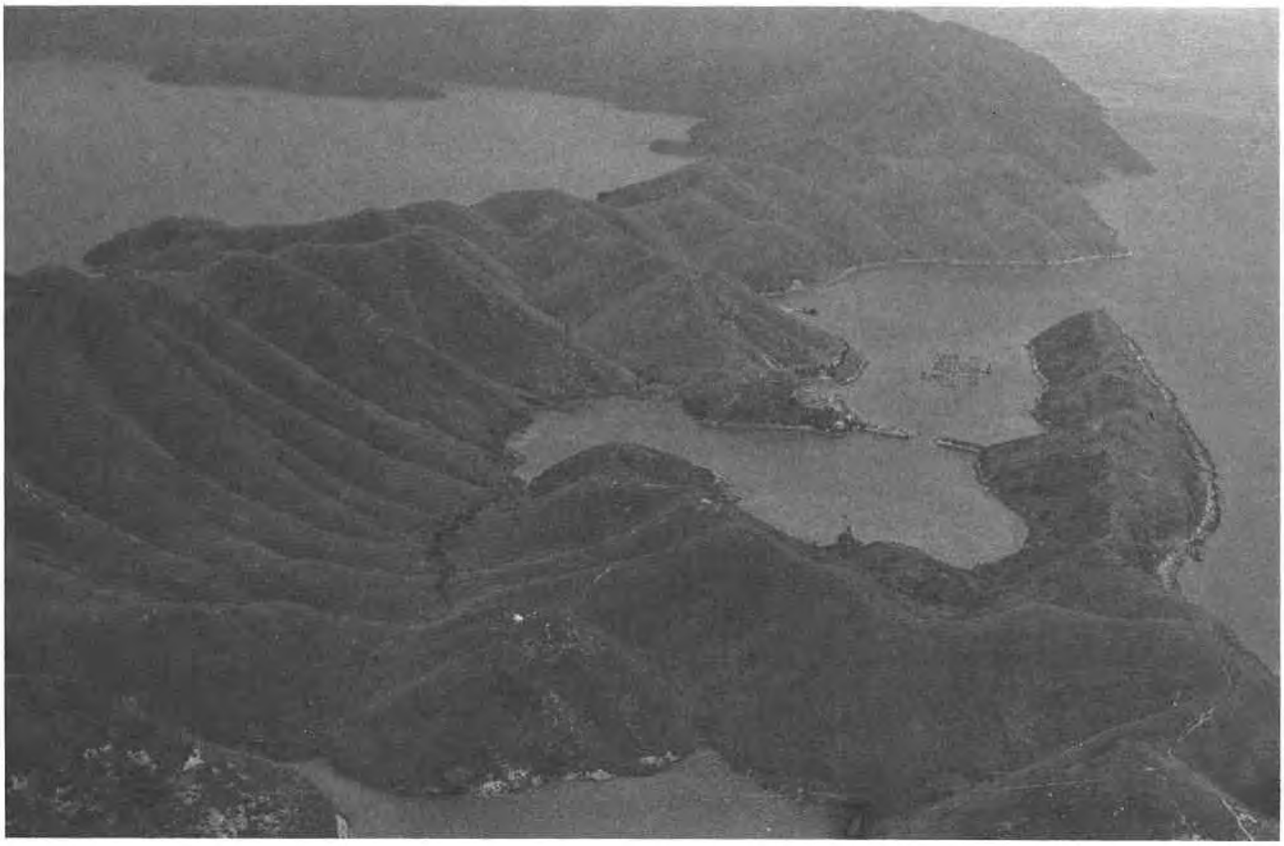


Plate 8. Ria Coastline with Drowned Valleys and Streams with Short Reaches. The ria coastline typically contains long bays separated from the seas by parallel ridges. (GCO/TP 1984/43–23).

Plate 9. Aerial View of Ping Chau. The steep sea cliff and wave cut platform are in the foreground with flat and rounded topography of the island in the background. (GCO/OAP 1984/8086).

Plate 10. Wave cut Platform at Ping Chau. The fine-grained sedimentary rocks dip inland and strike parallel to the coast producing a stepped wave cut platform. (GCO/TP 1984/36–23).

Plate 11. Coastal Instability on the East Coast of Tap Mun Island. Toppling failure of the Repulse Bay Formation Coarse Tuffs is evident on the steep coastal terrain shown in the lower left-hand side of the plate. (GCO/TP 1984/43–37).

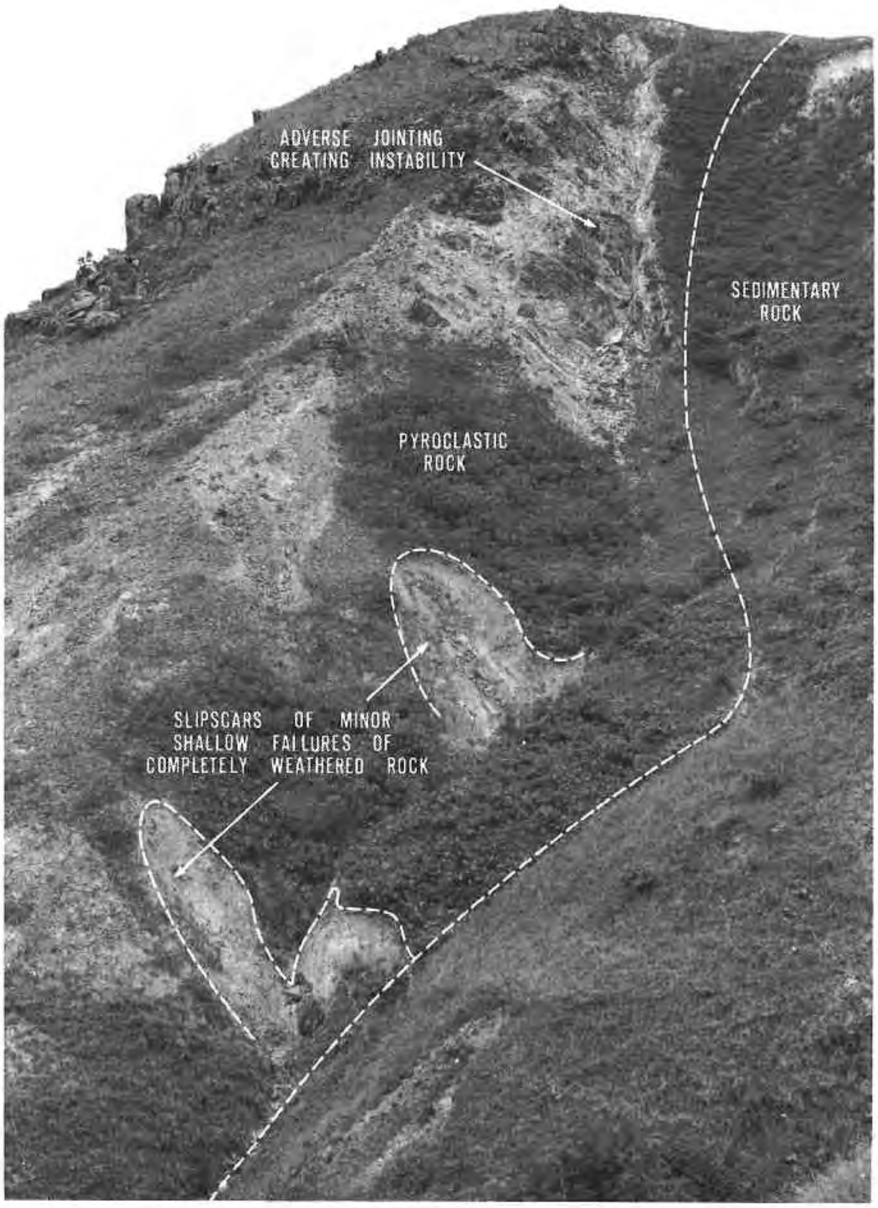


Plate 12. Multiple Landslips Resulting from Headward Erosion and Joint Control of Bedrock. The drainage line separates pyroclastic rocks from the sedimentary rocks of the Repulse Bay Formation, the pyroclastic rocks are on the left. (GCO/TP 1984/38–28A).

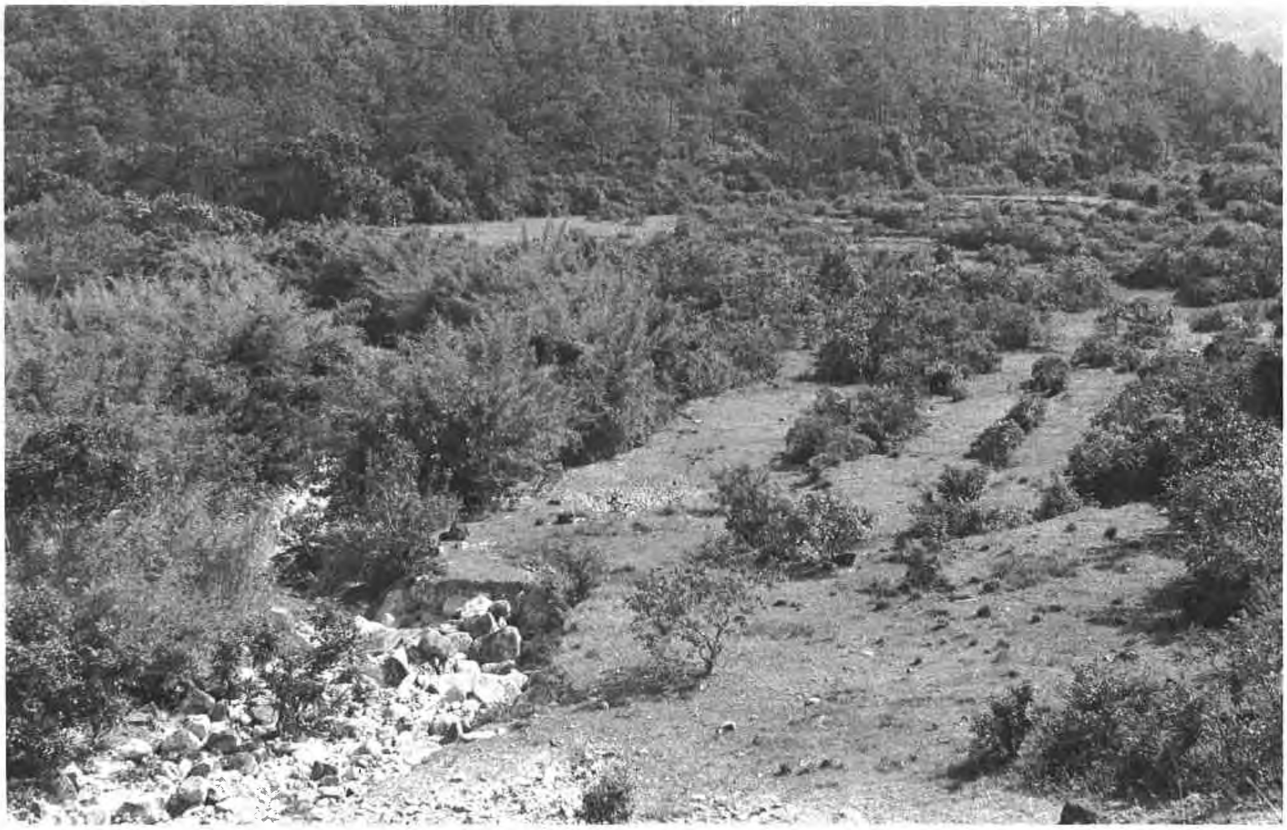


Plate 13. Upland Alluvial Terrace. This alluvial terrace occurs in the upper reaches of a river above a nick point. The stream enters the sea at Tai Tan. The alluvial deposits comprise a wide range of grain sizes from sand to large cobbles. (GCO/TP 1984/40–26).

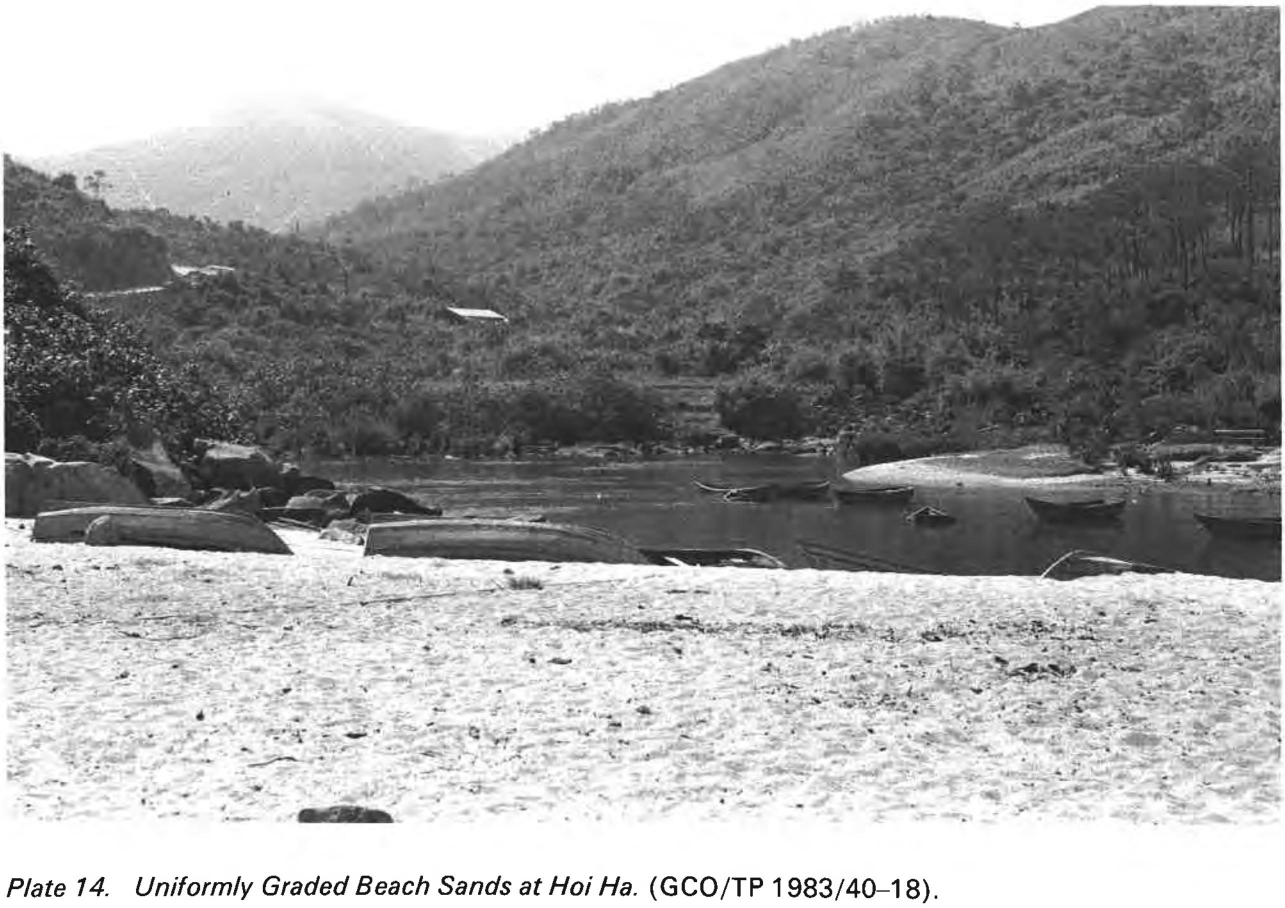


Plate 14. Uniformly Graded Beach Sands at Hoi Ha. (GCO/TP 1983/40–18).

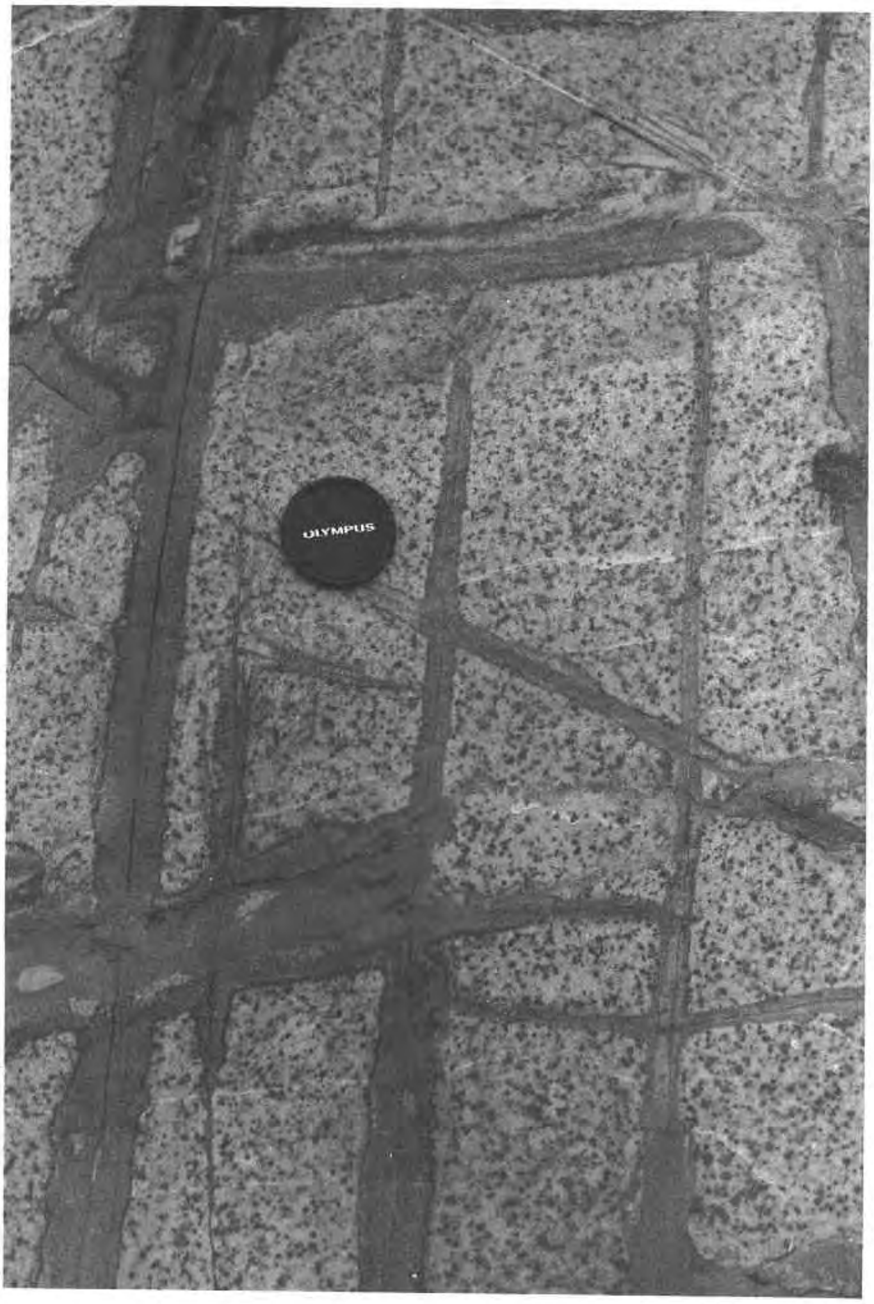


Plate 15. Jointing in Rocks of the Repulse Bay Formation. Preferential weathering has occurred along planes of weakness formed by the intersecting joints. The joint spacing is classified as moderately narrow (20 to 60 mm). (GCO/TP 1984/41–12).

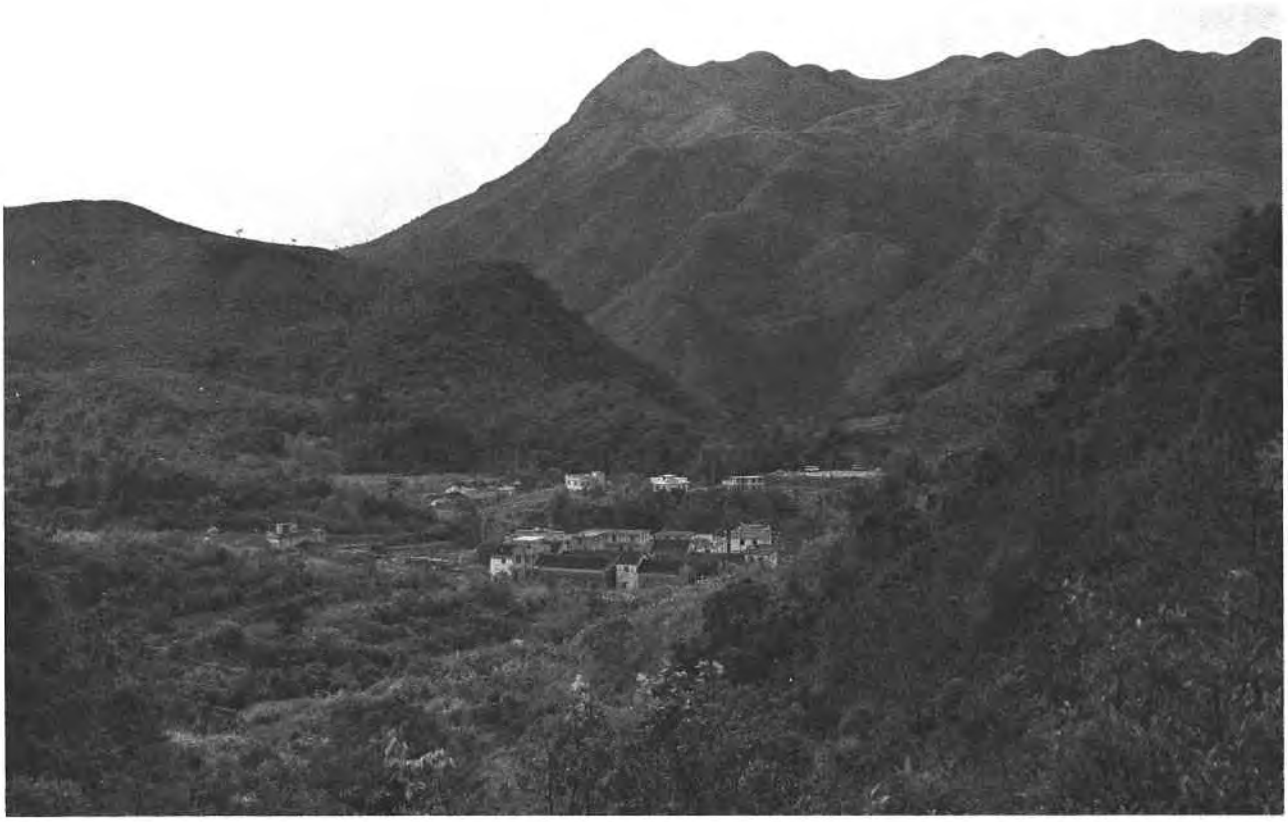


Plate 16. Alluvial Valley of Wu Kau Tang. This valley forms a part of Potential Development Area No. 3. (GCO/TP 1984/42–40).

Plate 17. Elevated View of the Lai Chi Chong Valley. This area forms part of Potential Development Area No. 6. (GCO/TP 1984/30–26A).

Plate 18. Pak Sha O Valley. This area forms part of Potential Development Area No. 8. (GCO/TP 1983/40–25).

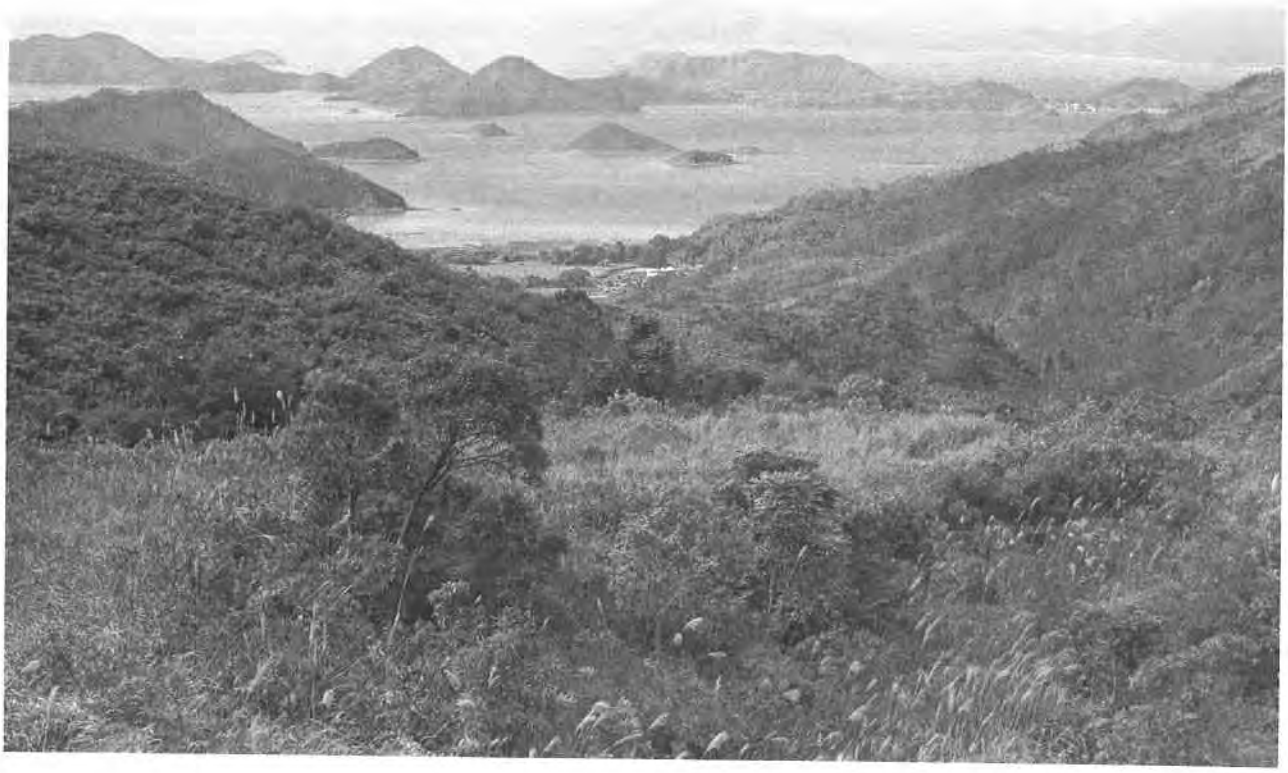


Plate 19. Lai Chi Wo Valley. This Valley forms Part of Potential Development Area No. 18. (GCO/TP 1984/42–31).

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.

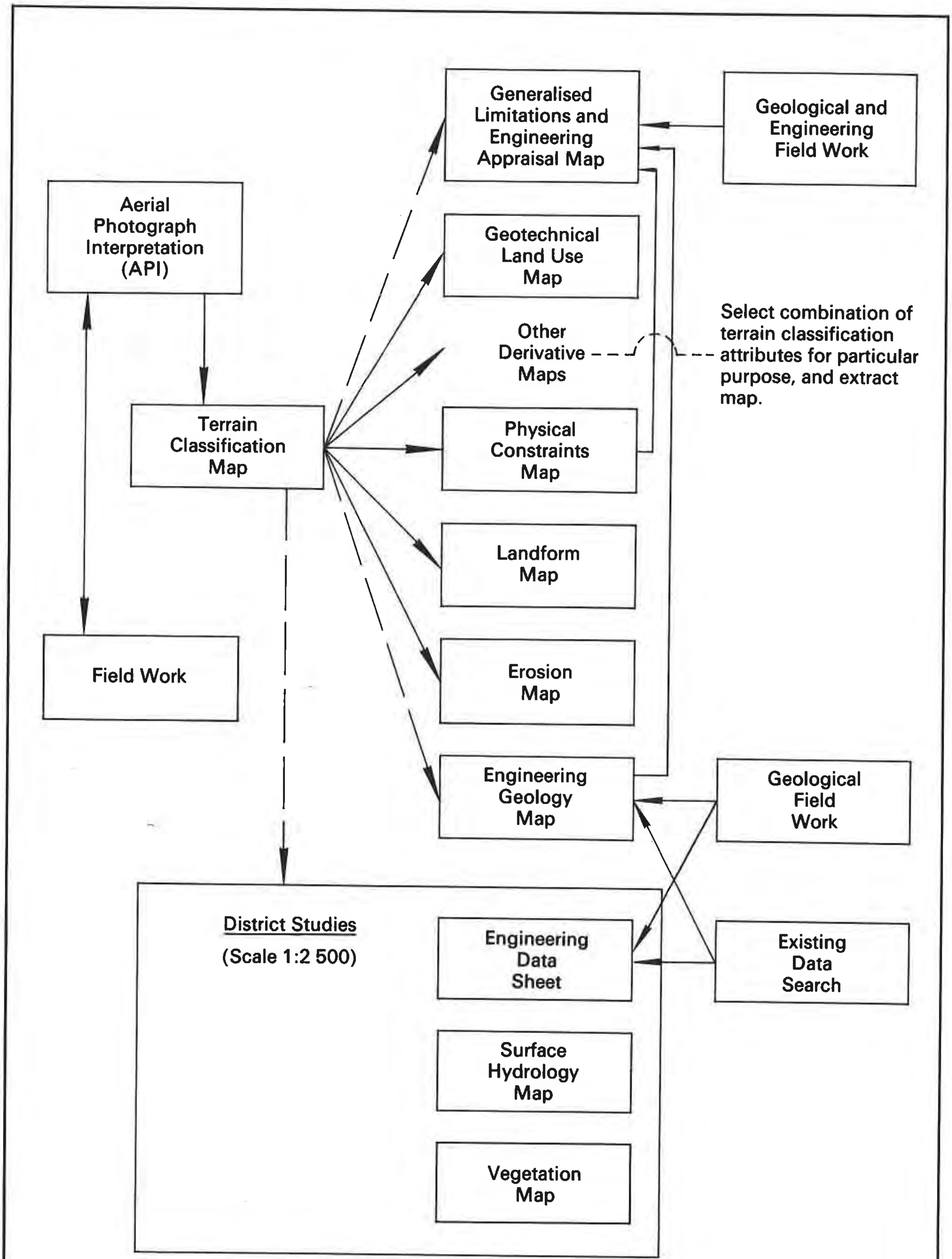
(*c*) Erosion and instability.

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	—relict	r
		—concave	O	Coastal instability	w
		—convex	P		
		Fill —straight	R		
		—concave	S		
		—convex	T		
		General disturbed terrain	V		
		Alluvial plain	X		
		Reclamation	Z		
		Wave cut platform	W		
		Waterbodies:			
		Natural stream	1		
		Man-made channel	2		
		Water storage	3		
		Fish pond	4		

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

A.3.1 *Slope Gradient*

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

A.3.2 *Terrain Component and Morphology*

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

There are 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 cut platforms.

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

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

A.6 Physical Constraints Map

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

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

The major constraints which are shown on the map are:

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

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

(*c*) Colluvium.

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

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

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

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

(*h*) Major waterbodies.

(*i*) Moderate and severe gully erosion.

(*j*) Instability on disturbed terrain.

A.7 Geotechnical Land Use Map

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

Table A2 GLUM Classification System

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

A.8 Engineering Geology Map

A.8.1 *Background*

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

The comments made in this Report with regard to the engineering geology of the 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 sediment derived.

(*d*) Essentially metasediment derived.

(*e*) Mixed origin.

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

A.8.4 *Data Collection*

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

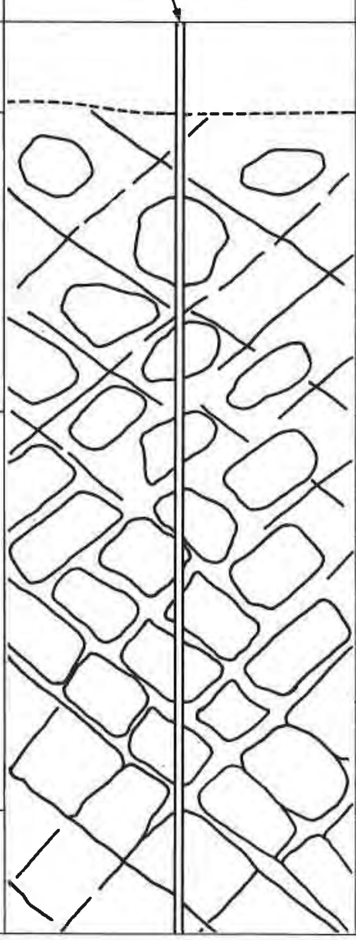
Details of the aerial photographs used for the terrain classification are given in Appendix C.3 and Table C.2.

A.9 Generalised Limitations and Engineering Appraisal Map

A.9.1 *Introduction*

Long-term strategic development planning requires an early and fundamental appreciation of areas suitable for extensive and/or intensive development. Development in the study area has been influenced by the geotechnical constraints associated with the terrain since the start of urban expansion in Hong Kong. With

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	Zone C
Zone D—Material of grades I or II constitutes more than 90% of the mass.		II I	Zone D

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

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

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

the 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.

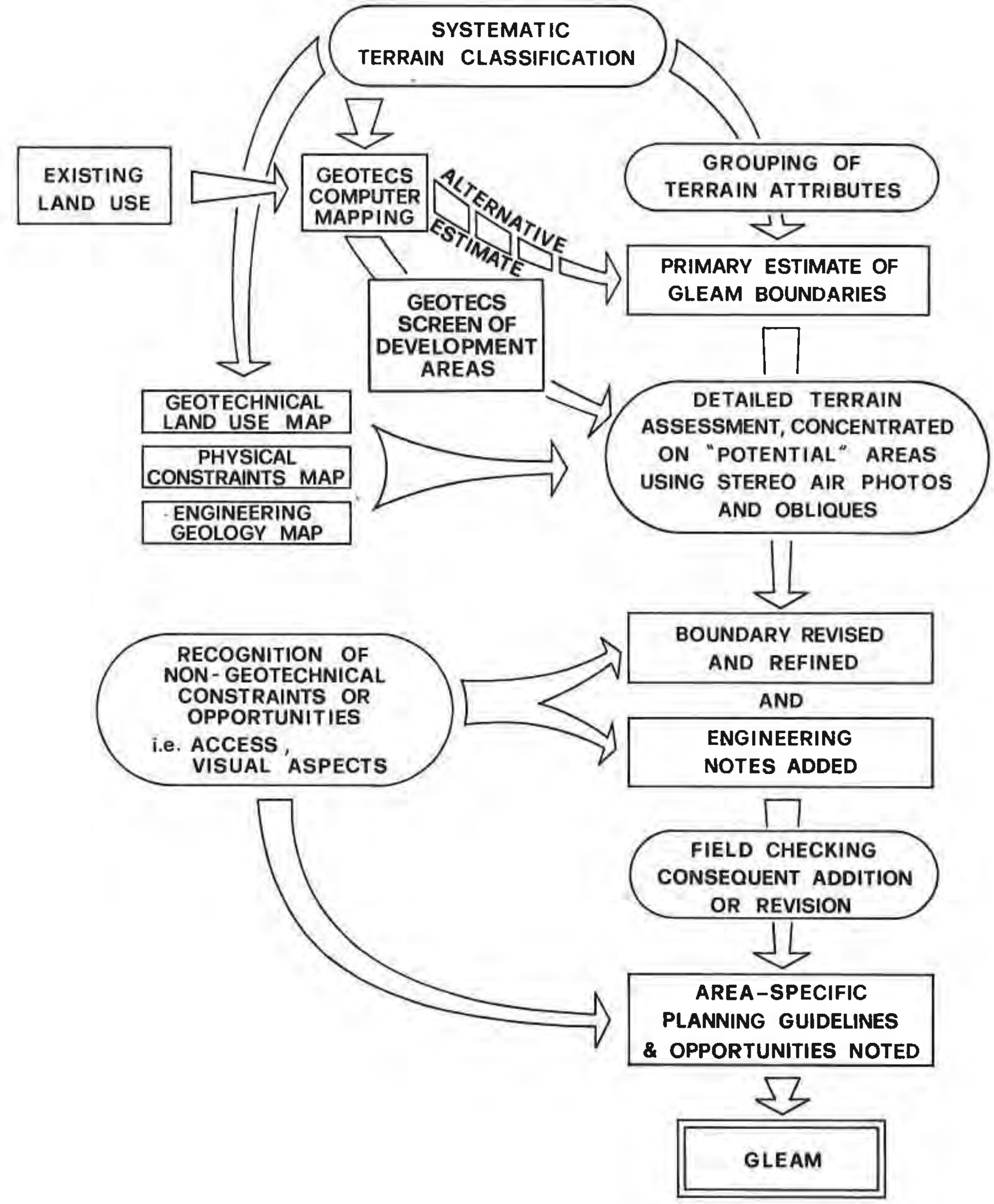
An appreciation of the non-geotechnical considerations of the potential development areas and of the implications of geotechnical suitability on planning considerations enables specific planning opportunities to be highlighted. These factors include the necessity for access across difficult terrain, 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.

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.



Derivation of Generalised Limitations and Engineering Appraisal Map

Fig. A2

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

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

$^{\Delta}$ 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.

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. D & S cont. = Drainage & Structure Control
7. Instability
   - indicated where the natural landform exhibits instability which poses a threat to development unless accommodated.
8. Steep slopes
   - indicated where the presence of a steeper slope would result in extensive cuts or high walls being necessary to produce a platform.
   - tends to restrict site formation possibilities.
9. Lineament
   - identified from aerial photography.
   - indicates a structural weakness or strength through an anomaly in the surface features.
   - lineaments (some) also shown on EGM.
   - further notes on lineaments in 2.

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

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

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

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

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

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

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

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

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

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

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

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

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

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

The terrain classification for this study is part of the small-scale (1:20 000) systematic terrain classification which has been completed for the entire Territory of Hong Kong. The GASP VIII data bank consists of 3 906 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 NORTH EAST NEW TERRITORIES GEOTECHNICAL AREA STUDY

Table B1 Slope Gradient

Slope Gradient	% of Total Area	Area (ha)
0– 5°*	17.6	1 406
5–15°	9.5	757
15–30°	51.3	4 084
30–40°	19.2	1 530
40–60°	2.2	173
>60°	0.2	18
	100.0	7 968

* Approximately 1 195 ha of reservoirs and ponds are included in the 0–5° Class.

Table B2 Erosion and Instability

Erosion		% of Total Area	Area (ha)
Instability			
—well-defined landslips		0.0	0
—coastal instability		2.1	169
—general instability		24.3	1 934
Appreciable Erosion	Sheet erosion—minor	5.2	412
	—moderate to severe	1.1	94
	Rill erosion —minor	<0.1	2
	—moderate to severe	0.0	0
	Gully erosion—minor	14.7	1 173
	—moderate to severe	0.9	73
No Appreciable Erosion*		51.6	4 111
		100.0	7 968

* Approximately 1 195 ha of reservoirs and ponds are included within No Appreciable Erosion.

Table B3 Aspect

Aspect	% of Total Area	Area (ha)
North	15.5	1 234
Northeast	9.1	726
East	10.0	798
Southeast	9.6	763
South	9.3	745
Southwest	7.4	592
West	10.4	830
Northwest	11.0	875
Flat/Unclassified*	17.8	1 405
	100.0	7 968

* Approximately 1 195 ha of 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	145	814	255	20	0	1 234
Northeast	88	459	157	20	2	726
East	131	488	151	25	4	799
Southeast	65	381	267	45	4	762
South	78	422	204	37	4	745
Southwest	59	343	165	22	2	591
West	94	575	161	0	0	830
Northwest	98	602	169	4	2	875
0–5° (Flat/Unclassified)*						1 405
						7 968

Includes 1 195 ha of reservoir and ponds

Table B5 Landform

Terrain (Landform)	Slope Gradient	% of Total Area	Area (ha)
Hillcrest		2.7	215
Sideslope	0– 5°	0.4	37
"	5–15°	3.8	304
"	15–30°	48.4	3 854
"	30–40°	18.9	1 503
"	>40°	1.6	129
Cliff/Rock outcrop	0–30°	0	0
"	>30°	0.7	55
Footslope (colluvium)		0	0
"	5–15°	0.9	75
"	15–30°	0.8	65
"	>30°	0.1	6
Drainage plain (colluvium)	0– 5°	0	0
"	5–15°	1.6	124
"	15–30°	1.1	86
"	>30°	<0.1	2
Alluvial plain	0– 5°	0.2	16
"	>5°	0.1	6
Floodplain	0– 5°	1.4	108
"	>5°	1.4	114
Littoral zone	0–15°	0.4	33
Cut platforms : insitu	0– 5°	<0.1	4
: colluvium	0– 5°	0	0
: alluvium	0– 5°	0	0
Cut slopes : insitu	>5°	<0.1	4
: colluvium	>5°	0	0
: alluvium	>5°	0	0
Fill platforms : insitu	0– 5°	<0.1	2
: colluvium	0– 5°	0	0
: alluvium	0– 5°	0	0
Fill slopes : insitu	>5°	0.2	16
: colluvium	>5°	0.1	8
: alluvium	>5°	0	0
Reclamation	0–30°	<0.1	4
Wave cut platform	<15°	<0.1	4
General disturbed terrain/platforms: insitu	0– 5°	<0.1	4
General distrubed terrain/slope: insitu	>5°	<0.1	2
: colluvium	>5°	0	0
: alluvium	>5°	0	0
Natural stream		0	0
Man-made channel		0	0
Water storage		14.8	1 777
Pond		0.2	18
		100.0	7 968

Table B6 Geology

Geological Unit	% of Total Area	Area (ha)
Alluvium: undifferentiated	18.0	1 436
: raised	<0.1	2
Colluvium: volcanic	3.3	263
: granitic	0	0
: sedimentary	1.2	96
: mixed	0	0
Littoral deposits	0.4	33
Reclamation	<0.1	4
Fill	0.4	32
Repulse Bay Formation: undifferentiated volcanics	1.7	135
: sedimentary rocks and waterlaid volcanics	4.6	365
: acid lavas	2.2	173
: mainly banded acid lavas, some welded tuffs	0	0
: coarse tuff	22.1	1 765
: agglomerate	0	0
: dominantly pyroclastics and some lavas	23.1	1 844
Kat O Formation	0.1	6
Port Island Formation	14.2	1 134
Bluff Head Formation	8.0	639
Tolo Harbour Formation	<0.1	4
Tolo Channel Formation	<0.1	0
Tai Po Granodiorite	<0.1	0
Unknown Bedrock	0.5	37
	100.0	7 968

Table B7 Vegetation

Vegetation	% of Total Area	Area (ha)
Grassland	21.5	1 716
Cultivation	3.4	271
Mixed broadleaf woodland	18.5	1 477
Shrubland (<50%)	23.5	1 873
Shrubland (>50%)	15.4	1 230
No vegetation on natural terrain	0.8	64
No vegetation due to disturbance of terrain by man	1.1	87
No vegetation due to rock outcrop	0.7	55
Zoological and botanical gardens	0	0
Waterbodies	15.1	1 195
	100.0	7 968

Table B8 Geology and GLUM Class

Geological Unit	Area in GLUM Class (ha)				
	I	II	III	IV	Unclassified
Alluvium: undifferentiated	0	222	16	0	1 198
: raised	0	2	0	0	0
Colluvium: volcanic	0	0	173	90	0
: granitic	0	0	0	0	0
: sedimentary	0	0	84	12	0
: mixed	0	51	292	51	0
Littoral deposits	0	0	0	0	33
Reclamation	0	4	0	0	0
Fill	0	12	0	2	0
Repulse Bay Formation: undifferentiated volcanics	2	51	53	29	0
: sedimentary rocks and water-laid volcanics	110	116	78	58	4
: acid lavas	8	53	51	61	0
: mainly banded acid lavas, some welded tuffs	0	0	0	0	0
: coarse tuffs	116	959	582	108	0
: agglomerate	4	69	61	21	0
: dominantly pyroclastics and some lavas	43	772	632	298	0
Kat O Formation	0	0	0	6	0
Port Island Formation	39	649	304	141	2
Bluff Head Formation	8	277	220	132	0
Tolo Harbour Formation	0	0	4	0	0
Tolo Channel Formation	0	0	0	0	0
Unknown bedrock	2	12	8	14	0
	328	3 129	2 211	1 063	1 237

Note: Tolo Channel Formation and Tai Po Granodiorite do not constitute mappable units.

Table B9 GLUM Class

GLUM Class	Geotechnical Limitations	% of Total Area	Area (ha)
I	Low	4.1	328
II	Moderate	36.7	2 927
IIS	Moderate	2.5	202
III	High	27.8	2 211
IV	Extreme	13.5	1 063
Unclassified		15.6	1 237
		100.0	7 968

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

Slope Gradient	Aspect	Surface* Geology	No Appreciable Erosion (ha)	Appreciable Erosion (ha) Sheet	Rill	Gully	Instability (ha) WDL*	GI*	Area (ha)	Area Instability Index
0–5°	Flat	V	41	0	0	0	0	0	41	0
		G	0	0	0	0	0	0	0	0
		S	2	0	0	0	0	0	2	0
		C	0	0	0	0	0	0	0	0
		A	1 246	0	0	71	0	0	1 317	0
		L	31	0	0	0	0	0	31	0
		F	6	8	0	0	0	0	14	0
5–15°	N	V	49	12	0	6	0	0	67	0
		G	0	0	0	0	0	0	0	0
		S	2	8	0	6	0	0	16	0
		C	0	4	0	37	0	0	41	0
		A	2	0	0	18	0	0	20	0
		F	0	0	0	0	0	0	0	0
	NE	V	24	0	0	6	0	0	30	0
		G	0	0	0	0	0	0	0	0
		S	6	4	0	10	0	0	20	0
		C	0	0	0	16	0	2	18	0.11
		A	6	0	0	10	0	0	16	0
		F	0	0	0	0	0	0	2	0
		U	2	0	0	0	0	0	0	0
	E	V	43	16	0	6	0	0	65	0
		G	0	0	0	0	0	0	0	0
		S	8	4	0	4	0	0	16	0
		C	12	0	0	20	0	0	32	0
		A	4	0	0	10	0	0	14	0
		F	0	2	0	0	0	0	2	0
	SE	V	18	2	0	4	0	0	24	0
		G	0	0	0	0	0	0	0	0
		S	6	0	0	0	0	0	6	0
		C	2	0	0	16	0	0	18	0
		A	0	0	0	16	0	0	16	0
		F	0	0	0	0	0	0	0	0
	S	V	16	2	0	0	0	0	18	0
		G	0	0	0	0	0	0	0	0
		S	2	6	0	0	0	0	8	0
		C	12	0	0	27	0	0	39	0
		A	0	0	0	8	0	0	8	0
		F	0	0	0	0	0	0	0	0
		U	2	0	0	0	0	0	2	0
	SW	V	22	4	0	0	0	0	26	0
		G	0	0	0	0	0	0	0	0
		S	2	0	0	0	0	0	2	0
		C	6	0	0	14	0	0	20	0
		A	0	0	0	10	0	0	10	0
		F	0	0	0	0	0	0	0	0
	W	V	35	12	0	2	0	0	49	0
		G	0	0	0	0	0	0	0	0
		S	12	2	0	0	0	0	14	0
		C	12	0	0	8	0	0	20	0
		A	2	0	0	8	0	0	10	0
		F	0	0	0	0	0	0	0	0
	NW	V	33	10	0	12	0	0	55	0
		G	0	0	0	0	0	0	0	0
		S	6	2	0	0	0	0	8	0
		C	0	0	0	10	0	0	10	0
		A	8	0	0	12	0	0	20	0
		F	0	2	0	0	0	0	2	0
		U	2	0	0	0	0	0	2	0
15–30°	N	V	233	16	0	51	2	180	482	0.38
		G	0	0	0	0	0	0	0	0
		S	165	16	0	63	0	53	297	0.18
		C	4	0	0	29	0	0	33	0
		F	0	0	0	0	0	0	0	0
		U	2	0	0	0	0	0	2	0
	NE	V	135	12	0	31	2	137	317	0.44
		G	0	0	0	0	0	0	0	0
		S	55	8	0	27	0	27	117	0.23
		C	2	0	0	20	0	2	24	0.08
		U	2	0	0	0	0	0	2	0
	E	V	145	35	0	53	4	129	366	0.36
		G	0	0	0	0	0	0	0	0
		S	61	10	0	16	0	18	656	0.03
		C	0	0	0	10	0	4	14	0.29
		F	0	0	0	0	0	0	0	0
		U	2	0	0	0	0	0	2	0
	SE	V	96	57	0	37	2	94	266	0.36
		G	0	0	0	0	0	0	0	0
		S	47	14	0	8	0	14	83	0.17
		C	8	2	0	20	0	2	32	0.06
		F	0	0	0	0	0	0	0	0
	S	V	122	24	0	53	2	67	268	0.26
		G	0	0	0	0	0	0	0	0
		S	63	24	0	10	0	31	128	0.24
		C	2	0	0	20	0	0	22	0
		F	2	0	0	0	0	0	2	0
	SW	V	110	35	0	51	0	63	259	0.24
		G	0	0	0	0	0	0	0	0
		S	31	10	0	14	0	16	71	0.23
		C	2	0	0	8	0	2	12	0.17
		F	0	0	0	0	0	0	0	0
	W	V	200	65	0	69	0	131	465	0.28
		G	0	0	0	0	0	0	0	0
		S	59	12	0	18	0	10	99	0.10
		C	2	0	0	8	0	0	10	0
		F	0	0	0	0	0	0	0	0
	NW	V	180	35	0	65	0	147	427	0.34
		G	0	0	0	0	0	0	0	0
		S	106	16	0	29	0	16	167	0.10
		C	2	0	0	4	0	0	6	0
		F	0	0	0	0	0	0	0	0
		U	2	0	0	0	0	0	2	0

* For legend see Table B10 (Continued) on page 105.

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

Slope Gradient	Aspect	Surface Geology	No Appreciable Erosion (ha)	Appreciable Erosion (ha)			Instability (ha)		Area (ha)	Area Instability Index
				Sheet	Rill	Gully	WDL	GI		
30–40°	N	V	53	0	0	18	4	94	169	0.58
		G	0	0	0	0	0	0	0	0
		S	31	0	0	16	6	31	84	0.44
		C	0	0	0	2	0	0	0	0
	NE	V	35	2	0	4	8	55	104	0.61
		G	0	0	0	0	0	0	0	0
		S	14	0	0	12	0	24	50	0.48
		C	0	0	0	0	0	0	0	0
		U	2	0	0	0	0	0	2	0
	E	V	20	2	0	2	18	65	107	0.78
		G	0	0	0	0	0	0	0	0
		S	20	0	0	2	4	12	38	0.42
		C	0	0	0	0	0	0	0	0
		U	2	0	0	0	2	0	4	0.50
	SE	V	43	2	0	0	12	88	145	0.69
		G	0	0	0	0	0	0	0	0
		S	43	4	0	18	8	45	118	0.45
		C	2	0	0	0	0	0	2	0
		U	0	0	0	2	0	0	2	0
		F	2	0	0	0	0	0	2	0
	S	V	37	0	0	27	2	47	113	0.43
		G	0	0	0	0	0	0	0	0
		S	43	4	0	12	2	29	90	0.34
		C	0	0	0	0	0	0	0	0
		U	0	0	0	0	2	0	2	0
	SW	V	53	2	0	12	0	51	118	0.43
		G	0	0	0	0	0	0	0	0
		S	18	6	0	0	2	8	34	0.29
		C	0	0	0	0	0	4	4	1.00
		U	2	0	0	0	4	0	6	0.29
		F	12	0	2	0	0	0	14	0
	W	V	37	6	0	4	2	57	106	0.56
		G	0	0	0	0	0	0	0	0
		S	33	0	0	6	0	14	53	0.26
		C	0	0	0	0	0	0	0	0
		U	0	0	0	0	2	0	2	0
	NW	V	26	0	0	10	0	71	107	0.66
		G	0	0	0	0	0	0	0	0
		S	37	0	0	4	0	18	59	0.31
		C	0	0	0	0	0	0	0	0
>40°	N	V	0	0	0	0	4	8	12	1.00
		G	0	0	0	0	0	0	0	0
		S	0	0	0	0	4	4	8	1.00
	NE	V	2	0	0	2	4	2	10	0.80
		G	0	0	0	0	0	0	0	0
		S	0	0	0	2	6	4	12	0.83
	E	V	0	0	0	0	10	8	18	1.00
		G	0	0	0	0	0	0	0	0
		S	2	0	0	0	6	2	10	0.80
	SE	V	0	0	0	0	2	6	8	1.00
		G	0	0	0	0	0	0	0	0
		S	4	0	0	2	20	10	36	0.83
		U	2	0	0	0	2	0	2	1.00
	S	V	2	2	0	0	6	16	26	0.85
		G	0	0	0	0	0	0	0	0
		S	4	0	0	0	6	2	12	0.67
		U	0	0	0	0	2	0	2	1.00
	SW	V	2	0	0	0	0	6	8	0.88
		G	0	0	0	0	0	0	0	0
		S	0	0	0	0	2	2	4	1.00
	W	V	0	0	0	0	0	0	0	0
		G	0	0	0	0	0	0	0	0
		S	0	0	0	0	0	0	0	0
	NW	V	2	0	0	0	0	0	2	0
		G	0	0	0	0	0	0	0	0
		S	0	0	0	0	0	4	4	1.00

Note: V=volcanic rocks G=granitic rocks F=fill and reclamation
A=alluvium C=colluvium S=sedimentary rocks
WDL=well defined landslips and coastal instability U=unknown rocks
GI=general instability

Table B11 Geology, Erosion and Instability

Geological Unit	No Apprecia-able Erosion (ha)	Appreciable Erosion (ha)			Instability (ha)		Total Area (ha)	Area Instability Index
		Sheet	Rill	Gully	Coastal Instability	General Instability		
Reclamation	2	2	0	0	0	0	4	0
Fill	20	10	2	0	0	0	32	0
Alluvium:								
—undifferentiated	1 267	0	0	169	0	0	1 436	0
—raised	2	0	0	0	0	0	2	0
Littoral Zone	8	6	0	0	0	0	14	0
Colluvium:								
—volcanic	37	6	0	206	0	14	263	0.05
—granitic	0	0	0	0	0	0	0	0
—sedimentary	33	0	0	6	0	2	96	0.02
—mixed	0	0	0	0	0	0	0	0
Repulse Bay Formation:								
—undifferentiated volcanics	45	14	0	4	2	69	134	0.53
—sedimentary rocks and waterlaid volcanics	226	8	0	43	6	82	365	0.24
—acid lavas	55	18	0	18	8	73	172	0.47
—mainly banded acid lavas some welded tuffs	0	0	0	0	0	0	0	0
—coarse tuff	647	243	0	255	51	568	1 764	0.35
—agglomerate	0	0	0	0	0	0	0	0
—dominantly pyroclastics and some lavas	840	51	0	206	18	728	1 843	0.40
Kat O Formation	0	0	0	0	4	2	6	1.00
Port Island Formation	549	97	0	186	29	276	1 137	0.27
Bluff Head Formation	331	57	0	96	37	118	639	0.24
Tolo Harbour Formation	4	0	0	0	0	0	4	0
Unknown bedrock	20	0	2	0	14	0	36	0.39
	4 111	506	2	1 246	169	1 932	7 968	—

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

Existing Land Use	% of Total Area	Area (ha)
Private development	0.1	8
2 Storey development	0.3	23
1 Storey development	0.6	47
Sports complex	0.0	2
Police/fire station	0.0	2
Horticulture	3.4	267
Fish farming	0.1	6
Undefined agriculture	0.2	18
Undeveloped/undisturbed areas	6.8	545
Country park	73.6	5 861
Water storage	14.9	1 189
	100.00	7 968

Table B13 Existing Land Use and GLUM Class

Existing Land Use	Area in GLUM Class (ha)				
	I	II	III	IV	Unclassified
Private development	2	4	2	0	0
2 Storey development	8	10	4	0	0
1 Storey development	4	28	8	4	2
Sports complex	0	2	0	0	0
Police/fire station	2	0	0	0	0
Horticulture	29	165	57	16	0
Fish farming	0	0	0	0	6
Undefined agriculture	0	16	0	2	0
Undisturbed/undeveloped areas	42	255	165	68	16
Country park	243	2 649	1 975	973	23
Water storage	0	0	0	0	1 189
Total 7 968	329	3 129	2 211	1 063	1 236

APPENDIX C

SUPPLEMENTARY INFORMATION

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APPENDIX C

SUPPLEMENTARY INFORMATION

C.1 Description of Geological Units

C.1.1 *Tolo Harbour Formation*

These rocks are amongst the oldest in the Territory. They are found only on Centre Island and the outcrop is only of limited extent. The type section of Tolo Harbour Formation occurs on Ma Shi Chau, outside the study area. The Formation consists of steeply dipping quartzites, marine mudstones and shales with pyrite, which are fossiliferous in places. Low grade thermal metamorphism has affected these rocks, which are also quite strongly folded. Fossil evidence indicates these rocks are of Permian age.

C.1.2 *Tolo Channel Formation*

These rocks are restricted in outcrop to a coastal section on the northern side of Tolo Channel. This is the only outcrop within the Territory. The rocks are exposed on a tidal platform and consist of steeply dipping to vertical, thin quartzites and black shales with abundant pyrite, the rocks are contorted and are lithologically similar to those of the Tolo Harbour Formation. There is evidence that these rocks occur offshore in Tolo Channel, from Harbour Island to Bluff Head, where they may conformably underlie the Bluff Head Formation basal conglomerate. The Tolo Channel Formation beds are noted for the occurrence of the fossil ammonite Hongkongites hongkongensis. The presence of the ammonite indicates that the Tolo Channel deposits are Lower Liassic in age.

C.1.3 *Bluff Head Formation*

The main outcrop of the Bluff Head Formation is on the north side of Tolo Channel, extending from Bluff Head to Harbour Island, in the southwest corner of the study area. The Bluff Head Formation is probably Lower Jurassic in age and represents an essentially deltaic sequence of sediments, that are conformable with the rocks of the Tolo Channel Formation. The rocks of the Bluff Head Formation develop a maximum thickness of 1 200 m on the east coast of Plover Cove Reservoir. The beds thin towards Bluff Head, where only the lower 250 m of the succession is exposed. The sediments comprise conglomerates, white current-bedded sandstones, and pink-weathering siltstones and shales. These sediments have been subjected to low grade thermal metamorphism.

The basal beds of the Bluff Head Formation are transitional between marine sediments (Tolo Harbour Formation) and deltaic sediments as seen in the upper beds of the Bluff Head Formation. Marine sedimentation is shown by thin rhythmic layers showing graded bedding, whilst the presence of a white conglomerate and thin current-bedded, coarse sandstones indicate the presence of deltaic conditions. The deltaic sequence is represented by thick current-bedded sandstones and quartzites. The presence of conglomerates and coarse sandstone probably indicate rapid sedimentation in a shallow water environment.

Thin sections of the sandstone in the above sequence reveal poorly graded, slightly metamorphosed sediment in which the quartz grains are angular and often interlocking. It may contain pyrite and rutile. Feldspars are absent, as is the argillaceous material which has been replaced by sericite.

The rocks of the Bluff Head Formation in the vicinity of Plover Cove Reservoir, show quartz veins and mineralisation in the form of hematite. These rocks generally weather to a red colour in their coarse-grained form, the finer-grained representatives weather to a darker colour.

Towards Bluff Head, the rocks exposed are those of the upper sequence, and contain red micaceous shale, grey phyllitic shale, and grey quartzite with medium to coarse-grained sandstone. Grits, conglomerates and some breccia are also present. Pebbles (quartzite) within the conglomerate, can reach 5.5 cm in diameter, and layers of these, up to 3 m thick, are interbedded between the grit sequence. The conglomerates in the sequence are locally derived, as are the breccias of similar material. Sandstones in this area are often current-bedded, but this feature is not persistent.

The upper beds of the Bluff Head Formation are conformably overlain by volcanic tuffs of the Repulse Bay Formation. These upper beds are generally conglomerates and are best seen at the eastern end of Plover Cove Reservoir. The overlying tuffs contain intercalations of siltstones, similar to those of the lower Bluff Head Formation. Elsewhere, the transitional beds between the Repulse Bay Formation and the Bluff Head Formation are represented by breccias. The sequence is interpreted as shallow water sedimentation giving way to a sequence of shallow water or terrestrial volcanic deposits. The volcanic centres affected the topography, producing steeper slope gradients with more rapid erosion that generated the conglomerates and breccias at the top of the Bluff Head Formation.

C.1.4 *Repulse Bay Formation*

These rocks consist of a succession of coarse tuffs, welded tuffs and lavas which are often rich in quartz. These rocks were deposited during the regional volcanic activity of the mid-Jurassic Period and conformably overlie the Bluff Head Formation within the study area. A disconformable boundary is occasionally evident between the two Formations. These rocks are approximately 160 million years old, and represent a period of intense volcanic activity interspersed with periods of quiescence, which are marked by thin sedimentary sequences deposited in lakes and streams. These sediments are impersistent, both laterally and vertically and are irregularly distributed throughout the main sequence of volcanics.

The Repulse Bay Formation has been faulted and folded and subjected to local metamorphism.

The rocks of the Repulse Bay Formation exposed in the study area are subdivided by Allen & Stephens (1971) into five units, including an undifferentiated category. Each of these units is discussed below.

(i) *Undifferentiated Volcanic Rocks (RB)*
Rocks are assigned to this category where they have not been mapped in detail due to remoteness, vegetation cover or abundance of surface boulders making bedrock indentification unreliable. A large tract of Double Island is designated as undifferentiated volcanic rock.

(ii) *Sedimentary and Water-laid Volcaniclastic Rocks (RBs)*
These rocks outcrop in two main localities in the study area, east of Three Fathoms Cove and north and east of Plover Cove Reservoir.

(*a*) East of Three Fathoms Cove—Two units of sedimentary rocks occur, separated by a thick bed of fine tuff and porphyritic rhyodacite. The upper succession, which is over 50 m thick and outcrops on the coast, north of Lai Chi Chong, extends southwards to Cheung Sheung. It consists of three lithologically distinct units; a lower unit of thinly bedded tuffs, cherty tuffaceous sandstone and coarse volcanic sandstone; a middle succession of black, pyritous, fossiliferous shale (petrified wood, Dale & Nash, 1984) and siltstone, and an upper sequence of water-laid pyroclastic rocks with volcanic conglomerate. The lower sedimentary succession, which is over 50 m thick, crops out along the coast north of Sham Chung. The lithology is dominantly black shale, thinly banded dark siltstone and fine sandstones. Ripple marks and other sedimentary structures in a siltstone, indicate a fluvial environment, and conglomerates and graphitic sandstone are exposed in minor localities.

(*b*) North and East of Plover Cove Reservoir—Sedimentary rocks are exposed along the shore of Starling Inlet and Crooked Harbour and immediately east of Plover Cove Reservoir. The rocks consist of purple or red laminated silty shale or sandy siltstones. Some minor beds of orthoquartzite also occur. Volcanic tuffs are rare within these beds. East of Plover Cove Reservoir, these beds conformably overlie the Bluff Head Formation. On Ledge Point and Kat O Chau, limestone boulders are seen in a quartzitic breccia, which has been attributed to volcanic activity around an active vent. The island of Ping Chau consists entirely of rocks of sedimentary origin within the Repulse Bay Formation.

(iii) *Acid Lavas (RBv)*
These rocks are usually rhyolitic to dacitic in composition, with subordinate trachyandesite. Acid lavas are exposed south of Lai Chi Chong on the Sai Kung Peninsula and on the eastern parts of Crescent Island and Crooked Island (Kat O Chau). The lava flow near Lai Chi Chong is probably the lowest representative of the acid lavas. This flow rests on fossiliferous shale near Cheung Sheung, but near Lai Chi Chong, a thick mass of tuff intervenes. The lavas in this locality are rhyodacitic with phenocrysts of plagioclase and potassium feldspar. Broad banding of the lava occurs in the southern-most outcrops. The lava flows on Crooked Island and Crescent Island cannot be correlated stratigraphically. The upper representative of acid lava occurs at Three Fathoms Cove outside the study area.

(iv) *Coarse Tuff (RBc)*
This is one of the most widespread rocks in Hong Kong and normally occurs as a coarse-grained crystal tuff. These beds outcrop both east and west of Long Harbour, including Grass Island and to the north of Tolo Channel, on the western part of Kat O Chau and Crescent Island.

The Coarse Tuffs usually occur as thick massive beds with no internal stratification. The rock is normally dark grey or greenish grey. The rock varies in grain size from a coarse tuff to a fine-grained lapillistone, grain size being determined by the dominant quartz and feldspar minerals. Biotite and hornblende occur as subsidiary minerals and determine the overall colour of the rock.

The rock is characterised by the presence of well-formed volcanic bombs, and lack of internal stratification. The rock contains a large variety of fragment sizes. Individual deposits are generally very thick and sometimes reach 400 m. These features indicate an explosive volcanic origin. Explosive strain and crystal fracture are readily identified in thin section.

In composition, the coarse tuff is fairly uniform rhyodacite or dacite. The coarseness of overall grain size is probably attributable to the partly crystallised condition of the parent magma at the time of eruption. The coarse tuff exposed on the northern part of the Sai Kung Peninsula is very coarse-grained and contains many bombs of porphyritic lava. Mineralised vugs occur in these rocks, in isloated localities east of Long Harbour.

(v) *Dominantly Pyroclastic Rocks With Some Lavas (RBp)*
These rocks form a varied volcanic suite some of which form thin mappable units. These are not shown on the Allen & Stephen (1971) map produced at 1:50 000 scale. These varied rock types are grouped together into the 'Dominantly Pyroclastic Rocks With Some Lavas', as described by Allen & Stephens (1971), and include explosively erupted fine-grained tuffs and ash flows, welded tuffs (ignimbrites), coarse and fine lapilli tuff and blocky lapilli tuff. White quartzose rock occurs in isolated localities.

Pyroclastics of the Repulse Bay Formation outcrop in a large area east of Three Fathoms Cove on the Sai Kung Peninsula. North of Tolo Channel, they flank the northern shore of Plover Cove Reservoir and form the greater part of the peninsula south of Starling Inlet, and also the major part of Kat O Chau and Crescent Island.

C.1.5 *Port Island Formation*

This Formation consists of fluviatile sediments that form a continuous outcrop from Bluff Head to Bride's Pool, and also outcrop on the eastern side of Port Island. This Formation is younger than the Repulse Bay Formation and probably post dates the intrusive igneous phase that affected the Territory. The Port Island Formation consists of conglomerates, pebbly sandstones, sandstones and shales. The Formation commences with a massive basal conglomerate which forms a dominant scarp and overlies the tuffs of the Repulse Bay Formation. Overlying sandstones are evident for considerable distances striking parallel to the basal conglomerate. The maximum thickness of this Formation exceeds 400 m but the top of the sequence is not exposed.

The sedimentary rocks on Port Island are all strongly coloured reddish-brown, the red colour extends into the underlying volcanic rocks which may be a result of leaching. The Port Island Formation starts with two beds of grit followed by a massive conglomerate 15 m thick. The succeeding beds are sandstone and pebbly sandstone with shales. The lithology of the Formation remains fairly constant between Bluff Head and Bride's Pool, however, the arenaceous and rudaceous representatives are increasingly unpigmented in a westward direction. The relationship between the Port Island Formation and the underlying beds is uncertain. At Bluff Head the basal conglomerate transgresses across the volcanics and lies unconformably on the steeply dipping sediments of the Bluff Head Formation. The contact of the Port Island Formation is also exposed on Port Island, indicating an unconformable succession.

The pebbles and boulders of the conglomerates of the Port Island Formation are almost entirely of volcanic origin and none are derived from the intrusive igneous rocks. This indicates that the Port Island Formation was deposited before the granitic rocks were exposed at the surface but it probably postdates the intrusive phase because no effects of thermal metamorphism or minor dyke intrusion are apparent.

C.1.6 *Kat O Formation*

These beds are extremely limited in outcrop, they occur only at Ledge Point, Sai Ap Chau, Ap Chau and Kat O Chau. At North Point on Kat O Chau, the Formation reaches 36 m in thickness. These beds unconformably overlie the Repulse Bay Formation, and consist of breccias with angular fragments of volcanic rock and coarse grits, interbedded with the breccias. The beds are reddish-brown in colour and are clearly of recent origin (Tertiary or Quaternary), being deposited against a pre-existing sea cliff. The contact follows the present coastline.

C.1.7 *Tai Po Granodiorite*

In the study area the Tai Po Granodiorite outcrops only on Centre Island. The outcrop on Centre Island is of extremely small extent and is the only representative of intrusive igneous rocks in the North East New Territories (Table C1). The rock is coarse or medium-grained, darkish in colour when fresh, and often porphyritic. Biotite is the main dark mineral and white plagioclase feldspar is present in small quantities. This rock is considered the oldest intrusive rock in Hong Kong as it is cut by most of the other intrusive rock types. The Tai Po Granodiorite weathers to a deep red-brown and forms a clay which is relatively free of quartz. Weathered granodiorite often contains large numbers of residual corestones.

C.1.8 *Colluvium*

Colluvium results from the concentration of material transported downslope through the influence of gravity, including such processes as soil creep, landslip and boulder fall. In addition, runoff and seepage increases the

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	No No No No
3	Quartz Monzonite Feldspar Porphyry Dyke Swarm	No No
4	Granophyric Microgranite Needle Hill Granite Hong Kong Granite	No No No
5	Dolerite	No

movement of detritus. Colluvium may occur as fan-shaped deposits on footslopes below steep rock faces and or as lenticular deposits along drainage lines.

Colluvial deposits consist of a wide range of materials and grain sizes depending on the parent rock type, the depositional environment and the degree of weathering of the deposit. In the study area, there are several areas with different types of deposit. These are:

(i) *South of Tolo Channel*
On the eastern coastal areas south of Tolo Channel, boulders of coarse tuff have been deposited along the foreshore and in depressions formed along drainage lines. These boulder fields are possibly caused by the exhumation of corestones of tuff which have subsequently been transported downslope with the fines being removed by stream and wave action. The boulders, which are up to 5 m in diameter, are usually subrounded to subangular.

(ii) *North of Plover Cove Reservoir*
The footslope terrain to the north of Plover Cove Reservoir is often associated with colluvial fans. This material is very variable in grain size and depends largely on the type of bedrock from which it is derived. Some deposits may show different degrees of weathering which may indicate different ages of deposition. The matrix is generally a silty sand, the size and degree of weathering of the cobbles or boulders depending largely on the source rock. The coarse-tuff tends to form larger, less weathered blocks because of its greater strength.

(iii) *Plover Cove Reservoir, Tolo Channel and Islands*
Along the south facing slopes north of Plover Cove Reservoir and Tolo Channel and on Crooked and Crescent Islands, talus/scree deposits occur below areas of exposed rock. The cobbles and boulders tend to form fan-shaped deposits but sometimes occur as lenticular deposits along drainage lines. The latter are frequently too narrow to map at a scale of 1:20 000. Loose rock debris will often be deposited at an angle close to the angle of repose, and is generally in a state of dynamic equilibrium.

(iv) *Drainage Lines*
Along drainage lines boulders and other debris accumulate from upstream sources or from the adjacent sideslopes. This material can vary from large boulder deposits to poorly sorted deposits depending on the degree of reworking and the removal of fines by fluvial action. Depending on the degree of transport and reworking, these deposits may be considered somewhat transitional and in places more alluvial than colluvial. These deposits are quite widely distributed throughout the study area, but the steeper examples of the deposit tend to occur around the coastal areas.

C.1.9 *Alluvium*
Alluvium deposits occur on the low-lying coastal plain and esturine areas. Large areas of alluvium-filled valleys also occur in more upland areas around Wu Kau Tang, Miu Tin and Sam A Chung to the north of Tolo Channel and around Pak Sha O to the south. The sediment in the valley at Wu Kau Tang is confined upstream from a major faulted nick-point at Bride's Pool.

The alluvium in the coastal areas has been deposited in drowned river valleys. Barriers or embankments have often been constructed to contain sediment for agricultural use. The coastal sediments are generally composed of yellow brown clayey silt with sand, gravels and some organic material. The coastal areas may contain intercalations of marine sediments and dune sands in the more fluviatile sediments. Large areas of alluvium have probably been 'drowned' by sea-level change.

Similar types of sediment occur in the detritus-filled valleys, but intercalations of colluvium from the sideslope terrain is common. Both the coastal areas and infilled valleys are likely to have high water tables.

C.1.10 *Littoral Deposits*

Much of the coastline has some development of littoral deposits although many areas are too narrow to delineate at a scale of 1:20 000. The major littoral deposits occur on the eastern foreshores of Tap Mun and on the mainland south of Tap Mun. Some larger beach deposits exist on Ping Chau with boulder deposits on the foreshore. Areas of boulders also litter parts of the wave cut platforms throughout the area. Some of the littoral deposits around the stream mouths are cemented with clay detritus and iron oxides.

C.1.11 *Marine Deposits*

The marine deposits around the Territory are sometimes classified according to a four-fold division related to sea level change. The marine deposits may interdigitate with alluvium and colluvium, which were deposited during periods of lower sea level, but have subsequently been drowned. Close to the present sea level, the dark coloured marine muds alternate with coarser deposits of silty sand with shell fragments and occasional conglomerates. At depth, fine silt and clayey silt predominate. The marine deposits are generally soft and unconsolidated.

C.1.12 *Reclamation and Fill*

Only minor areas of reclamation and fill are present in the North East New Territories. The largest area consists of the dams and associated fill for the Plover Cove Reservoir. Smaller areas of fill and reclamation are visible around the coastal villages and include coastal embankments which have been constructed for agricultural areas. Other small areas of fill occur along roadways and around the inland villages.

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 North East New Territories 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 C1.

C.4 Rainfall Data Relevant to the North East New Territories Study Area

A general appreciation of the annual and monthly rainfall distributions for the North East New Territories 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. There are a total of 5 rainfall stations within the study area the locations of which are indicated on Figure C4. Detailed monthly and annual rainfall information for these stations is available from the Royal Observatory.

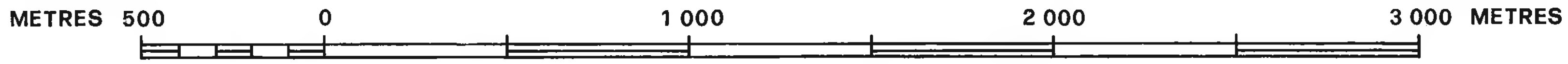
ATTENTION : USERS

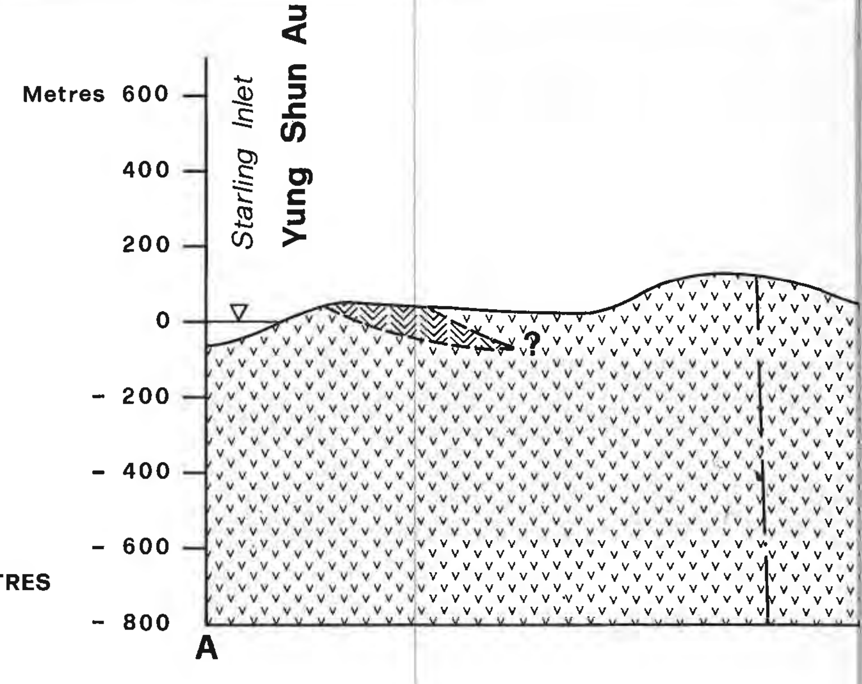
The bedrock geology shown on this sheet is that of Allen & Stephens (1971). Geological remapping of the Territory is currently underway and new geological maps at a scale of 1:20 000 and their accompanying memoirs should be consulted where available.

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

- For location of sections refer to Engineering Geology Map.
- For legend see Figure 17a.
- 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.

Scale 1:20 000



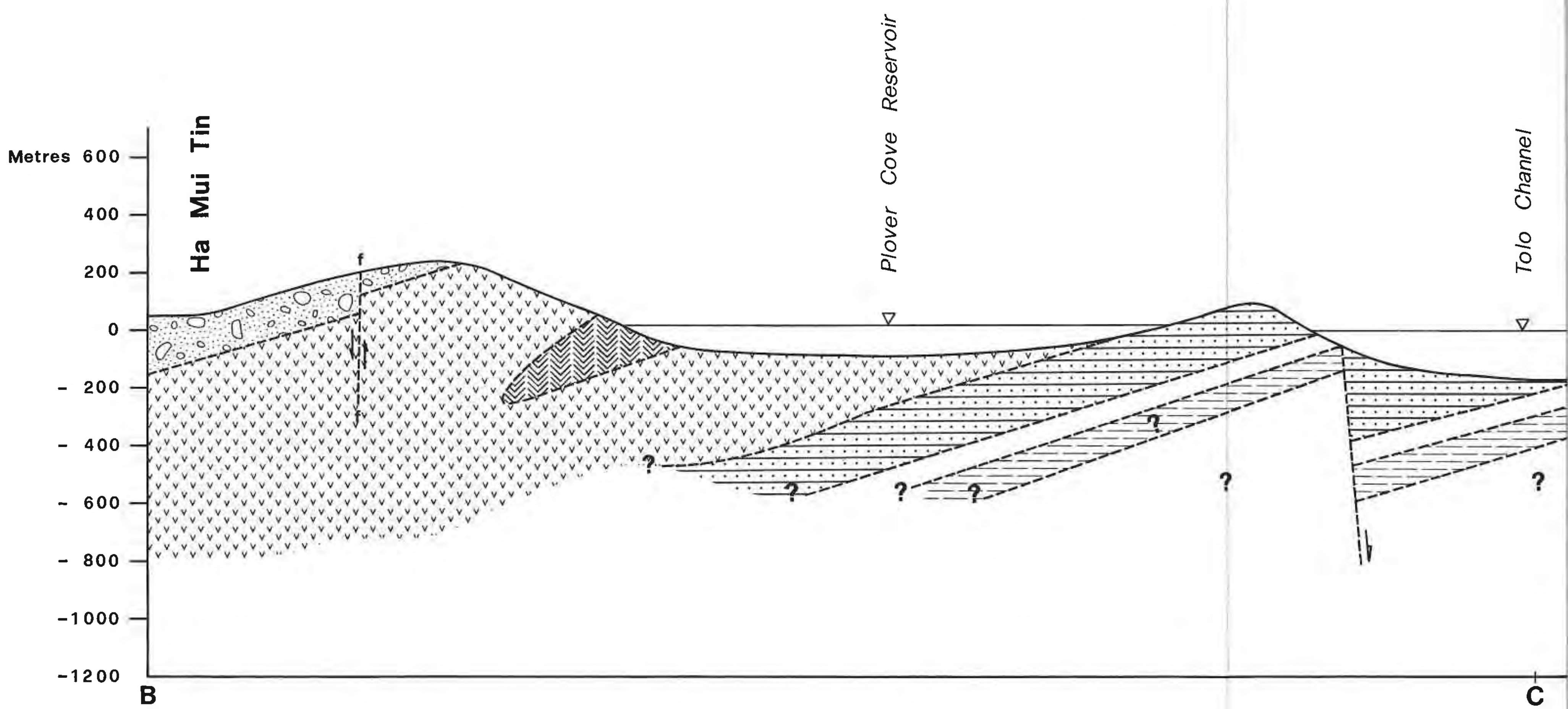


LEGEND

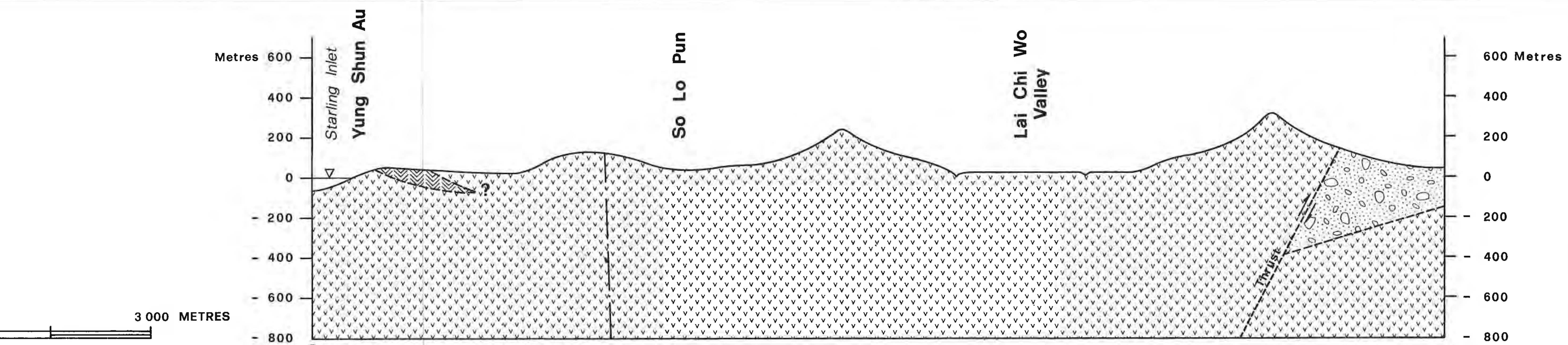
- Port Island Formation
- Bluff Head Formation
- Tolo Channel Formation
- Tolo Harbour Formation
- Pyroclastics and Lavas
- Coarse Tuff
- Acid Lavas
- Sedimentary rocks and water-laid volcaniclastic rocks

(Pyroclastics and Lavas, Coarse Tuff, Acid Lavas, and Sedimentary rocks and water-laid volcaniclastic rocks: Repulse Bay Formation)

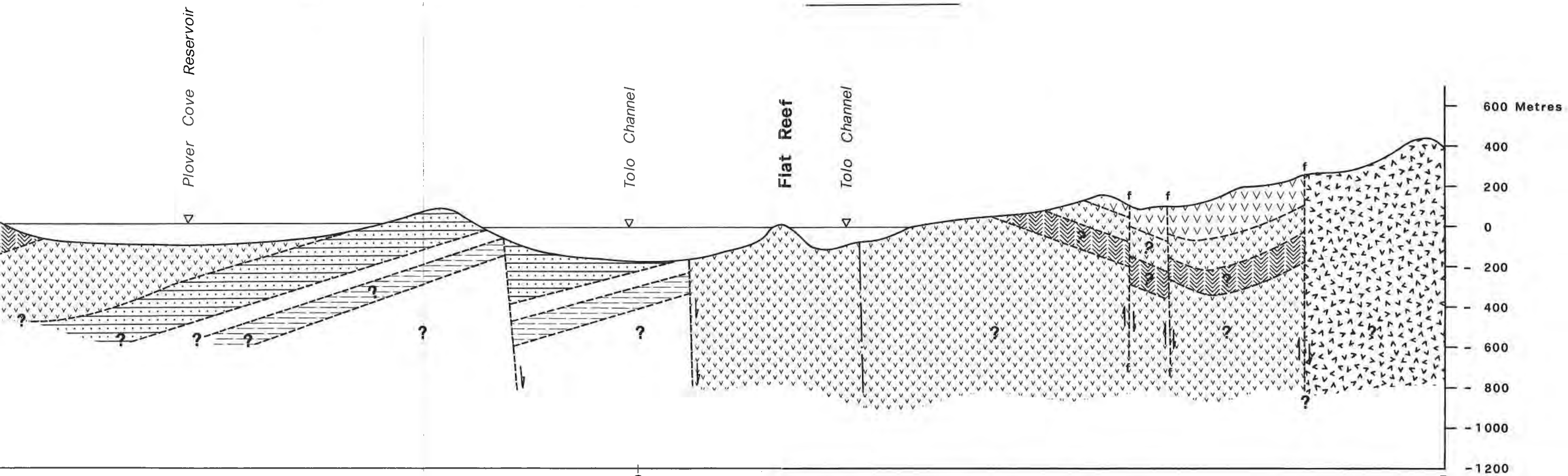
- Lithological boundary
- Geological photolineament
- Fault
- Block fault
- Thrust plane
- ? Uncertain
- Water surface level



Geological Cross-sections – North East New Territories



Section A-B



Section B-D

North East New Territories

Compiled: J. M. Nash	Drawn: S. M. Wan	Fig. C1
Scale: 1:20 000	Date: July, 1985	

Table C2 Selection of Aerial Photographs

Year	Photograph Serial Number	Photograph Scale (Approx.)
1983	52332–52337	1:20 000
	52316–52321	1:20 000
	52307–52313	1:20 000
	52271–52277	1:20 000
	52261–52263	1:20 000
	52255–52259	1:20 000
	51606–51613	1:40 000
	51558–51568	1:40 000
	51547	1:40 000
	51501–51509	1:40 000
	51480–51481	1:20 000
	51468–51476	1:20 000
	47071–47081	1:40 000
	47047–47055	1:40 000
	47045	1:40 000
	47043	1:40 000
	46998–47006	1:40 000
1982	44770–44773	1:20 000
	44766–44768	1:20 000
	44749–44755	1:20 000
	44748	1:20 000
	44700–44707	1:20 000
	44691–44697	1:20 000
	44649–44657	1:20 000
1981	39469–39471	1:20 000
	39462–39467	1:20 000
	39456	1:20 000
	39321–39327	1:20 000
	39314–39316	1:20 000
	39287–39293	1:20 000
	39278–39286	1:20 000
	39237–39244	1:20 000
	38125–38133	1:20 000
	38103–38106	1:20 000
	38083–38088	1:20 000
	38055–38060	1:20 000
	38029–38035	1:20 000
	38021–38028	1:20 000
	37973–37985	1:20 000
1979	28454–28460	1:20 000
	28366–28373	1:20 000
	28349–28355	1:20 000
	28322–28331	1:20 000
	28285–28289	1:20 000
	28253–28267	1:20 000
	28231–28235	1:20 000
	28227–28229	1:20 000
	27785–27792	1:20 000
1978	24562	1:25 000
	24530–24531	1:25 000
	24520–24528	1:25 000
	24513–24519	1:25 000
	24471–24482	1:25 000
	24444–24449	1:25 000
	24439–24442	1:25 000
	24380	1:20 000
	22361	1:20 000
	20646–20649	1:25 000
	20644	1:25 000
	20621–20625	1:25 000
	20610–20614	1:25 000
	20590–20593	1:25 000
	20588–20589	1:25 000
1977	19896	1:25 000

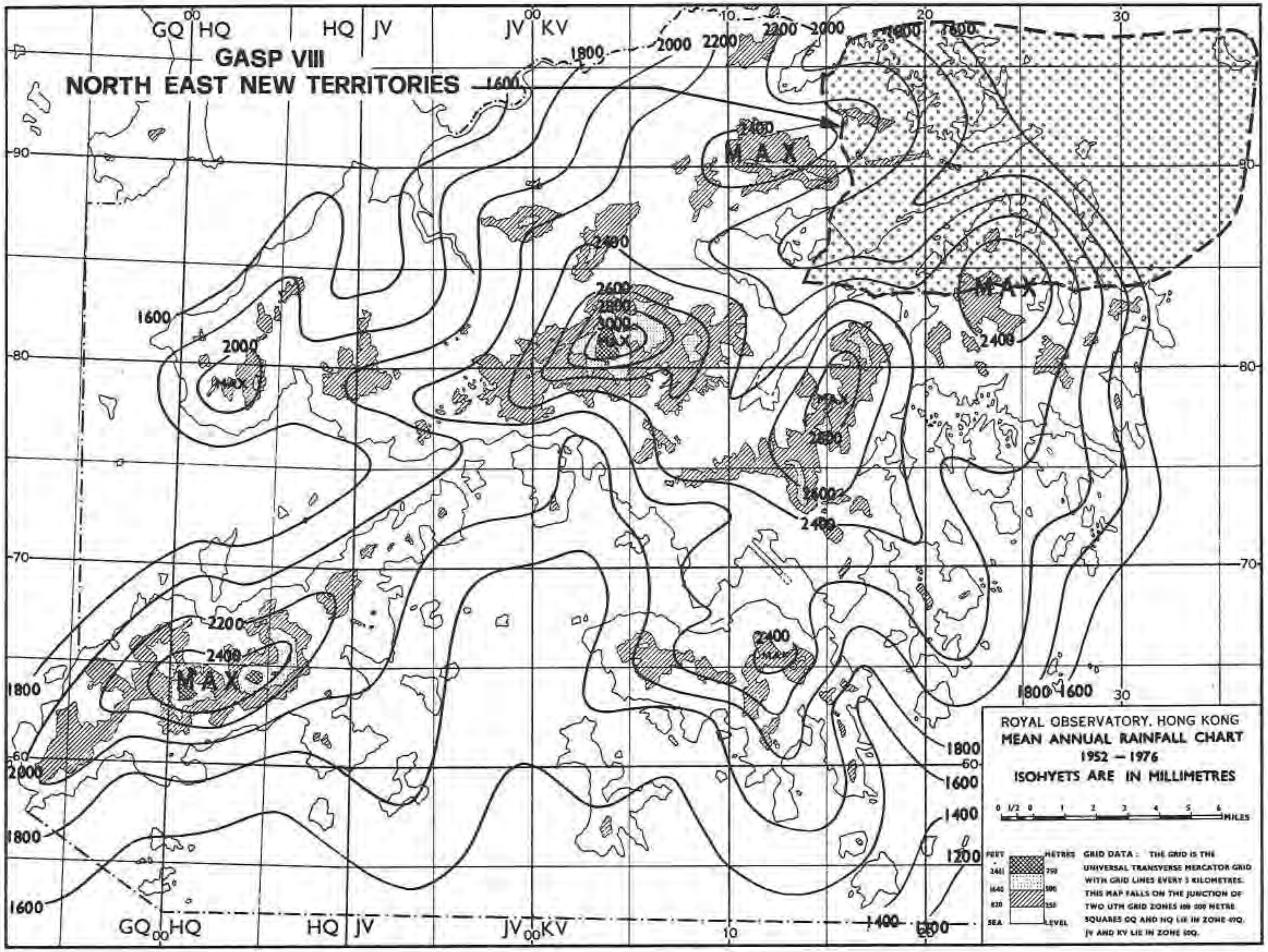
Table C2 Selection of Aerial Photographs *(Continued)*

Year	Photograph Serial Number	Photograph Scale (Approx.)
1976	16481–16482	1:25 000
	16457–16464	1:25 000
	16454–16455	1:25 000
	16413–16422	1:25 000
	16397–16404	1:25 000
	16290–16297	1:25 000
	16281–16289	1:25 000
	16011–16016	1:25 000
1975	11944–11951	1:25 000
	11941–11942	1:25 000
	11943	1:25 000
	11906–11913	1:25 000
	11891–11898	1:25 000
	11837–11843	1:25 000
	11830–11835	1:25 000
1974	10046–10052	1:25 000
	10033–10038	1:25 000
	10029–10030	1:25 000
	9862	1:25 000
	9856	1:25 000
	9843	1:25 000
	8235–8240	1:25 000
1973	7940	1:25 000
	7900–7907	1:25 000
	7890–7896	1:25 000
	7820–7821	1:25 000
	7817–7819	1:25 000
	7811–7812	1:25 000
1970	2543	Not calculated
	2538	Not calculated
1969	1451–1452	Not calculated
	1418–1419	Not calculated
	1275–1276	Not calculated
	1267–1274	Not calculated
	1187–1188	Not calculated
	1153–1155	Not calculated
1964	4437	1:3 600
	3389	1:3 600
	3381	1:3 600
	3363	1:3 600
	3209–3211	1:3 600
	3153–3154	1:3 600
	3141–3143	1:3 600
	3087	1:3 600
	2818–2822	1:25 000
	2766–2776	1:25 000
	2760–2764	Not calculated
1924	2712–2718	1:25 000
	2696	1:25 000
	2686–2692	1:25 000
1963	9932–9948	1:7 800
	9883–9902	1:7 800
	9835–9851	1:7 800
	9515–9525	1:7 800
	9432–9444	1:7 800
	9415–9430	1:7 800
	9400–9413	1:7 800
	9380–9398	1:7 800
	9297–9318	1:7 800
	8665	1:7 800
	8650	1:7 800
	9643–8644	1:7 800
	8619–8641	1:7 800

Table C2 Selection of Aerial Photographs *(Continued)*

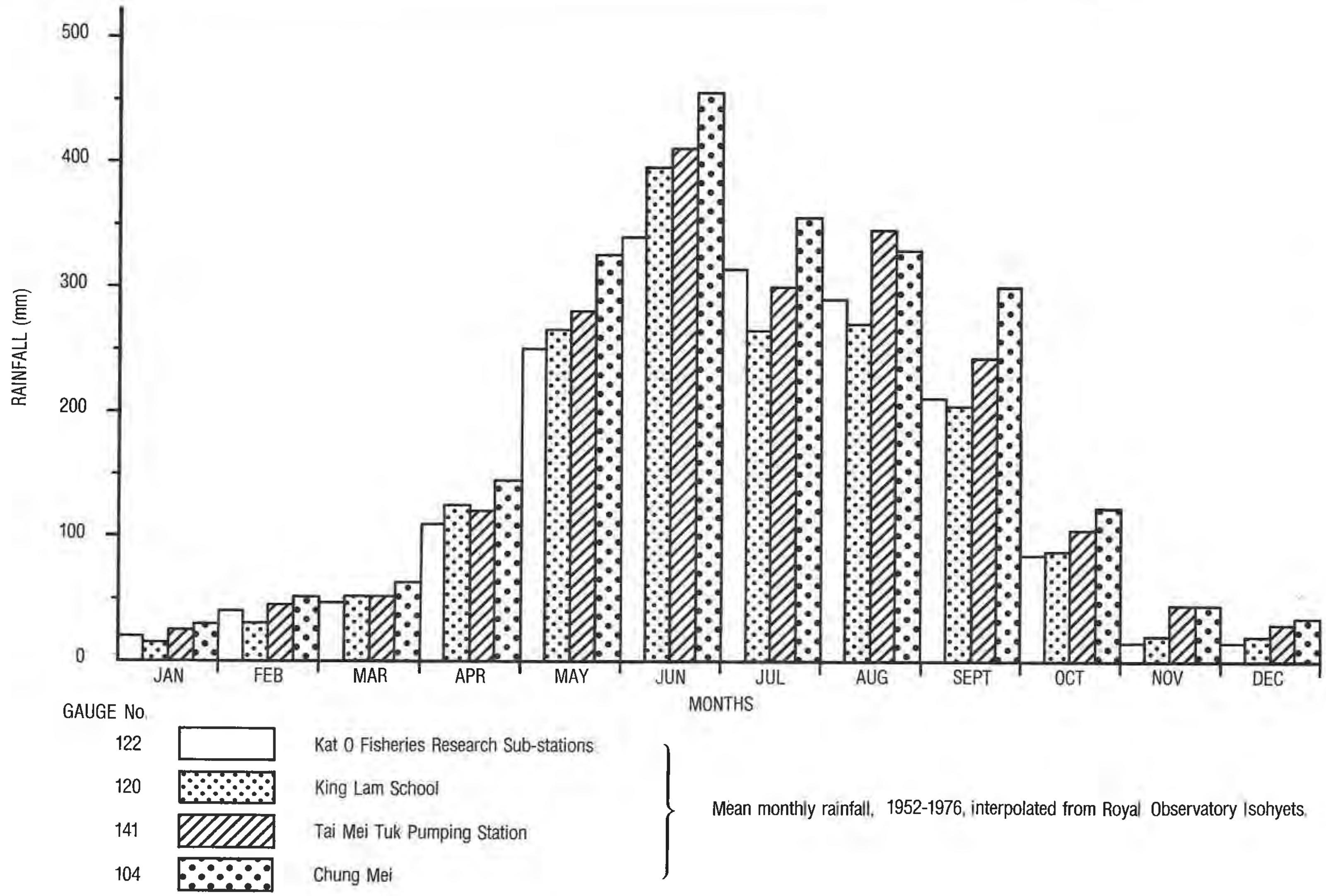
Year	Photograph Serial Number		Photograph Scale (Approx.)
1963		8484–8485	1:7 800
		8478–8481	1:7 800
		8371	1:7 800
		5612	1:7 800
		5413–5414	1:7 800
		5363	1:7 800
		5305	1:7 800
		0850–0864	1:7 800
		0844–0848	1:14 000
		0167–0184	1:14 000
		0081–0065	1:14 000
		0020–0030	1:14 000
		0000–0018	1:14 000
1954	V81A/RAF/550	89–50	1:25 000
	V81A/RAF/548	80–84	1:25 000
	V81A/RAF/548	66–73	1:25 000
	V81A/RAF/550	56	1:25 000
	V81A/RAF/550	4–7	1:25 000
1949	81A/130	6097	1:2 400
	81A/134	5156	1:11 600
	81A/125	5149–5153	1:11 600
	81A/125	5111–5146	1:11 600
	81A/118	5030–5038	1:11 600
	81A/125	5001–5010	1:11 600
1945	681/4	4199–4212	1:12 000
	681/4	4154–4163	1:12 000
	681/4	4074–4082	1:12 000
	681/4	4032–4040	1:12 000
	681/4	3128–3139	1:12 000
	681/4	3050–3061	1:12 000
1924	H28	13–17	1:14 000

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



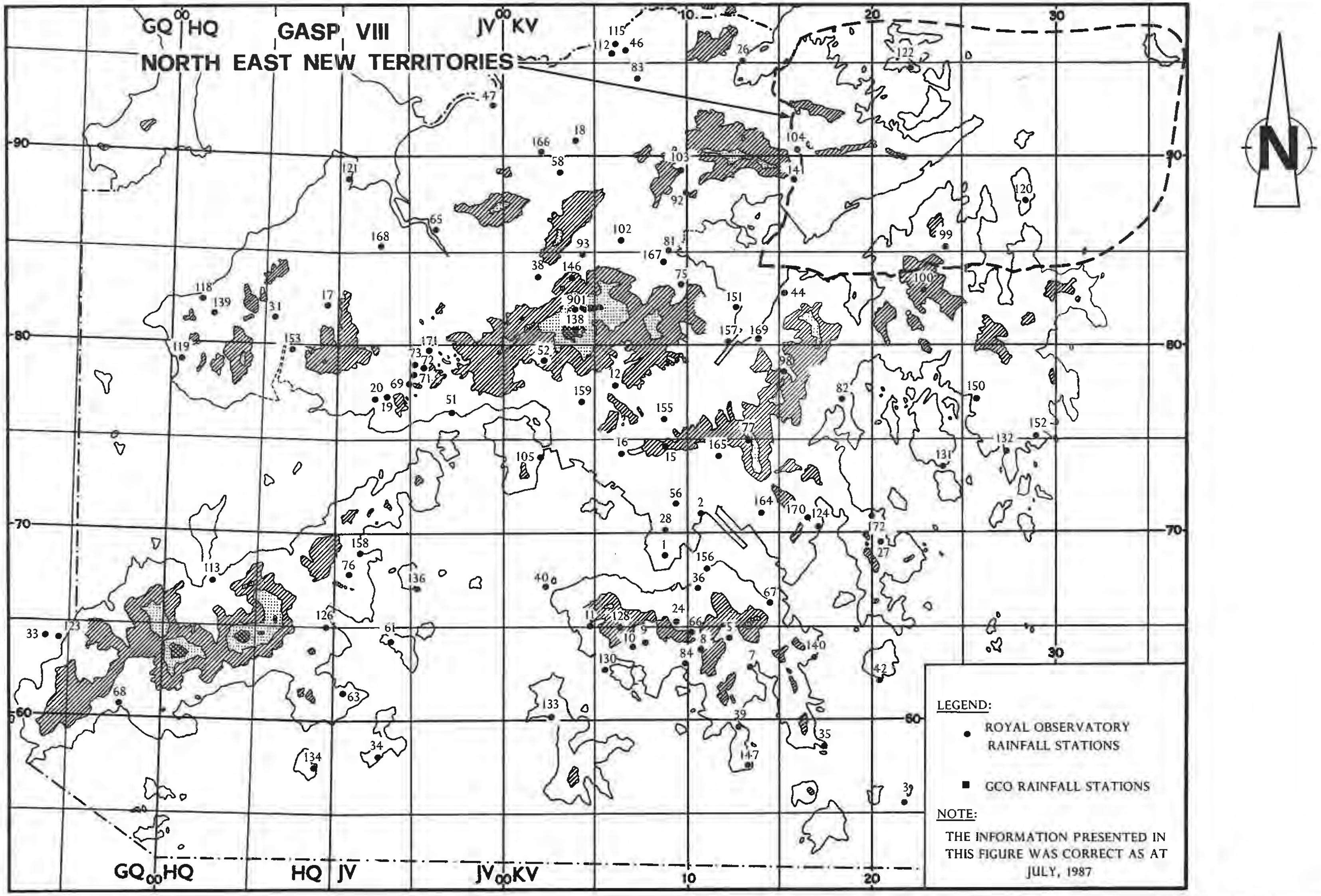
Mean Annual Rainfall Isohyets (1952–1976)

Fig. C2



Summary of Mean Monthly Rainfall Data

Fig. C3



Locations of Rainfall Stations	Fig. C4

APPENDIX D

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

List of Figures

APPENDIX D

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

D.1 Introduction

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

D.2 Rock Mass Characteristics

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

The portion of Figure D1 devoted to Rock Mass Characteristics, and reproduced in Figure D2, shows in sequence the factors which contribute to rock properties and which, through mass strength and structure, permeability and chemical stability, contribute to the control of landforming processes and engineering performance. The succeeding sections explain in general terms how the variations in rock mass characteristics arise. They are not intended to be thorough from the geological point of view. 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.

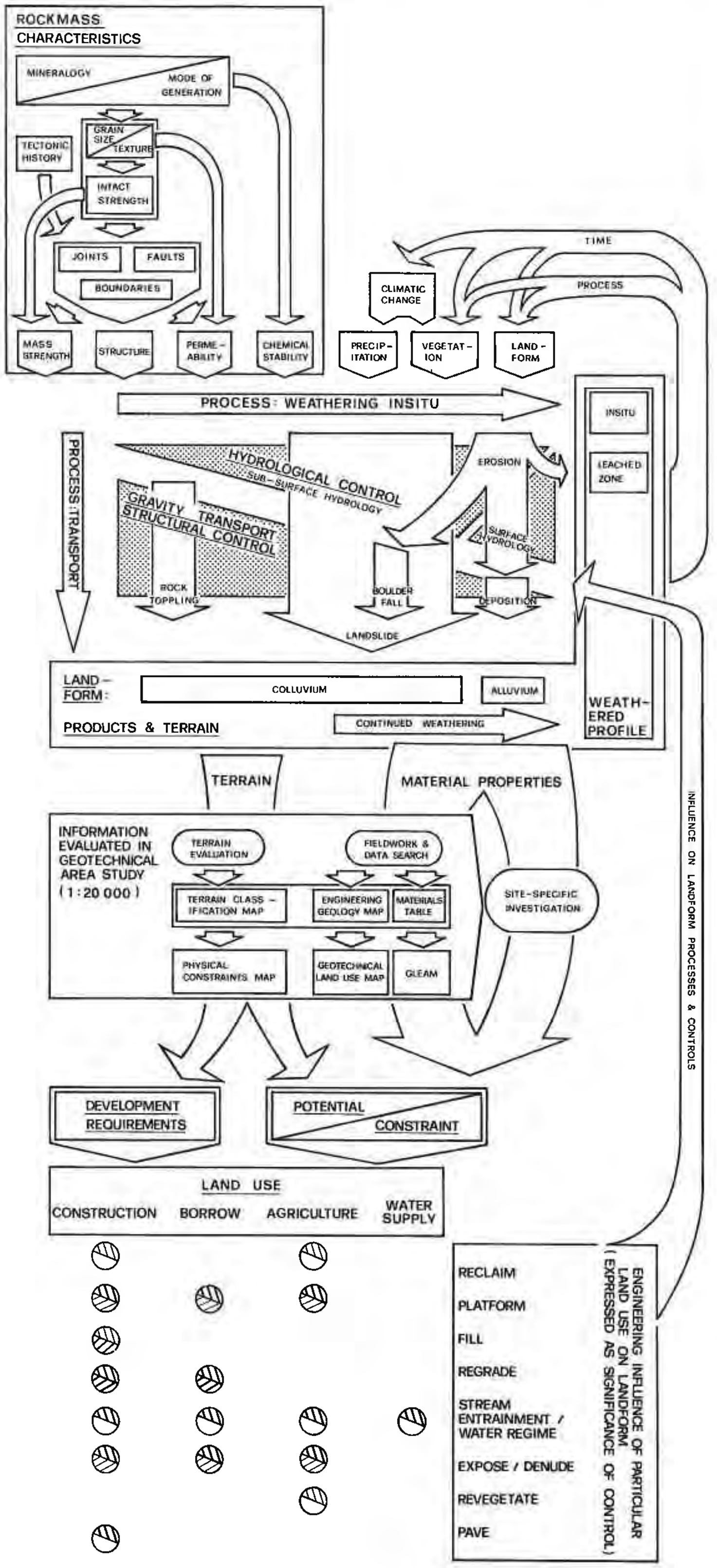
LANDFORMING PROCESSES :
RELATIVE INFLUENCE OF HYDROLOGY, STRUCTURE & WEATHERING ON TYPES OF TRANSPORT PROCESS. (BACKGROUND TRIANGLES SHOW PROPORTION OF INFLUENCE OF CONTROL).

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



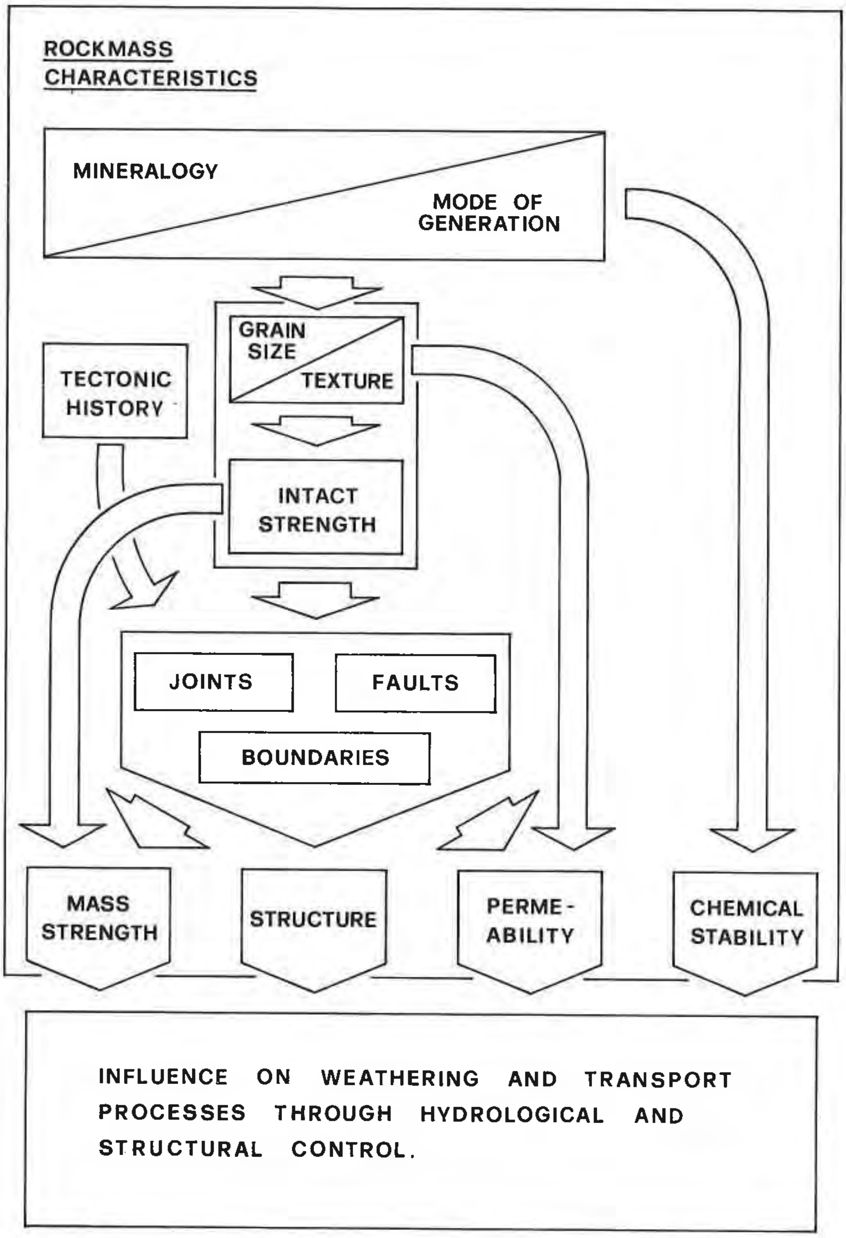
LEGEND :

BOXES INDICATE : CAUSE OR PRODUCT

ARROWS INDICATE : INFLUENCE, PROCESS, OR MECHANISM

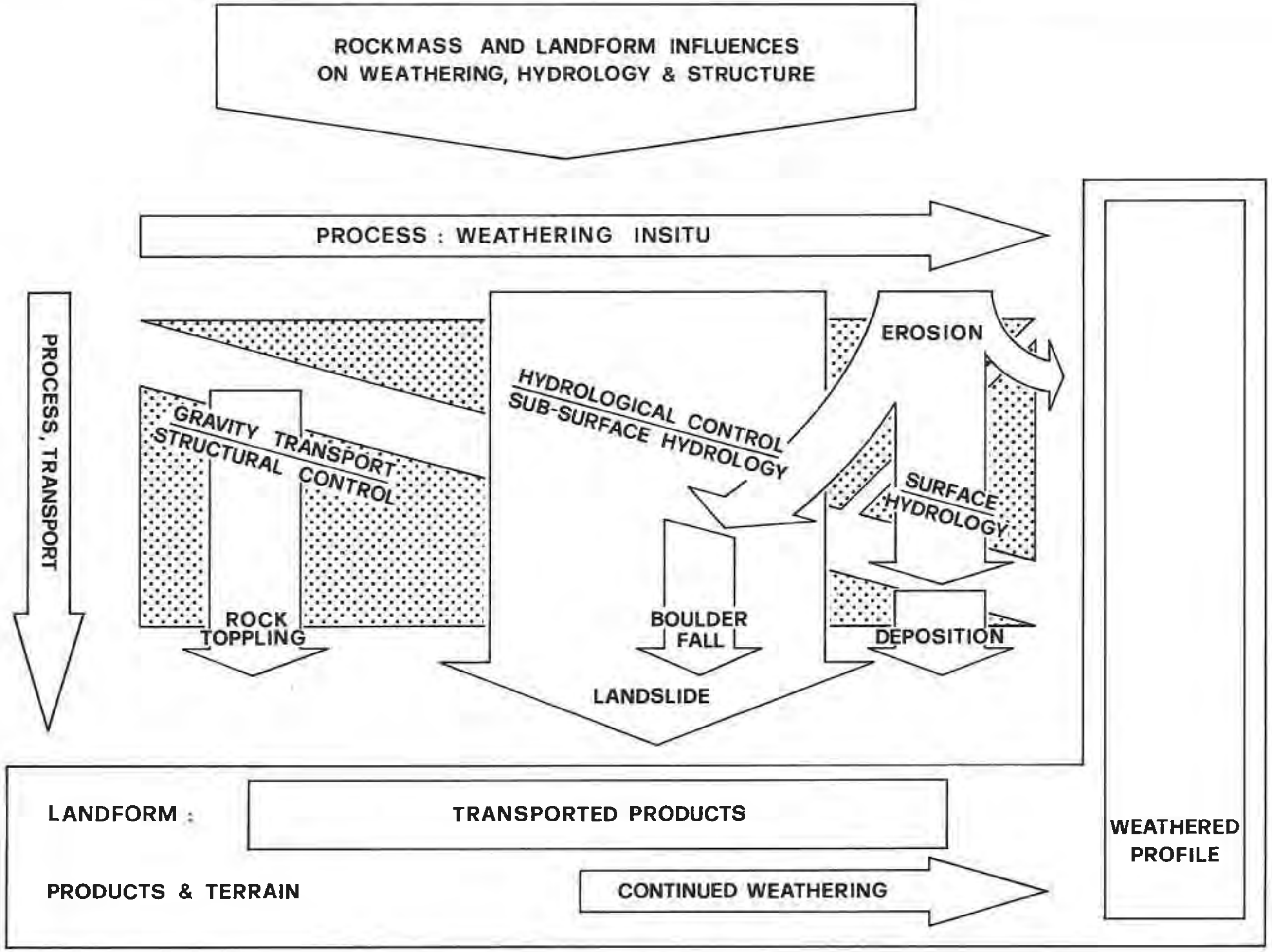
CIRCLES INDICATE : HUMAN INVOLVEMENT

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, 1972 a & b, 1977), fill has been recognised as a potentially hazardous engineering material. Consequently, recent fill platforms and slopes are designed and constructed to stringent requirements. Common problems in older fills on steep terrain are due to the fact that many were 'end tipped'. This results in:

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

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

(*c*) Unpredictable, large settlements.

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

(*e*) Erratic water flows within landfill.

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

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

D.3.4 *Geological Photolineaments*

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

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

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

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

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

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

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

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

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

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

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

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

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

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

(v) *Seismic Influence*
Some photolineaments are identified on the Engineering Geology Map (after Allen & Stephens, 1971) as faults, and other major photolineaments may also indicate faults. Faults may extend laterally for a short distance or many thousands of kilometres. The Government of the People's 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 engineering point of view in this Report, except in relation to reclamation. Their geological characteristics are discussed in Appendix C.

D.3.9 *Cut Slopes*

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

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

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

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

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

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

(iii) *Colluvial Terrain*
The creation of extensive cuts in colluvium should be avoided. Aspects of this material affecting stability are noted in Section 3.1.3. 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.

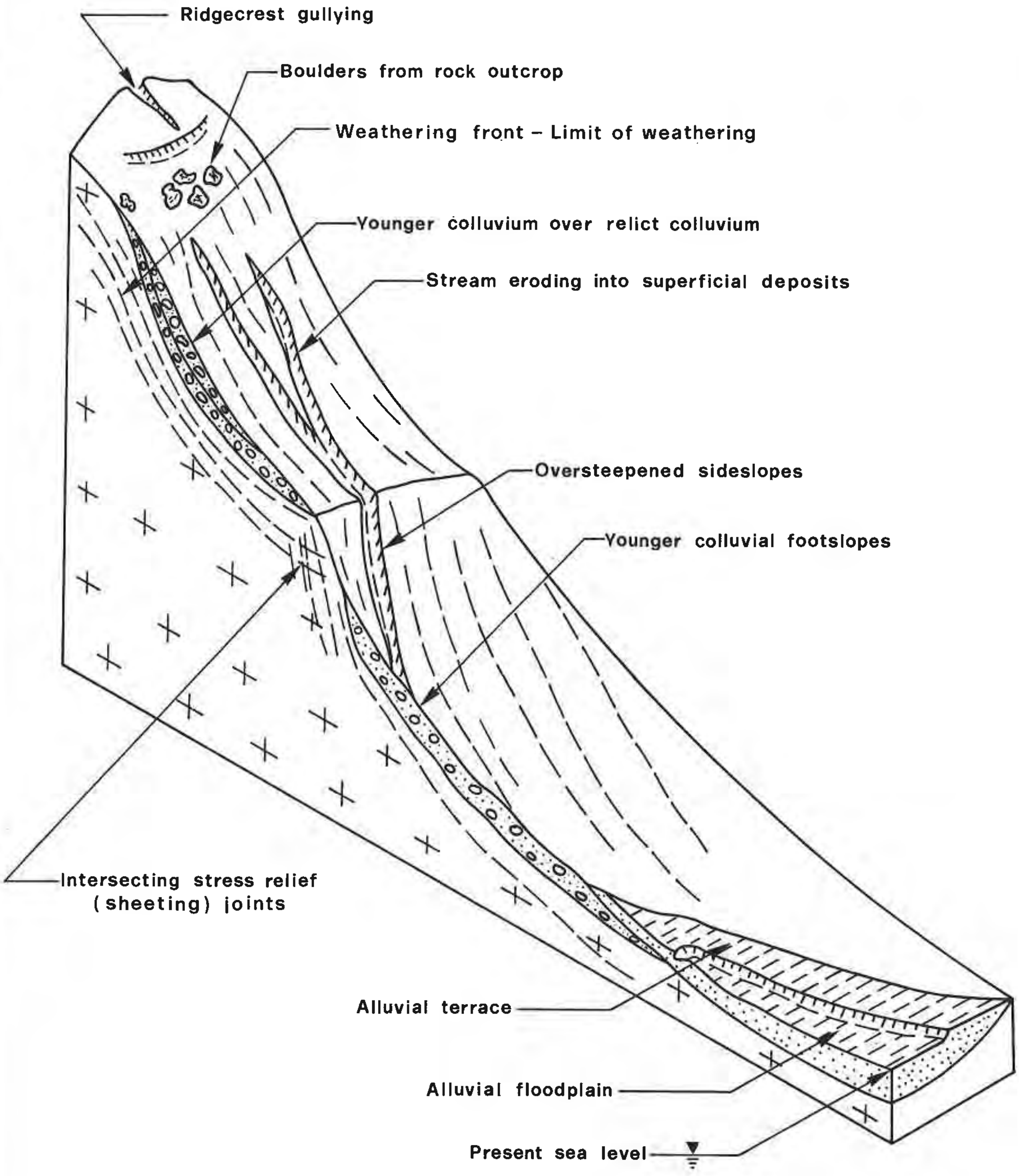
(*c*) The site investigation should be designed to highlight the scope of any available information, the anticipated material, its nature and variability, and the type and form of the engineering project.

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



Hillslope Model | Fig. D4

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

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

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

APPENDIX E

GLOSSARY OF TERMS

AERIAL PHOTOGRAPH INTERPRETATION

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

AGGLOMERATE

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

ALLUVIAL FAN

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

ALLUVIUM

Sediment transported and deposited by a river or stream.

APHANITE

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

AQUIFER

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

AREA INSTABILITY INDEX

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

ASPECT

Direction in which a slope faces.

BATHOLITH

Large intrusive igneous rockmass.

BEDROCK (=SOLID GEOLOGY)

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

BLOCKS

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

BOMBS

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

BRECCIA

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

CATCHMENT AREA

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

CHLORITISATION

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

CHUNAM

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

COASTAL PLAIN

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

COLLUVIUM

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

COUNTRY ROCK (=HOST ROCK)

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

CUT SLOPE AND CUT PLATFORM

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

DACITE

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

DETRITAL

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

DIP (or TRUE DIP)

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

DIP DIRECTION

Direction or azimuth of dip.

DISCONTINUITY

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

DISTURBED TERRAIN

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

DOLOS

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

DRAINAGE PLAIN

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

DURICRUST (=HARD PAN)

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

DYKE

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

EPHEMERAL STREAM

Stream which only flows for short periods of the year.

EROSION

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

FABRIC

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

FAULT

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

FAULT BRECCIA

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

FILL SLOPE AND FILL PLATFORM

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

FLOODPLAIN

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

FOOTSLOPE

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

GENERAL INSTABILITY

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

GENERALISED LIMITATIONS AND ENGINEERING APPRAISAL MAP (GLEAM)

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

GEOTECHNICAL AREA STUDIES PROGRAMME (GASP)

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

GEOTECHNICAL LAND USE MAP (GLUM)

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

GRABEN

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

GULLY EROSION

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

HILLCREST

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

HORNFELS

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

HYDROGRAPH

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

IGNIMBRITES (=WELDED TUFFS)

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

IMBRICATE STRUCTURE

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

INCISED DRAINAGE CHANNEL

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

INDURATION

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

INSITU MATERIAL

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

INTRUSION

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

LAND CAPABILITY

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

LANDFORM

General shape and characteristic morphology of the land surface.

LANDSLIP (=LANDSLIDE)

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

LAPILLI

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

LENTICULAR COLLUVIUM

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

LITHOLOGY

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

LITHOSTRATIGRAPHY

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

LITHOTYPE

Rock defined on the basis of certain selected physical characteristics.

LITTORAL ZONE

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

MANTLE

Weathered rock material overlying fresh rock.

MASS WASTING

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

MATRIX

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

MAXIMUM DRY DENSITY

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

NATURAL SLOPE

Area of sloping ground substantially unaltered by man.

NICK POINT

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

OUTCROP

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

PEGMATITE

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

PERENNIAL STREAM

Stream that flows throughout the year.

PHYLLITE

Argillaceous rock of intermediate metamorphic grade.

PHYSICAL LAND RESOURCES

Physical characteristics of land.

PIPE (=SOIL PIPE)

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

POLYCYCLIC

Many cycles of development.

PYROCLASTIC ROCK

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

RECLAMATION

Area of land reclaimed from the sea or other waterbody.

RELICT

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

RESIDUAL SOIL

Soil resulting from the weathering of rock insitu.

RILL EROSION

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

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

Discrete area of rock exposed at surface.

ROOF PENDANT

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

SCREE (=TALUS)

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

SESQUIOXIDES

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

SHEET EROSION

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

SHEETING JOINT

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

SIDESLOPE

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

SPHERULITE

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

STRIKE

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

STRUCTURE

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

TECTONIC

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

TERRAIN ATTRIBUTE

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

TERRAIN CLASSIFICATION

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

TERRAIN COMPONENT

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

TERRAIN EVALUATION

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

TEXTURE

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

TOR

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

TRANSMISSIVITY

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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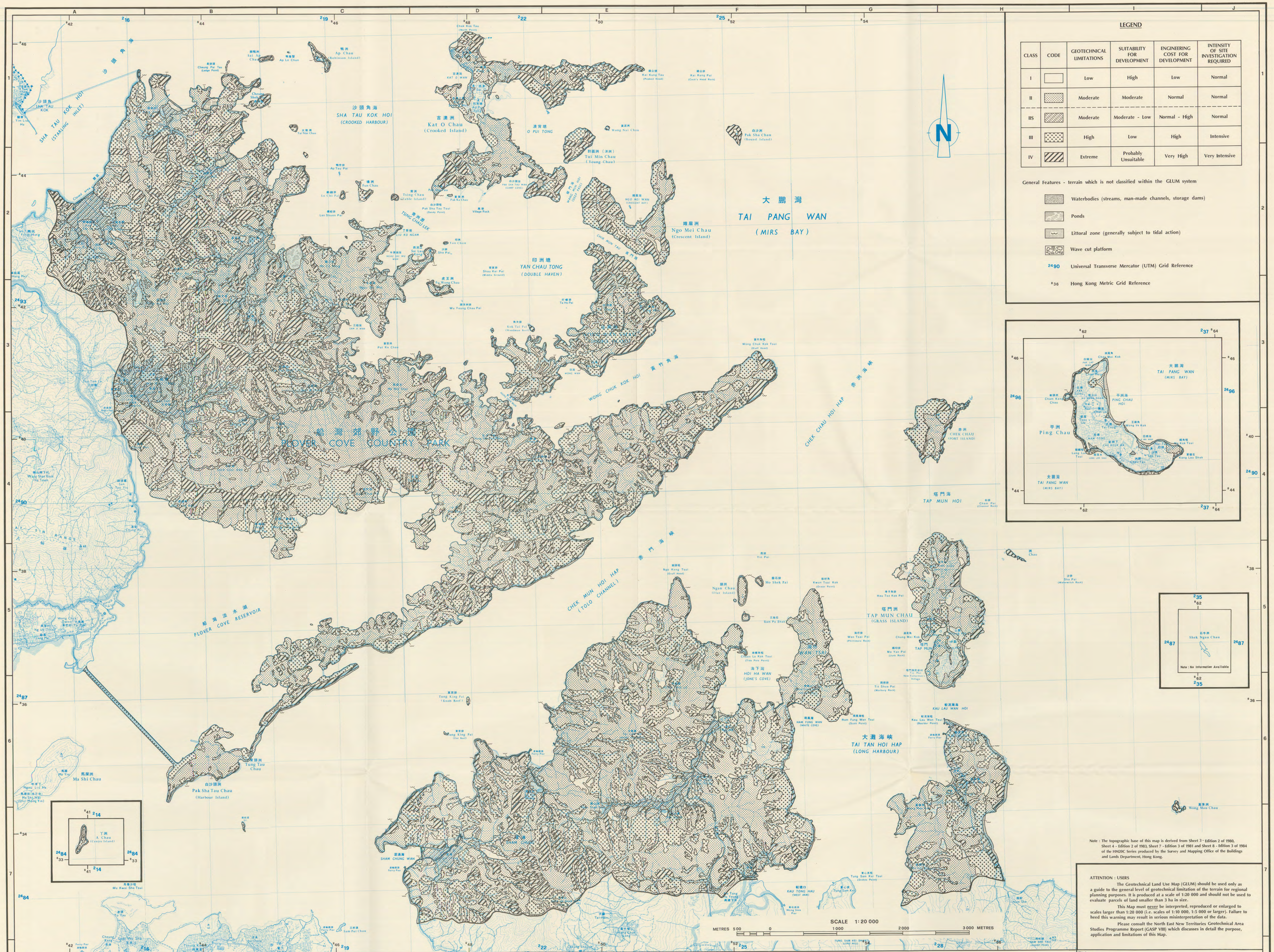

LEGEND

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
- 2490 Universal Transverse Mercator (UTM) Grid Reference
- 836 Hong Kong Metric Grid Reference

Note : The topographic base of this map is derived from Sheet 3 - Edition 2 of 1980, Sheet 4 - Edition 2 of 1983, Sheet 7 - Edition 3 of 1981 and Sheet 8 - Edition 3 of 1984 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 North East New Territories Geotechnical Area Studies Programme Report (GASP VIII) which discusses in detail the purpose, application and limitations of this Map.

Geotechnical Control Office
Civil Engineering Services Department

GEOTECHNICAL AREA STUDIES PROGRAMME

GEOTECHNICAL LAND USE MAP — NORTH EAST NEW TERRITORIES

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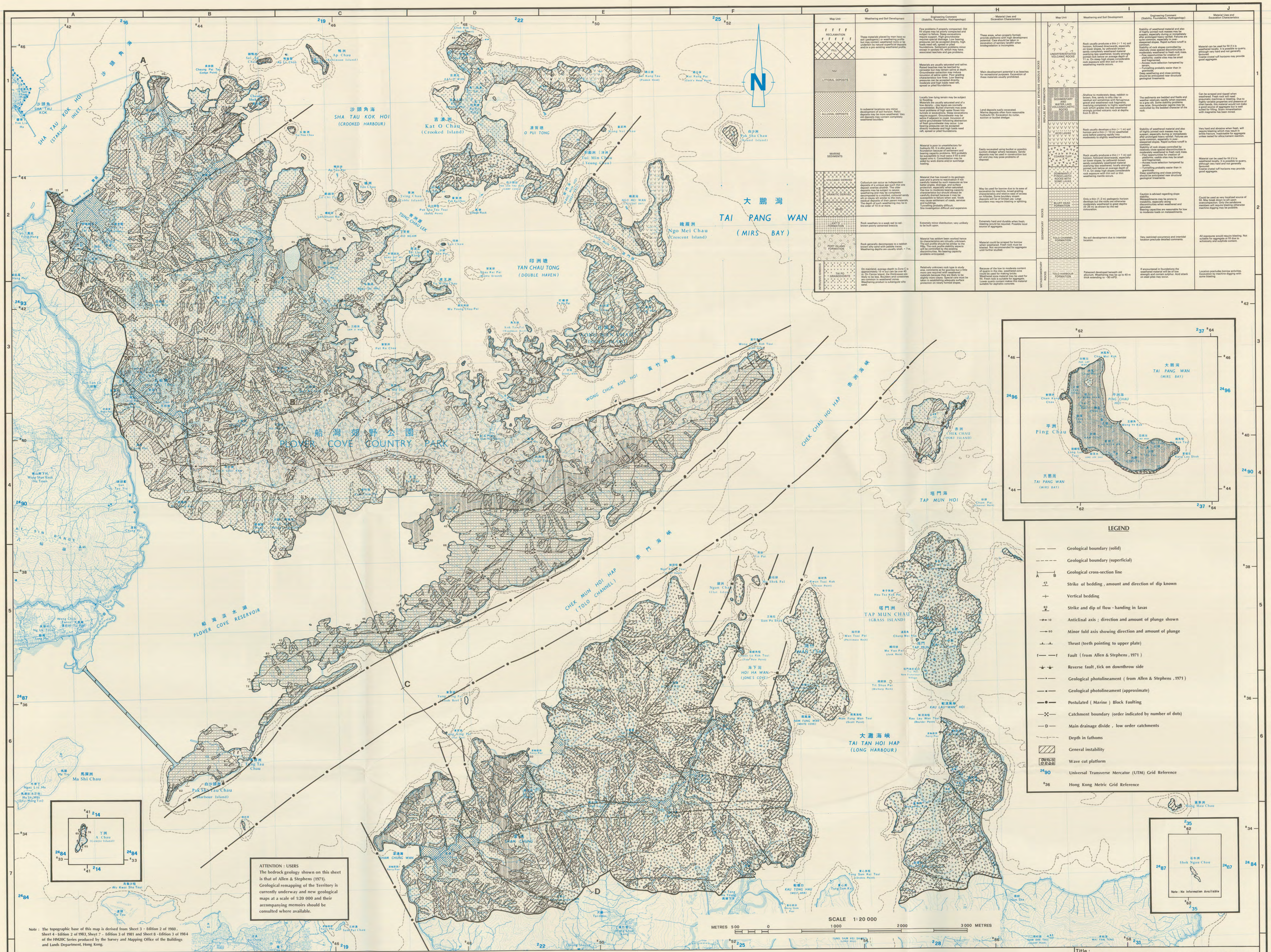

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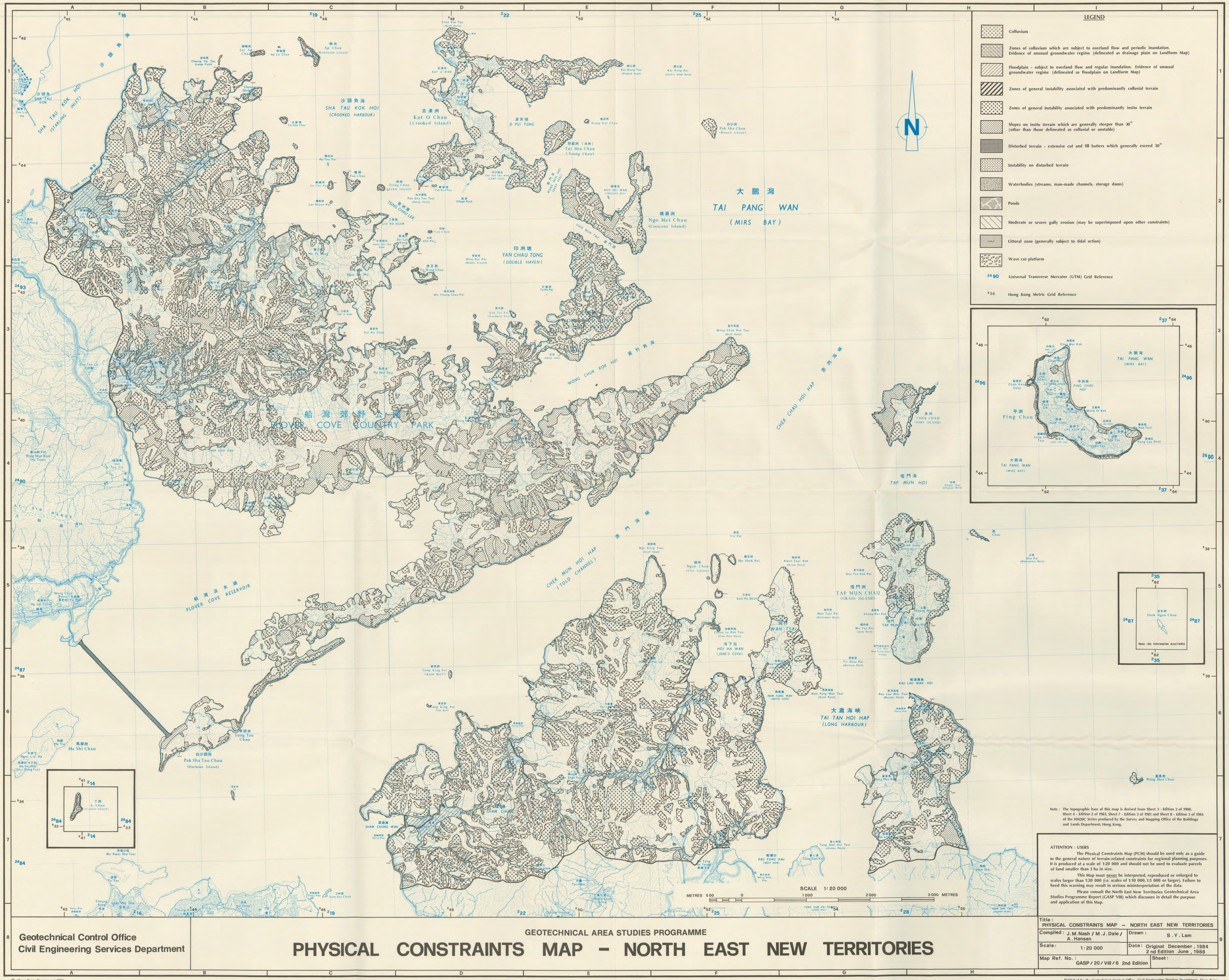

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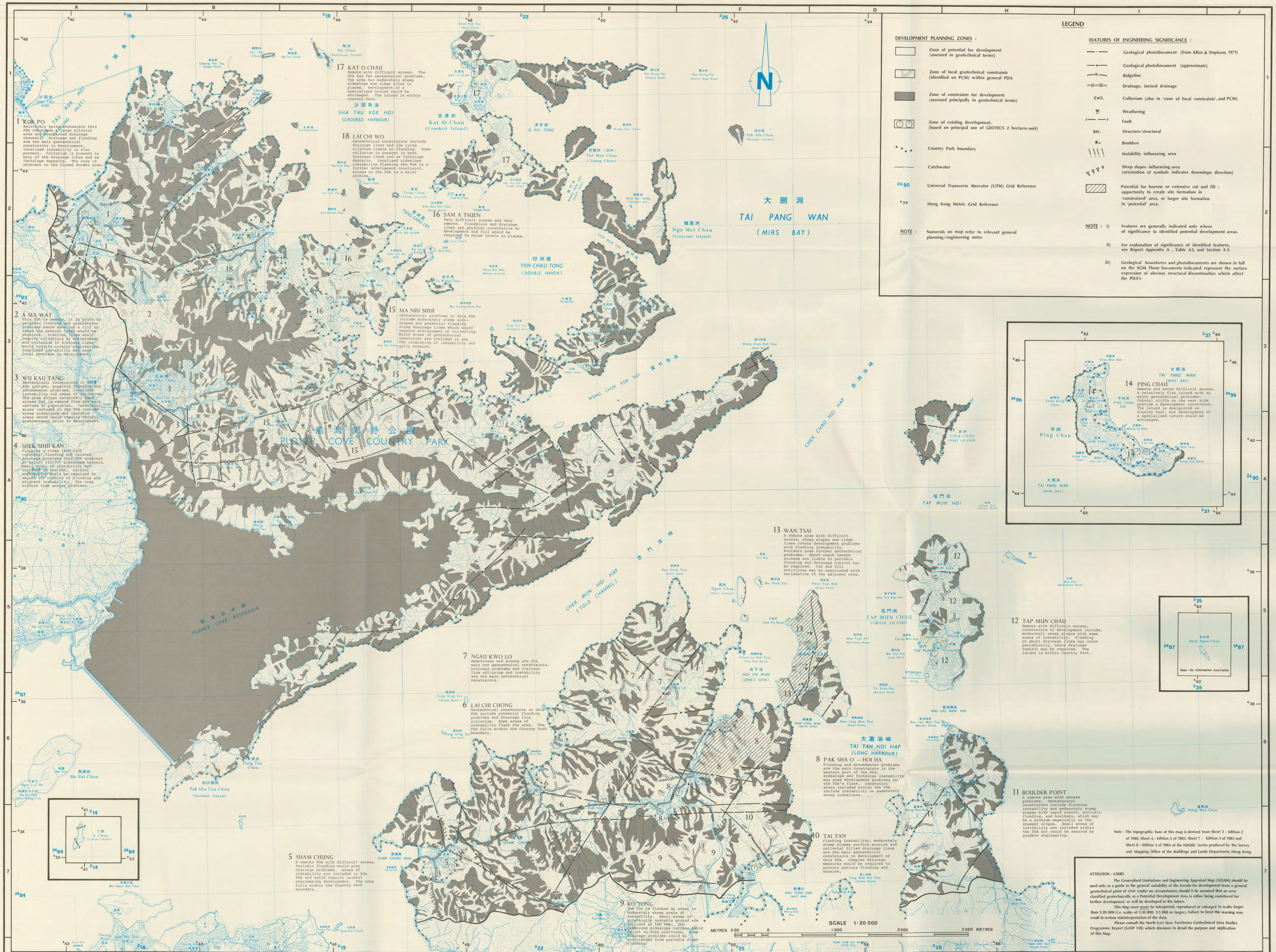

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GEOTECHNICAL AREA STUDIES PROGRAMME

GENERALISED LIMITATIONS AND ENGINEERING APPRAISAL MAP - NORTH EAST NEW TERRITORIES

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