Geotechnical Area Studies Programme

GASP Report IV

North West New Territories

Geotechnical Control Office
Civil Engineering Services Department
Hong Kong

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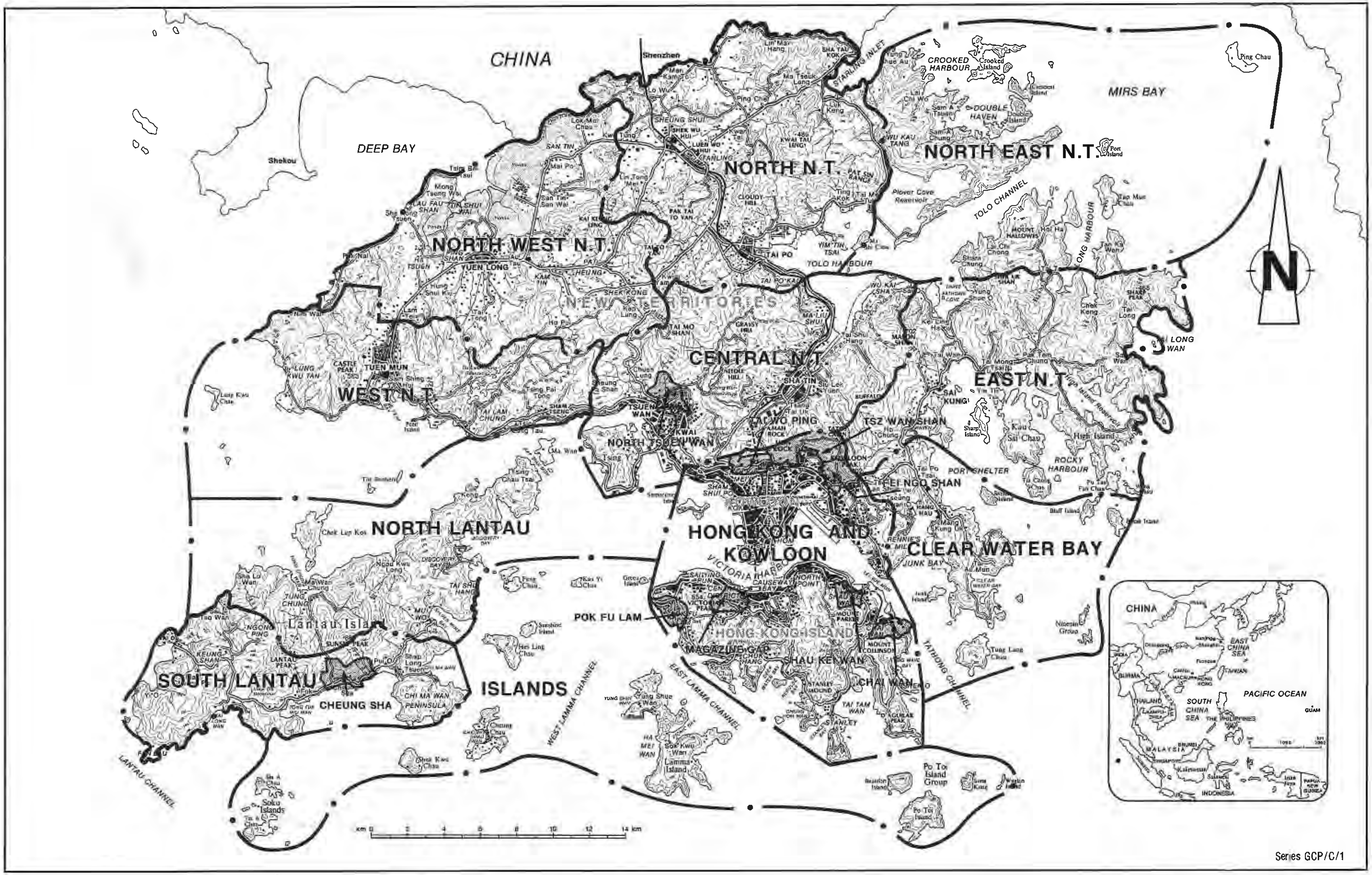

Map of the Territory of Hong Kong Showing the Locations of the Geotechnical Area Studies.
(Boundaries of the Regional Studies are shown by dashed lines and locations of District Studies are indicated by dark screens)

FOREWORD

This Report aims to provide an adequate geotechnical basis for the planning and land use management of the North West New Territories, mainly by way of information presented on a series of maps at a scale of 1:20 000. It is the fourth 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 six user-oriented maps. Three of these are supplied with this published Report—the Engineering Geology Map (EGM), Geotechnical Land Use Map (GLUM) and Physical Constraints Map (PCM). The GLUM classifies the terrain into four classes according to the level of geotechnical limitations and the PCM presents the major physical constraints that are likely to influence development. In addition to the three maps accompanying this Report, the Terrain Classification Map, Landform Map and Erosion Map can be consulted in the Geotechnical Information Unit of the Geotechnical Control Office.

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

This Report was originally produced in January 1981, for use within the Hong Kong Government on the basis of information assembled during the period December 1979 to October 1980. This fact should be borne in mind by users, who should also note that the contents of the Report have for the most part not been updated. Further, although every effort has been made to ensure the accuracy of the information contained in the Report, this cannot be guaranteed. The Geotechnical Control Office cannot therefore accept any liability for errors in the data or for misinterpretations made during the study.

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

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

The Geotechnical Control Office acknowledges the co-operation and assistance given by the Commissioner of the Soil Conservation Service of New South Wales, Australia, who made available Mr. P. D. Houghton, a specialist Aerial Photograph Interpreter, to participate in the study. Acknowledgements are also due to the Survey & Mapping Office, Buildings & Lands Department of the Hong Kong Government, who provided most of the aerial photographs used in the study.

E. W. Brand
Principal Government Geotechnical Engineer
February 1988

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1. INTRODUCTION

1.1 The North West New Territories Geotechnical Area Study

This Report presents the results of a 1:20 000 scale Regional Geotechnical Area Study of the North West New Territories which was carried out in the Geotechnical Control Office between December 1979 and October 1980. The area covered by the study, which is designated as GASP IV, 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 three new maps which cover the area dealt with in this GASP Report will be available soon together with an accompanying Memoir (Langford *et al,* 1988). A small portion in the southeast of the study area is described in Addison (1986) and the accompanying geological map (Geotechnical Control Office, 1986).

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 fourth of the Reports to be published; eight others will follow in due course. A number of District Studies: Stage 1 have been carried out; whilst these District Study 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 Appendix A.

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

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

1.4 Organisation of the Report

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

Section 2 describes the topography, geology, geomorphology, hydrology, vegetation, erosion, instability and land use of the North West New Territories.

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 suitability for development.

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 19 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, and these are presented as Plates 1 to 10. 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 site investigations, aerial photographs and rainfall relevant to the North West New Territories. 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) and the Engineering Geology Map (EGM) 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.

There are six conventional line maps produced at a scale of 1:20 000 for this 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.9.

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 18a.

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 19a.

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 *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
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 West New Territories.

2. DESCRIPTION OF THE NORTH WEST NEW TERRITORIES STUDY AREA

2.1 Geographical Location

The study area occupies approximately 15 734 ha in the northwest portion of the New Territories, as shown in Figures 1 to 3. It includes the main towns of Yuen Long, Kam Tin, Shek Kong and Lau Fau Shan. The eastern boundary is formed by the catchment which passes between Shek Kong and Kadoorie Farm in the Lam Tsuen Valley. The southern boundary of the area crosses Castle Peak Road near Lam Tei and then follows the northern perimeter of the Military Firing Range. The Tsim Bei Tsui peninsula marks the western boundary with Deep Bay and the northern boundary is demarcated by the Shum Chun River.

2.2 Topography

The topography of the study area ranges from flat to precipitous. Approximately 61% (9 576 ha) is low-lying with slope gradients of less than 5°. These flat low-lying areas occur in the vicinity of Yuen Long and the other larger towns. Of the flat land, some 2 558 ha are occupied by duck and fish ponds and a further 740 ha by littoral deposits, below the level of high tide. Table 3.1 presents the distribution of slope gradients within the North West New Territories. A large portion of the very steep to precipitous terrain occurs on the slopes of Kai Keung Leng and the western slopes of Tai Mo Shan. The topography in the southern portion is steep-to-undulating with a large proportion of the terrain between 15 and 40°.

Tables B1, B3, B4 and B5 in Appendix B give basic physiographic data on slope gradient, aspect and landforms. The GEOTECS Plot at Figure 5 shows the general distribution of slope gradient within the area.

Table 2.1 Distribution of Slope Gradient

Slope Gradient	% of Total Area	Area (hectares)
0– 5°	60.9	9 576
5–15°	3.7	581
15–30°	10.0	1 567
30–40°	23.4	3 684
40–60°	1.8	287
>60°	0.2	39
	100.0	15 734

2.3 Geology

2.3.1 *General*

The geology of the study area is unusual in that a smaller area of solid bedrock is exposed at the surface relative to the area of superficial materials. The former includes the sediments of the Lok Ma Chau and Kat O Formations, the volcanic rocks of the Repulse Bay Formation and the various granites, whereas the latter consists of colluvium and extensive alluvial deposits.

The oldest rocks of the area are the Lok Ma Chau Formation (Allen & Stephens, 1971). These consist of metamorphosed sedimentary and volcanic rocks which lie in a northeast trending belt of low relief from Tuen Mun to Lo Wu. Overlying these rocks is the extensive suite of Middle Jurassic volcanic rocks of the Repulse Bay Formation consisting of pyroclastics together with some sedimentary and water-laid volcanic rocks. This sequence of rocks was intruded by a massive batholith of granitic rocks during the Upper Jurassic period. The batholith was of such regional extent that the older sedimentary and volcanic rocks exist as a number of roof pendants. At a late stage of intrusion, numerous dykes were injected into both the early sediments and the relatively newly emplaced granitic rocks. A long period of quiescence may have followed emplacement of the granites. During this hiatus, prolonged periods of weathering and erosion created an unconformity with the overlying sediments.

During the Quaternary, the very minor Kat O Formation was deposited, and the older deposits of colluvium were formed. The latter probably blanketed the terrain to varying thicknesses as a result of numerous episodes of colluvial formation.

In recent times, the undifferentiated and raised terrace alluvium were deposited under the combined influence of higher sea levels and fluctuating fluvial conditions. These sediments almost certainly cover portions of older colluvial deposits in the Shek Kong, Yuen Long and Castle Peak Valley regions. The final episode in the geological history of the area was the deposition of the littoral sediments and the continued, but much subdued, formation of colluvium on mountain slopes and footslope terrain.

The locations of the various geological materials are presented in the Engineering Geology Map located in the Map Folder of this Report. The general distribution of the major geological units is summarised in the GEOTECS Plot in Figure 6.

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

The Geotechnical Control Office is currently preparing a new series of geological maps at a scale of 1:20 000 which will result in a more precise definition of the distribution of the geological units than is presented in this Report. These new geological maps of the area are soon to be published, together with an explanatory Memoir (Langford et al, 1988).

As a precursor to the 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 perspective Davis (1952) is of considerable interest. The rocks in the area of Sheet 7 are described by Addison (1986) which accompanies the geological map (Geotechnical Control Office, 1986).

On the basis of this GASP study, the relative proportions of the geological materials are graphically illustrated in the Pie Chart in Figure 4, the GEOTECS Plot in Figure 6, and the percentages are presented in tabulated form in Table B6 in Appendix B.

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

The nature of the individual rock types is summarised and their general engineering behaviour and planning significance are discussed in Section 3 and summarised in Table 3.1.

2.3.2 *Metasedimentary Units*

According to Allen & Stephens (1971), the Lok Ma Chau Formation is of Lower Jurassic age and consists of low-grade regionally metamorphosed, deeply weathered schists of dark grey colour. The surface outcrop of this Formation occupies approximately 5% (800 ha) of the area and it underlies a large portion of the alluvial plain from Tuen Mun to Lo Wu. The outcrop extends along the eastern side of the Castle Peak Range north of Tuen Mun, northeast through Yuen Long towards Lok Ma Chau and Lo Wu.

The terrain is characterised by low, rounded hills in the southwest where the sediments are argillaceous in nature. Phyllites occur near Yuen Long and sandstones, sandy shales and quartzites are evident in the northeast near Mai Po. In the north, the main rock type is white, massive, well-cleaved quartzite with subsidiary sericitic schists. These more resistant rocks result in well-defined, prominent, landform features.

Recent mapping work within the revised Geological Survey of the Territory has confirmed the occurrence of marble within the Lok Ma Chau Formation (as defined by Allen & Stephens, 1971). The marble is fine- to coarse-grained and is partly dolomitic or tremolitic. The marble sequence, which may be up to 300 m thick (Lai & Mui, 1985), is treated in greater detail in Geological Memoir No. 3 (Langford *et al*, 1988) and on the accompanying geological maps, sheets 2, 5 and 6 (Geotechnical Control Office, 1988a, b and c). In the Yuen Long area, marble was reported by Siu & Kwan (1982), and Siu & Wong (1984a, b).

2.3.3 *Volcanic and Volcaniclastic Units*

The Repulse Bay Formation (Allen & Stephens, 1971) consists of a succession of coarse tuffs, ignimbrites and generally acid lavas which were deposited subaerially with several intercalated sedimentary rock units. Allen & Stephens (1971) indicate that these rocks are of Middle Jurassic age. The Formation is severely folded and metamorphosed in places, probably resulting from the intrusion of the granites.

Within the study area, three main units of the Repulse Bay Formation occur.

(i) *Sedimentary Rocks and Water-laid Volcaniclastic Rocks (RBs)*
These rocks occupy less than 1% (69 ha) of the study area. They outcrop fairly extensively on the footslope terrain of the Castle Peak Valley near Tuen Mun and also to the south of Yuen Long along the contact with the granite hills. Exposures are rare due to the extensive colluvial and alluvial cover and the soft, easily weathered character of the sediments. The rocks generally consist of thinly bedded, black or grey, hard siltstones with minor black shales or fine sandstones. The sediments are likely to be of continental lacustrine or fluviatile origin.

(ii) *Coarse Tuff (RBc)*
This rock generally forms thick, massive beds (without internal stratification) 'inter-bedded' within the dominantly pyroclastic rocks. In the study area, the rock is a very dark grey, dominantly felspathic, coarse-grained, welded crystalline tuff and occurs on 3.0% (469 ha) of the terrain.

(iii) *Pyroclastic Rocks with Some Lavas (RBp)*
These rocks form the major unit of the Repulse Bay Formation and occupy 16% (2 561 ha) of the study area. The main rock type within this unit is formed of explosively erupted, fine-grained tuffs and ignimbrites produced during a major period of volcanicity during the Middle Jurassic. The rock is usually white, creamy grey or pale green, very fine-grained and easily weathered with outcrops and boulders having pitted surfaces. It occupies a considerable proportion of the mountainous terrain north and immediately south of the Shek Kong valley. The regional strike of the volcanic rocks is almost certainly related to the geological structure and this, in turn, controls many topographic features noted in the study area.

2.3.4 *Intrusive Igneous Units*

Several different intrusive igneous rock types have been noted in the regional batholith underlying Hong Kong. These rock types have been mapped and placed in a relative age sequence by Allen & Stephens (1971), and five phases of intrusive activity have been established. The first four are part of a single episode of late tectonic intrusive activity, while the fifth is post tectonic. In the North West New Territories area, representatives of the all but the third phase occur as shown in Table 2.2. The more important of these are described below.

Table 2.2 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 Yes No
3	Quartz Monzonite Feldspar Porphyry Dyke Swarm	No No
4	Granophyric Microgranite Needle Hill Granite Hong Kong Granite	Yes Yes Yes
5	Dolerite	Yes

(i) *Tai Po Granodiorite (XT)*
This is the oldest intrusive rock, and it forms numerous small intrusions in all parts of the Territory and in two locations in the study area (both near Shek Kong) where it occupies some 173 ha of terrain. The rock is usually coarse or medium-grained, dark coloured, porphyritic and consists of plagioclase, quartz, potassium feldspar, biotite and amphibole. Xenoliths are common. The rock weathers easily, and it forms a dark orange residual soil with many rounded core boulders.

(ii) *Cheung Chau Granite (CC)*
This variety of granite occupies approximately 9% (1 442 ha) of the area. It forms a major mountain range stretching between Castle Peak and Lau Fau Shan and also occurs to the east of Castle Peak Valley to the north of Tai Lam Chung Reservoir. The rock is usually pale grey or very pale pink when fresh and is medium-grained (3–5 mm) with very few feldspar phenocrysts. Mineralogically, this granite contains potassium feldspar, quartz (35–40%), plagioclase (often andesine) and biotite. The potassium feldspar proportion lies between 50 to 66% of the total feldspar content.

This granite is known to weather relatively easily and weathering begins along joints or discontinuities and then permeates inwards to form rounded corestones. Some of the corestones are in a fresh crystalline condition while others are highly weathered.

Cheung Chau Granite often resembles the medium-grained phases of the Sung Kong and Hong Kong Granite and, in these instances, only field exposures of one granite intruding another, or indirect evidence such as feldspar porphyry dykes not intruding Cheung Chau Granite, allow identification of the two granites.

(iii) *Needle Hill Granite (NH)*
This occurs on 327 ha of terrain in the southern portion of the study area, where it displays a complex but intrusive relationship with the Cheung Chau Granite. Evidence from other exposures around the Territory indicate that the Needle Hill Granite is younger than the Tai Po and Cheung Chau Granites and is only intruded by dolerites of the fifth igneous phase. Two main variations of Needle Hill Granite are noted in the Tai Lam Chung Area. One is primarily uniform, medium-grained and contains phenocrysts of quartz and feldspar, usually less than 10 mm long and this grades into the second variety of fine-grained porphyritic granite with somewhat larger phenocrysts. Both varieties of this granite weather fairly readily, especially the fine-grained variety, which decomposes to a sandy white clay. Sheet and gully erosion are typical on both phases of the Needle Hill Granite.

(iv) *Dyke Rocks*
Although, Allen & Stephens (1971) do not indicate a concentration of dykes in the study area, field inspection indicates that they are not uncommon. Several dolerite dykes and quartz veins have been observed. These dykes are generally thin and are always fine-grained and black, with a very thin chilled margin. Offshoot dykes often follow joints in the granite country rock.

In summary, many members of the intrusive igneous rock suite have similar physical properties and, from a general engineering point of view, appear to behave in a similar manner. Intrusive igneous rocks occur in approximately 12.3% of the study area.

2.3.5 *Sedimentary Unit*

Only a very small outcrop of red breccia occurs within the study area. This exposure forms a coastal headland north of Lau Fau Shan. This exposure was classified as Kat O Formation by Allen & Stephens (1971) on the basis of its lithological similarity to the outcrop on Kat O Chau.

2.3.6 *Superficial Units*

In addition to the bedrock geology, both natural and man-made superficial deposits constitute almost 63% of the land surface. These superficial deposits are classified as follows:

(i) *Colluvium*

The colluvial materials occur over 2 672 ha of the study area. These deposits are formed by gravity transport of rock and soil debris down slope, and occur as recent or relict deposits. They are heterogeneous in their physical properties and, in this Report, are subdivided only on the basis of the parent rock type. The majority of the colluvium is derived from volcanic detritus (Table 2.3), and these deposits tend to be relatively thicker than the colluvium formed from the granites and metasediments.

Table 2.3 Distribution of Colluvium

Type of Colluvial Detritus	Area (hectares)	% Total Colluvium	% Total Area
Volcanic	1 538	57.5	9.8
Granitic	365	13.7	2.3
Metasediments	451	16.9	2.9
Mixed	318	11.9	2.0
Total	2 672	100.0	17.0

The colluvium derived from the volcanics is characterised by a diverse variety of cobble-size and boulder-size fragments within a matrix of fine material. There is generally no apparent uniformity in weathering of the detrital fragments, although complete weathering may be evident in some of the older (relict) deposits.

The colluvial deposits forming the footslope terrain on the north and west-facing slopes below Tai Mo Shan are derived from the volcanics of the Repulse Bay Formation. The colluvium at Shek Kong forms a thick blanket which mantles the underlying volcanics. These deposits also occur on the northern and southern slopes of Kai Keung Leng. Deposition of detritus from erosion of the granites in the southern portion of the area tends to form relatively thin, well-sorted, colluvium.

The colluvial deposits consist of a wide range of materials from silty and sandy, fine slope wash typical of the granites, through sandy, cobble and sandy boulder beds, to boulder fields. Large voids and tunnel erosion are often associated with colluvium and along drainage paths. In many instances, there is no surface evidence of these subsurface features.

(ii) *Alluvium*

The alluvial deposits occur over an extensive area of the North West New Territories including the floor of Castle Peak Valley, Yuen Long, the Shek Kong Valley and the Mai Po and San Tin coastal plain. They occupy approximately 40% of the study area. These deposits occur as either raised terraces or as undifferentiated deposits. The terraces are generally apparent due to their slightly higher elevation and small steep escarpments adjacent to current drainage lines. They also occur in the upper parts of the valley complex and become much more difficult to distinguish toward the lower, open or seaward end of the valleys where they may grade into undifferentiated alluvium.

The raised terraces may indicate past eustatic fluctuation and result from either emergence (isostatic/tectonic) of the land mass or fall in sea level associated with palaeoclimatic variation during the late Quaternary.

Lithologically, the deposits consist of medium to thickly bedded horizons of dark grey, sandy silt or clayey silt with some sandy layers and very occasional horizons of silt-bound gravel. The origin of these deposits may be littoral or deltaic in character rather than strictly alluvial. Only the upper most beds, possibly the raised terraces, and the recent sediments of the Castle Peak Valley, are of fluvial origin.

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

(iv) *Littoral Deposits*
These deposits occur on the seaward edge of the alluvial plain in Deep Bay near Mai Po, the mouth of the Shum Chun River and along the coast southwest of Tsim Bei Tsui. They are intertidal in nature and, generally, consist of saline beach sand and mud flats.

(v) *Reclamation*
Approximately 151 ha of the area exists as reclamation. This figure represents approximately 1.0% of the study area. The material used to form the reclamation is highly variable and may contain weathered and fresh rocks from any of the previously discussed groups, old masonry sea walling and/or refuse.

(vi) *Fill*
During site formation, areas of fill have been placed which now total approximately 1.5% of the study area. The engineering behaviour of the material is generally dependent on the degree of compaction at the time of placement and any subsequent densification as a result of settlement.

2.4 Geomorphology

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

The two major lithologies, namely the granite and volcanic rocks, weather in very dissimilar ways to produce markedly different landform features. Evidence of eustatic variation is apparent as bench marks in alluvial and colluvial deposits and the occurrence of alluvium and marine clays at elevations considerably higher than current sea level.

Table B5 in Appendix B presents the distribution of the major landforms within the study area. The low-lying alluvial plain occupies about 10.5% (1 659 ha) of the area. Much of this terrain is affected by periodic inundation and is delineated as floodplain. Yuen Long is located at the focal point of three substantial floodplains, and this partially explains why much of the town is inundated during periods of intense rainfall.

Colluvial deposits exist over approximately 17% of the terrain in the study area. Deposits are delineated if they are of significance to engineering at a scale of 1:20 000 (Styles, 1983). The mapped distribution is shown on the Physical Constraints Map and, the Engineering Geology Map, and is summarised on the GEOTECS Plot in Figure 6. A breakdown of the 2 672 ha of colluvial terrain according to slope angle is also summarised in Table B5 in Appendix B. Approximately 2 162 ha is less than 15° in slope angle and 206 ha is steeper than 30°. There is 294 ha within the 15 to 30° slope range. Almost 13% of the deposits which occur within the latter slope range are located on terrain which is subject to possible groundwater flow.

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

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

Colluvium is common on footslope terrain, and thick deposits are generally associated with the volcanics of the Repulse Bay Formation. An extensive deposit of boulder colluvium occurs at Shek Kong Village on terrain which varies in slope gradient between approximately 15 and 40°. Large colluvial fans are characteristic of the footslope and drainage plain terrain of Kai Keung Leng and Tai To Yan. There is minimal colluvial development associated with the granitic terrain in the southern portion of the area. Deposits in this area are mainly thin, relatively weathered, uniformly graded accumulations of slopewash.

The steepest terrain is associated with the highly jointed volcanics. Considerable general instability is evident on the relatively steep north-facing coarse tuffs.

Much of the volcanic terrain is controlled by a strongly developed joint system and tends to be steeply sloping. The granitic areas are generally characterised by convex-concave slope elements, and the major slope gradients associated with this terrain are in the range of 15 to 40°. Many of these slopes, particularly on the volcanics, vary from 30 to 40°, and this appears to relate to the relatively high incidence of slope failure (Table B11).

Unlike the volcanics and granites, a large proportion (74% or 1983 ha) of the undisturbed colluvium occurs on slope gradients of less than 5° (Table 204). A further 187 ha lie between 5 and 15°, and 496 ha occur on slopes steeper than 15°. Much of the steep colluvium occurs within drainage lines and steep stream courses. These drainage lines discharge across the flatter footslope terrain where thick deposits of colluvium are common. The footslope terrain subject to periodic inundation is important because the hazard of slope failure is higher than on adjacent relatively well-drained areas of colluvium. Within the Territory, there is considerable evidence of instability associated with low angle (less than 15°) colluvial terrain in this type of hydrogeological setting. Approximately, 41% of the colluvium with slope gradients up to 5° constitute areas of concentration of surface runoff. These. areas require careful planning and land use management to minimise the likelihood of slope failure.

Table 2.4 Slope Gradient on Natural Colluvial Terrain

Slope Gradient	Area of Colluvium (hectares)	% Colluvium Occupied by Drainage Plain	% of Total Colluvium	% of Total Area
0– 5°	1 983	88.3	74.4	12.6
5–15°	187	6.9	7.0	1.2
15–30°	290	3.5	10.9	1.9
>30°	206	1.3	7.7	1.3
Total	2 666	100.0	100.0	17.0

In the eastern portion of the study area, there is considerable evidence of raised alluvial deposits. These deposits, which were delineated by Allen & Stephens (1971) at Shek Kong and near Nam Hang (Yuen Long catchment), may result from alluvial deposition at a time of higher sea level during the Quaternary. The large deposits occur at levels approximately 5 to 15 m above current sea level.

A large colluvial deposit occurs on the midslope to footslope terrain of Tai Mo Shan, in the vicinity of Route TWISK near Shek Kong. The colluvium was, almost certainly, deposited as an extensive blanket during a period of rapid weathering, erosion and detrital accumulation. The current geomorphological setting is not that of colluvial terrain efficiently balanced to a fluvial regime but rather is a drainage system controlled by the underlying bedrock geology. On the footslopes upslope of Shek Kong, drainage lines are deeply incised into the colluvium, in some cases down to bedrock. There is evidence of a large fault or major lithological contact across this terrain, because the sub-parallel drainage lines which are incised through the colluvium are significantly deflected to the northeast. A possible explanation for this is that sea (base) level has fallen, and the hydrological regime has readjusted by incision through the colluvial blanket until it has reached bedrock. The current drainage pattern, therefore, reflects the pre-colluvial landform. This conclusion is consistent with the general pattern of colluvial geomorphology elsewhere in the Territory.

2.5 Surface Hydrology

The natural drainage pattern in the North West New Territories study area is partially disrupted by development, extensive agriculture, viticulture and large tracts of marsh land. Nonetheless, the study area boundaries generally coincide with major physiographic catchments. The Engineering Geology Map shows the location of the major catchments. Each catchment boundary is annotated with the highest order of stream which exists within it. The system of stream ordering is described in Appendix A.

Within the built up areas, the principal changes caused by urban development are the channelisation coupled with possible realignment of drainage paths, together with the formation of an impervious surface to the ground. The climate in the Territory is characterised by periods of intense rainfall, as illustrated in Appendix C.3, and storm channels in urban areas require a large capacity due to the extremely high volume of runoff. Runoff is removed through a system of storm drains into the main channels. Discharges within urban channels are high, and the times to peak discharge are short. Peak discharges under these conditions will be much higher than for a natural drainage system, and proposals for development should take this into account. Also, the extension of a reclamation area may cause a reduction in overall gradient of a drainage channel or nullah, thus possibly necessitating regrading to maintain a sufficient gradient for efficient discharge. Alternatively, an increase in channel cross-section may be required in the lower reaches to accommodate large flows. Some of the channels are covered, and the alignments are not necessarily apparent from a visual inspection of an area.

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

The surface hydrology of the North West New Territories is based on four major catchment areas and a number of subsidiary catchments. The major catchments are Shek Kong, Yuen Long, Shek Po Tsuen and Ngau Tam Mei.

(i) *Shek Kong Catchment*
This is the largest catchment area and is located in the southeastern portion of the area. It drains the slopes of Kai Keung Leng, Tai To Yan and the western slopes of Tai Mo Shan. The major drainage lines flow west and northwest to join the fish pond system near Kam Tin.

(ii) *Yuen Long Catchment*
This catchment lies to the south of Yuen Long and is predominately on granitic terrain. The major flow paths drain in a northerly direction and are contained within large drainage nullahs. The alluvial plain and lower footslope terrain in this catchment are particularly susceptible to flooding and inundation during the wet season. Yuen Long has a history of flooding which is due to the convergence of three major floodplain systems in the vicinity of the town centre.

(iii) *Shek Po Tsuen Catchment*
This catchment crosses the Castle Peak Road between Tuen Mun and Yuen Long and drains the steep terrain on the northern Castle Peak Range and the granites near Tan Kwai Tsuen. Much of the alluvial plain is low-lying and is subject to regular inundation and high ground water table conditions.

(iv) *Ngau Tam Mei Catchment*
This is the smallest of the major catchments and is located in the northern part of the study area. It drains the northern slopes of Kai Keung Leng, and the major flow line trends in a westerly direction.

The drainage patterns within the major catchments are influenced by the structural and tectonic geological controls. Subparallel northeast and easterly trending lineations provide locii for surface runoff. A further, subparallel, set of lineations trend in a northwesterly direction. Within the subdued relief of the granitic terrain, the structural control has led to the development of a 'trellis' drainage pattern, whereas the structural control exhibited in the volcanics produces a 'directional trellis' pattern similar to the form described by Howard (1967).

2.6 Vegetation

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

The vegetation classes are:

(i) *Grassland*
This class generally consists of indigenous or introduced grass species which occur after the clearing of shrubland or woodland. Grassland occupies 18.2% of the study area. Large areas of grassland occur throughout the undeveloped terrain within the study area.

(ii) *Cultivation*
This occupies 18.6% of the study area. Urban expansion has alienated some of the agricultural land in the area.

(iii) *Mixed Broadleaf Woodland*
This class usually contains a wide variety of introduced and exotic species. A total of 13.9% of the study area is covered by this class of vegetation.

(iv) *Shrubland (Less than 50% Ground Cover)*
Shrubland occurs as regrowth on areas which have been affected by disturbance of some form or other. Shrubland generally develops after grassland, particularly in areas protected from hill fire. This class forms 3.5% of the study area.

(v) *Shrubland (Greater than 50% Ground Cover)*
This class is similar to (iv) but is characterised by denser vegetation. It covers 3.6% of the study area and is scattered throughout the undeveloped land.

(vi) *No Vegetation on Natural Terrain*
Predominantly bare soil which is, or has in the recent past been, affected by moderate or severe soil erosion is usually marked by the absence of vegetation. This class occupies 6.9% of the area, mainly on ridgecreats and spurs of granitic terrain.

(vii) *No Vegetation due to Man's Disturbance*
Approximately 17.2% of the study area is affected by urban development and associated activities. Existing land use is discussed in Section 2.8.

(viii) *Rock Outcrop*

Areas of general rock outcrop may contain sparse intermittent grass and shrub vegetation but the land surface is predominantly rock with little soil. Only 4 ha of the terrain is classified in this group.

(ix) *Waterbodies*

Natural streams, man-made channels and reservoirs occupy approximately 18.1% of the area.

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

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

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

2.7 Erosion and Instability

2.7.1 *General*

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

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

The areas affected by the severe forms of erosion and slope instability are shown on the Physical Constraints Map and the latter on the Engineering Geology Map. A summary of the distribution of erosion and instability is given in the pie charts in Figure 4, tabulated in Table 2.5, and illustrated in the GEOTECS Plot in Figure 8.

Erosion and instability affect 25.3% (3 977 ha) of the study area. However, approximately 7.6% (1 200 ha) of the study area is currently developed, with erosion occurring on unprotected platforms and slopes. In the study area, almost 25% of the natural terrain is subject to erosion or instability.

Table 2.5 Erosion and Instability

Erosion		% of Total Area	Area (ha)
Instability			
—well-defined landslips		<0.1	4
—coastal instability		0	0
—general instability		9.7	1 522
Appreciable Erosion	Sheet erosion—minor	6.0	938
	—moderate to severe	4.1	649
	Rill erosion —minor	<0.1	8
	—moderate to severe	2.3	365
	Gully erosion —minor	1.4	214
	—moderate to severe	1.8	277
No Appreciable Erosion		74.7	11 757
		100.0	15 734

2.7.2 *Erosion*

(i) *Sheet Erosion*
This form of erosion produces extensive areas of bare ground devoid of vegetation. A total of 10.1% (1 587 ha) of the study area is affected by sheet erosion.

(ii) *Rill Erosion*
This form of erosion is usually associated with cut and fill batters but may also occur on natural terrain. It is characterised by numerous subparallel drainage rivulets, which produce a striated appearance and result in significant soil loss. Within the study area, it is a minor class affecting less than 2.4% of the terrain, mostly on deeply weathered granite sideslopes and ridgecrests.

(iii) *Gully Erosion*
This form of erosion produces deep dissection of the surface with consequent disruption of drainage and may precipitate slope instability. It affects 3.2% (491 ha) of the study area, mainly on the granitic terrain and on colluvial terrain subject to incision by steep, fast flowing streams.

The relationships between the broad erosional forms and geology have been assessed from the information collected in the study. The results are summarised in Tables B10 and B11 at Appendix B. The distributions of the major geological materials and erosion and instability are presented in Figures 6 and 8. The Coarse Tuffs and Undifferentiated Pyroclastics of the Repulse Bay Formation have the highest incidences of slope failure. Approximately 48 and 30% of these units are affected by instability. The volcanic colluvium is also affected by instability, with evidence of slope failure on 15% of the unit. In comparison to the volcanics and colluvium, the granitic terrain is not severely affected by general instability. However, the granites are significantly influenced by sheet, rill and gully erosion. 70% of the Cheung Chau Granite suffers from appreciable erosion. This trend is also evident in the Needle Hill Granites, where the medium-grained phase has a higher incidence of sheet and gully erosion than the fine-grained phase.

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 1 526 ha of the terrain displays some form of instability, and this represents 9.7% of the study area.

(i) *Well-defined Landslips*
Within the study area, mappable 'well-defined landslips' occupy only 4 ha of the land surface.

(ii) *Coastal Instability*
This form of instability is uncommon in the study area which is noted for its coastal deposition rather than erosion.

(iii) *General Instability—Recent*
This form of instability relates to colluvial and insitu terrain where many 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 class occupies 0.8% (120 ha) of the area and is widespread on steep terrain.

(iv) *General Instability—Relict*
This form of instability occupies 8.9% (1 402 ha) of the area, but it does not appear to follow any particular geographical pattern. This class is no less important in terms of constraints upon development than *general instability-recent*, as it may be reactivated by construction or earthworks.

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

2.8 Land Use

2.8.1 *Existing Development*

A large proportion of the North West New Territories is utilised for primary production although extensive urban development is currently taking place. Agriculture, horticulture and fish farming are widespread within the area. There are significant levels of secondary production and light industrial usage at Yuen Long and to a lesser extent at Kam Tin.

Extensive fish and duck ponds occur in the northwest of the area between Tsim Bei Tsui and the Shum Chun River. A number of large quarries exist on the granitic terrain south of Yuen Long. The southwestern boundary of the study area is demarcated by the northern limits of the Castle Peak Firing Range.

Shek Kong airfield is located on a raised alluvial terrace at Kam Tin and occupies a central position on the valley floor. The village of Shek Kong is located on colluvial terrain on the footslopes of Tai Mo Shan.

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 pattern of the four classes is shown in the GEOTECS Plot in Figure 10. The relationship between existing land use and GLUM class is tabulated in Table B13 in Appendix B. The following is a summary of the geotechnical characteristics of the terrain associated with the current principal land uses.

(i) *Natural and Undeveloped Areas*
Some 14 537 ha or 92% of the study area is as yet undeveloped, and of this over 27% is GLUM Class III and over 24% is GLUM Class IV, whilst some 34% is GLUM II, less than 5% is GLUM Class I whilst the remainder consists of waterbodies and littoral zone which are unclassified. Deducting the areas designated as Country Park, the area available for development is reduced to about 6 200 ha (39%) of the study area.

Of the undeveloped natural areas outside the Country Parks, agricultural use, fish and duck ponds, occupy about 41%, mostly on GLUM Class II terrain, and squatters constitute a further 5.8%.

(ii) *Squatters*
Squatters are located on 906 ha, which represents 5.8% of the study area. Approximately 12% of the terrain occupied by squatters is classified as having high to extreme geotechnical limitations. Single storey housing occupies a further 400 ha, also mostly on GLUM Class II terrain.

(iii) *Residential*
Residential development, including two storey housing, occupies about 6% of the study area, mostly situated on GLUM Class II terrain. It is significant that 8% of residential development is situated on GLUM Class III terrain. This indicates that, in some parts of the study area, development has been possible on terrain with high geotechnical limitations. Therefore, areas of GLUM Class III on natural terrain should not be discounted for development purely on the grounds of high geotechnical constraint. However, it also highlights that some residential development is encroaching onto difficult terrain, and that careful land management and sound engineering practice are necessary to minimise the likelihood of slope failure.

Residential development consists of about 11% of GLUM Class I, 81% of GLUM Class II and 8% of GLUM Class III terrain. No GLUM Class IV terrain is occupied by residential development although adjacent terrain may include cut and fill slopes. These figures include residential development intermixed with commercial or industrial use.

(iv) *Commercial and Industrial*
Commercial and industrial areas together occupy less than 1% of the study area and occur almost entirely on GLUM Class II terrain. This observation seems to be valid for commercial or industrial uses intermixed with predominantly residential activities.

(v) *Recreational*
Sporting facilities and urban recreational areas occupy less than 1% of the study area. They are generally located on terrain of low GLUM class.

(vi) *Community and Institutional*
Community facilities and institutions such as schools and hospitals occupy less than 1% of the study area, mostly on GLUM Class II terrain.

(vii) *Cemeteries*
These occupy a small proportion of the study area. They involve little disturbance to natural ground profiles but, because they usually are located in 'auspicious' situations (fung shui) on steeper terrain. Hence, they characteristically occur on GLUM Classes II & III terrain. The burial areas which utilise GLUM Class III terrain are too small to be included within the GEOTECS database.

(viii) *Transportation*
Roads occupy a small portion of the study area. They occur almost entirely on GLUM Class II terrain because they generally utilise the alluvial valley floors.

(ix) *Service Facilities*
Of the community service facilities, sewerage and water treatment plants occupy the largest area, although it is less than 1% of the study area. Due to the requirement for adequate water pressures, service reservoirs are located on upper slopes and therefore involve significant areas of high GLUM class.

(x) *Military*
Military uses form nearly 4% of the study area on mostly GLUM Classes II & III terrain.

(xi) *Quarries and Borrow Areas*
These occupy about 0.5% of the study area. Whilst a pattern of associated high GLUM class is apparent, this is generally a function of quarrying practice. Most other developed land uses tend to be more severely influenced by pre-existing geotechnical limitations.

(xii) *Incomplete Development*
Construction zones, areas of unused reclamation and temporary usage occupy approximately 1% of the study area. Most of this is on GLUM Class II terrain.

2.8.3 *Future Development*

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

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

Statutory restrictions 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 characteristics and engineering performance (column 8). The suitability for borrow and possible uses of the material are given in column 9.

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.

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 5 of Table 3.1 are for general guidance only. For example, granites are normally weathered to a depth of about 20 m, but where ridgecrests are severely eroded, the remaining soft material is much thinner.

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. Erosion removes the soft products of weathering and thus reduces the actual thickness of the profile. Major streams, if not filled with colluvium, generally have fresh rock exposed in their beds.

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

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

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

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

(iii) *Material Resources*

The wide variety of geological materials found in the study area all have some potential for use in engineering activities. The geological suitability of these materials is summarised in column 9 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.

Potential sources of crushed rock aggregate are relatively common in the North West New Territories. Several large quarries already exist in the area, and there appears some scope for development of current resources. The main rock type which has been used by the quarries is the Cheung Chau Granite and it is likely that this material will continue to provide sound, strong, coarse aggregate as well as a satisfactory crushed rock fine aggregate.

The non-sedimentary members of the Repulse Bay Formation, in particular the coarse tuffs, may provide both a good quality coarse aggregate and a crushed rock fine aggregate, although this material would be more difficult to extract. Blasting and crushing costs would be less economical because of the harder and more abrasive nature of the rock.

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

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

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

(*a*) Colluvium.

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

(*c*) Volcanic and volcaniclastic rocks.

(*d*) Intrusive igneous rocks.

(*e*) Sedimentary and metasedimentary rocks.

3.1.2 *Characteristics of Colluvium*

Colluvium is a complex heterogeneous material which is highly variable in its engineering character. It's distribution is described in Sections 2.3 and 2.4.

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

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.

One of the engineering problems associated with or related to colluvium is instability. The most dramatic example is the landslip disaster at Po Shan Road on Hong Kong Island in 1972 (Government of Hong Kong, 1972 a & b). Colluvium consists of material transported by gravity, and the deposits accumulate at approximately the angle of repose of the detrital material. Although the deposits may settle and become more dense with time, they are liable to slope failure if disturbed either by stream undercutting, ground movements or by man's activities.

Slope failures in colluvium 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 much 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.

Granitic and mixed colluvium show a low incidence of instability which is considerably less than the colluvium derived from volcanic rocks. Metasedimentary colluvium has a very low incidence of instability due to the low topography in which it occurs.

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.

Boreholes and trial pits are used to obtain samples and exposures for the classification of colluvial deposits. Care should be taken 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, it may be necessary to rely on more empirical relationships for stability assessment.

Colluvium is often up to 30 m thick and is essentially unconsolidated; therefore, it has some potential for use as a soft borrow material. The grading of the material in relict weathered fans is generally suitable for use as fill, as it has good compaction characteristics.

The more recent bouldery colluvium in stream channels is of limited use, as the major natural constraints, instability and concentrated groundwater flow, restrict their suitability. Within the study area, there are no obvious sites that can be recommended for soft borrow in colluvium. Site formation work may involve the excavation and use of colluvial materials, which should prove satisfactory provided adequate care is taken in the design of cut slopes. Excavation by machine methods could be difficult if large boulders are encountered.

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

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

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

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

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

Erosion is not a major problem in these materials in their undisturbed state due to their predominantly flat gradient. Stream flows are normally low or confined to man-made channels or conduits. Littoral deposits are subject to continuous erosion and redeposition by the sea. It should be noted that all these materials are erodible if hydrological conditions are adversely altered by construction activity.

The GEOTECS data presented in Tables B10 and B11 of Appendix B indicate that there is no incidence of slope instability in these materials. This is primarily due to the low slope angles associated with most of these deposits. When disturbed, however, these materials are liable to become unstable unless adequate precautions are taken. All steep-sided excavations require strutting or shoring to minimise the likelihood of slope failure, and cut slopes require cutting to low angles or require retaining structures.

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

The shear strength of these materials is extremely variable. The highest strength is developed in well-compacted fill and the least in marine muds. All these materials are characterised by low values of cohesion. It has been demonstrated that these materials are extremely variable in physical properties and frequently occur within a complex subsoil stratigraphy. Consequently, appropriate laboratory testing of representative undisturbed samples is required in order to obtain relevant strength parameters for design.

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	Engineering Comment (Stability, Foundation, Hydrogeology)	Material Uses and Excavation Characteristics
SUPERFICIAL DEPOSITS	QUATERNARY – RECENT	P	POND AREAS	Generally dark grey loose to medium dense sandy silt with some fine quartz gravel.	Extensive area of small shallow (± 5–6 m) constructed ponds separated by bunds or earth embankments the material for which is usually won from the pond area.	No weathering or soil development	Extensive area of standing water subdivided by man-made bunds.	Fish ponds and minor cultivation. Soil easily dug by hand or machine.
		R	RECLAMATION/FILL	Generally local or imported borrow of colluvium, decomposed volcanics or plutonics and crushed quarry rock. Often a mixture of silt, sand, gravel and cobbles. Some building waste, mine waste or sanitary fill may also be included.	Extensive planer 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.	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 pile 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 zones forming beaches and sandbars. Occasionally raised beaches may occur.	Nil	Materials are usually saturated and saline. Raised beaches may be leached by rainwater but may remain saline at depth. Groundwater extraction may induce incursion of saline water. Poor grading characteristics—low fines. Low bearing pressures can be accepted directly, moderate and high loads need raft, spread or pile foundations.	Main development potential is as beaches for recreational purposes. Excavation of these materials usually prohibited.
	QUATERNARY – PLEISTOCENE	A	ALLUVIAL DEPOSITS: UNDIFFERENTIATED INCLUDING FLOODPLAIN	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.	Materials are usually saturated and of a low density—clay layers are normally consolidated. Buried channels may pose local problems of high water flows into tunnels or excavations. Steep excavations require support.	Land deposits easily excavated. Marine deposits often form reasonable hydraulic fill. Excavation by cutter, suction or bucket dredger.
		Al	ALLUVIAL DEPOSITS: RAISED TERRACES		Higher alluvial terraces, stepped, level-to-gently sloping with short steep slopes between terrace levels.			
		C	COLLUVIUM: VOLCANIC DERIVED; GRANITIC DERIVED; MIXED VOLCANIC & GRANITIC DERIVED; METASEDIMENT DERIVED	Composed of a range of materials which vary from boulder colluvium, to gravelly colluvium with clay and sand, to finer textured gravelly sands and clay slopewash. The boulder colluvium with sand and gravel occurs on the higher sideslopes, while the gravelly sands, 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 gentle to moderately steep, broad, low, rounded, dissected outwash-fan slopes and interfluves with undulating and hummocky surfaces; elsewhere irregular planer-to-shallow concave colluvial footslopes, leading 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.	This material has moved in its geologic past and is prone to reactivation if not carefully treated by such measures as low batter angles, drainage and surface protection, especially when saturated. Has low to moderate bearing capacity characteristics but should always be carefully drained because it may be susceptible to failure when wet. Voids may cause settlement of roads, services and buildings. Tunnelling probably difficult. Site investigation may be difficult and expensive.	May be used for borrow due to its ease of excavation by machine, broad grading characteristics and relative ease of access on hillsides. Some bouldary stream deposits will be of limited use. Large boulders may require blasting or splitting.
BEDROCK		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 some 700 m north of Lau Fau Shan composed of Kat O rocks to the seaward, faulted against Lok Ma Chau sediments.	Rock weathers to a weak red to red-brown poorly cemented breccia.	Extremely minor distribution; very unlikely to be built upon.	Extremely hard and durable when fresh; blasting would be required. Possible local source of aggregate.
	UPPER JURASSIC	D	PLUTONIC ROCKS: DOLERITE	Black to very dark grey, fine to medium-grain rock. Smooth joints normal to boundaries result from cooling.	Generally occur as linear structural features transecting the volcanic and granite units. May be of slightly depressed or elevated topographic form due to variable resistance to erosion compared to country rocks. This geological structure often controls local surface runoff and may act as loci for subsurface water concentration.	Weathers deeply to a dark red silty clay.	Restricted extent precludes detailed comment. Weathered mantle will have low relative permeability and will affect near-surface groundwater hydrology by forming barriers, divides and boundary conditions. Sub-vertical dykes may dam groundwater leading to locally high ground-water levels.	Restricted extent precludes deliberate borrow or quarry activities—weathered material would make poor fill but fresh rock would make suitable high density aggregate or railway ballast.
		La	PLUTONIC ROCKS: FELDSPAR PORPHYRY	Grey to greenish-grey. Fine-grained groundmass with up to 20% large (8–10 mm) phenocrysts of feldspar.		**Generally weathers faster than volcanic rocks but slower than granitic rocks. Develops a thick reddish soil. Weathering depths are generally in the range 7–15 m.**	Surface hydrology can be affected by these rocks with drainage networks aligning with the strike of the dykes. Subsurface hydrology and foundation levels will be affected by the variable rockhead.	Restricted extent precludes deliberate borrow or quarry activities. May be suitable as aggregate when fresh. Excavation conditions may be difficult and expensive.
		q	PLUTONIC ROCKS: QUARTZ VEIN	White or translucent microcrystalline quartz rarely over 100 mm thick. Can be associated with narrow dykes of microgranite.	Too narrow to have any significant effect on topography.	Quartz veins undergo only mechanical disintegration as they are very resistant to decomposition. Coarse angular gravel is the product.	Generally too small to affect structure but contained sulphides may affect groundwater chemistry and react with concrete and steel in foundations.	Restricted extent precludes deliberate borrow activity for these rocks. Weathering results in mechanical break up only of quartz and a decomposition of sulphides. Fresh rock not suitable for aggregate due to potential sulphide reaction with cement. Molybdenite has been commercially mined.
		NH	PLUTONIC ROCKS – NEEDLE HILL GRANITE: FINE-GRAINED PORPHYRITIC PHASE	Fine-grained, pink, with phenocrysts of quartz and potassium feldspar in varying proportions. Pyrite is a common accessory mineral. Jointing is similar to other granites.	Occurs as strongly dissected plateaux or extensively eroded granite ridges and spurs. Narrow but rounded ridge and spurcrests. Moderate to steep planar sideslopes.	Shallow to deep residual soils over deeply weathered granite. Local occurrence of less weathered rock outcrop and/or massive boulders on upper sideslopes and incised gully floors.	Unstable areas result from deep weathering and joint controlled rock slopes. Extensive rill and sheet erosion affects the weathered mantle. Bearing capacity characteristics are generally favourable for moderate to high loads. Materials are generally free draining.	When weathered, the material can be machine excavated to considerable depth and is thus strongly favoured as a source of granular borrow. When fresh or slightly weathered, blasting is required. These rocks are highly favoured for aggregate production.
		NHm	PLUTONIC ROCKS – NEEDLE HILL GRANITE: MEDIUM-GRAINED PORPHYRITIC PHASE	Medium-grained gradational with above with similiar mineralogy and jointing.				

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	Engineering Comment (Stability, Foundation, Hydrogeology)	Material Uses and Excavation Characteristics
BEDROCK	UPPER JURASSIC	CC	PLUTONIC ROCKS	CHEUNG CHAU GRANITE	Pale grey or pink, medium to coarse-grained, sparingly prophyritic, strong granite. Potassium feldspar is prevalent in this widely spaced rough jointed rock.	Forms extensive areas of moderate relief, broad convex hill-crests are common. Occasionally occurs as steep to precip-litous terrain. Drainage is dendritic in nature although structural control may dislocate the general pattern. Sheet and gully erosion are common on hillcrest and sideslope terrain.	Rock sometimes produces a poor, thin (<1 m) soil (pedogenic) horizon. At depth the decomposed rock is a silty sand with variable fine gravel content. Depth of weathering i.e. soft material, is often great and an average of 18 m has been quoted. Weathering to produce corestones is common.	**Stability of the weathered material can be suspect, i.e. Zones A & B, where soil type failures may occasionally occur. Insitu material is prone to severe erosion. Special care must be taken in establishing adequate surface protection on newly formed slopes. Bearing capacity characteristics are good for moderate to high loads. Generally free draining. Rock is prone to discontinuity controlled failure in the fresh to moderately weathered state.**	When weathered, the material can be machine excavated to considerable depth and is thus strongly favoured as a source of granular borrow. When fresh or slightly weathered, blasting is required. These rocks are highly favoured for aggregate production.
		SK		SUNG KONG GRANITE	Pale grey or pink, coarse-grained, porphyritic, strong granite. Medium-grained and non-porphyritic phases exist. Generally displays widely spaced joints. Quartz is often very abundant.				
		XT		TAI PO GRANODIORITE	Grey to dark grey, coarse to medium-grained, porphyritic granitoid rock. Large well formed crystals of white feldspar up to 15 mm are present in a coarse-grained matrix. Matrix minerals are potassium feldspar, plagioclase, biotite and minor quartz. Xenoliths are common. Jointing is similar to granite in that rough sheeting joints and widely spaced tectonic joints are present.	Forms areas of moderate relief with colluvial and boulder cover. Broad convex hillcrests and well vegetated slopes.	Average depth to Zone C is approximately 15 m but can be over 40 m. Boulders and corestones are common in weathered zones. Weathering product is subangular silty sand.	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.
	LOWER TO MIDDLE JURASSIC	RBs	REPULSE BAY FORMATION	SEDIMENTARY AND WATER-LAID VOLCANICLASTIC ROCKS	Middle Jurassic rocks, essentially of sedimentary and water-laid volcaniclastic origin, generally composed of thinly bedded black or grey hard siltstone within thin interbeds of fine-grained volcanic sandstone. Very occasional fine tuffs and dark lavas.	Occasionally forms hills, usually ridges, spurs and dissected footslopes with broad, low, irregular, rounded interfluves formed at lower elevations. At higher elevations, ridges and spurs are mainly narrow and sharply rounded.	Shallow to moderately deep, reddish to brown, fine, sandy to silty clay, i.e. residual soil sometimes with ferruginous gravel and weathered rock fragments, overlying completely to highly weathered rock which grades into less weathered strongly jointed volcanic rock at depths from 5–20 m.	The sediments are bedded and fissile and weather relatively rapidly when exposed, to a grey silt. Some stability problems may arise. Groundwater regime may be controlled by the bedded character of the rock.	Can be scraped and ripped when weathered. Fresh rock will need pneumatic machines or blasting. Due to highly variable properties and presence of chert bands this material would not make a good source of aggregate but is well suited for filling. Scarn mineralisation with magnetite has been mined.
		RBc		COARSE TUFF	Grey to dark grey, fine matrix with coarse well formed crystals of feldspar and quartz. Forms massive beds of crystal tuff with no internal stratification. Jointing tends to be moderately closely spaced and smooth.	Massive volcanic peaks with deeply dissected slopes forming a system of subparallel ridges and spurs. Crests are narrow and sharply convex with steep to very steep valley slopes. Rock outcrops are common on the upper slopes.	Rock usually produces a thin (<1 m) soil horizon, followed downwards, especially on lower slopes, by yellowish brown sandy completely weathered material overlying less weathered, locally strongly jointed rock below an average depth of 11 m. On steep, high slopes considerable rock exposure with thin soil or thin weathering cover occurs.	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.	Material can be used for fill if it is weathered locally. It is possible to quarry, although very hard and not generally favoured. Coarse crystal tuff horizons may provide good aggregate.
		RBp		DOMINANTLY PYROCLASTIC ROCKS	The principal rock type is grey to dark grey fine-grained rhyodacitic tuff but welded tuffs, coarse tuffs, lavas and sedimentary rocks may also be found in this unit. Jointing is usually smooth and closely spaced.				
		LMC		LOK MA CHAU FORMATION	Metamorphosed sedimentary and volcanic rocks including schist, phyllite, quartzite, metasediments and marble.	Forms hills of moderate to low relief due to its low resistance to erosion. Occurs extensively beneath colluvial and alluvial cover. Local areas of surface boulders and occasional rock outcrops on sideslopes and in gullys.	Metasediments generally weather to produce moderately deep (1–2 m), uniform or gradational, red to red-brown clayey metasediments. Marble (metamorphosed limestone) weathers in two forms: (i) Complete solution, originating along discontinuities, to produce interconnecting cavities which may exceed 1 m in size; (i) Intergranular solution which produces a weak granular layer at the marble surface.	Considerable care is required during investigation, design and formation in materials of the Lok Ma Chau Formation. Metasediments may be prone to instability, especially along discontinuities when weathered and saturated. Bearing capacities are reasonable for low to moderate loads on metasediments and marble without large cavities. Interconnecting cavities within the marble provide excellent hydraulic conductivity. Whilst this may be beneficial for water supply wells, rapid fluctuations of the groundwater table can lead to the formation of either collapse. sinkholes or gradual settlement in the overlying superficial deposits if hydraulic continuity exists, as soil is washed into the void system.	Weathered horizon can be excavated by machine; fresh needs pneumatic tools or blasting. Possible use as borrow.

None of the materials in this group have high bearing capacities, and all large loads need to be transferred to underlying bedrock. Low to moderate loads can be accepted on raft foundations, but problems of differential settlement may be experienced. The appropriate piling technique used to transfer high loads is dependent on the overall stratigraphy, but nearly all members of this group are amenable to driven piles. The exception is that some areas of reclamation may contain old masonry walls, large boulders or construction refuse which may require caisson-type construction to overcome penetration problems.

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

In general, the materials in this class are easily excavated by machine methods and have potential for use as soft fill. Marine deposits of sand may exist offshore, but marine silts and clays are generally unsuitable for hydraulic fill. The extensive existing and planned future urban development on areas of alluvium restricts generally the use of this material for borrow.

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

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

The location and type of volcanic and volcaniclastic rocks found in the study area are discussed in Section 2.3.3. 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 sometimes 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.

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

On weathering, the volcanic rocks tend to produce a clayey silt with minor sand and a fairly uniform profile. The coarse tuffs, if widely jointed, may produce corestones and boulders in a similar manner to granitic rocks.

The higher clay contents of the weathered materials tend to reduce the incidence of erosion in these rocks even though they occur on steep slopes. The GEOTECS data in Tables B10 and B11 and Figure 4 indicate that the Repulse Bay Formation rocks show a general trend of relatively low levels of erosion. This is probably a reflection of the erodibility of these materials due to the large statistical sample and the relative lack of urban development on these rocks. The incidence of instability, on the volcanic rocks is relatively high, due in part to the steep, high slopes formed in these materials. 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, their foundation depths are fairly shallow.

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

3.1.5 *Characteristics of the Intrusive Igneous Rocks*

The intrusive igneous rocks that underlie much of the southern and western portions of the study area are of similar origin and consequently have similar engineering characteristics. A moderate amount of site investigation and laboratory information is already available, and these materials are generally quite well understood (Lumb 1962 a & b, 1965, 1983).

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

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

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

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

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

The intrusive igneous rocks normally weather inwards away from discontinuities, and quite thick weathering zones may occur along joints even in Zone C rock. Within the profile, large boulders are developed due to the wide joint spacing, and these may be concentrated on the surface by the erosion and removal of the soft completely decomposed material.

As a result of weathering, joints lose their effective roughness which, combined with the concentration of clay minerals, leads to a reduction in shear strength. The intact rock becomes weaker and more porous.

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

As the residual soil is predominantly sandy, it is highly erodible in nature. The GEOTECS data presented in Figure 4 and in Tables B10 and B11 indicate a general decrease in erosion within the intrusive igneous rocks when compared to the volcanics, although there appear to be significant differences between the individual intrusive rocks. Tai Po Granodiorite appears to be generally uneroded within the study area, but experience elsewhere in the Territory indicates that it can be highly erodible if vegetation is removed. The Cheung Chau Granite and the medium-grained phase of the Needle Hill Granite shows a greater incidence of erosion.

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

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

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

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

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

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

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

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

3.1.6 *Characteristics of the Sedimentary and Metasedimentary Rocks*

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

(i) *Lok Ma Chau Formation*

The Lok Ma Chau Formation includes metamorphosed sedimentary units and a marble-bearing unit which may be up to 300 m thick (Lai & Mui, 1985).

The metamorphosed sedimentary units generally exhibit close, smooth jointing, often with some related cleavage. The rockmass is usually significantly weathered to depths in excess of 20 m. Although this facilitates easy excavation, the weathered rockmass is inherently weak, especially along joints and other discontinuities. Discontinuity surveys are essential for the safe design and construction of cut slopes and excavations. Bearing capacities are reasonable for low to moderate loads. Fresh material is usually stronger and is generally more stable. Where accessible, this material is suitable for low grade bulk fill but is not suitable for use as concrete aggregate or roadstone.

Marble has been encountered in boreholes and excavations through the alluvium of the Yuen Long plain. It occurs in isolated patches beneath an approximately 2 km wide strip of land between Lo Wu and just north of Tuen Mun, and is particularly prevalent in the Yuen long area. Ha *et al* (1981) refer to the existence of cavities within the marble, while Siu & Kwan (1982) and Siu & Wong (1984a and b) describe problems encountered with the construction of building foundations on marble in Yuen Long.

Marble does not occur everywhere under the Yuen Long plain and not all of the marble contains cavities. Care is required during site investigation to identify the existence of cavities within the marble if it occurs beneath a site.

Weathering of the marble has two effects. Solution along discontinuities creates interconnecting void systems; solution of marble adjacent to another rock or competent sediment can also create a void. Surface solution of marble leaves a clay-rich residual soil which may exist beneath the overlying alluvium. Many of the void surfaces also have a coating of this clay-rich material. Intergranular solution of the near-surface marble produces a weak granular layer up to several metres thick.

Interconnecting cavities within the marble provide excellent hydraulic conductivity. Whilst this may be beneficial for water supply wells, rapid fluctuations of the groundwater table can lead to the formation of collapse sinkholes in overlying superficial deposits with which there is hydraulic continuity.

Collapse of cavities and inwashing of sediment into cavities can lead to settlement and other foundation problems.

(ii) *Kat O Formation*

An outcrop of coarse breccias forms a small headland some 700 m north of Lau Fau Shan (Allen & Stephens, 1971). The breccia consists of abundant angular fragments of volcanic rocks with very steeply dipping bedding. This material may be suitable as a source of fill but is of limited extent.

4. GEOTECHNICAL ASSESSMENT FOR PLANNING PURPOSES

4.1 Geotechnical Limitations

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. The Geotechnical Land Use Map is described in detail in Appendix A7 and a copy is enclosed in the Map Folder which accompanies this Report.

The distribution of the four GLUM classes is shown in the GEOTECS Plot presented in Figure 10, the proportions of the classes are presented in Table 4.1 and Figure 4.

Table 4.1 presents the distribution of each GLUM Class within the study area, and relates it to the area presently occupied by intensive development. The many small villages and rural settlements are considered as 'undeveloped' within the context of this study and developed, refers to areas such as Yuen Long and the large reclamation sites. It should be noted that the extensive area of ponds within the study area are not classified within the GLUM system. In situations where reclamation has been carried out on previous pond terrain, the newly formed terrain is allocated to GLUM Class II.

Table 4.1 Distribution of GLUM Classes

GLUM Class	Geotechnical Limitations	Area					
		Developed		Undeveloped		Total	
		ha	%	ha	%	ha	%
I	Low	116	0.7	645	4.1	761	4.8
II	Moderate	789	5.1	3 422	21.7	4 211	26.8
IIS	"	135	0.9	1 524	9.6	1 659	10.5
III	High	115	0.7	3 975	25.3	4 090	26.0
IV	Extreme	20	0.1	1 406	9.0	1 426	9.1
Unclassified (Waterbodies)		22	0.1	3 565	22.7	3 587	22.8
		1 197	7.6	14 537	92.4	15 734	100.0

4.1.2 *Land with Low to Moderate Geotechnical Limitations*

Within the study area, there exists a relatively small area (761 ha) of land with low geotechnical limitations. Another 5 870 ha is subject to moderate geotechnical limitations. Both these classes (GLUM Classes I & II) occupy 42.1% of the study area and are shown schematically in the GEOTECS Plot in Figure 10. Some 15% of the GLUM Class I land is already developed, as is 16% of the GLUM Class II terrain. This leaves approximately 5 591 ha of terrain which is undeveloped with low to moderate geotechnical limitations.

The areas of GLUM Class I generally lie on well-drained, gently sloping terrain on insitu material. They often occur as foothill terrain associated with small spur lines and within the valley floor as small outcrops of insitu material. These areas, although rather scattered in distribution, range from 20 to 200 ha in size, with a typical parcel being about 150 ha. Within Class I alone, therefore, there exists considerable potential for development.

As indicated in Table 4.1, GLUM Class II includes a subclass (IIS), which is land which will require careful management because it is subject to periodic inundation or flooding. The table also shows that the combined Class II terrain accounts for 5 870 ha (37.3%) of the study area, of which only 924 ha (6.0%) is currently developed. Considerable potential exists for future development on land in this class. If Class IIS is excluded from development, there still remain 3 422 ha (21.7%) of Class II terrain suitable for development.

Although Class IIS is marginally less suitable than the remainder of Class II, it may be suitable for development provided that the hydrogeological conditions are considered during planning and in engineering design. The major advantage of Class II terrain is that it occurs as flat, extensive and continuous areas of alluvial or colluvial plain and on sideslopes of gentle gradient. Access is easy, and a communications network exists which links the three major valleys of Castle Peak, Shek Kong and Yuen Long. In the North West New Territories, the alienation of agricultural land is important. Since the GLUM Class II areas of alluvium and floodplain are also prime areas for horticultural and agricultural production, a possible alternative to wholesale development would be to concentrate agricultural practices on the floodplain terrain. This would maintain the general continuity of the drainage system; however, some drainage measures would be necessary in order to minimise flood damage to agriculture and livestock.

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 but, in certain situations, foundation conditions could be more complex than for GLUM Class I, and costs of site formation, foundation and drainage works should not be high. GLUM Class II terrain includes those areas where instability or erosion are not problems: insitu terrain of moderate steepness or flat or gently sloping alluvial terrain. Areas of reclamation are also included in GLUM Class II.

4.1.3 *Land with High Geotechnical Limitations*

Approximately 26% (4 090 ha) of the study area has a high level of geotechnical limitation (GLUM Class III). The general pattern is shown in the GEOTECS Plot in Figure 10. Some 3% of this terrain is already developed.

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

4.1.4 *Land with Extreme Geotechnical Limitations*

Approximately 9.1% (1 426 ha) of the area is classified as GLUM Class IV. This terrain should not be developed if alternatives exist. The general pattern is indicated in the GEOTECS Plot in Figure 10. Only 1.4% of this terrain occurs within areas of current development.

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

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

Other isolated areas of GLUM Class IV terrain are the consequence of locally steep areas of drainage across colluvium, or the presence of instability or steep cut slopes. Such features are emphasized on the Physical Constraints Map.

4.2 Suitability of Land for Development

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 discussed some of the constraints associated with the terrain within the study area which cause geotechnical problems for engineering works. Some of these problems are initiated during development. For this reason, the interaction between engineering and the terrain should be an important consideration during the planning process, since not only efficient construction is important but long term serviceability and safety should be fundamental aims.

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

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

4.2.2 *Land of High Suitability for Development*

The general suitability for development in the North West New Territories study area is reflected on the GLUM. An extensive area of GLUM Classes I & II (not IIS) terrain occurs in the study area, and this land is highly suitable for development. These areas have low geotechnical limitations and should require only a 'normal' intensity of site investigation.

The most favourable areas for development, from a geotechnical point of view, occur in four relatively continuous belts:

(i) The northeast trending parcel of Class II terrain about 500 m wide either side of the Tuen Mun to Yuen Long highway. This extends for about 3.5 km from Lam Tei (the southern boundary of the study area) to Yuen Long.

(ii) A broad (average 1 km wide) rather diffuse band of north northwest trending land which extends from Tai Tong and Nam Hang in the south, through central and eastern Yuen Long town, northwards to Tai Tseng Wai on the edge of the pond area. The overall length of this parcel is approximately 4 km.

(iii) The very extensive, roughly elliptical area centred on, and with elongate axis coincident with, the runway of the Shek Kong airfield. The dimensions of the area are some 4 km in an east southeast direction on the long axis and 2.5 km across the short axis. Several incised local drainage lines traverse the area, and these are classified as Class IIS terrain; the longest and most extensive of the floodplain terrain bounds the Shek Kong Camp to the north and drains into the pond area near Kam Tin.

(iv) The 'T'—shaped area which follows the Au Tau to Mai Po road and lies between Pak Wai and Mai Po, with the leg of the 'T' following the Ngau Tam Mei Road to the east. This area measures about 4 by 5 km in length (Pak Wai to Mai Wo) and 2.5 by 0.5 km in width (along Ngau Tam Mei Valley).

4.2.3 *Land of Moderate to Low Suitability for Development*

Land in this category occurs mainly in GLUM Class IIS (floodplain) in the North West New Territories and, as such, lies essentially on flat, low-lying, alluvial plains subject to periodic flooding and inundation. Several major concentrations of this land exist:

(i) The floodplains which lie in a north to south band from Lam Tei to Sha Kong Miu and which drain the Castle Peak Range eastwards towards the Castle Peak Valley.

(ii) A second north to south band which extends southwards from western Yuen Long and is centred around the Pak Sha Tsuen drainage channel.

(iii) Several westward draining tributaries and their accompanying narrow (200 to 400 m wide) floodplains to the north and south of Shek Kong. These are the floodplains which dissect the Shek Kong alluvial plain.

(iv) The narrow drainage line which forms the floor of the Ngau Tam Mei Valley and fans out, as the river anastomoses in its lower reaches, near the pond area in the vicinity of Sheun Chuk Yuen to the west of the Au Tau to Mai Po road.

(v) Various northwest trending streams and their accompanying narrow (100 to 200 m) floodplains which drain the hills south and east of San Tin near the villages of Tsing Lung Tsuen and Chau Tau.

4.2.4 *Land of Low Suitability for Development*

A major portion (approximately 26%) of the North West New Territories study area occurs in GLUM Class III. This terrain is intermediate between land of high suitability and that which is regarded as being generally unsuitable for development. The most problematic areas are the colluvial drainage plains which occur on gently sloping footslope terrain. In general, development on Class III terrain will require intensive investigations at the planning and design stages to minimise the likelihood of landslips.

Much of the land which occurs in Class III is a result of naturally steep terrain. Development of these slopes will probably be difficult. The remaining areas of Class III are often covered by extensive deposits of colluvium. This colluvium varies widely with respect to depth, origin and matrix composition. Stability problems encountered during the formation of borrow areas elsewhere in the New Territories indicates that development of GLUM Class III terrain must be approached with caution.

4.2.5 *Land which is Probably Unsuitable for Development*

Undeveloped parcels of land within GLUM Class IV are considered unsuitable for development if viable alternatives exist. These areas are delineated by virtue of containing one or more of the following geotechnical constraints:

(i) *Very Steep Slopes*
All areas which have slopes with gradients greater than 60°, no matter what their terrain component or erosion characteristics, fall into GLUM Class IV. Those areas with average slope gradients between 40 and 60° and which are colluvial footslope, drainage plain, cliff, fill or disturbed terrain are also classified as GLUM Class IV.

(ii) *Appreciable Erosion*
The terrain classification classes within this category do not in themselves constitute a severe geotechnical limitation. However, steep slopes associated with the more severe forms of erosion are classified as GLUM Class IV.

(iii) *Instability*
Areas affected by instability usually pose severe geotechnical constraints for development. Instability is designated as either Classes III or IV depending on the terrain component and slope angle. All sideslope, footslope, cut and fill terrain with slopes in excess of 15° which display landslip features, as well as all colluvial drainage plain terrain with instability, are allocated to Class IV.

The Geotechnical Land Use Map shows that Class IV terrain is highly fragmented and is dispersed mainly within the larger more extensive bands of Class III terrain. The highest concentration of Class IV occurs towards the eastern edge of the study area in the range of mountains stretching northwards from Tai Mo Shan to Tai To Yan, westwards to Kai Keung Leng, and northwards past Cheung Lek to Crest Hill.

The most extensive parcel of Class IV terrain occurs on the north-facing sideslopes of the westerly trending Kai Keung Leng mountain range.

4.2.6 *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 1.5.8 and described in detail in Appendix A.10.

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) *Flood-prone Terrain and Development*
The low-lying floodplain areas within the North West New Territories are highlighted on the GEOTECS Plot at Figure 11. The general areas of flood-prone terrain are delineated together with areas of developed land. This GEOTECS Plot highlights the zones which may be subject to inundation and delineates the associated pockets of development.

Some 1 659 ha of floodplain terrain occur within the study area and this contains some 1 202 ha of agricultural land and 216 ha of developed terrain. A number of options could be derived for floodplain management using the GEOTECS System.

(ii) *Potential Quarry Sites*

The GEOTECS Plot in Figure 12 indicates other areas which exhibit quarry potential on the basis of several terrain attributes. The selection criterion for areas without intensive existing land use is primarily 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 1 224 ha of undesignated natural terrain has potential for quarry sites. A further 879 ha with potential for quarrying occur within existing Country Parks or are under cultivation. These figures indicate that many options exist, but the number of options would be reduced when rock type is specified.

5. CONCLUSIONS

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

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

5.1 Materials and Land Resource Distribution

(*a*) Slope instability of some form or other is relatively common within the study area. Approximately 1 526 ha of the terrain (9.7%) is associated with or affected by instability. Instability is associated with most of the geological materials. Failures in the colluvium and volcanics are generally characterised by small landslip scars with extensive debris trails. This is probably due to the relatively steep slopes on which failure occurs. Landslips on the granites are also common but tend to be relatively small rotational failures on natural terrain or joint-controlled failures associated with cut slopes. Granitic failures generally cause less impact on the terrain than failures in volcanics and colluvium.

(*b*) The geology of the area is complex, and several aspects require careful investigation. Weathering depths are variable, with very deep weathering occurring in some granitic areas. There are numerous photolineaments present, many of which are likely to be faults, shear zones, major joint zones or dykes. Surface erosion is more pronounced on the granitic terrain than on the volcanics. The area is currently being remapped as part of the revised geological survey of the Territory. The new Geological Maps and accompanying Memoir will be published in 1988. Marble has been reported in the Yuen Long District associated with the metasediments of the Lok Ma Chau Formation underlying the alluvium. Subsurface voids and caverns are common problems associated with marble and limestone. Settlement and foundation problems may occur on this terrain. Although the cavities can be large, they do not occur everywhere under the Yuen Long Plain. However, investigation, design and construction for heavy structures and structures sensitive to differential settlement should be carefully undertaken if marble is found to exist beneath a site.

(*c*) Approximately 2 666 ha of the footslope terrain is covered by extensive colluvial deposits; 9.3% of the colluvium is affected by instability. Significant geotechnical limitations should be anticipated on zones of runoff and surface drainage across the colluvium.

(*d*) The granitic terrain has a slightly higher proportion of GLUM Classes I & II (30%) than the volcanics (26%). Of the 2 666 ha of colluvial terrain which occurs within the study area, some 57% is subject to high to extreme geotechnical constraints (GLUM Classes III & IV).

(*e*) Approximately 65% of the study area is characterised by slopes which have gradients between 0 and 15°. A further 33% of the terrain has slope gradients between 15 and 40°.

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

(*g*) There is approximately 151 ha of reclamation (1%) within the study area. The siting of development on extensive reclamation that is underlain by thick compressible sediments may give rise to foundation problems and settlement of services. This aspect will require careful design and control during construction.

(*h*) Approximately 11% of the study area is currently developed in some form or other, including 8% which is subject to intensive development. Squatters occupy 6% of the area, and 18% is allocated to Country Park. The remaining 65% consists of undeveloped natural terrain, agricultural land or fish ponds.

5.2 Land Management Associated with Planning and Engineering Feasibility

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

(*b*) Opportunities do exist for urban expansion in the study area, but it is unrealistic to envisage that all future development can avoid areas with geotechnical limitations.

(*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 3 829 ha of currently undisturbed natural terrain, which does not include agricultural land, fish ponds or Country Park. Of this figure, GLUM Classes I & II occur on some 27% of the terrain, and of the remaining land, 2 038 ha is associated with high to extreme geotechnical limitations (GLUM Classes III & IV) and a further 740 ha of littoral zone exists below high water mark. There is approximately 2 844 ha of land within the boundaries of the Country Parks.

(*e*) Squatters occur on some 906 ha within the study area. At the time of data collection, 12% of this terrain was affected by high to extreme geotechnical limitations.

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

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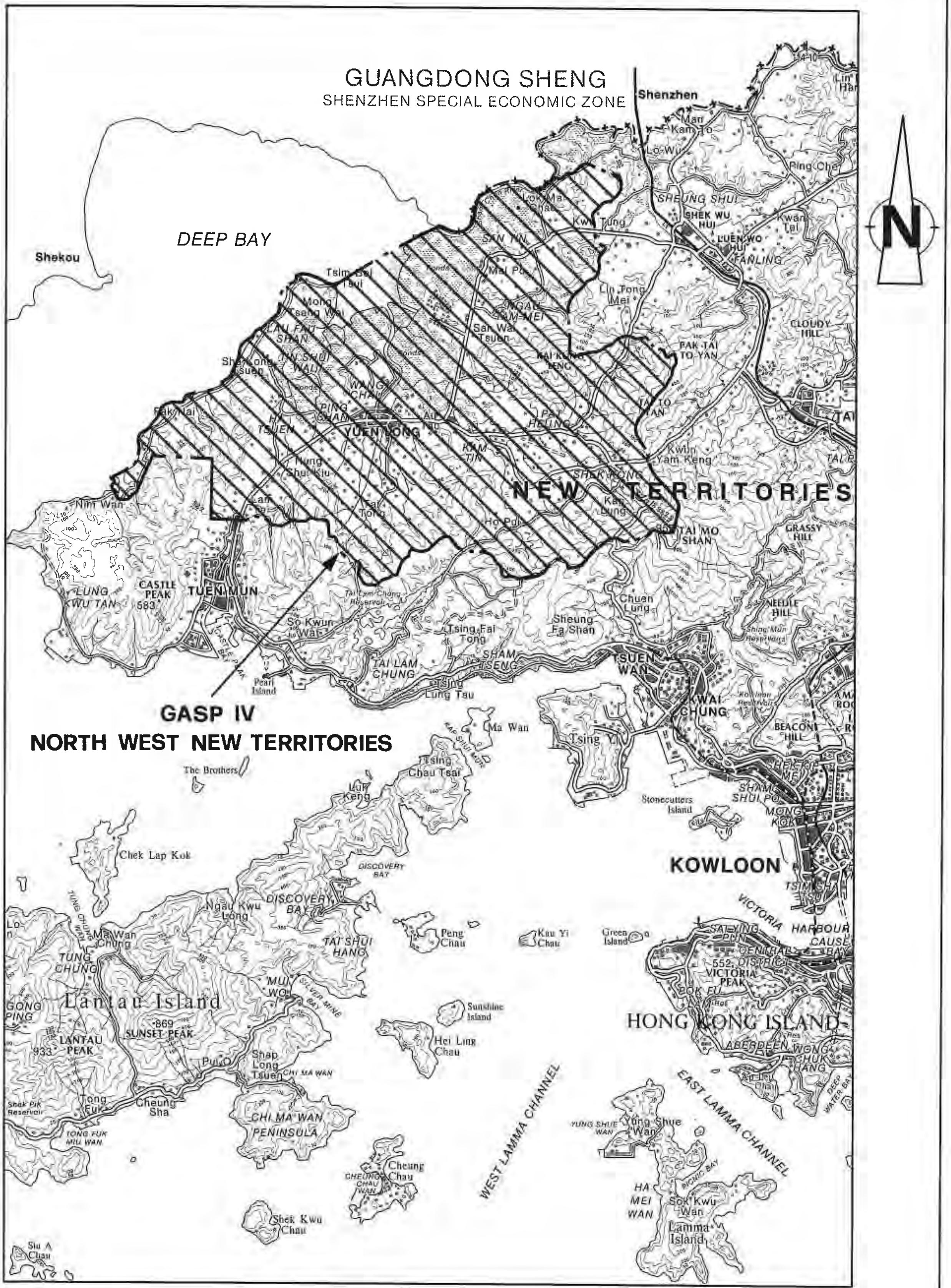
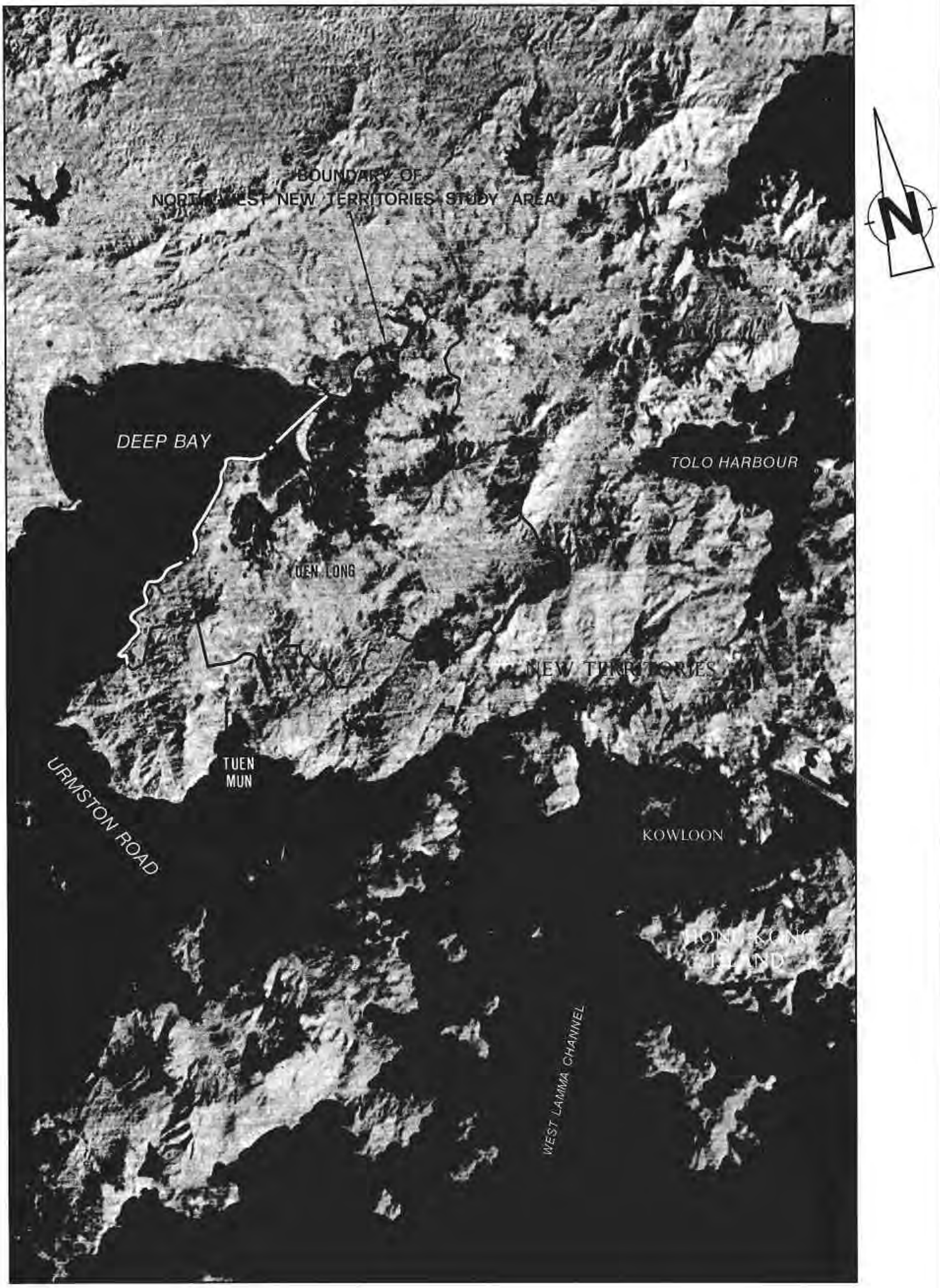
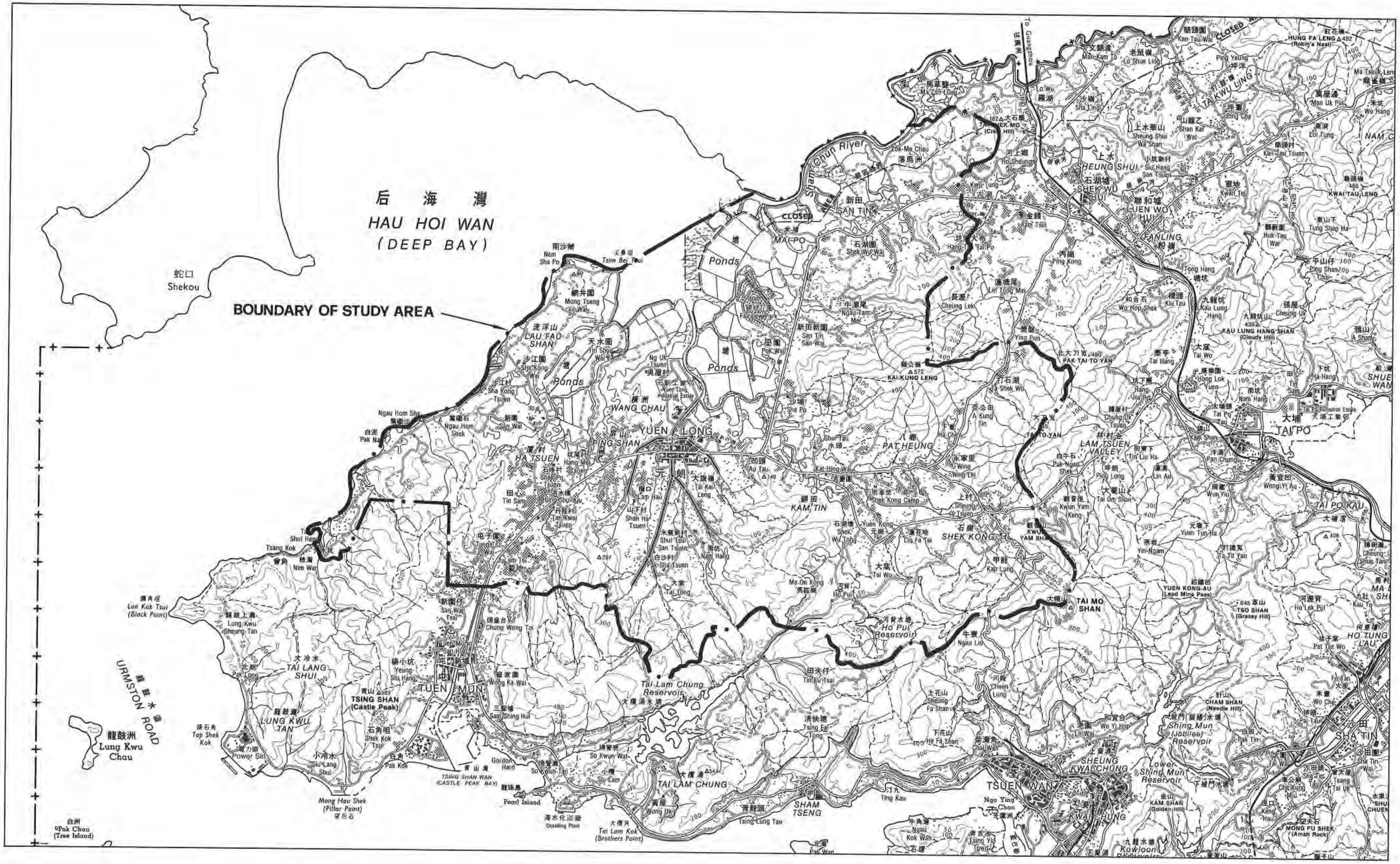


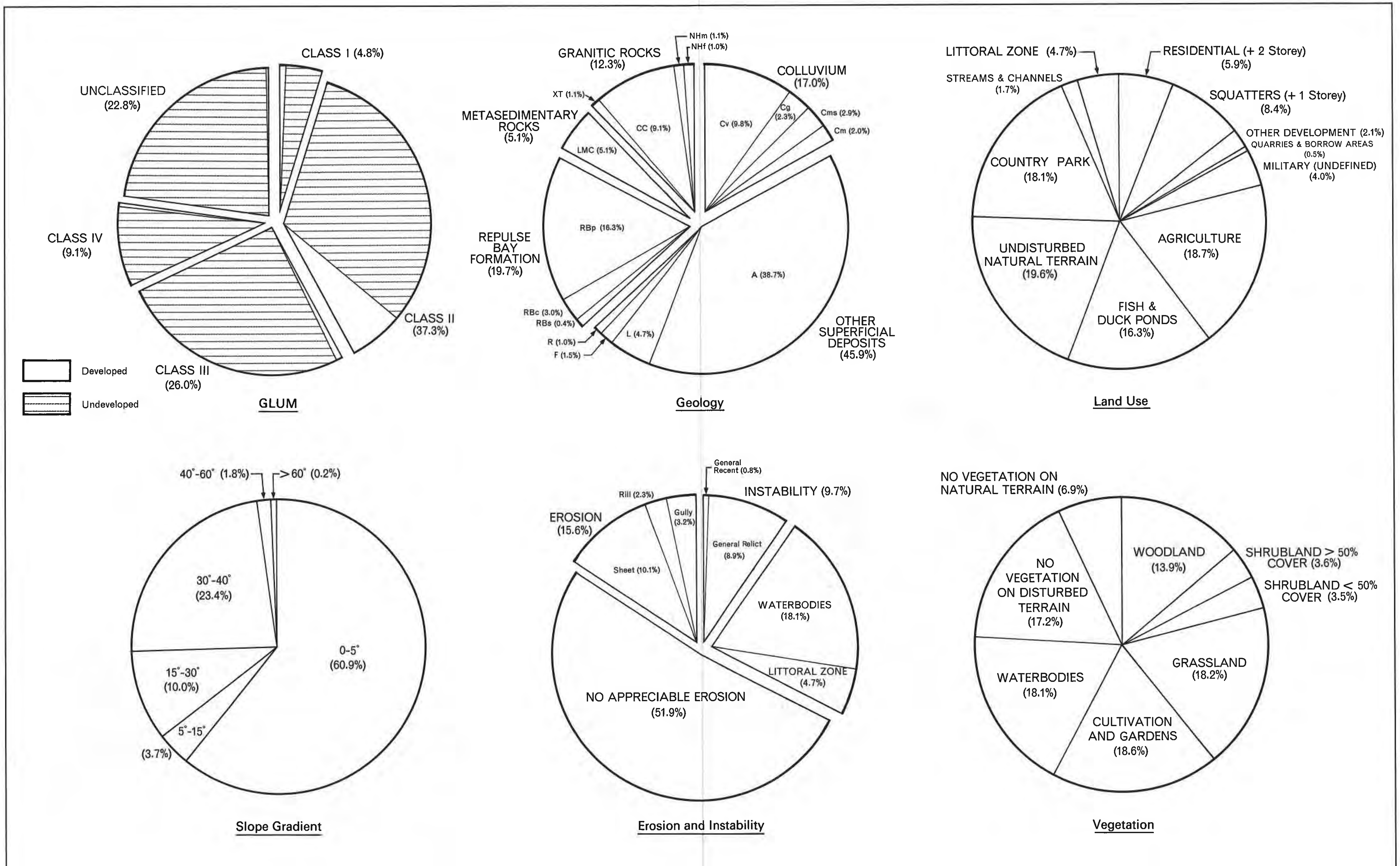
Scale 1:200 000	Location Map of the North West New Territories Study Area	Fig. 1



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



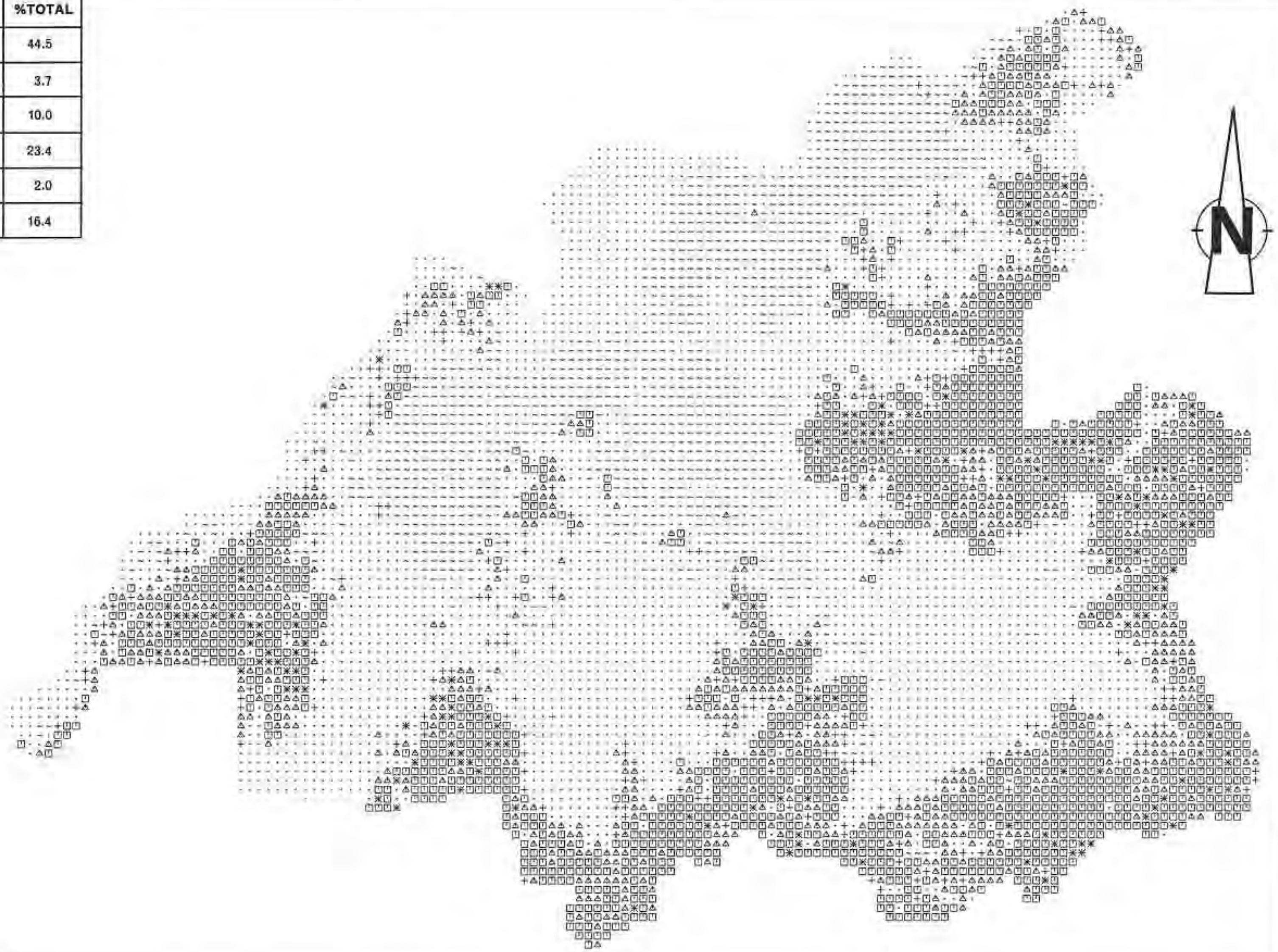
Scale 1:100 000	North West New Territories Study Area	Fig. 3



Pie Charts of Selected Attributes of the North West New Territories

Fig. 4

SYMBOL	MEANING	%TOTAL
·	SLOPE GRADIENT < 5°	44.5
+	SLOPE GRADIENT 5-15°	3.7
△	SLOPE GRADIENT 15-30°	10.0
◫	SLOPE GRADIENT 30-40°	23.4
✳	SLOPE GRADIENT > 40°	2.0
~	RESERVOIR OR POND	16.4



Scale
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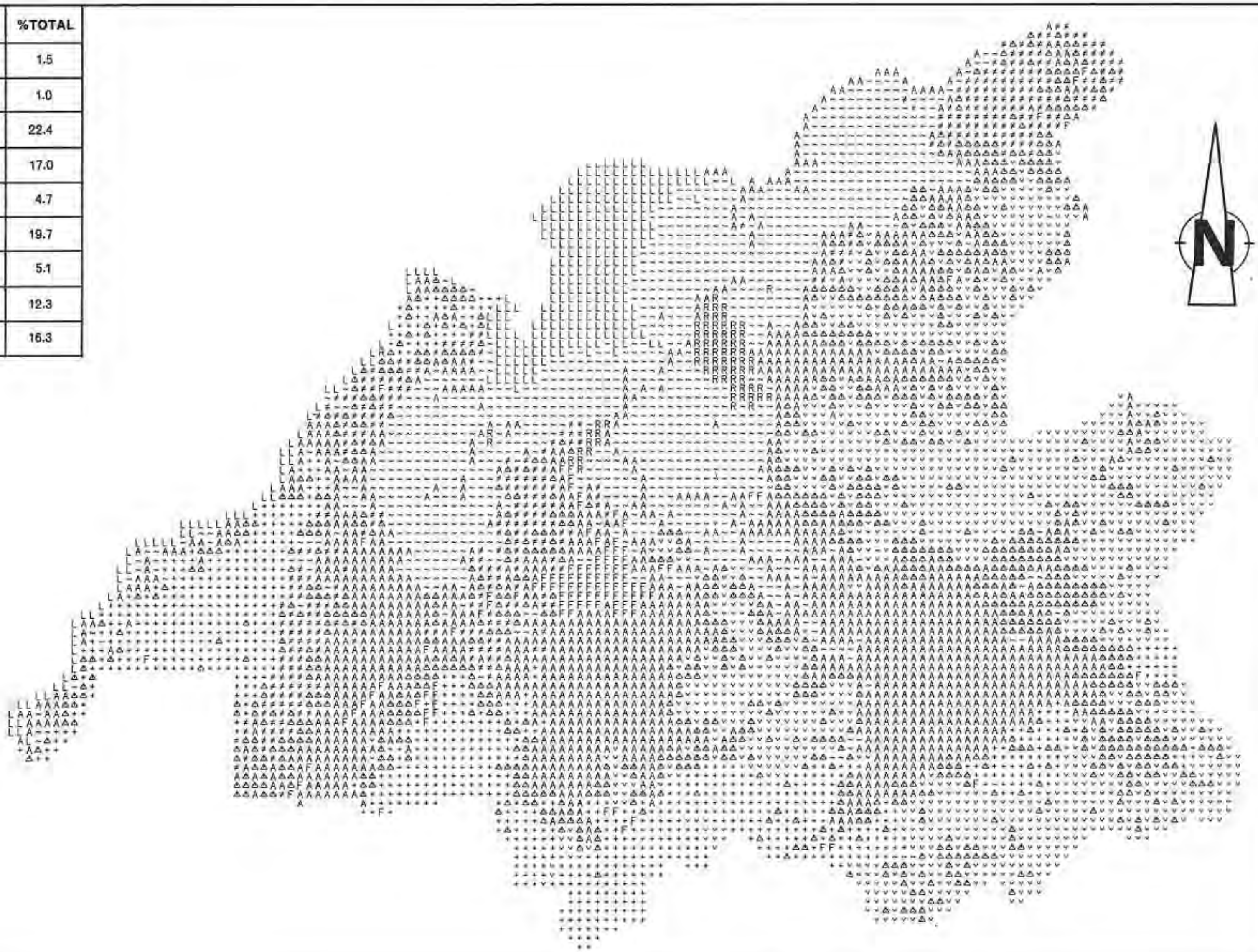
GEOTECS Plot - Slope Gradient

Fig. 5

SYMBOL	MEANING	%TOTAL
F	FILL	1.5
R	RECLAMATION	1.0
A	ALLUVIUM	22.4
⧍	COLLUVIUM	17.0
L	LITTORAL DEPOSITS	4.7
v	VOLCANIC ROCKS	19.7
≠	METASEDIMENTARY ROCKS	5.1
+	INTRUSIVE IGNEOUS ROCKS	12.3
~	RESERVOIR OR POND	16.3



Scale
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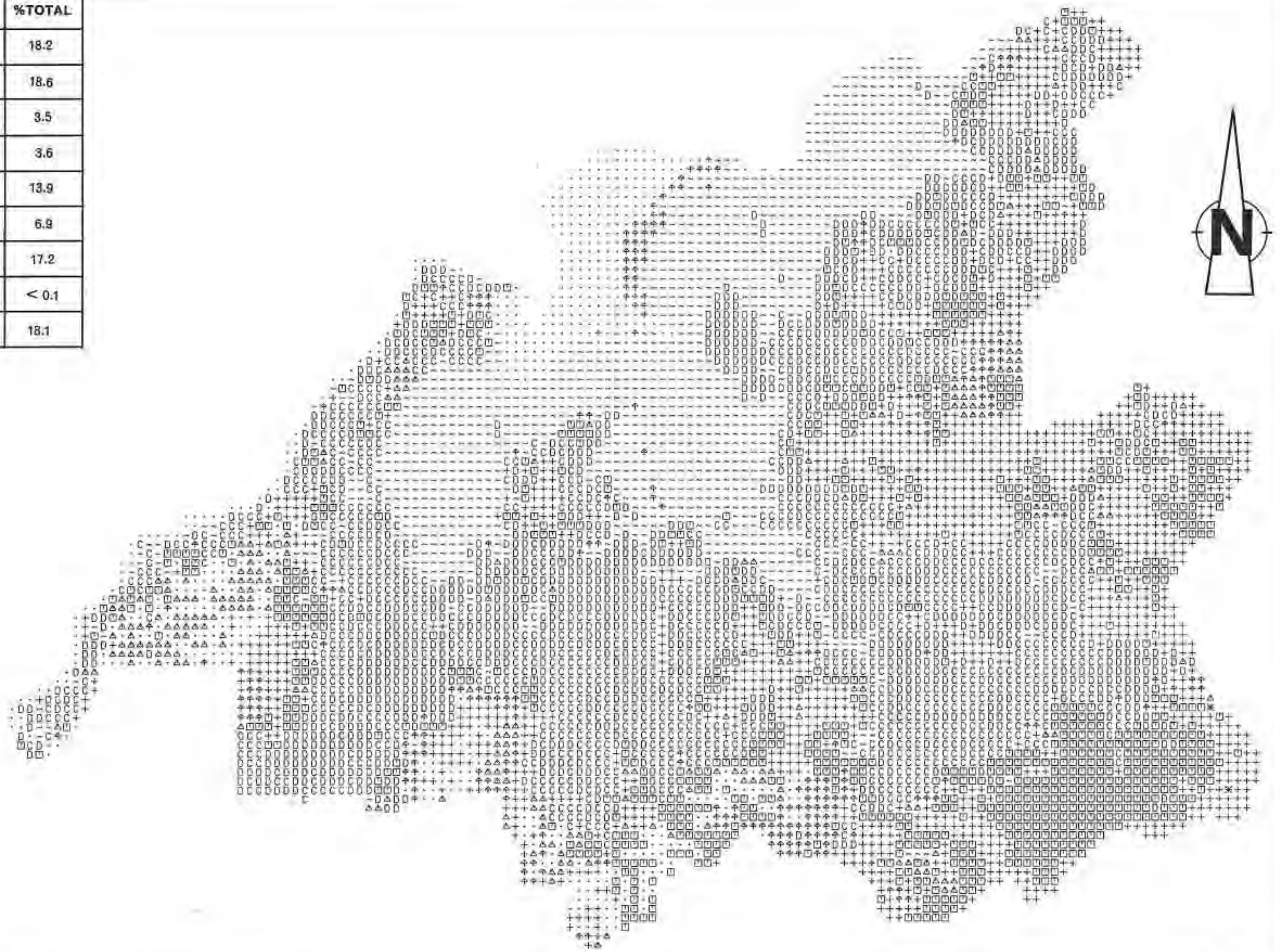
GEOTECS Plot - Geology

Fig. 6

SYMBOL	MEANING	%TOTAL
+	GRASSLAND	18.2
C	CULTIVATION	18.6
Δ	SHRUBLAND (<50% CANOPY COVER)	3.5
↟	SHRUBLAND (>50% CANOPY COVER)	3.6
⊡	MIXED BROADLEAF WOODLAND	13.9
·	NO VEGETATION ON NATURAL TERRAIN	6.9
D	NO VEGETATION ON DISTURBED TERRAIN	17.2
✳	NO VEGETATION ON ROCK OUTCROPS	< 0.1
~	WATERBODIES (STREAM, CHANNEL, RESERVOIR & PONDS)	18.1

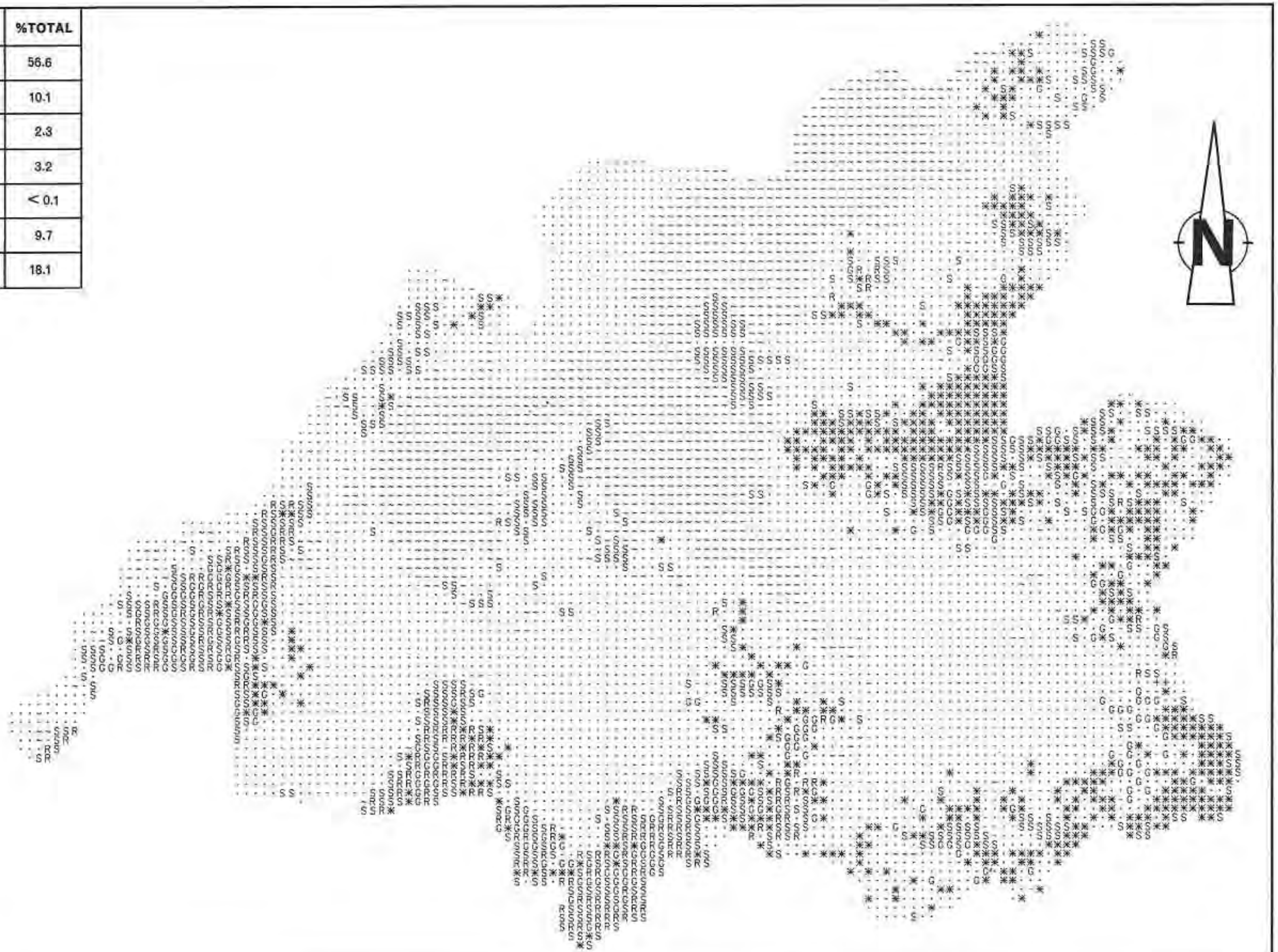


Scale 1:100 000

GEOTECS Plot - Vegetation

Fig. 7

SYMBOL	MEANING	%TOTAL
·	NO APPRECIABLE EROSION (AND LITTORAL ZONE)	56.6
S	SHEET EROSION	10.1
R	RILL EROSION	2.3
G	GULLY EROSION	3.2
+	WELL-DEFINED LANDSLIPS AND COASTAL INSTABILITY	< 0.1
✳	GENERAL INSTABILITY	9.7
~	NATURAL STREAM, ARTIFICAL CHANNEL, RESERVOIR OR POND	18.1



Scale
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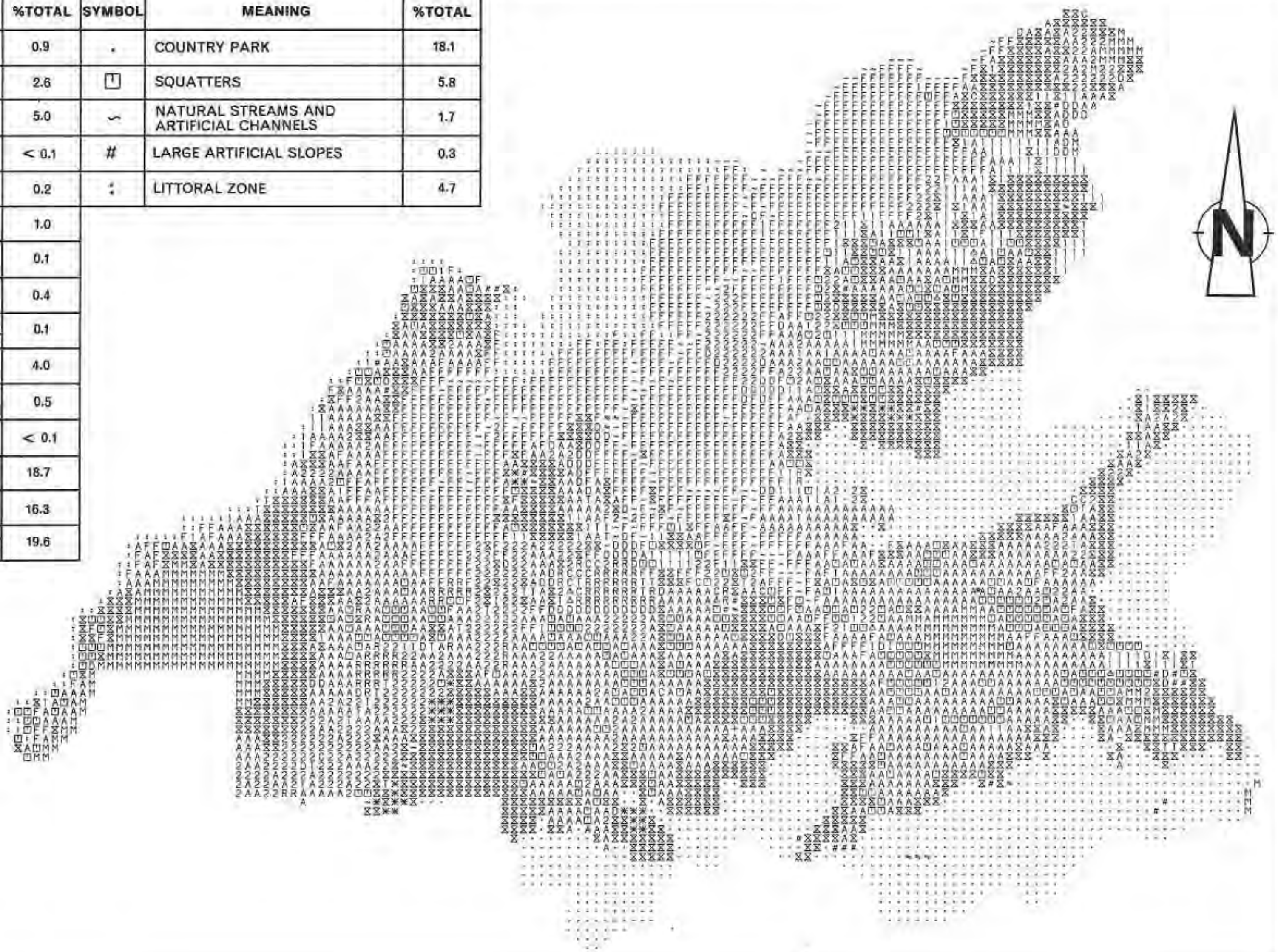
GEOTECS Plot - Erosion and Instability

Fig. 8

SYMBOL	MEANING	%TOTAL	SYMBOL	MEANING	%TOTAL
R	RESIDENTIAL (INCLUDED MIXED)	0.9	·	COUNTRY PARK	18.1
1	SINGLE STOREY HOUSING	2.6	⍐	SQUATTERS	5.8
2	DOUBLE STOREY HOUSING	5.0	~	NATURAL STREAMS AND ARTIFICIAL CHANNELS	1.7
I	COMMERCIAL AND INDUSTRIAL	< 0.1	#	LARGE ARTIFICIAL SLOPES	0.3
C	COMMUNITY AND INSTITUTIONAL	0.2	:	LITTORAL ZONE	4.7
D	INCOMPLETE DEVELOPMENT	1.0			
△	SPORTS AND RECREATIONAL	0.1			
T	TRANSPORT	0.4			
≈	WATER SUPPLY- INCLUDING RESERVOIR & SEWAGE TREATMENT	0.1			
M	MILITARY	4.0			
✳	QUARRIES AND BORROW AREAS	0.5			
+	CEMETERY	< 0.1			
A	AGRICULTURE	18.7			
F	FISH OR DUCK FARMING	16.3			
⌛	UNDISTURBED NATURAL TERRAIN	19.6			

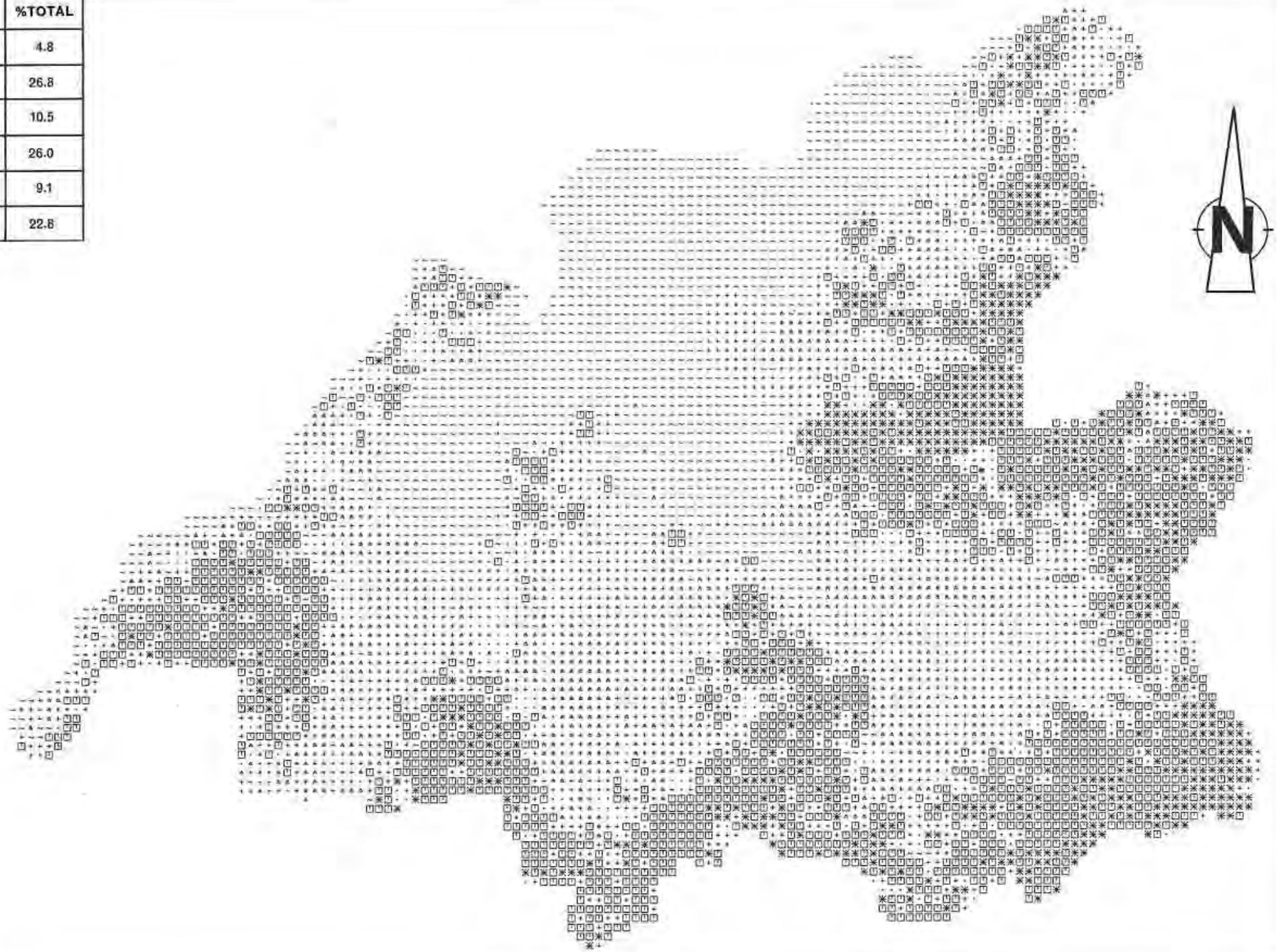


Scale 1:100 000

GEOTECS Plot - Land Use

Fig. 9

SYMBOL	MEANING	%TOTAL
·	GLUM CLASS I	4.8
+	GLUM CLASS II	26.8
△	GLUM CLASS IIS	10.5
⊡	GLUM CLASS III	26.0
✳	GLUM CLASS IV	9.1
~	UNCLASSIFIED	22.8



Scale
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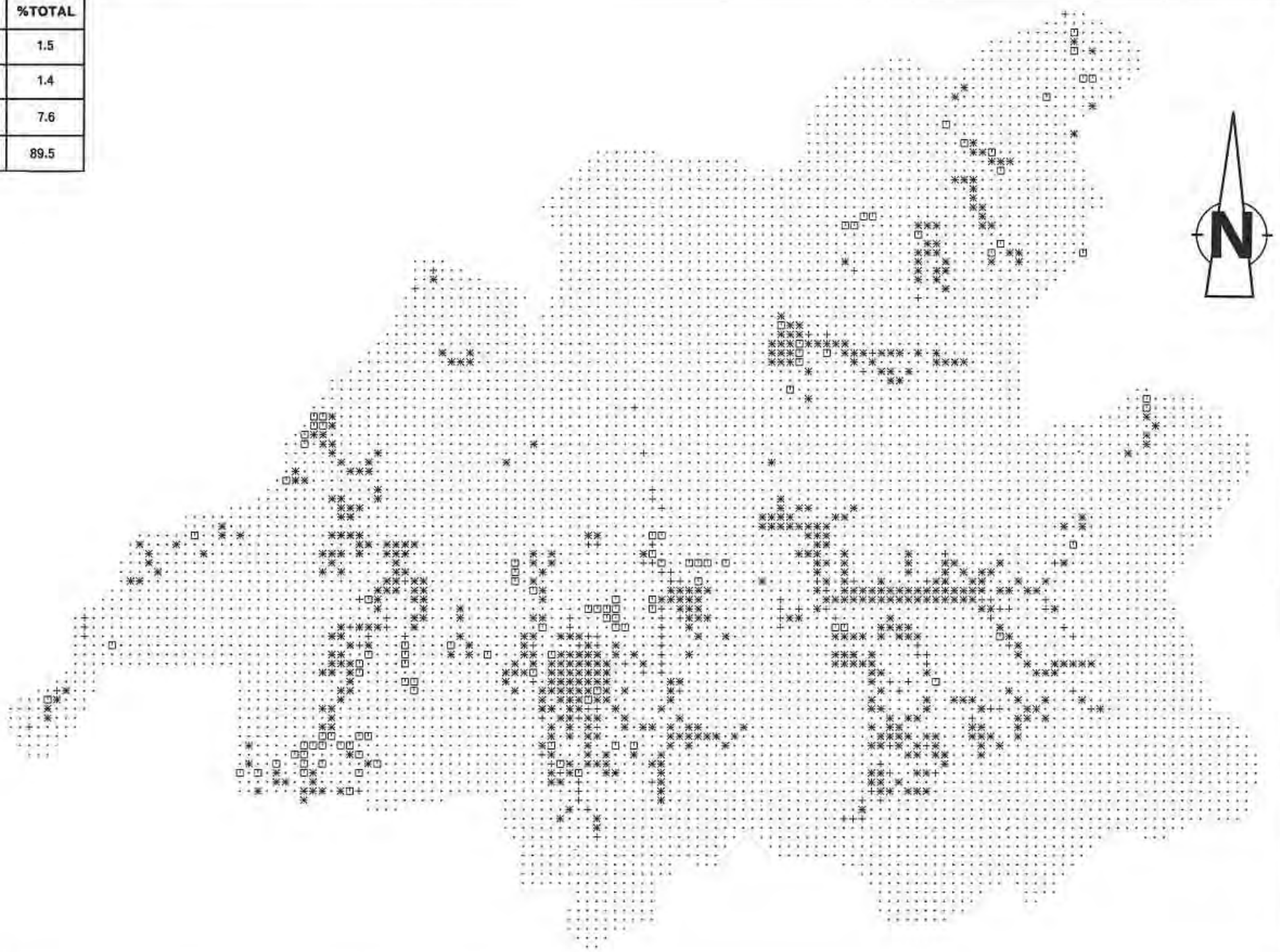
GEOTECS Plot - Geotechnical Land Use Map

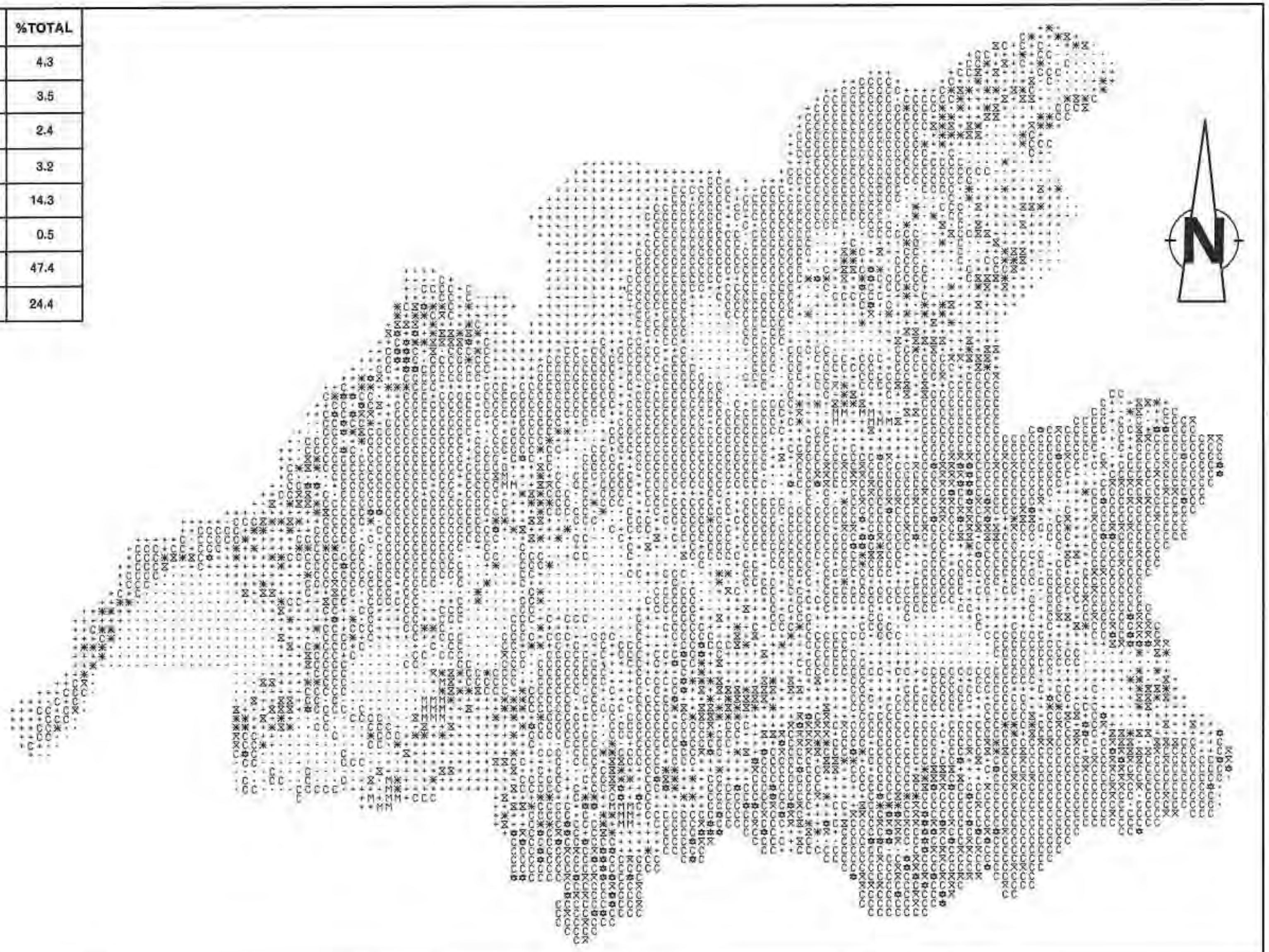
Fig. 10

SYMBOL	MEANING	%TOTAL
+	FLOOD-PRONE TERRAIN	1.5
⊡	EXISTING DEVELOPMENT ON FLOOD-PRONE TERRAIN	1.4
✳	AGRICULTURAL USE ON FLOOD-PRONE TERRAIN	7.6
·	OTHER TERRAIN	89.5



Scale 1:100 000	GEOTECS Plot – Flood-prone Terrain and Development	Fig. 11

SYMBOL	MEANING	%TOTAL
✳	POTENTIAL (TERRAIN) (NO CURRENT USEAGE)	4.3
⌛	POTENTIAL (SLOPE) (NO CURRENT USEAGE)	3.5
✡	POTENTIAL (TERRAIN) COUNTRY PARK / CULTIVATION	2.4
X	POTENTIAL (SLOPE) COUNTRY PARK / CULTIVATION	3.2
·	EXISTING USEAGE, RESERVOIR OR CHANNEL	14.3
M	EXISTING QUARRY	0.5
C	OTHER TERRAIN IN COUNTRY PARK, CULTIVATION OR POND	47.4
+	UNDESIGNATED	24.4



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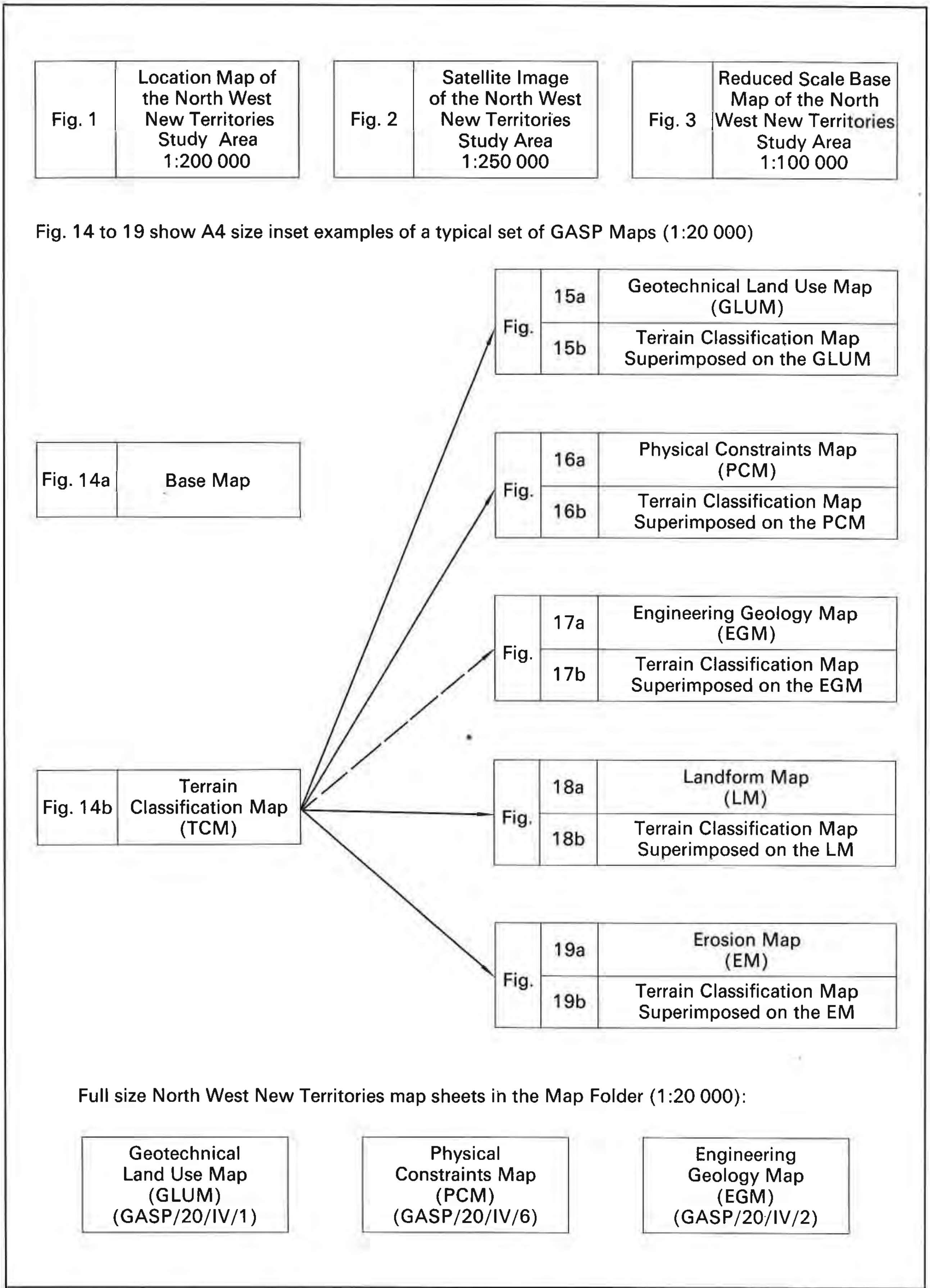
GEOTECS Plot – Potential Quarry Sites

Fig. 12



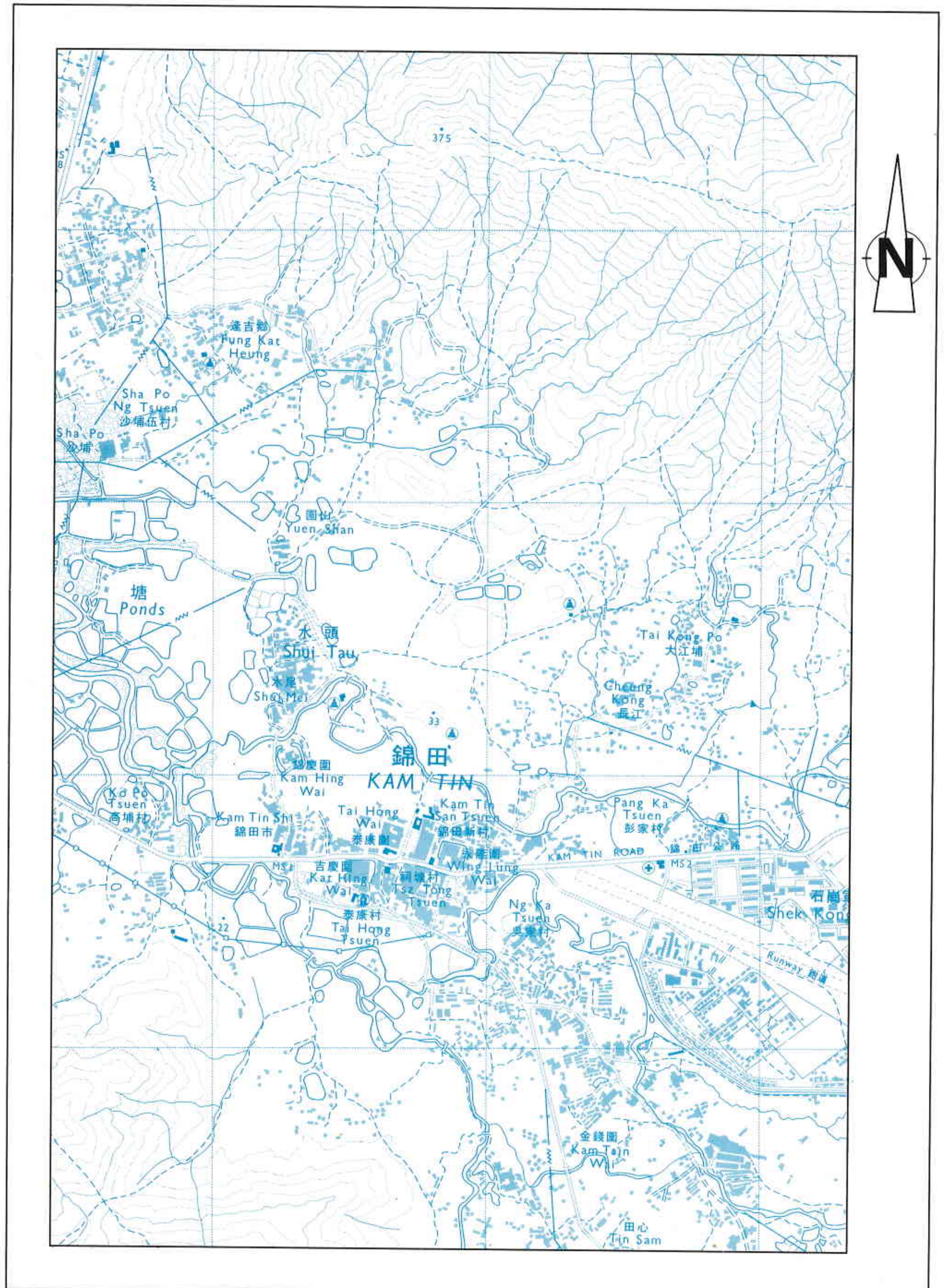
Presentation of Maps — Fig. 13

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig.14b)

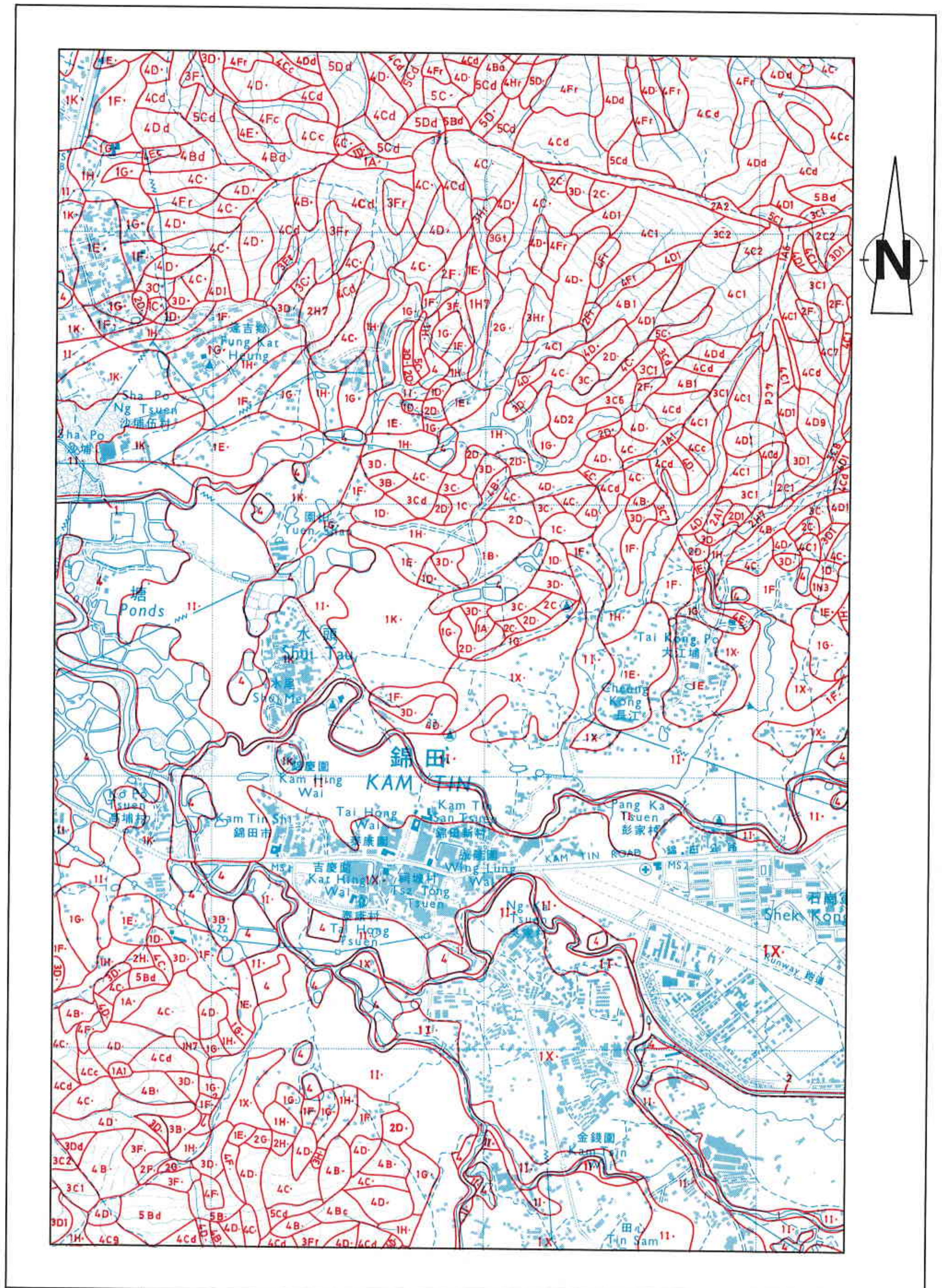
SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

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
Cliff/Rock outcrop		M
Cut	- straight	N
	- concave	O
	- convex	P
Fill	- straight	R
	- concave	S
	- convex	T
General disturbed terrain		V
Reclamation		Z
Alluvial plain		X
Waterbodies	- Natural stream	1
	- Manmade 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	- integral	- recent	a
		- relict	b
	- scar	- recent	c
		- relict	d
	- debris	- recent	g
		- relict	k
Development of general instability	- integral	- recent	n
		- relict	o
	- scar	- recent	p
		- relict	r
	- debris	- recent	s
		- relict	t
Coastal	- integral		w
	- scar		y
	- debris		z



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



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

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

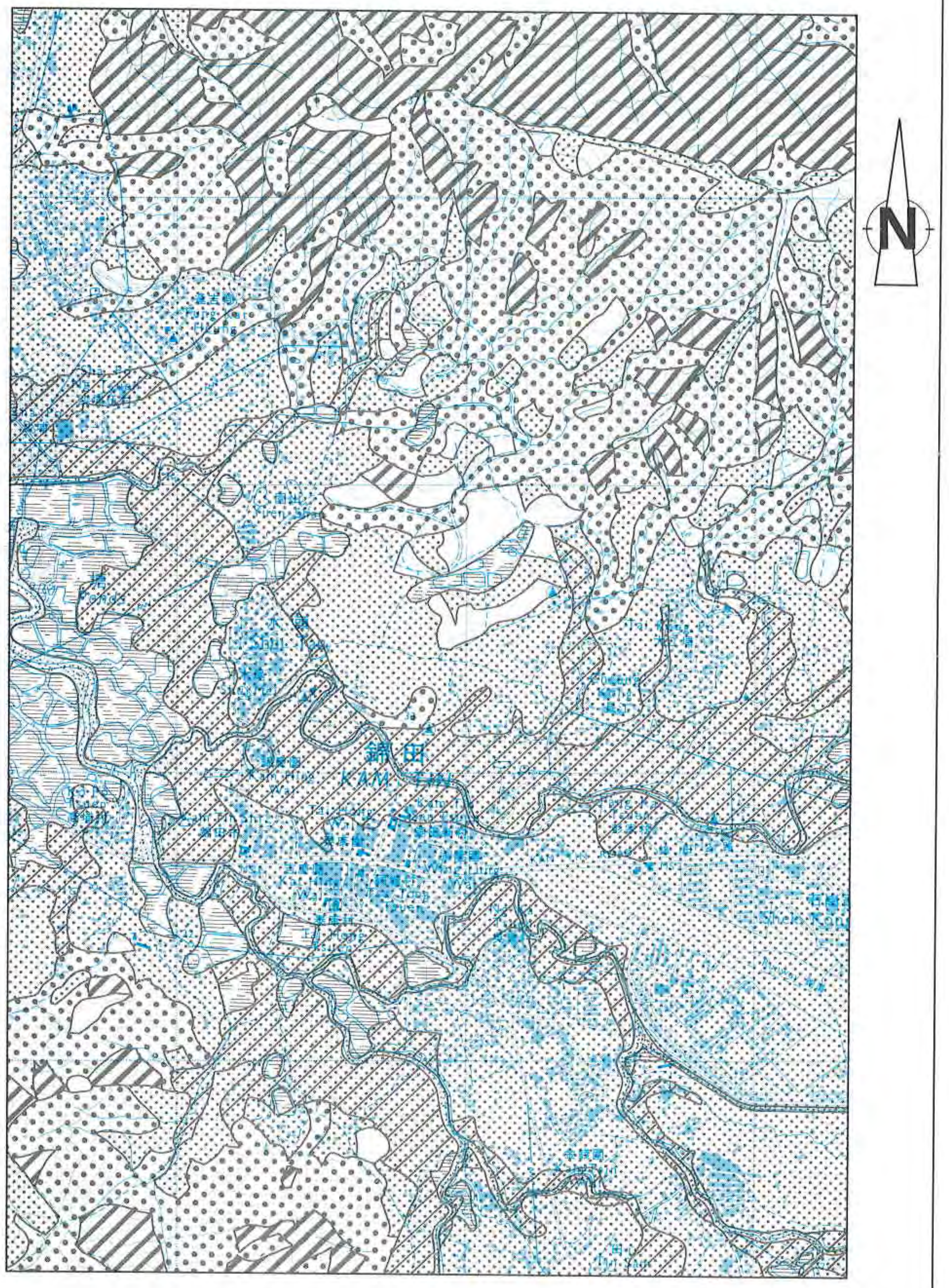
Class I	- Low Geotechnical Limitations
Class II	- Moderate Geotechnical Limitations
Class IIS	- Moderate Geotechnical Limitations (including flooding)
Class III	- High Geotechnical Limitations
Class IV	- Extreme Geotechnical Limitations
Waterbodies (streams, man-made channels, storage dams)	Unclassified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

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. 15b)

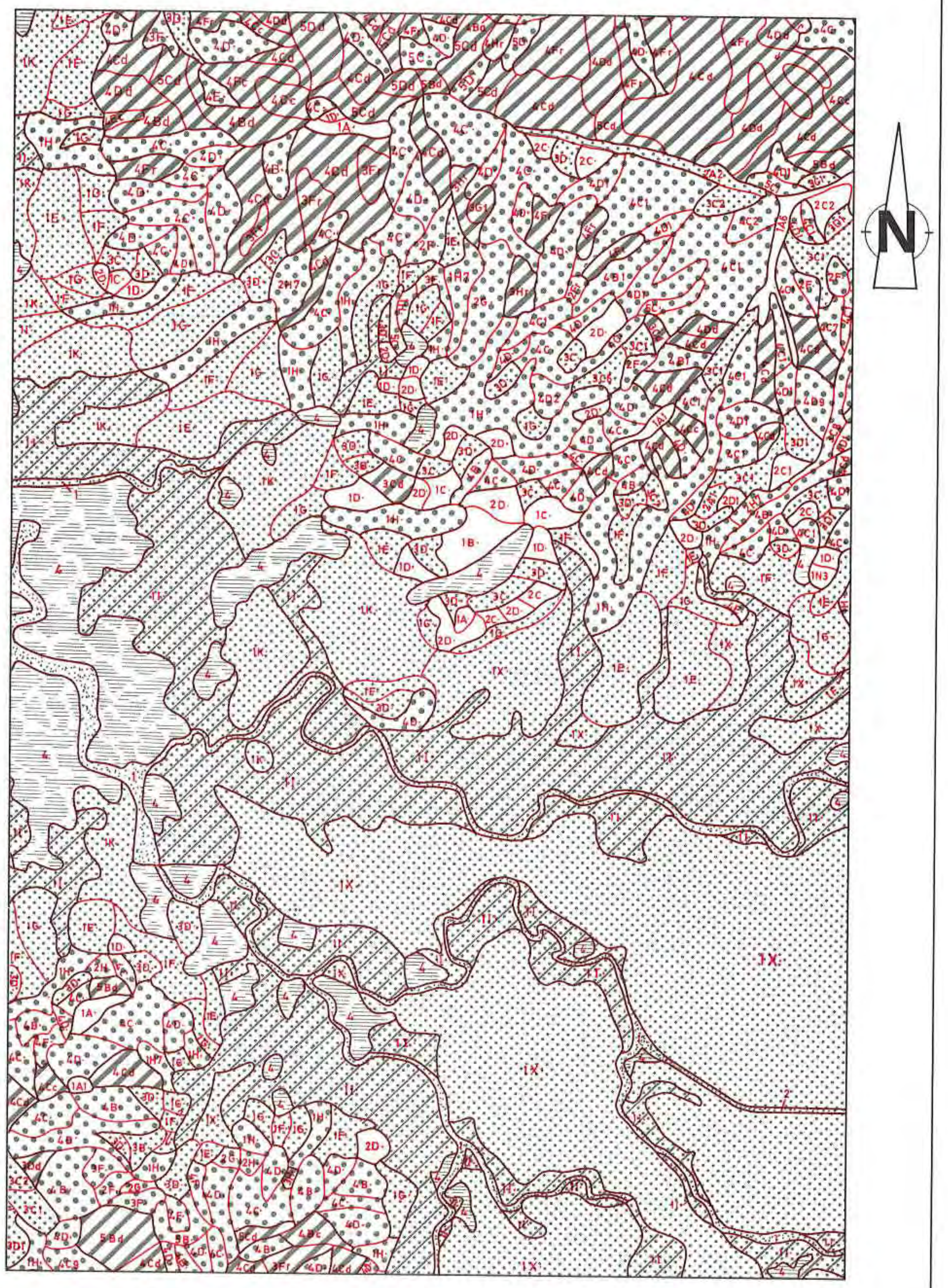
SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

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
Cliff/Rock outcrop		M
Cut	- straight	N
	- concave	O
	- convex	P
Fill	- straight	R
	- concave	S
	- convex	T
General disturbed terrain		V
Reclamation		Z
Alluvial plain		X
Waterbodies	- Natural stream	1
	- Manmade 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	- integral	- recent	a
		- relict	b
	- scar	- recent	c
		- relict	d
	- debris	- recent	g
		- relict	k
Development of general instability	- integral	- recent	n
		- relict	o
	- scar	- recent	p
		- relict	r
	- debris	- recent	s
		- relict	t
Coastal	- integral		w
	- scar		y
	- debris		z



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)

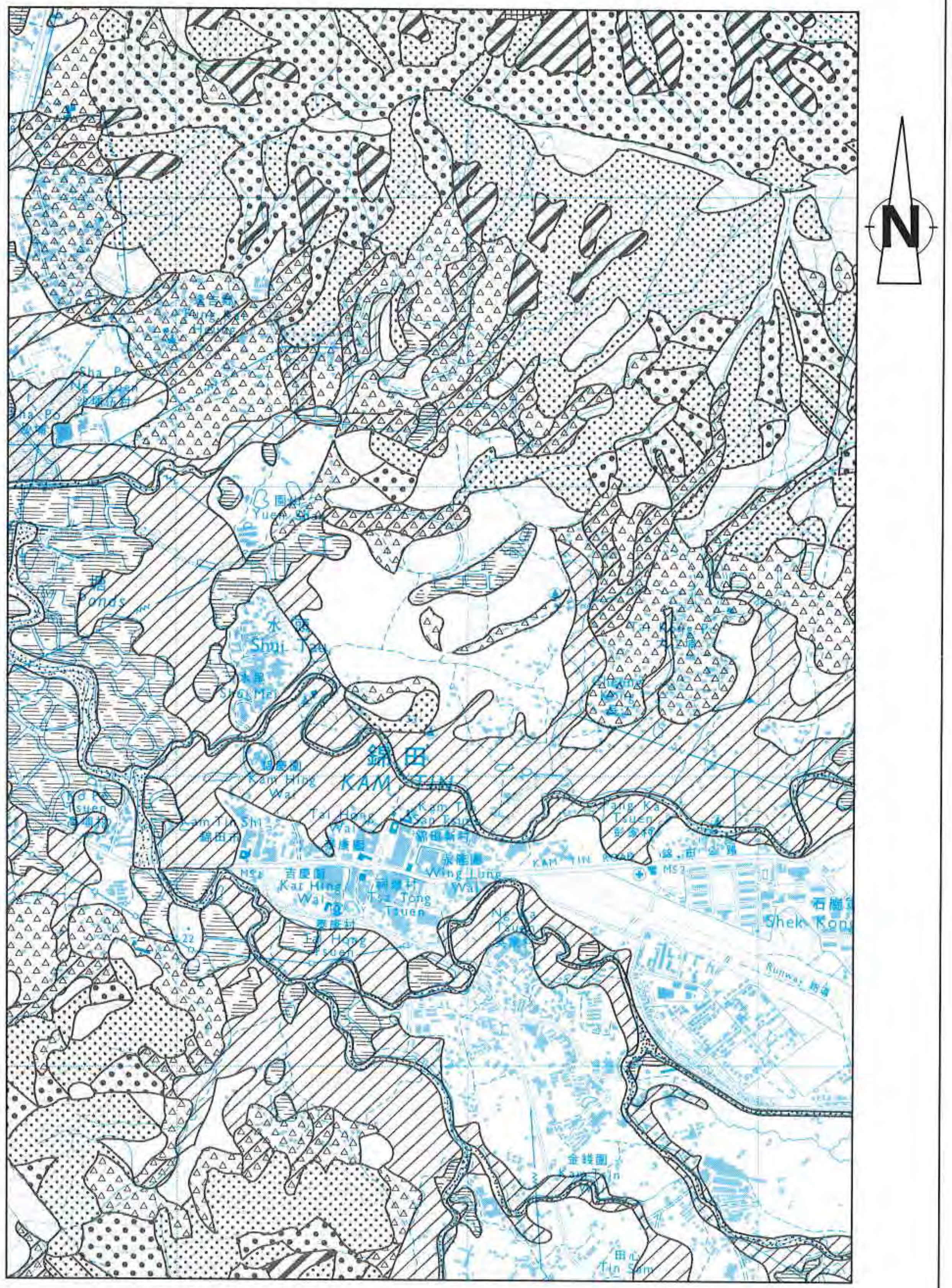
- Colluvium
- Zones of colluvium which are subject to overland flow and periodic inundation. Evidence of unusual groundwater regime (delineated as drainage plain on Landform Map)
- Floodplain - subject to overland flow and regular inundation. Evidence of unusual groundwater regime (delineated as floodplain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

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. 16b)

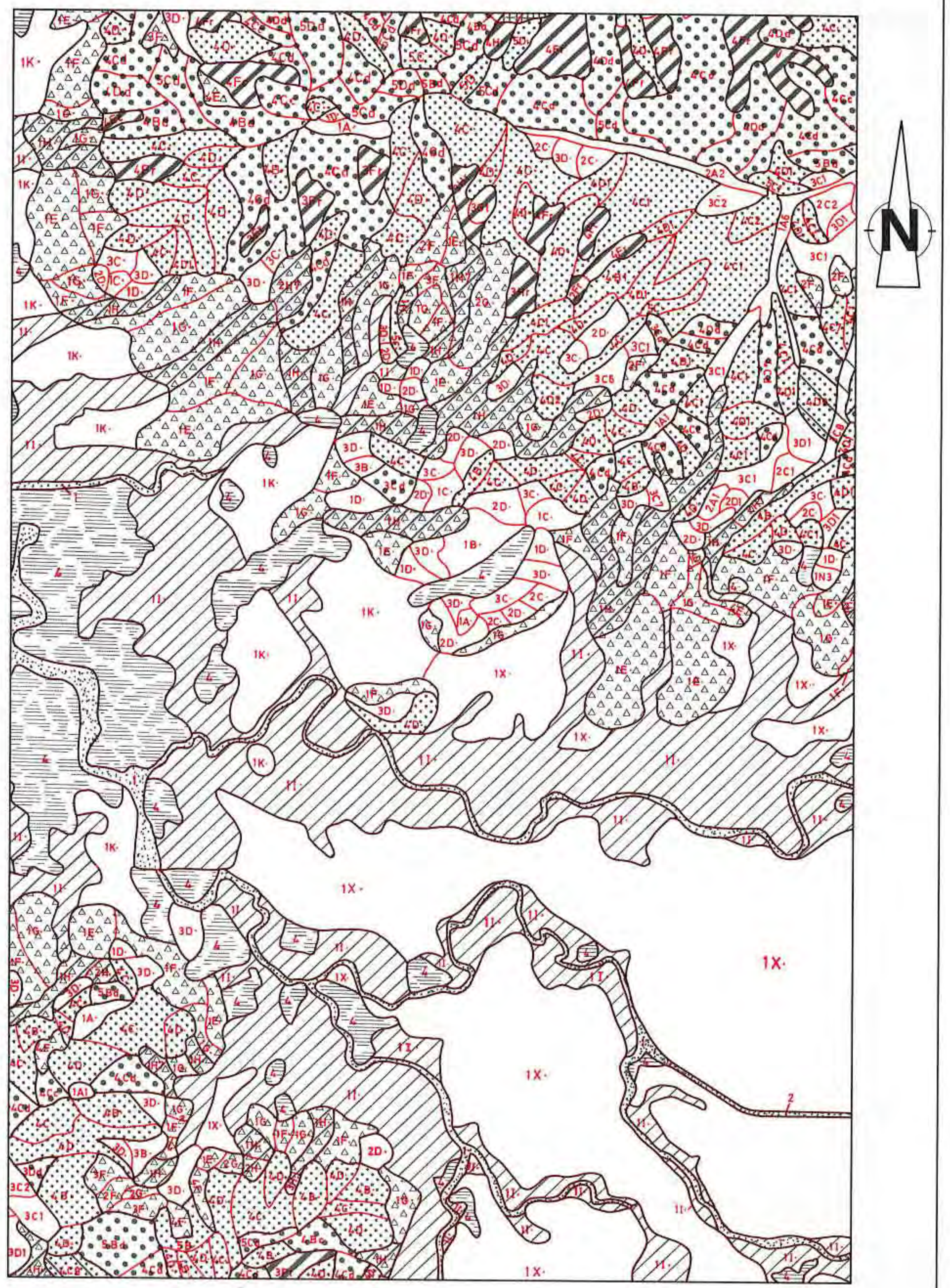
SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

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
Cliff/Rock outcrop	M
Cut - straight	N
- concave	O
- convex	P
Fill - straight	R
- concave	S
- convex	T
General disturbed terrain	V
Reclamation	Z
Alluvial plain	X
Waterbodies - Natural stream	1
- Manmade 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	- integral	- recent	a
		- relict	b
	- scar	- recent	c
		- relict	d
	- debris	- recent	g
		- relict	k
Development of general instability	- integral	- recent	n
		- relict	o
	- scar	- recent	p
		- relict	r
	- debris	- recent	s
		- relict	t
Coastal	- integral		w
	- scar		y
	- debris		z



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 - exposed at surface
- Alluvium - underlying ponds
- Raised alluvial terrace
- Colluvium (undifferentiated)
- Sedimentary rocks and water-laid volcaniclastic rocks) Repulse Bay Formation
- Coarse tuff) Repulse Bay Formation
- Dominantly pyroclastic rocks with some lavas) Repulse Bay Formation
- Kat O Formation
- Lok Ma Chau Formation
- Needle Hill Granite : fine-grained porphyritic phase
- Needle Hill Granite : medium-grained porphyritic phase
- Cheung Chau Granite
- Tai Po Granodiorite

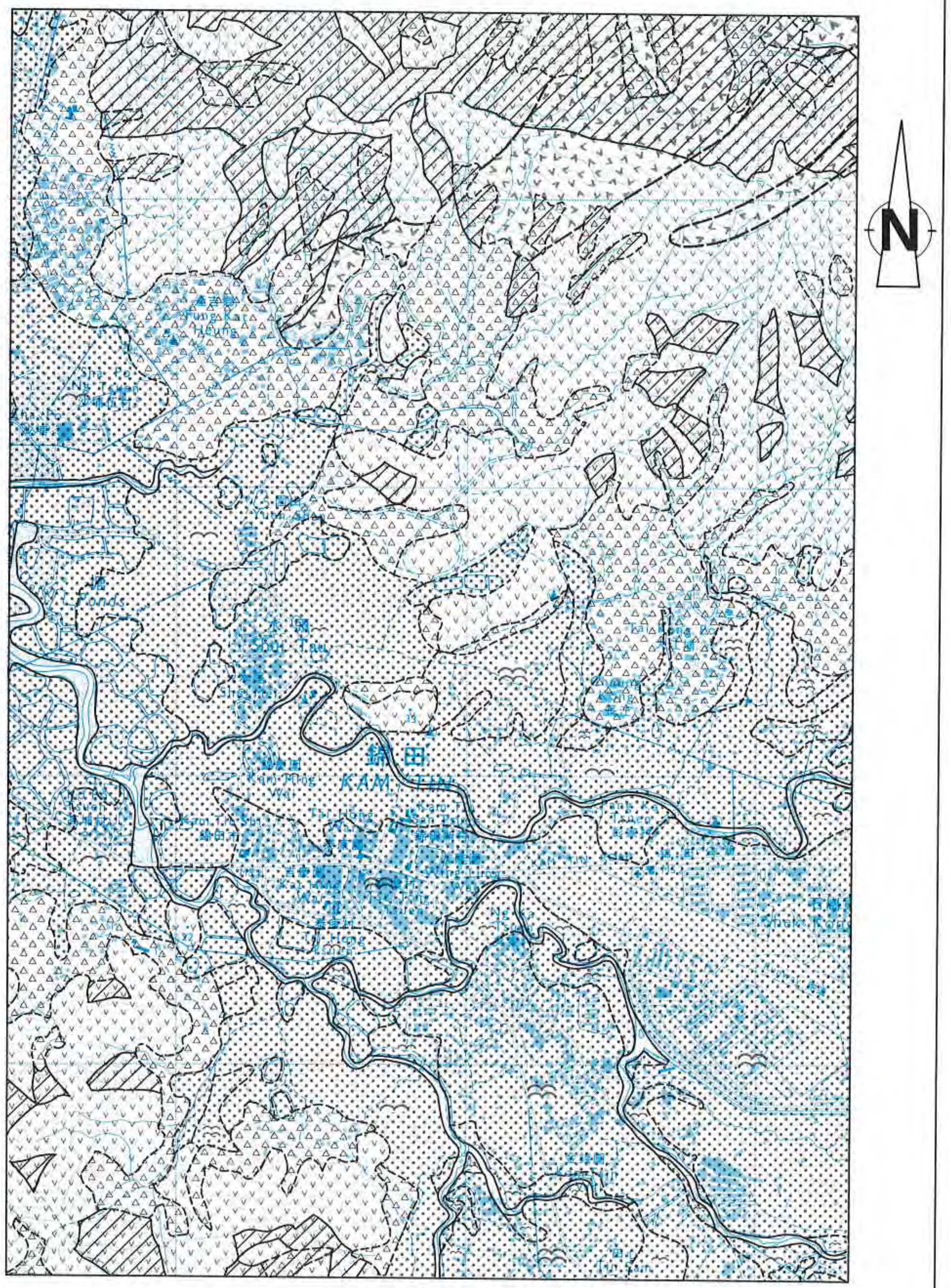
- General instability
- Geological boundary (solid)
- Geological boundary (superficial)
- Geological photolineament
- Fault
- Southern limit of zone of metamorphism
- Thrust (teeth pointing to upper plate)
- Catchment boundary (order indicated by number of dots)

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. 17b)

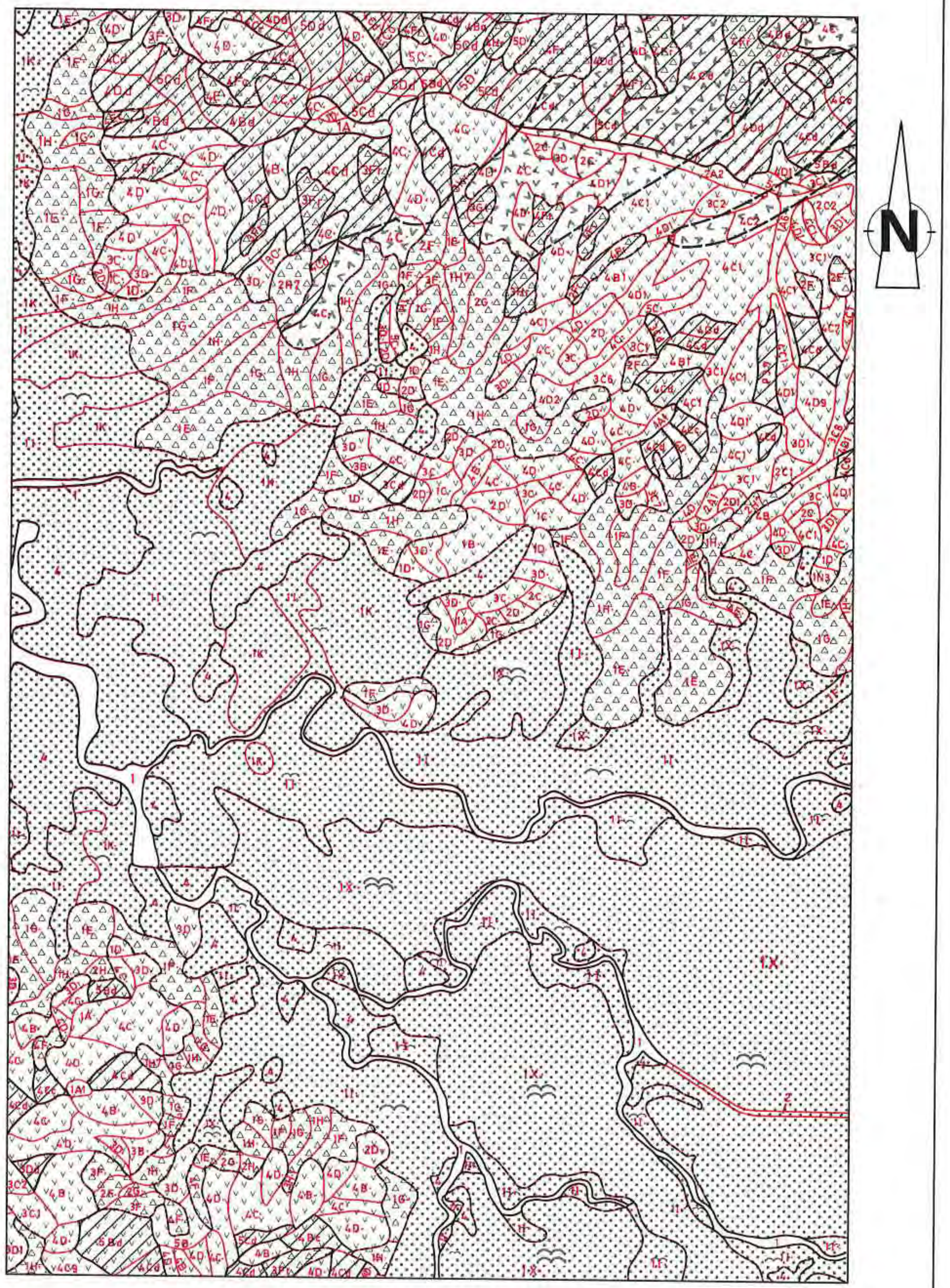
SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

TERRAIN COMPONENT		CODE
Crest or ridge		A
Sideslope	- straight	B
	- concave	C
	- convex	D
Footslope	- straight	E
	- concave	F
	- convex	G
Drainage plain		H
Floodplain		I
Coastal plain		K
Littoral zone		L
Cliff/Rock outcrop		M
Cut	- straight	N
	- concave	O
	- convex	P
Fill	- straight	R
	- concave	S
	- convex	T
General disturbed terrain		V
Reclamation		Z
Alluvial plain		X
Waterbodies	- Natural stream	1
	- Manmade 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	- integral	- recent	a
		- relict	b
	- scar	- recent	c
		- relict	d
	- debris	- recent	g
		- relict	k
Development of general instability	- integral	- recent	n
		- relict	o
	- scar	- recent	p
		- relict	r
	- debris	- recent	s
		- relict	t
Coastal	- integral		w
	- scar		y
	- debris		z



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 LANDFORM MAP (Fig. 18a)

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

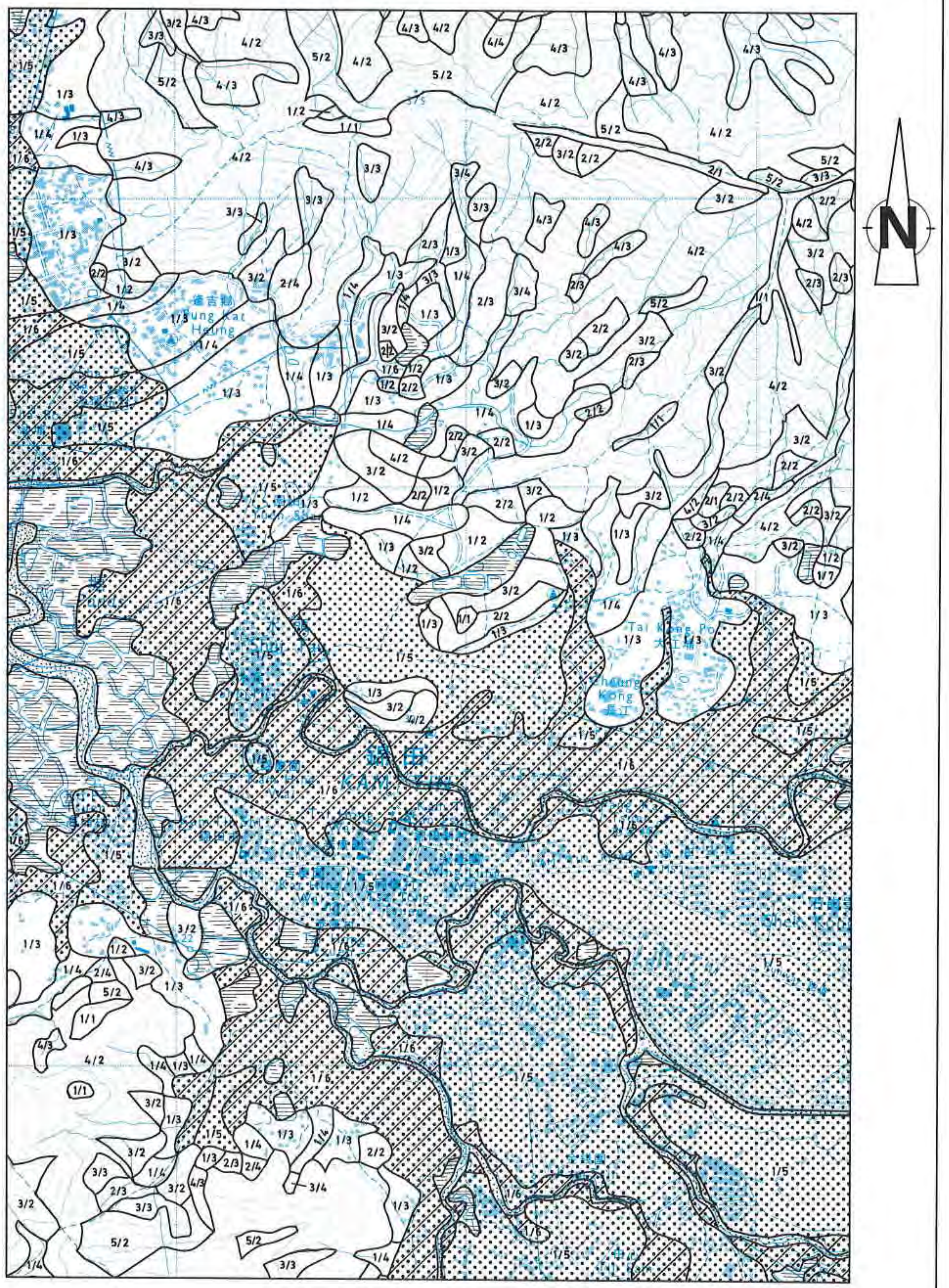
DESCRIPTION	CODE
Crest or ridge	1
Sideslope - insitu	2
Footslope - colluvium	3
Drainage plain - colluvium subject to overland flow and regular inundation. Unusual groundwater regime.	4
Alluvial plain - includes raised terraces.	5
Flood plain - portion of alluvial plain subject to overland flow and regular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

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. 18b)

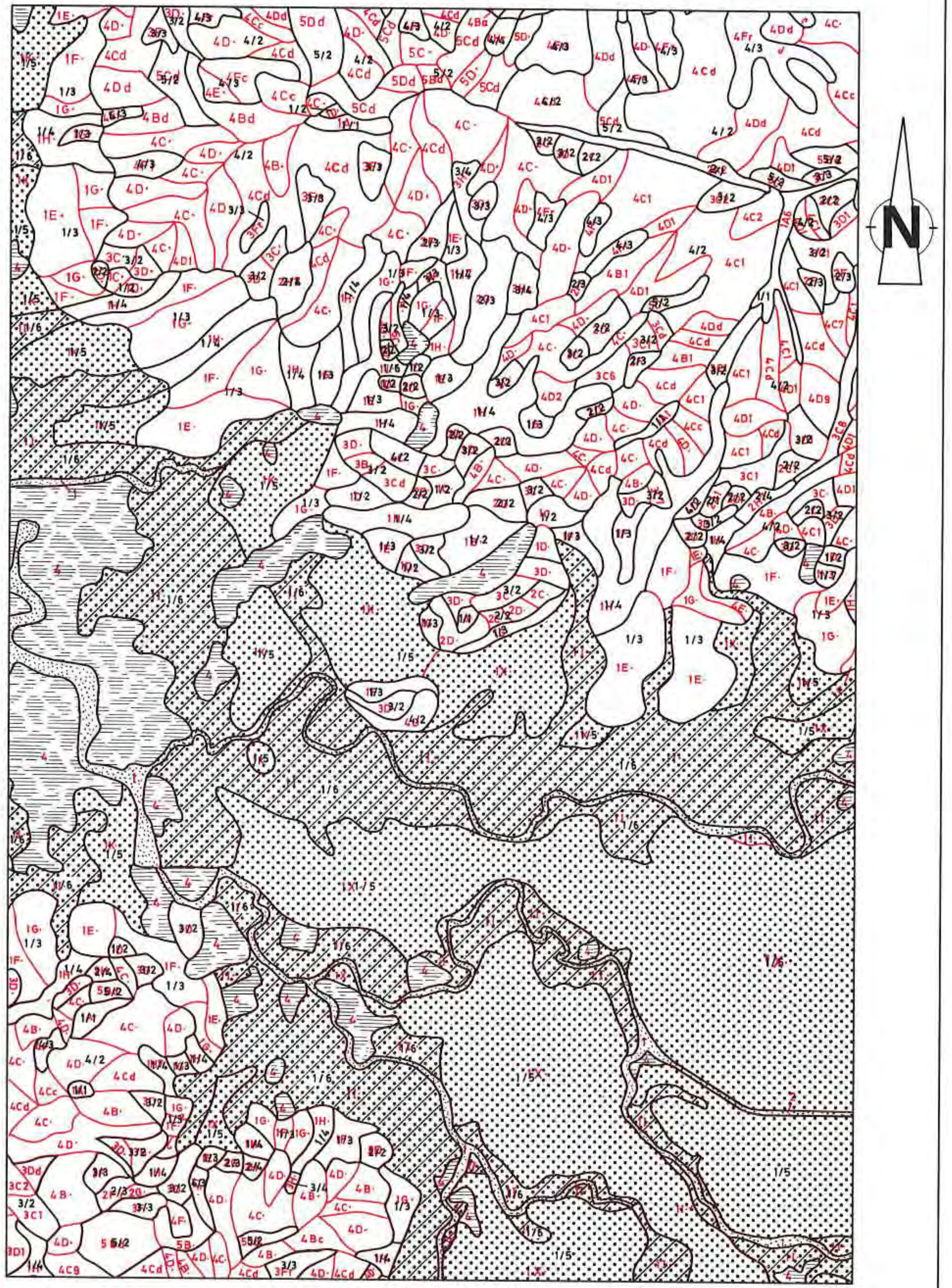
SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

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
Cliff/Rock outcrop		M
Cut	- straight	N
	- concave	O
	- convex	P
Fill	- straight	R
	- concave	S
	- convex	T
General disturbed terrain		V
Reclamation		Z
Alluvial plain		X
Waterbodies	- Natural stream	1
	- Manmade 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	- integral	- recent	a
		- relict	b
	- scar	- recent	c
		- relict	d
	- debris	- recent	g
		- relict	k
Development of general instability	- integral	- recent	n
		- relict	o
	- scar	- recent	p
		- relict	r
	- debris	- recent	s
		- relict	t
Coastal	- integral		w
	- scar		y
	- debris		z



Scale 1:20 000	Example of the Landform Map (LM)	Fig. 18a



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

LEGEND FOR EROSION MAP (Fig. 19a)

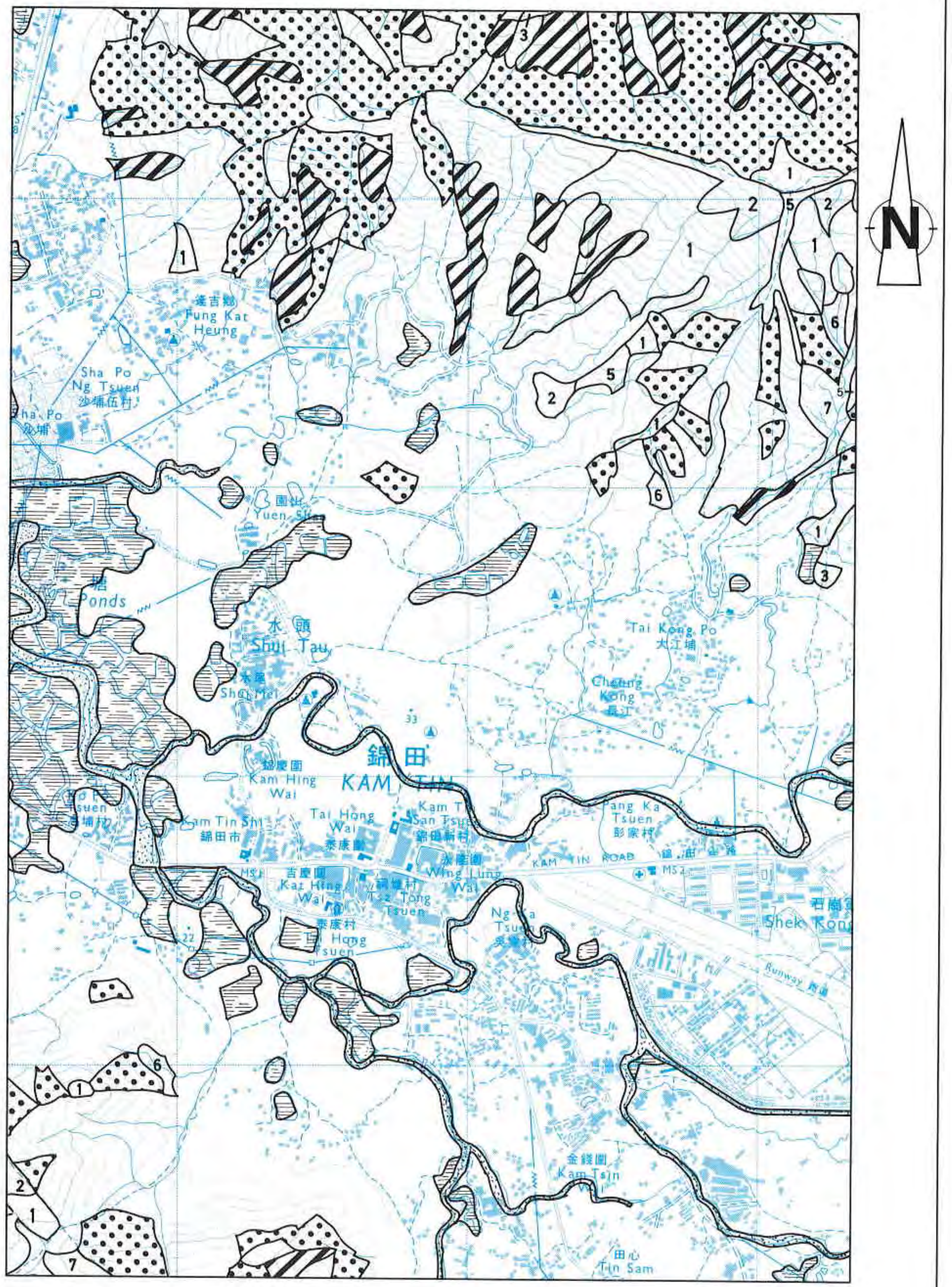
	No appreciable erosion
1	Minor sheet erosion
2	Moderate sheet erosion
3	Severe sheet erosion
4	Minor rill erosion
5	Moderate to severe rill erosion
6	Minor gully erosion
7	Moderate to severe gully erosion
	Zones of general instability associated with predominantly insitu terrain
	Zones of general instability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

LEGEND FOR TERRAIN CLASSIFICATION MAP (Fig. 19b)

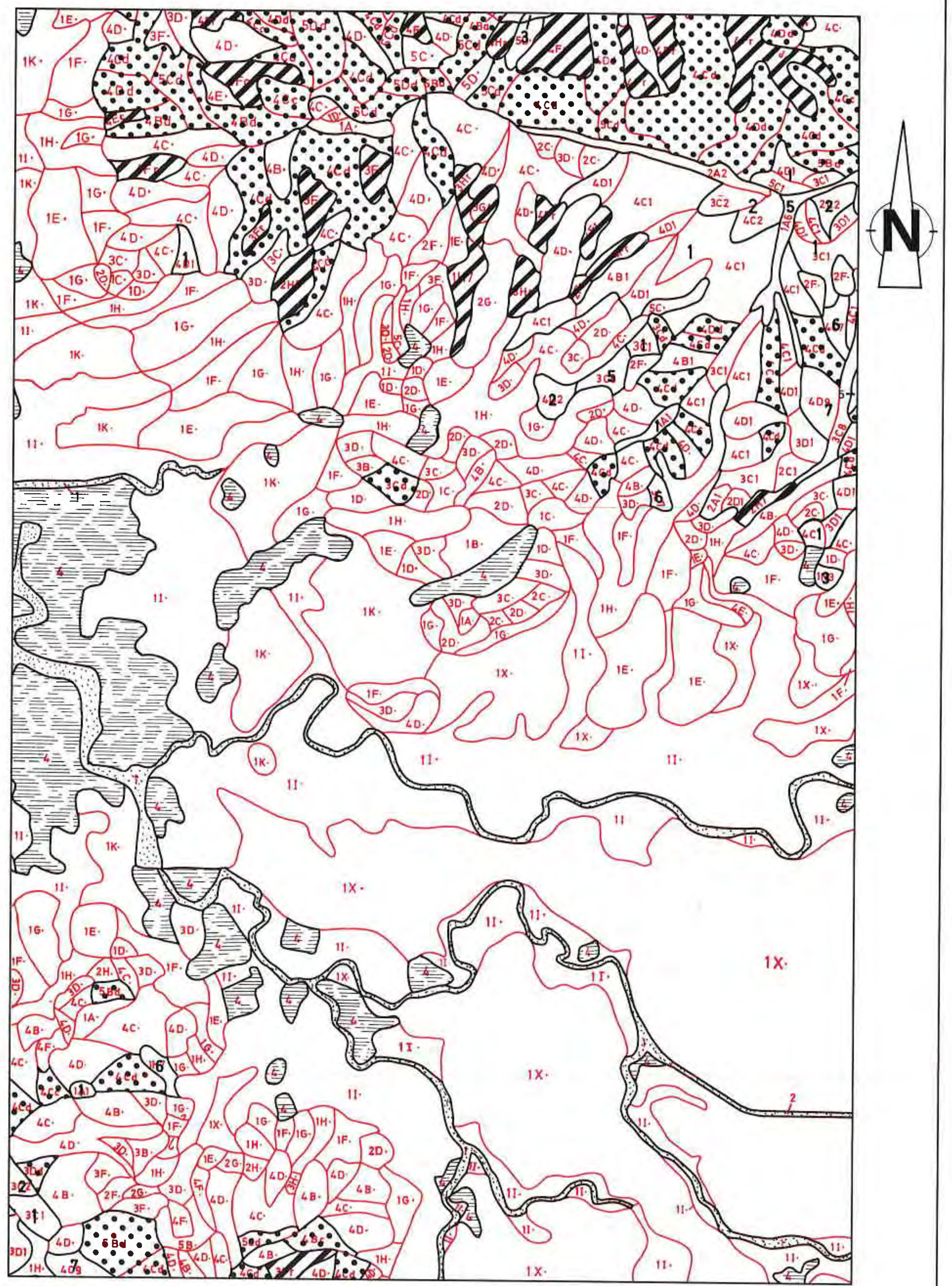
SLOPE GRADIENT	CODE
0 - 5°	1
5 - 15°	2
15 - 30°	3
30 - 40°	4
40 - 60°	5
> 60°	6

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
Cliff/Rock outcrop		M
Cut	- straight	N
	- concave	O
	- convex	P
Fill	- straight	R
	- concave	S
	- convex	T
General disturbed terrain		V
Reclamation		Z
Alluvial plain		X
Waterbodies	- Natural stream	1
	- Manmade 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	- integral	- recent	a
		- relict	b
	- scar	- recent	c
		- relict	d
	- debris	- recent	g
		- relict	k
Development of general instability	- integral	- recent	n
		- relict	o
	- scar	- recent	p
		- relict	r
	- debris	- recent	s
		- relict	t
Coastal	- integral		w
	- scar		y
	- debris		z



Scale	Example of the Erosion Map	Fig. 19a
1:20 000	(EM)	



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

Plate 1. Oblique Aerial Photograph Looking North across Yuen Long towards Deep Bay. (GCO/OAP 1980/3755).

Plate 2. Oblique Aerial Photograph Looking Northwest across the Village of Ha Tsuen. (GCO/OAP 1980/3781).

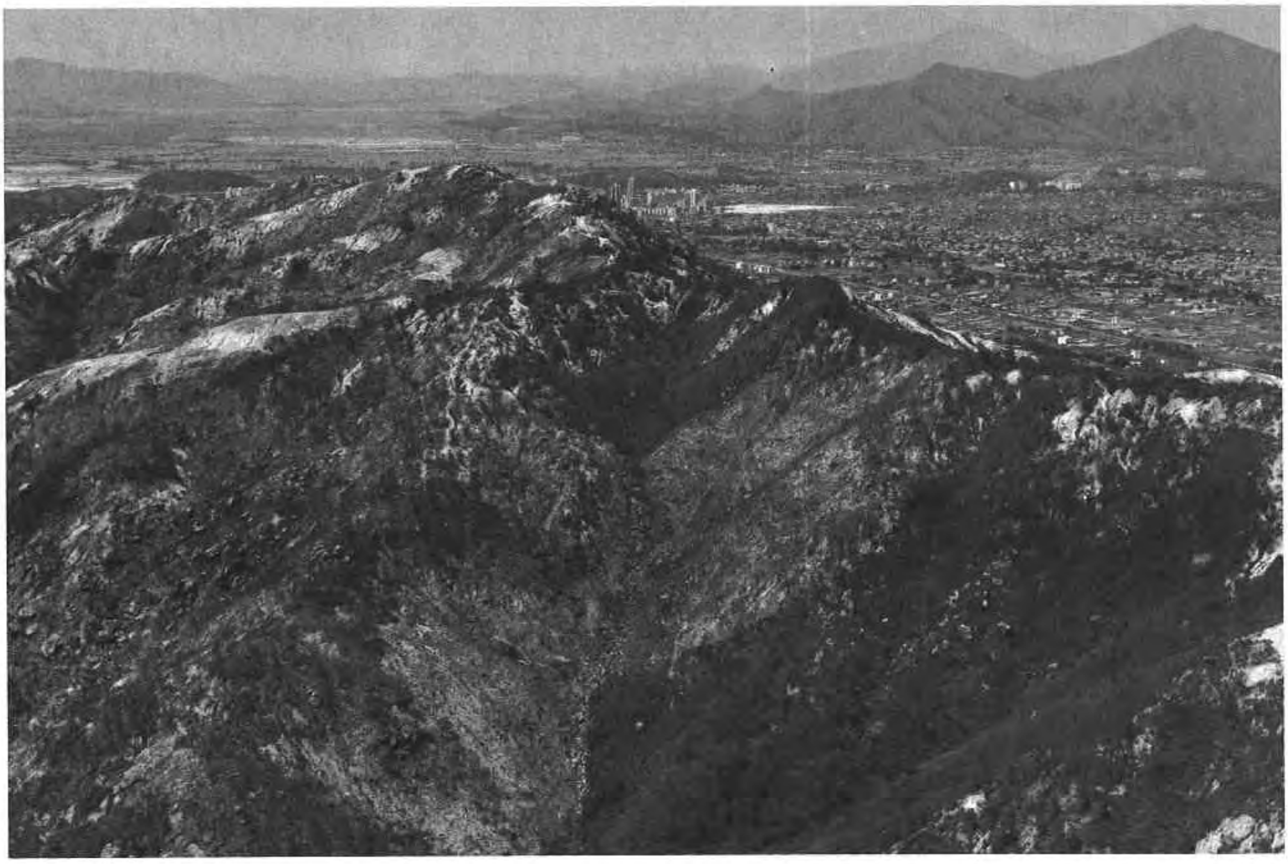


Plate 3. Oblique Aerial Photograph Looking North across Severely Eroded Granitic Terrain towards Yuen Long and Kai Keung Leng. (GCO/OAP 1980/3683).

Plate 4. Oblique Aerial Photograph Looking Northeast across Fish Ponds towards the Reclamation Site of Fairview Park. (GCO/OAP 1980/3784).

Plate 5. Oblique Aerial Photograph of Severe Gully Erosion on Granitic Terrain near Tan Kwai Tsuen. (GCO/OAP 1980/3687).

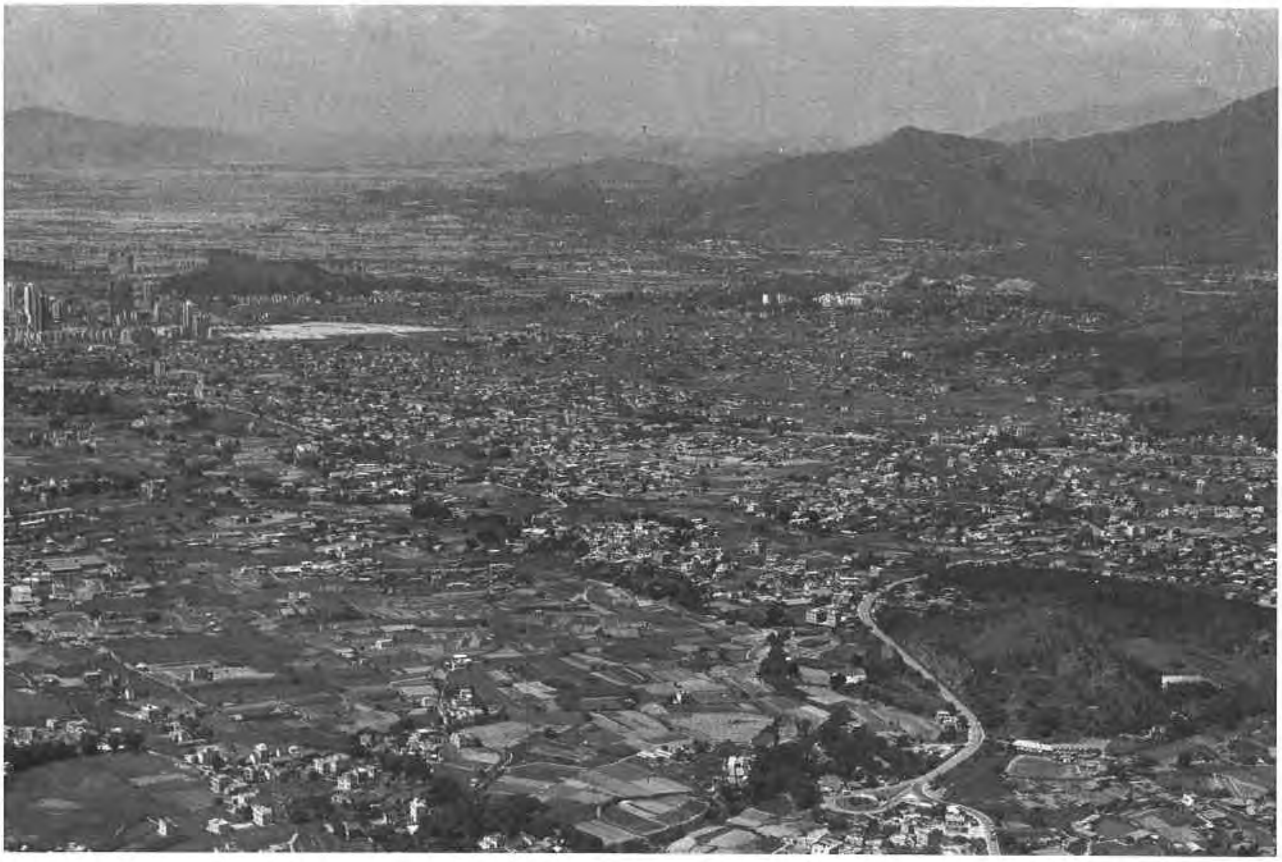


Plate 6. Oblique Aerial Photograph Looking Northeast across the Alluvium of Shap Pat Heung towards Kai Keung Leng. (GCO/OAP 1980/3754).

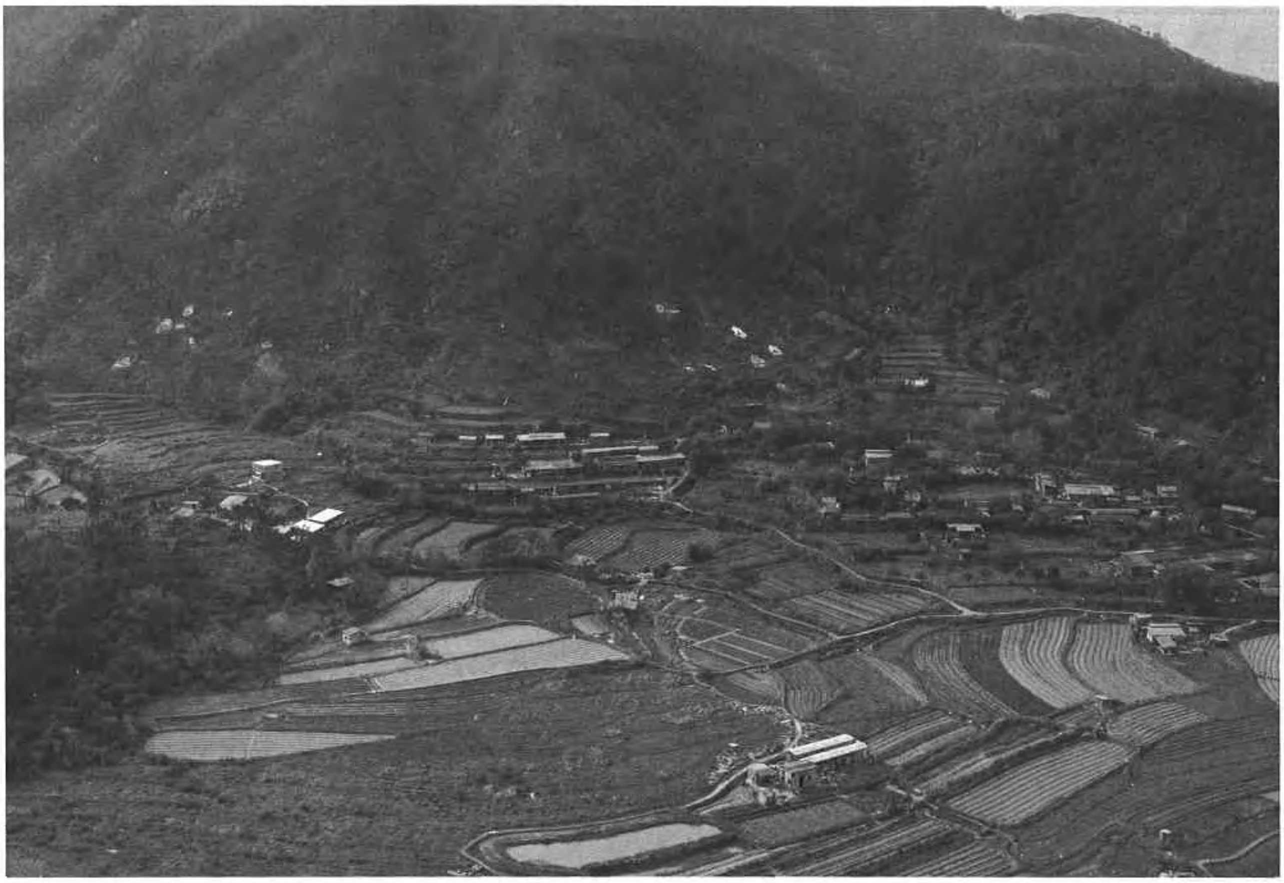


Plate 7. Oblique Aerial Photograph Looking Northwest towards Leung Tin Tsuen. (GCO/OAP 1980/3779).

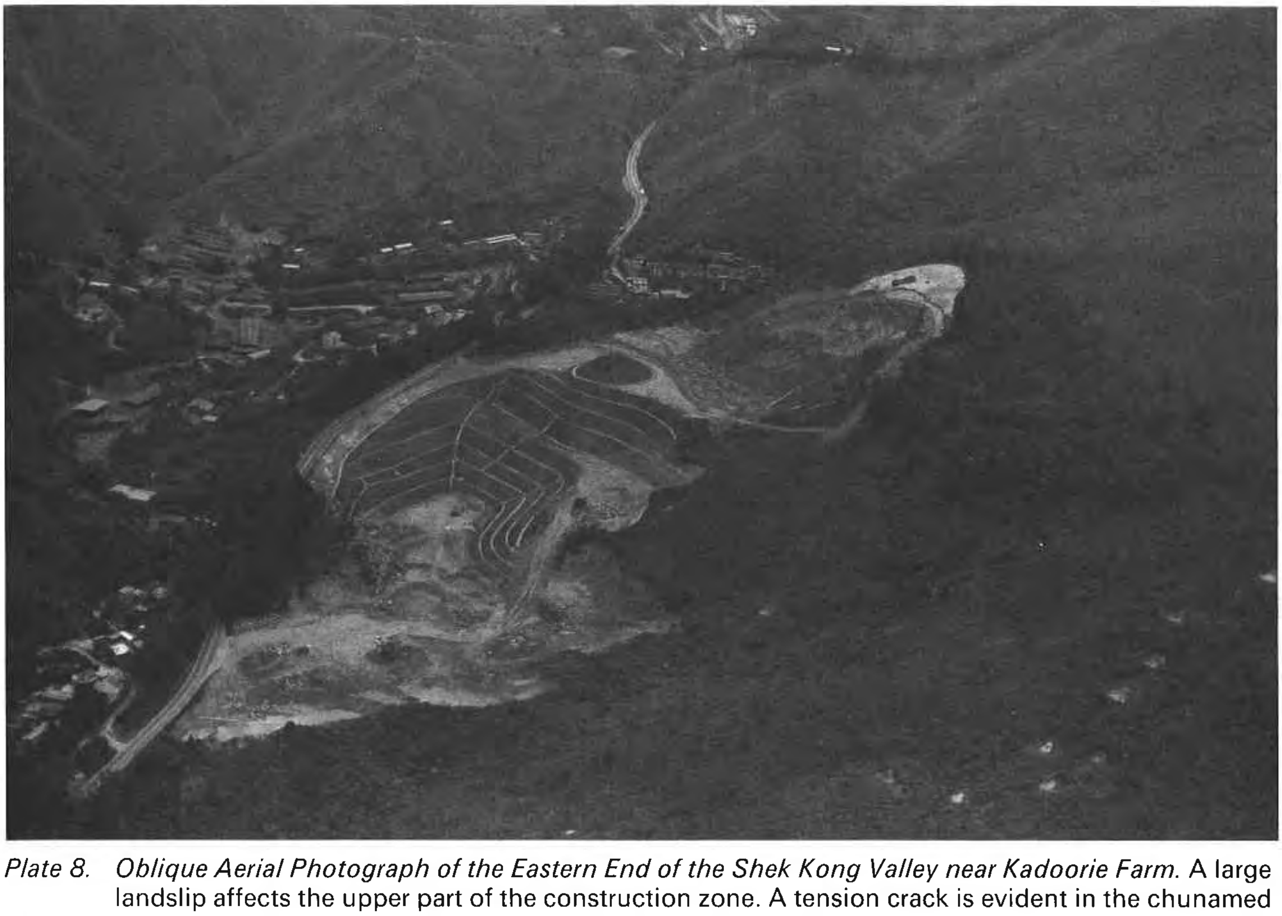


Plate 8. Oblique Aerial Photograph of the Eastern End of the Shek Kong Valley near Kadoorie Farm. A large landslip affects the upper part of the construction zone. A tension crack is evident in the chunamed cut slope at the upslope margin of the site. (GCO/OAP 1979/584).

Plate 9. Oblique Aerial Photograph Looking Northwest along Shek Kong Valley towards Tsim Bei Tsui. Deposits of raised alluvium form the gentle slopes of the foreground, with low-lying floodplains bordering the streams in the centre of the Plate. (GCO/OAP 1980/3764).

Plate 10. Oblique Aerial Photograph Looking North across Deeply Weathered Granitic Terrain towards Yuen Long. The granites in this area are severely eroded. (GCO/OAP 1980/3751).

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) and the Physical Constraints Map (PCM). 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.

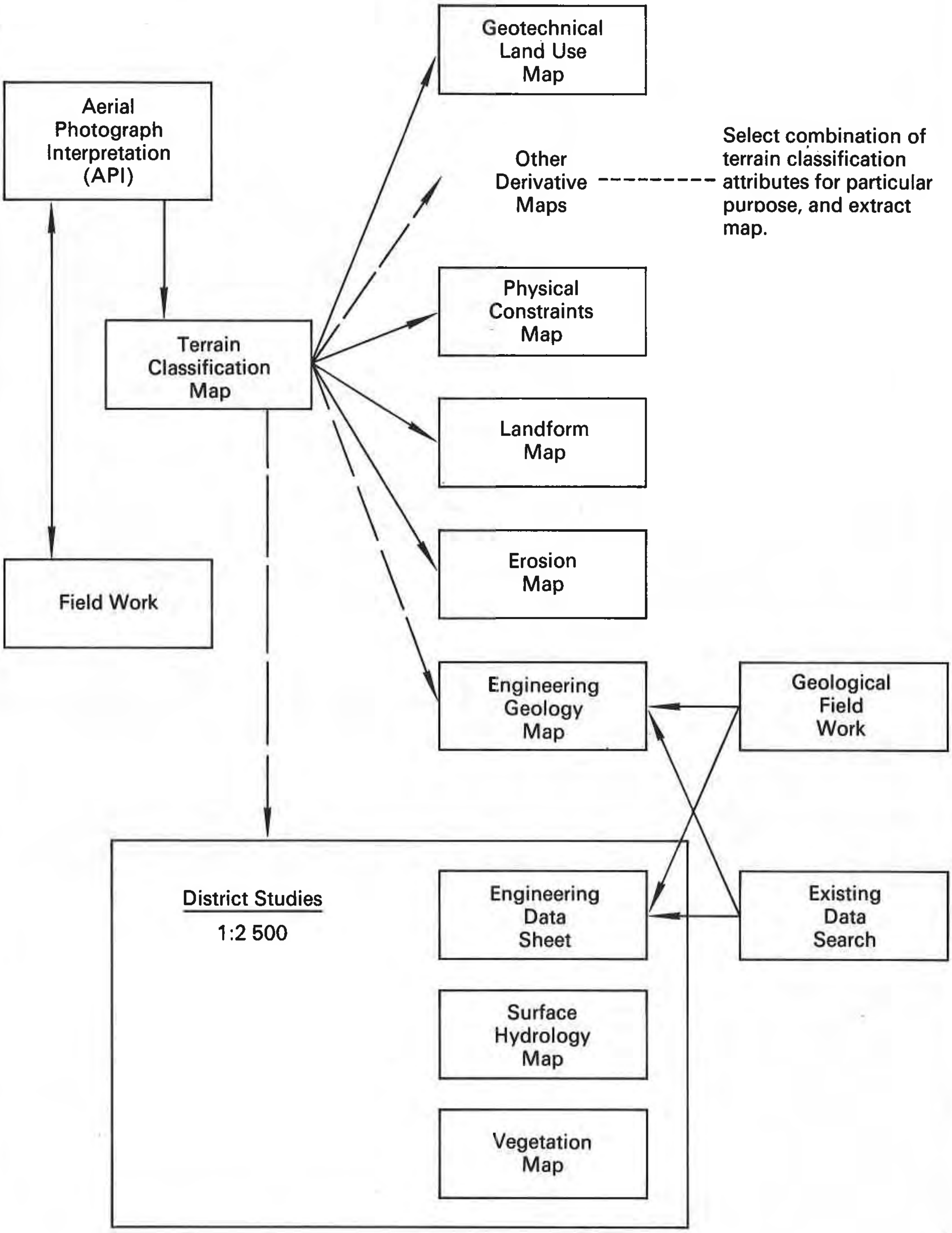
(*c*) Erosion and instability.

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), which is discussed briefly in Sections 1.5.8 and A.10.

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 —integral—recent	a
		Rock outcrop	M	—relict	b
				—scar —recent	c
		Cut —straight	N	—relict	d
		—concave	O	—debris —relict	g
		—convex	P	—relict	k
		Fill —straight	R	Development of general instability —integral—recent	n
		—concave	S	—relict	o
		—convex	T	—scar —recent	p
				—relict	r
		General disturbed terrain	V	—debris —relict	s
		Alluvial plain	X	—relict	t
		Reclamation	Z	Coastal instability —integral	w
		Waterbodies:		—scar	y
		Natural stream	1	—debris	z
		Man-made channel	2		
		Water storage dam	3		
		Fish pond	4		

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

A.3.1 *Slope Gradient*

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

A.3.2 *Terrain Component and Morphology*

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

There are the following 13 major terrain component classes:

(*a*) Hillcrest (Code A).

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

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

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

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

(*f*) Floodplain (Code I).

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

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

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

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

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

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

(*m*) Reclamation (Code Z).

In this study, all the footslope and drainage plain terrain consists of colluvium, and all the flood and alluvial plains consist of alluvium, whereas all the sideslope terrain consists of insitu geological materials. Other colluvial and alluvial subclasses occur in the cut slope, fill slope and general disturbed terrain components (see 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 to z) 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 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 18a) extracts from the Terrain Classification Map the significant terrain component and slope gradient classes. This information is presented as a separate map. In this form, it is easier to appreciate, understand and interpret the pattern of landform distribution.

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

(*a*) Hillcrest or ridge.

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

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

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

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

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

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

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

(*i*) Cliff and rock outcrop.

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

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

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

A.5 Erosion Map

The Erosion Map is derived from the Terrain Classification Map and delineates the major forms of erosion within the North West New Territories. The pattern of erosion can be related to the weathering characteristics of the geological units and to land use (Hansen & Nash, 1984). An example of this type of map is given in Figure 19a.

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 to z).

(*j*) General instability associated with colluvial terrain (Codes a to z).

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.

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.

(*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.

(*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.

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 North West New Territories are intended for use at a planning level and are based on the following:

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

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

A.8.2 *Production of the Engineering Geology Map*

The Engineering Geology Map was compiled from selected information from the Terrain Classification Map, to which was added various existing data (Allen & Stephens, 1971) and information collected during the field reconnaissance. The Engineering Geology Map presents 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 North West New Territories GASP 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*) Zones of general instability.

(*e*) Boundaries of major catchments.

(*f*) Zones of reclamation.

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

A.8.3 *Colluvium Classification System*

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

(*a*) Essentially volcanic derived.

(*b*) Essentially granite derived.

(*c*) Essentially metasediment derived.

(*d*) Mixed origin.

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

A.8.4 *Data Collection*

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

Details of the aerial photographs used for the terrain classification are given in Appendix C.2 and Table C.1.

A.9 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:

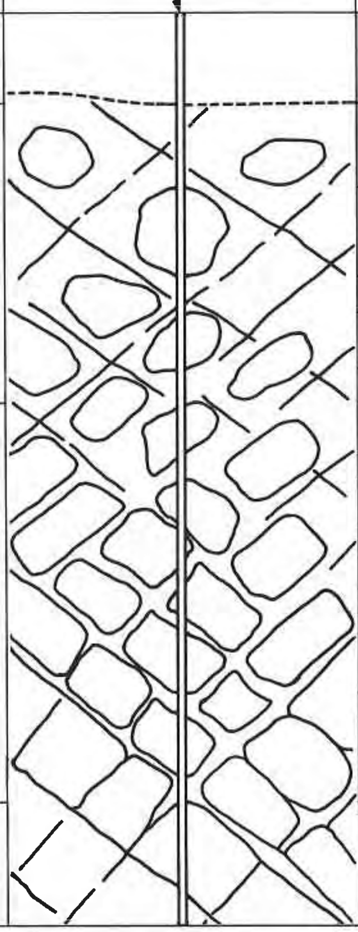
(*a*) The maps are designed for use at a scale of 1:20 000. They should never be enlarged to scales larger than the published scale.

(*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.

Table A3 Rock Weathering System

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

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

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

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

A.10 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 IV data bank consists of 7 713 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 1.5.8. 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 WEST NEW TERRITORIES GEOTECHNICAL AREA STUDY

Table B1 Slope Gradient

Slope Gradient	% of Total Area	Area (ha)
0– 5°*	60.9	9 576
5–15°	3.7	581
15–30°	10.0	1 567
30–40°	23.4	3 684
40–60°	1.8	287
>60°	0.2	39
	100.0	15 734

* Approximately 740 ha of littoral zone and 2 560 ha of ponds are included in the 0–5° Class.

Table B2 Erosion and Instability

Erosion		% of Total Area	Area (ha)
Instability			
—well-defined landslips		<0.1	4
—coastal instability		0	0
—general instability		9.7	1 522
Appreciable Erosion	Sheet erosion—minor	6.0	938
	—moderate to severe	4.1	649
	Rill erosion —minor	<0.1	8
	—moderate to severe	2.3	365
	Gully erosion—minor	1.4	214
	—moderate to severe	1.8	277
No Appreciable Erosion*		74.7	11 757
		100.0	15 734

* Approximately 740 ha of littoral zone and 2 560 ha of ponds are included within No Appreciable Erosion.

Table B3 Aspect

Aspect	% of Total Area	Area (ha)
North	6.7	1 053
Northeast	4.4	689
East	3.9	618
Southeast	2.8	438
South	2.6	410
Southwest	3.5	553
West	7.1	1 116
Northwest	8.1	1 281
Flat/Unclassified*	60.9	9 576
	100.0	15 734

* Approximately 740 ha of littoral zone and 2 560 ha of ponds are included in the Flat/Unclassified category.

Table B4 Aspect and Slope Gradient

Aspect	Slope Gradient					Total Area (ha)
	5–15°	15–30°	30–40°	40–60°	>60°	
North	76	165	735	65	12	1 053
Northeast	55	139	440	55	0	689
East	61	145	369	43	0	618
Southeast	51	143	232	10	2	438
South	47	171	192	0	0	410
Southwest	51	210	284	8	0	553
West	114	284	659	47	12	1 116
Northwest	126	310	773	59	13	1 281
0–5° (Flat/Unclassified)						9 576
						15 734

Table B5 Landform

Terrain (Landform)	Slope Gradient	% of Total Area	Area (ha)
Hillcrest		0.4	67
Sideslope	0– 5°	1.7	267
″	5–15°	2.4	384
″	15–30°	8.0	1 259
″	30–40°	21.9	3 448
″	>40°	1.8	276
Cliff/Rock outcrop	0–30°	0	0
″	>30°	<0.1	4
Footslope (colluvium)	0– 5°	7.3	1 151
″	5–15°	0.8	122
″	15–30°	1.6	257
″	30–40°	1.2	194
″	>40°	0	0
Drainage plain (colluvium)	0– 5°	5.3	832
″	5–15°	0.4	65
″	15–30°	0.2	33
″	30–40°	0.1	12
″	>40°	0	0
Floodplain		10.5	1 659
Alluvial plain		10.1	1 591
Littoral zone	0–15°	4.7	740
Cut platforms : insitu	0– 5°	0.5	73
: colluvium	0– 5°	<0.1	2
: alluvium	0– 5°	0	0
Cut slopes : insitu	>5°	0.4	63
: colluvium	>5°	<0.1	4
: alluvium	>5°	0	0
Fill platforms : insitu	0– 5°	<0.1	4
: colluvium	0– 5°	<0.1	8
: alluvium	0– 5°	1.2	184
Fill slopes : insitu	>5°	0.1	17
: colluvium	>5°	<0.1	2
: alluvium	>5°	0	0
General disturbed terrain/platforms : insitu	0– 5°	0	0
: colluvium	0– 5°	<0.1	6
: alluvium	0– 5°	0	0
General distrubed terrain/slope : insitu	>5°	0.1	12
: colluvium	>5°	0	0
: alluvium	>5°	0	0
Reclamation		1.0	151
Natural stream		1.7	265
Man-made channel		0.1	12
Water storage		<0.1	10
Pond		16.3	2 560
		100.0	15 734

Table B6 Geology

Geological Unit	% of Total Area	Area (ha)
Fill	1.5	233
Reclamation	1.0	151
Alluvium: undifferentiated	38.7	6 097
Colluvium: volcanic	9.8	1 538
: granitic	2.3	365
: metasedimentary	2.9	451
: mixed	2.0	318
Littoral deposit	4.7	740
Repulse Bay Formation: sedimentary rocks and water-laid volcaniclastic rocks	0.4	69
: coarse tuff	3.0	469
: dominantly pyroclastic rocks with some lavas	16.3	2 561
Lok Ma Chau Formation	5.1	800
Needle Hill Granite: fine-grained porphyritic phase	1.0	157
: medium-grained porphyritic phase	1.1	170
Cheung Chau Granite	9.1	1 442
Tai Po Granodiorite	1.1	173
	100.0	15 734

Table B7 Vegetation

Vegetation	% of Total Area	Area (ha)
Grassland	18.2	2 856
Cultivation	18.6	2 923
Mixed broadleaf woodland	13.9	2 181
Shrubland (<50%)	3.5	549
Shrubland (>50%)	3.6	569
No vegetation on natural terrain*	6.9	1 093
No vegetation due to disturbance of terrain by man	17.2	2 711
No vegetation due to rock outcrop	<0.1	4
Waterbodies	18.1	2 848
	100.0	15 734

* Approximately 740 ha of littoral zone are included in this class.

Table B8 Geology and GLUM Class

Geological Unit	Area in GLUM Class (ha)				
	I	II	III	IV	Unclassified
Fill	0	206	25	2	0
Reclamation	0	151	0	0	0
Alluvium: undifferentiated	0	3 250	0	0	2 847
Colluvium: volcanic	0	610	765	163	0
: granitic	0	122	241	2	0
: metasedimentary	0	282	169	0	0
: mixed	0	137	175	6	0
Littoral deposits	0	0	0	0	740
Repulse Bay Formation: sedimentary rocks and water-laid volcaniclastic rocks	12	37	16	4	0
: coarse tuff	29	41	175	224	0
: dominantly pyroclastics rocks with some lavas	243	432	1 132	754	0
Lok Ma Chau Formation	261	235	239	65	0
Needle Hill Granite: fine-grained porphyritic phase	20	22	88	27	0
: medium-grained porphyritic phase	0	31	129	10	0
: Cheung Chau Granite	174	267	838	163	0
: Tai Po Granodiorite	22	47	98	6	0
	761	5 870	4 090	1 426	3 587

Table B9 GLUM Class

GLUM Class	% of Total Area	Area (ha)
I	4.8	761
II	26.8	4 211
IIS	10.5	1 659
III	26.0	4 090
IV	9.1	1 426
Unclassified*	22.8	3 587
	100.0	15 734

* Approximately 740 ha of littoral zone and 2 560 ha of ponds are unclassified

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

Slope Gradient	Aspect	Surface* Geology	No Appreciable Erosion (ha)	Appreciable Erosion (ha)			Instability (ha)		Area (ha)	Area Instability Index
				Sheet	Rill	Gully	WDL	GI		
0–5°	Flat	V	88	43	4	0	0	0	135	0
		G	76	35	2	2	0	0	114	0
		S	118	31	0	2	0	0	151	0
		C	1 834	82	2	67	0	0	1 985	0
		A	6 082	14	0	2	0	0	6 104	0
		L	740	0	0	0	0	0	740	0
		F	145	208	0	0	0	0	353	0
5–15°	N	V	18	0	0	0	0	0	18	0
		G	12	0	0	0	0	0	12	0
		S	12	0	0	0	0	0	12	0
		C	25	2	0	2	0	2	31	0.06
		A	0	0	0	0	0	0	0	0
		F	0	2	0	0	0	0	2	0
	NE	V	12	0	2	0	0	0	14	0
		G	14	0	0	2	0	0	16	0
		S	8	0	0	0	0	0	8	0
		C	14	0	0	2	0	0	16	0
		A	0	0	0	0	0	0	0	0
		F	0	0	0	0	0	0	0	0
	E	V	8	0	0	0	0	0	8	0
		G	14	4	0	0	0	0	18	0
		S	10	6	0	0	0	0	16	0
		C	18	0	0	0	0	0	18	0
		A	0	0	0	0	0	0	0	0
		F	0	0	0	0	0	0	0	0
	SE	V	14	4	4	2	0	0	24	0
		G	0	2	0	0	0	0	2	0
		S	12	2	0	0	0	0	14	0
		C	8	0	0	2	0	0	10	0
		A	0	0	0	0	0	0	0	0
		F	0	0	0	0	0	0	0	0
	S	V	8	4	0	0	0	0	12	0
		G	0	0	0	0	0	0	0	0
		S	10	0	0	0	0	0	10	0
		C	16	2	0	6	0	0	24	0
		A	0	0	0	0	0	0	0	0
		F	0	0	0	0	0	0	0	0
	SW	V	6	4	0	0	0	0	10	0
		G	2	4	0	0	0	0	6	0
		S	6	6	0	2	0	0	14	0
		C	16	0	0	4	0	0	20	0
		A	0	0	0	0	0	0	0	0
		F	0	0	0	0	0	0	0	0
	W	V	31	10	0	0	0	0	41	0
		G	12	17	2	4	0	0	35	0
		S	10	4	0	0	0	0	14	0
		C	12	0	0	8	0	2	22	0.09
		A	0	0	0	0	0	0	0	0
		F	0	2	0	0	0	0	2	0
	NW	V	23	2	0	4	0	0	29	0
		G	21	4	2	2	0	0	29	0
		S	25	0	0	0	0	0	25	0
		C	33	2	0	8	0	2	45	0.05
		A	0	0	0	0	0	0	0	0
		F	0	0	0	0	0	0	0	0
15–30°	N	V	39	6	0	0	0	2	47	0.04
		G	20	15	8	6	0	0	49	0
		S	14	0	0	0	0	0	14	0
		C	33	0	0	4	0	18	55	0.33
		F	0	0	0	0	0	0	0	0
	NE	V	39	2	2	2	0	0	45	0
		G	16	14	15	8	0	2	55	0.04
		S	14	2	0	0	0	0	16	0
		C	16	0	0	0	0	6	22	0.27
		F	0	0	0	0	0	0	0	0
	E	V	23	0	2	8	0	4	37	0.11
		G	8	10	10	11	0	0	39	0
		S	33	12	0	0	0	8	53	0.15
		C	12	0	0	2	0	2	16	0.13
		F	0	0	0	0	0	0	0	0
	SE	V	18	15	0	6	0	2	41	0.05
		G	8	22	4	8	0	2	45	0.09
		S	35	6	0	0	0	4	45	0.09
		C	8	0	0	0	0	4	12	0.33
		F	0	0	0	0	0	0	0	0
	S	V	35	43	0	14	0	6	98	0.06
		G	2	4	6	0	0	0	12	0
		S	23	4	0	0	0	0	27	0
		C	6	0	0	0	0	29	35	0.82
		F	0	0	0	0	0	0	0	0
	SW	V	53	25	0	2	0	12	92	0.13
		G	14	6	6	13	0	0	39	0
		S	25	12	0	0	0	2	39	0.05
		C	16	4	0	4	0	17	41	0.40
		F	0	0	0	0	0	0	0	0
	W	V	77	29	0	0	0	6	112	0.05
		G	18	35	19	20	0	2	94	0.02
		S	29	2	0	0	0	2	33	0.06
		C	16	2	0	2	0	17	37	0.44
		F	0	6	2	0	0	0	8	0
	NW	V	72	14	2	4	0	10	102	0.10
		G	24	33	37	16	0	0	110	0
		S	20	0	2	0	0	2	24	0
		C	43	0	0	16	0	12	71	0.17
		F	0	2	0	0	0	0	2	0

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

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

Slope Gradient	Aspect	Surface* Geology	No Appreciable Erosion (ha)	Appreciable Erosion (ha)			Instability (ha)		Area (ha)	Area Instability Index
				Sheet	Rill	Gully	WDL	GI		
30–40°	N	V	154	6	2	2	0	224	338	0.58
		G	47	33	37	16	0	43	222	0.19
		S	29	69	41	22	0	12	43	0.29
		C	18	0	0	0	0	55	73	0.75
		F	2	4	2	0	0	0	8	0
	NE	V	131	2	0	2	0	55	190	0.29
		G	45	55	45	31	0	18	194	0.09
		S	31	0	0	0	0	4	35	0.12
		C	14	0	2	0	0	6	22	0.27
		F	0	0	0	0	0	0	0	0
	E	V	61	29	0	4	0	63	157	0.40
		G	31	53	33	8	0	33	157	0.21
		S	39	4	0	0	0	8	51	0.16
		C	2	2	0	0	0	0	4	0
		F	0	0	0	0	0	0	0	0
	SE	V	31	49	0	14	0	35	129	0.27
		G	10	16	12	6	0	17	61	0.27
		S	27	4	0	0	0	8	39	0.21
		C	0	0	0	0	0	2	2	1.00
		F	2	0	0	0	0	0	2	0
	S	V	69	51	0	8	0	37	165	0.22
		G	2	10	2	0	0	4	18	0.22
		S	6	2	0	0	0	0	8	0
		C	0	0	0	0	0	0	0	0
		F	0	0	0	0	0	0	0	0
	SW	V	80	80	0	6	0	57	223	0.26
		G	10	8	11	6	0	2	37	0.06
		S	6	2	0	2	0	4	14	0.29
		C	0	0	0	0	0	8	8	1.00
		F	2	0	0	0	0	0	2	0
	W	V	139	43	0	14	0	155	351	0.44
		G	45	78	49	47	0	20	237	0.09
		S	27	10	0	0	0	4	0	0.10
		C	6	2	0	0	0	18	26	0.69
		F	0	0	2	0	0	0	2	0
	NW	V	184	12	0	10	0	241	447	0.54
		G	45	77	31	33	0	35	220	0.16
		S	19	2	0	0	0	10	31	0.33
		C	20	0	0	4	4	45	73	0.67
		F	0	2	0	0	0	0	2	0
>40°	N	V	16	4	2	0	0	25	47	0.52
		G	4	15	2	0	0	6	27	0.23
		S	0	0	0	0	0	2	2	1.00
	NE	V	10	2	0	0	0	15	27	0.54
		G	6	8	0	2	0	4	20	0.20
		S	4	0	0	0	0	4	8	0.50
	E	V	8	0	0	0	0	14	22	0.64
		G	4	10	0	0	0	0	14	0
		S	4	0	0	0	0	2	6	0.33
	SE	V	2	0	0	0	0	4	6	0.67
		G	2	2	0	0	0	0	4	0
		S	4	0	0	0	0	0	4	0
	S	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
	SW	V	4	2	0	0	0	2	8	0.25
		G	0	0	0	0	0	0	0	0
		S	0	0	0	0	0	0	0	0
	W	V	17	4	0	0	0	14	35	0.41
		G	0	20	2	0	0	0	22	0
		S	0	2	0	0	0	0	2	0
	NW	V	12	4	2	0	0	23	41	0.55
		G	4	19	2	0	0	6	31	0.33
		S	0	0	0	0	0	0	0	0

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

Table B11 Geology, Erosion and Instability

Geological Unit	No Apprecia-able Erosion (ha)	Appreciable Erosion (ha)			Instability (ha)		Total Area (ha)	Area Instability Index
		Sheet	Rill	Gully	WDL	GI		
Fill	131	96	6	0	0	0	233	0
Reclamation	20	131	0	0	0	0	151	0
Alluvium: undifferentiated	6 081	14	0	2	0	0	6 097	0
Colluvium: volcanic	1 167	35	2	108	4	222	1 538	0.15
: granitic	314	27	2	10	0	12	365	0.03
: meta-sedimentary	412	33	0	4	0	2	451	<0.01
: mixed	296	4	0	10	0	8	318	0.03
Littoral deposits	740	0	0	0	0	0	740	0
Repulse Bay Formation:								
—sedimentary rocks and water-laid volcanic rocks	53	6	2	2	0	6	69	0.09
—coarse tuff	176	58	2	6	0	227	469	0.48
—dominantly pyroclastic rocks with some lavas	1 251	422	19	96	0	773	2 561	0.30
Lok Ma Chau Formation	598	116	2	6	0	78	800	0.10
Needle Hill Granite:								
—fine-grained porphyritic phase	82	18	18	14	0	25	157	0.16
—medium-grained porphyritic phase	2	72	49	37	0	10	170	0.06
Cheung Chau Granite	279	549	269	194	0	151	1 442	0.10
Tai Po Granodiorite	155	6	2	2	0	8	173	0.05
	11 757	1 587	373	491	4	1 522	15 734	0.10

Note: WDL=well-defined landslips
GI=general instability

Table B12 Existing Land Use (From aerial photograph interpretation by the Geotechnical Control Office in 1980)

Existing Land Use	Area (ha)	Existing Land Use	Area (ha)
Government housing estate	12	Cemetery	2
Private development	18	Service reservoir	6
2 Storey development	786	Horticulture	906
1 Storey development	400	Fish Farming	2 538
Temporary resettlement area	6	Duck Farms	20
Intermixed	78	Poultry or pigs	20
Industrial	8	Undefined agriculture	2 014
Commercial/residential	41	Undisturbed areas	3 829
Park	4	Country park	2 844
Sports complex	12	Water storage	10
School	10	Natural stream	265
Hospital	8	Man-made channel	12
Temple	4	Squatters – low intensity	845
Police/fire station	12	Squatters – medium intensity	61
Roads	56	Squatters – high intensity	0
Sewerage works	6	Construction	73
Military (unspecified)	626	Reclamation	18
Quarries – private	35	Temporary land use	69
Quarries – borrow	37	Artificial slope	43
		Total	15 734

Table B13 Existing Land Use and GLUM Class

Existing Land Use	Area in GLUM Class (ha)				
	I	II	III	IV	Unclassified
Government housing estate	4	8	0	0	0
Private development	0	18	0	0	0
2 Storey development	96	616	74	0	0
1 Storey development	37	267	96	0	0
Temporary resettlement area	0	6	0	0	0
Intermixed	4	74	0	0	0
Industrial	0	8	0	0	0
Commercial/residential	0	41	0	0	0
Park	0	4	0	0	0
Sports complex	4	8	0	0	0
School	0	10	0	0	0
Hospital	0	8	0	0	0
Temple	0	4	0	0	0
Police/fire station	2	6	4	0	0
Roads	6	46	4	0	0
Sewerage works	0	6	0	0	0
Military (unspecified)	37	251	312	24	2
Quarries – private	6	0	12	17	0
Quarries – borrow	17	8	4	8	0
Cemetery	0	2	0	0	0
Service reservoir	0	0	6	0	0
Horticulture	69	727	110	0	0
Fish farming	0	0	0	0	2 538
Duck farms	0	0	0	0	20
Poultry or pigs	6	10	4	0	0
Undefined agriculture	59	1 722	233	0	0
Undisturbed areas	243	808	1 489	549	740
Country park	92	343	1 603	806	0
Water storage	0	0	0	0	10
Natural stream	0	0	0	0	265
Man-made channels	0	0	0	0	12
Squatters – low intensity	55	688	100	2	0
Squatters – medium intensity	0	57	4	0	0
Squatters – high intensity	0	0	0	0	0
Construction	0	69	4	0	0
Reclamation	0	18	0	0	0
Temporary land use	24	37	8	0	0
Artificial slopes	0	0	23	20	0
Total	761	5 870	4 090	1 426	3 587

APPENDIX C

SUPPLEMENTARY INFORMATION

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APPENDIX C

SUPPLEMENTARY INFORMATION

C.1 Site Investigation Data

Numerous site investigations have been conducted both onshore and offshore by the public and private sector. 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.

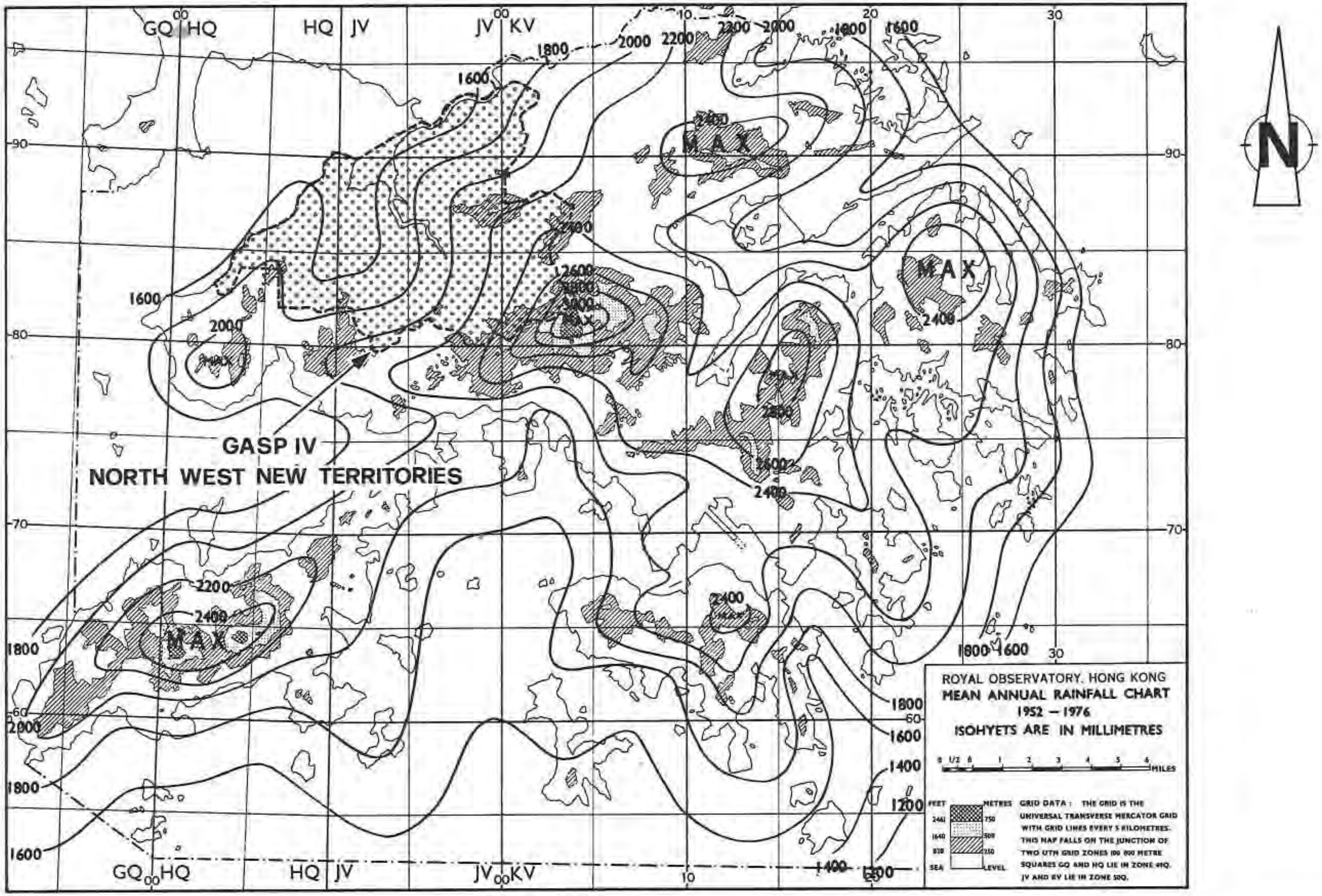
The Geotechnical Control Office GIU report entry and retrieval system is based on a master grid marked on reference sheets. Each grid block is provided with an index card listing all the reports held within that individual grid block.

C.2 Aerial Photographs

The North West 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 Photographic Library of the Survey & Mapping Office, Buildings & Lands Department. An abbreviated list of photographs is presented in Table C1.

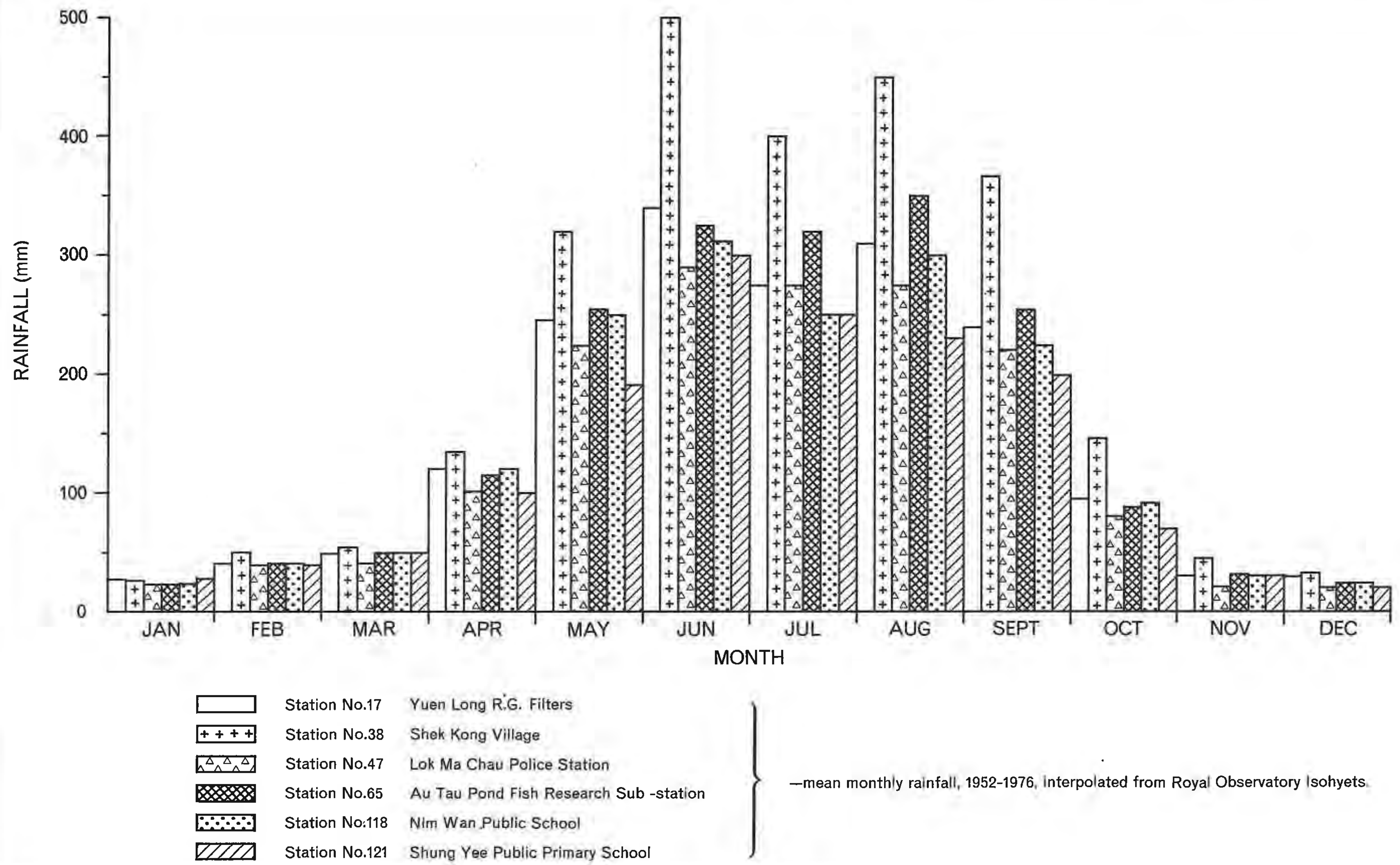
C.3 Rainfall Data Relevant to the North West New Territories Study Area

A general appreciation of the annual and monthly rainfall distributions for the North West New Territories can be obtained from Figures C1 and C2. Figure C1 is a reproduction of the mean annual rainfall isohyets for the years 1952 to 1976, published by the Royal Observatory. Figure C2 is a histogram of monthly rainfall for six selected Royal Observatory rainfall stations. There are a total of 10 rainfall stations within the study area the locations of which are indicated on Figure C3. Detailed monthly and annual rainfall information for these stations is available from the Royal Observatory.



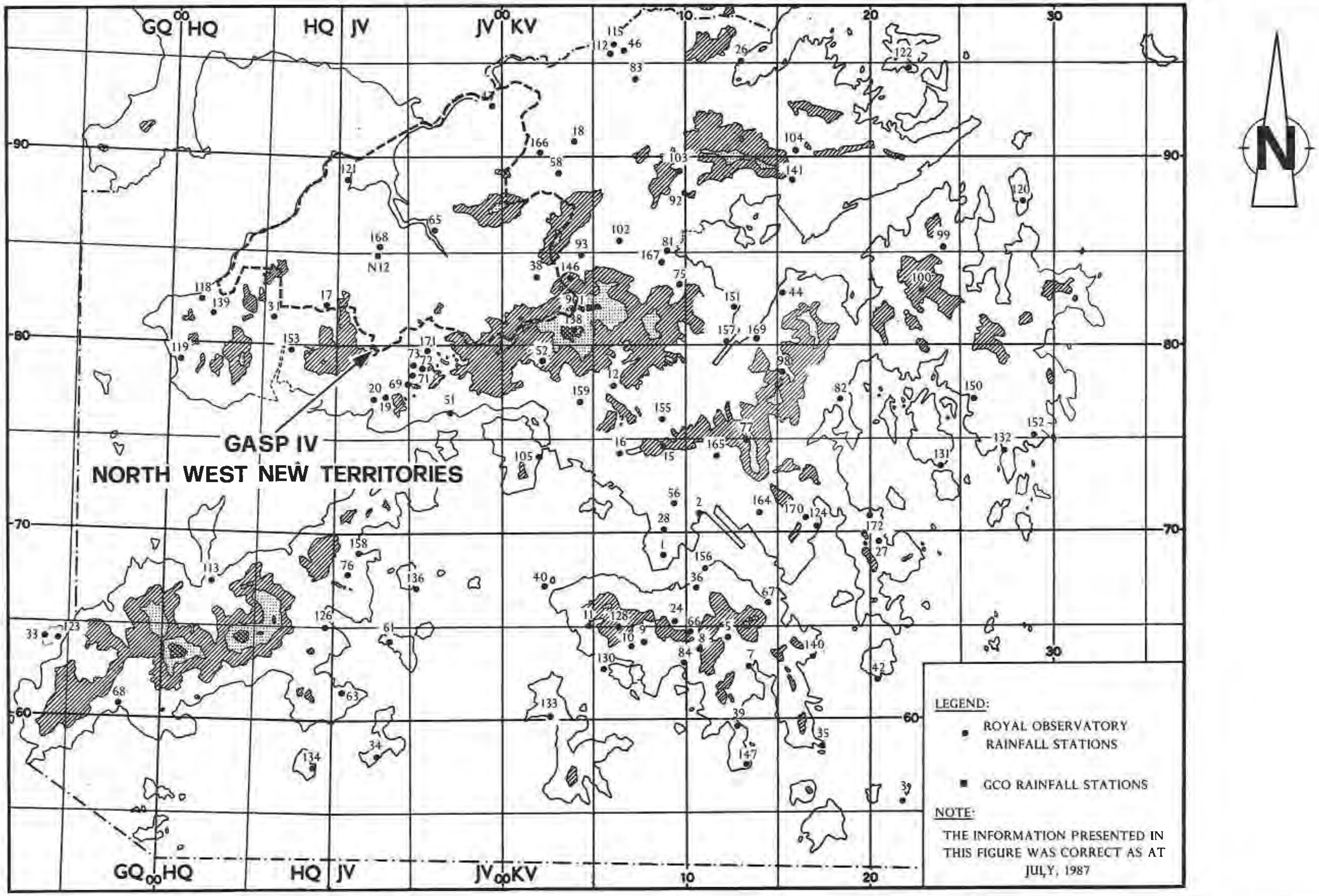
Mean Annual Rainfall Isohyets (1952–1976)

Fig. C1



Mean Annual Rainfall Isohyets (1952–1976)

Fig. C2



Locations of Rainfall Stations

Fig. C3

Table C1 Selection of Aerial Photographs

Year	Photograph Serial Number	Photograph Scale (Approx.)
1979	28440 – 28442	1:20 000
"	28340 – 28348	1:20 000
"	28275 – 28284	1:20 000
"	28240 – 28252	1:20 000
"	28185 – 28198	1:20 000
1978	24492 – 24505	1:20 000
"	24534 – 24557	1:20 000
"	23582 – 23587	1:4 000
"	23195 – 23205	1:4 000
"	10698 – 20706	1:20 000
1977	19818 – 19834	1:8 000
"	17893 – 17920	1:4 000
"	17758 – 17780	1:4 000
"	17607 – 17706	1:4 000
"	17300 – 17337	1:4 000
"	17190 – 17281	1:4 000
1976	16487 – 16500	1:25 000
"	16442 – 16451	1:25 000
"	16427 – 16437	1:25 000
"	16330 – 16335	1:25 000
1945	4109 – 4118 (681/1)	1:12 000
"	4145 – 4158 (681/5)	1:12 000
"	3020 – 3033 (681/6)	1:12 000
"	4025 – 4037 (681/6)	1:12 000
"	4059 – 4075 (681/6)	1:12 000
"	3055 – 3069 (681/6)	1:12 000
"	3122 – 3133 (681/6)	1:12 000
"	4131 – 4140 (681/6)	1:12 000
"	4146 – 4149 (681/6)	1:12 000
1924	2 – 16 (H19)	1:14 000
"	10 – 19 (H25)	1:14 000
"	14 – 16 (H12)	1:14 000
"	27 – 35 (H26)	1:14 000
1975	11919 – 11939	1:25 000
"	11739 – 11728	1:25 000
1964	RUN 5: 2625 – 2638	1:25 000
"	RUN 4: 2700 – 2710	1:25 000
"	RUN 3: 2798 – 2790	1:25 000
"	RUN 1: 2800 – 2807	1:25 000
1954	81A/552 51 – 64	1:25 000
"	81A/552 23 – 34	1:25 000
"	81A/550 106 – 120	1:25 000
"	81A/550 70 – 85	1:25 000
"	81A/550 46– 55	1:25 000
1949	81A/136 6001 – 6138	1:4 800
"	81A/125 6001 – 6032	1:4 800
"	81A/124 6001 – 6048	1:4 800
"	81A/122 6033 – 6197	1:4 800
1945	4001 – 4020 (681/5)	1:12 000
"	4215 – 4285 (681/4)	1:12 000
"	4132 – 4145 (681/4)	1:12 000
"	4090 – 4098 (681/4)	1:12 000
"	3174 – 3191 (681/4)	1:12 000
"	3102 – 3116 (681/4)	1:12 000
"	3073 – 3084 (681/4)	1:12 000

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

APPENDIX D

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

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APPENDIX D

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

D.1 Introduction

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

D.2 Rock Mass Characteristics

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

The portion of Figure D1 devoted to Rock Mass Characteristics, and reproduced in Figure D2, shows in sequence the factors which contribute to rock properties and which, through mass strength and structure, permeability and chemical stability, contribute to the control of landforming processes and engineering performance. The succeeding sections explain in general terms how the variations in rock mass characteristics arise. They are not intended to be thorough from the geological point of view. Geological descriptions of the particular rock types are given in Section 2.3. 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 CHARA – CTERISTICS AND PROCESSES WHICH INFLUENCE LAND USE POTENTIAL , AND THEIR EVALUATION WITHIN THE GAS PROGRAMME.

NATURAL LANDFORMING INFLUENCES :
SUBSURFACE & SURFACE VARIABLES.

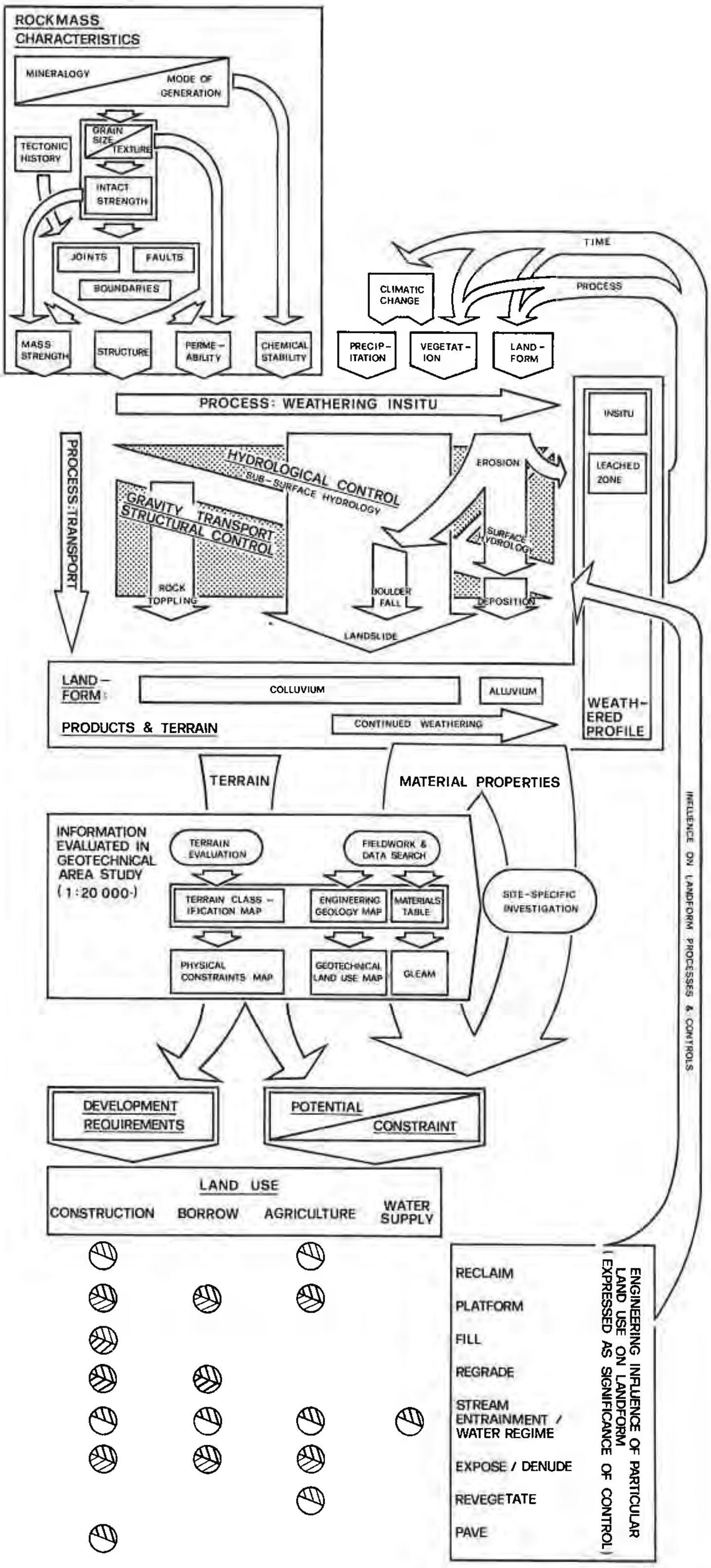
LANDFORMING PROCESSES :
RELATIVE INFLUENCE OF HYDROLOGY, STRUCTURE & WEATHERING ON TYPES OF TRANSPORT PROCESS. (BACKGROUND TRIANGLES SHOW PROPORTION OF INFLUENCE OF CONTROL).

LANDFORM :
INDICATED AS PRODUCTS OF VARIOUS LANDFORMING PROCESSES.

GEOTECHNICAL AREA STUDIES :
CLASSIFICATION OF TERRAIN & ENGINEERING MATERIALS, INTERPRETATION OF LANDFORM IN TERMS OF GEOTECHNICAL POTENTIAL & CONSTRAINT FOR STRATEGIC PLANNING & ENGINEERING 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



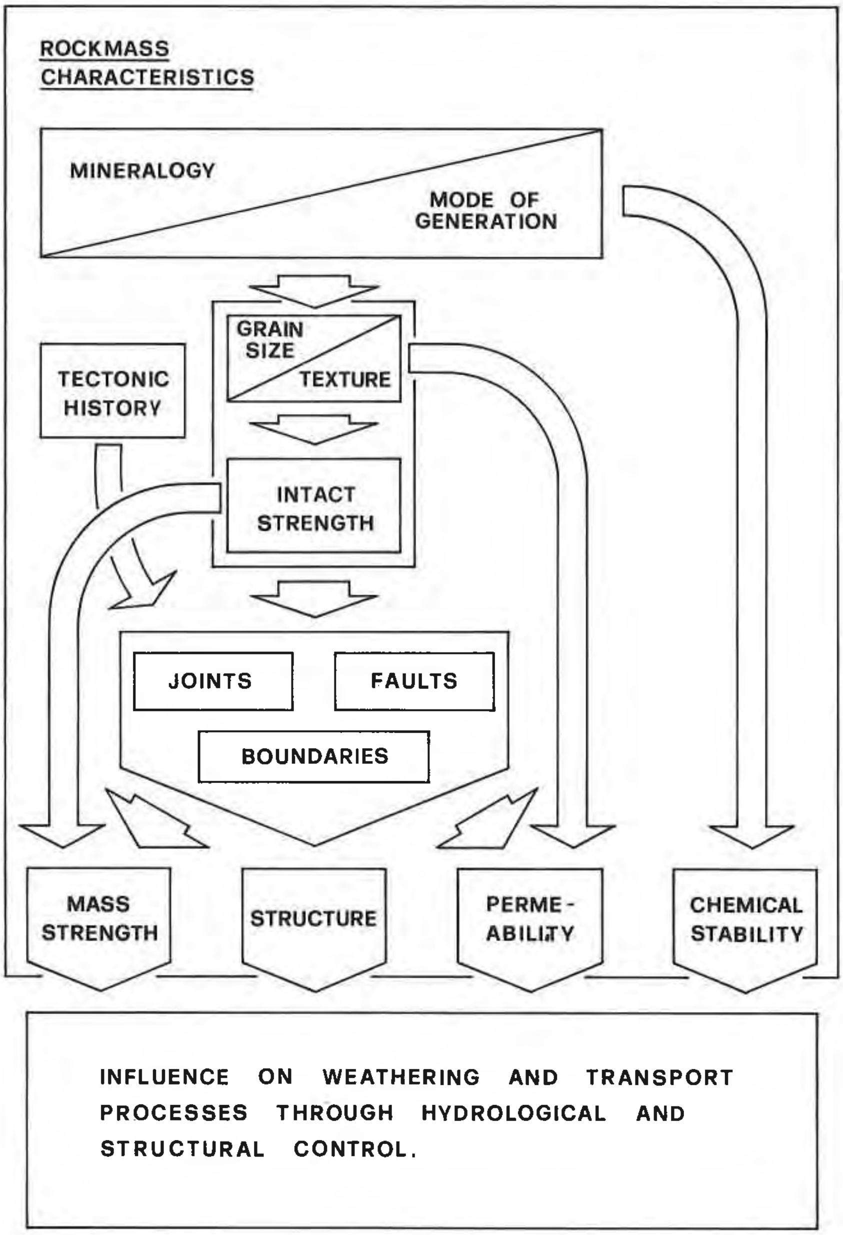
LEGEND :

BOXES INDICATE : CAUSE OR PRODUCT

ARROWS INDICATE : INFLUENCE, PROCESS, OR MECHANISM

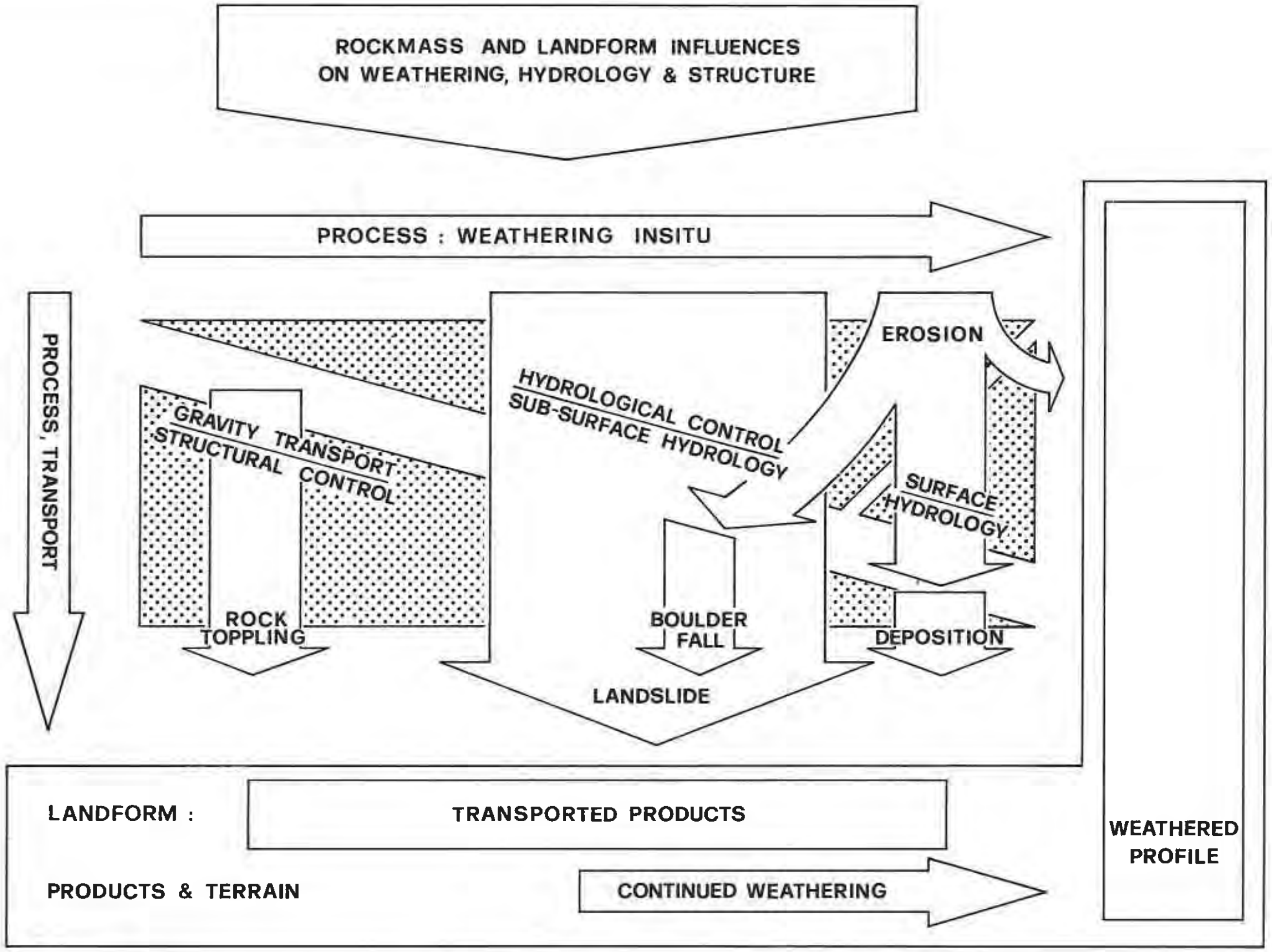
CIRCLES INDICATE : HUMAN INVOLVEMENT

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 this 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. Large areas of fill are associated with developments which occur on the floodplain and fish ponds.

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

(i) *Cut and Fill Platforms on Steep Terrain*
This technique is used in the Territory to provide level platforms on otherwise steep terrain. A typical example is associated with development on the slopes below Kadoorie Farm, where numerous cut slopes, platforms, and or fill slopes mask the natural slope profile.

Since the disastrous fill slope failures at Sau Mau Ping in 1972 and 1976, (Government of Hong Kong, 1972a & 1977) fill has been recognized as a potentially hazardous engineering material. Consequently, recent fill platforms and slopes are designed and constructed to stringent requirements. Common problems in older fills on steep terrain are due to the fact that many were 'end tipped'. This results in:

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

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

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

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

(ii) *Fill on Low-lying Terrain*
The Yuen Long District formerly consisted of a few isolated hills separated by alluvial areas. Some of these have been drained or raised to prevent flooding. Few engineering problems are envisaged in these areas, with the exception of settlement. Large buildings are generally piled. Deep excavations may experience difficulties due to high groundwater tables in underlying alluvium.

(iii) *Land Reclaimed from the Sea*
Many 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.

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. Many photo lineaments are major features which are continuous across the study area.

(ii) *Slickensiding*

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

(iii) *Changes in Rock Mass Structure and Properties*

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

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

Regular patterns of lineaments are evidence of the regional pattern of structure present at smaller scale. Engineering works in the area may experience instability problems on cut slopes at particular orientations. In areas of active coastal erosion, the local rock structure is often apparent from the pattern of erosion and instability.

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

(iv) *Preferential Groundwater Flow*

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

(v) *Seismic Influence*

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

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

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

D.3.5 *Colluvial Deposits*

Colluvium is a transported material, whose nature and engineering characteristics depend on the origin of the material, the conditions of its deposition and its subsequent history. Various types of colluvium exist within the study area, and their location, nature and material properties are discussed in Sections 2.3, 2.4 and 3.1.2. The extent of colluvium as identified by terrain classification is shown on the Engineering Geology Map.

Colluvium need not necessarily be regarded as a constraint for engineering. Relict colluvium in a completely weathered state may be strengthened by over-consolidation 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 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 usually require the use of hand dug caissons. As discussed for boulder colluvium in Section 3.1.2, measures should be taken to avoid any adverse influence on the groundwater regime.

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

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

Particular attention should be paid to material boundaries, voids and seepage zones. These may render modelled design conditions doubtful. Many of the cuts in colluvium in 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 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. (see Section 3.1.3).

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 may indicate a degree of control of the landforms being exerted by the underlying geological structure. 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 granitic terrain. Large structures founded in this terrain will generally require caisson foundations to bedrock. If large flat site formations are to be created in steep granitic terrain, major cuttings and retaining structures should be provided through a range of weathered rock. The only advantage of this is that shallower caissons can be used, and that extensive flat areas can be created.

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

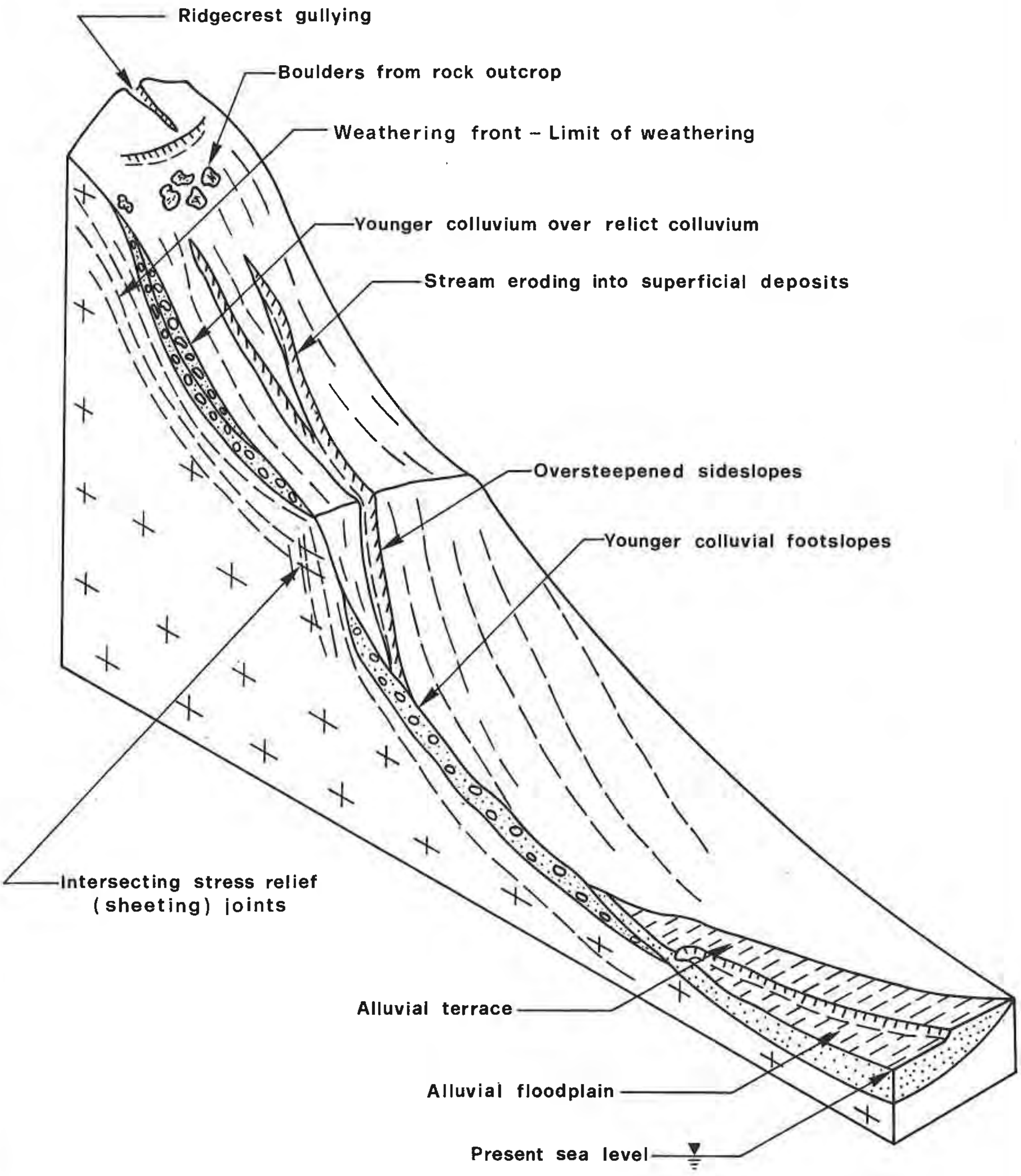
(iii) *Colluvial Terrain*
The creation of extensive cuts in colluvium should be avoided. Aspects of this material affecting stability are noted in Section 3.1.2. Colluvium overlies the insitu rocks to some extent in many of the areas suitable for development outlined in this Report. Colluvium has been 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.



Hillslope Model	Fig. D4

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 GLUM, EGM and PCM. Only in determining the engineering feasibility of a large uninvestigated area should a preliminary site investigation be based only on a 1:20 000 GASP Report.

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

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

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

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

D.4 Landform Model of the Terrain in Hong Kong

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

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

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

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.

ALLUVIUM

Sediment transported and deposited by a river or stream.

ALLUVIAL FAN

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

AQUIFER

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

AREA INSTABILITY INDEX

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

ASPECT

Direction in which a slope faces.

BATHOLITH

Large intrusive igneous rockmass.

BEDROCK (=SOLID GEOLOGY)

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

BLOCKS

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

BOMBS

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

BRECCIA

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

CATCHMENT AREA

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

CHLORITISATION

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

CHUNAM

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

COASTAL PLAIN

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

COLLUVIUM

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

COUNTRY ROCK (=HOST ROCK)

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

CUT SLOPE AND CUT PLATFORM

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

DETRITAL

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

DIP (or TRUE DIP)

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

DIP DIRECTION

Direction or azimuth of dip.

DISCONTINUITY

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

DISTURBED TERRAIN

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

DRAINAGE PLAIN

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

DURICRUST (=HARD PAN)

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

DYKE

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

EPHEMERAL STREAM

Stream which only flows for short periods of the year.

EROSION

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

FABRIC

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

FAULT

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

FAULT BRECCIA

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

FILL SLOPE AND FILL PLATFORM

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

FLOODPLAIN

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

FOOTSLOPE

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

GENERAL INSTABILITY

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

GEOTECHNICAL AREA STUDIES PROGRAMME (GASP)

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

GEOTECHNICAL LAND USE MAP (GLUM)

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

GULLY EROSION

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

HILLCREST

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

HYDROGRAPH

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

IGNIMBRITES

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

INCISED DRAINAGE CHANNEL

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

INDURATION

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

INSITU MATERIAL

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

INTRUSION

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

LAND CAPABILITY

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

LANDFORM

General shape and characteristic morphology of the land surface.

LANDSLIP (=LANDSLIDE)

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

LAPILLI

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

LENTICULAR COLLUVIUM

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

LITHOLOGY

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

LITHOSTRATIGRAPHY

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

LITHOTYPE

Rock defined on the basis of certain selected physical characteristics.

LITTORAL ZONE

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

MANTLE

Weathered rock material overlying fresh rock.

MASS WASTING

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

MATRIX

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

MAXIMUM DRY DENSITY

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

NATURAL SLOPE

Area of sloping ground substantially unaltered by man.

OUTCROP

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

PEGMATITE

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

PERENNIAL STREAM

Stream that flows throughout the year.

PHYSICAL LAND RESOURCES

Physical characteristics of land.

POLYCYCLIC

Many cycles of development.

PYROCLASTIC ROCK

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

RECLAMATION

Area of land reclaimed from the sea or other waterbody.

RELICT

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

RESIDUAL SOIL

Soil resulting from the weathering of rock insitu.

RILL EROSION

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

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

Discrete area of rock exposed at surface.

ROOF PENDANT

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

SCREE (=TALUS)

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

SESQUIOXIDES

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

SHEET EROSION

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

SHEETING JOINT

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

SIDESLOPE

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

STRIKE

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

STRUCTURE

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

TECTONIC

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

TERRAIN ATTRIBUTE

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

TERRAIN CLASSIFICATION

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

TERRAIN COMPONENT

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

TERRAIN EVALUATION

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

TEXTURE

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

TOR

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

TUFF

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

VOLCANICLASTIC

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

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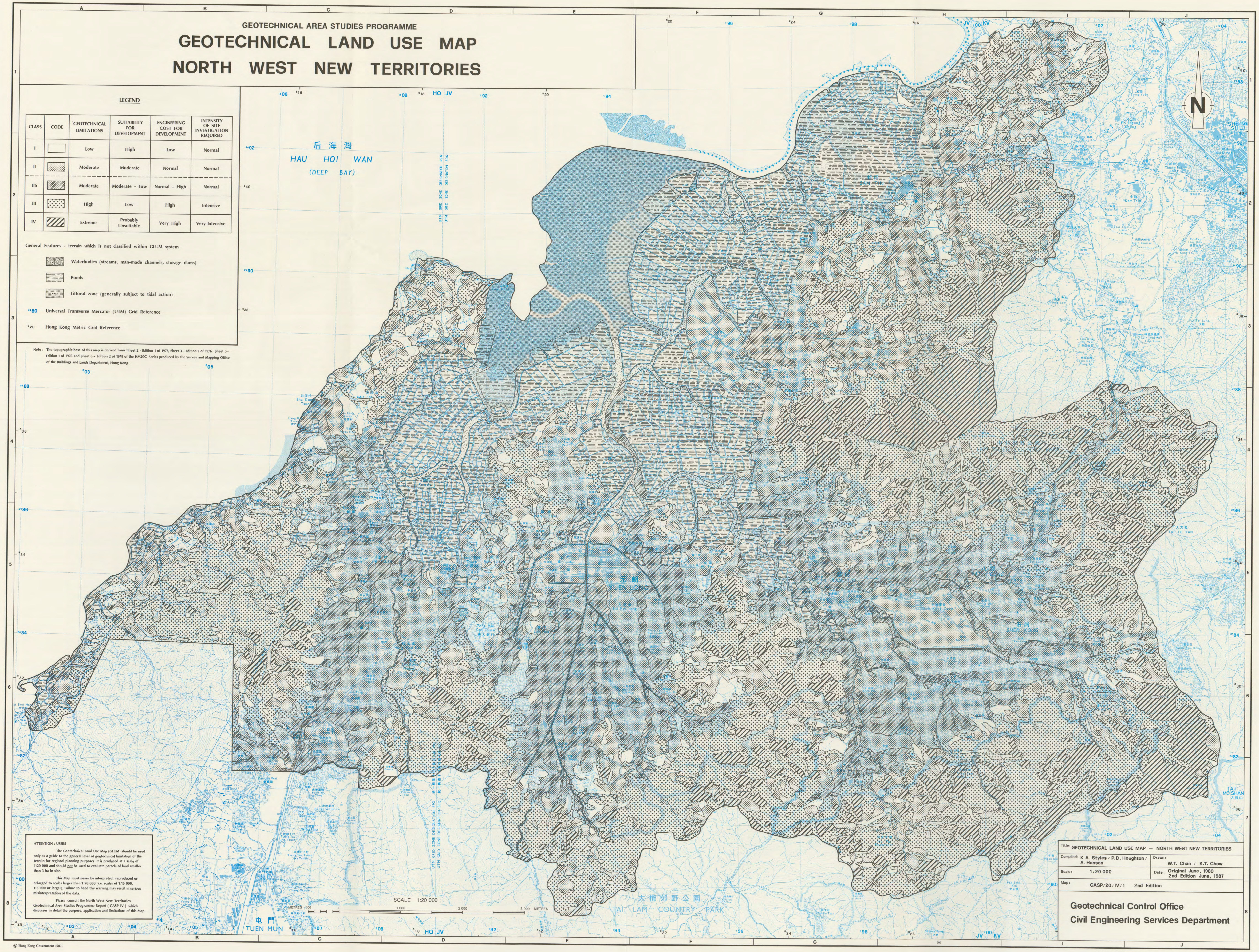
GEOTECHNICAL AREA STUDIES PROGRAMME

GEOTECHNICAL LAND USE MAP
NORTH WEST NEW TERRITORIES



LEGEND

CLASS	CODE	GEOTECHNICAL LIMITATIONS	SUITABILITY FOR DEVELOPMENT	ENGINEERING COST FOR DEVELOPMENT	INTENSITY OF SITE INVESTIGATION REQUIRED
I		Low	High	Low	Normal
II		Moderate	Moderate	Normal	Normal
IIS		Moderate	Moderate - Low	Normal - High	Normal
III		High	Low	High	Intensive
IV		Extreme	Probably Unsuitable	Very High	Very Intensive

General Features - terrain which is not classified within GLUM system

Waterbodies (streams, man-made channels, storage dams)

Ponds

Littoral zone (generally subject to tidal action)

24 80 Universal Transverse Mercator (UTM) Grid Reference

8 20 Hong Kong Metric Grid Reference

Note : The topographic base of this map is derived from Sheet 2 - Edition 1 of 1976, Sheet 3 - Edition 1 of 1976, Sheet 5 - Edition 1 of 1976 and Sheet 6 - Edition 2 of 1979 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 West New Territories Geotechnical Area Studies Programme Report (GASP IV) which discusses in detail the purpose, application and limitations of this Map.

Title: GEOTECHNICAL LAND USE MAP — NORTH WEST NEW TERRITORIES	
Compiled: K.A. Styles / P.D. Houghton / A. Hansen	Drawn: W.T. Chan / K.T. Chow
Scale: 1:20 000	Date: Original June, 1980 2nd Edition June, 1987
Map: GASP/20/IV/1 2nd Edition	

Geotechnical Control Office
Civil Engineering Services Department

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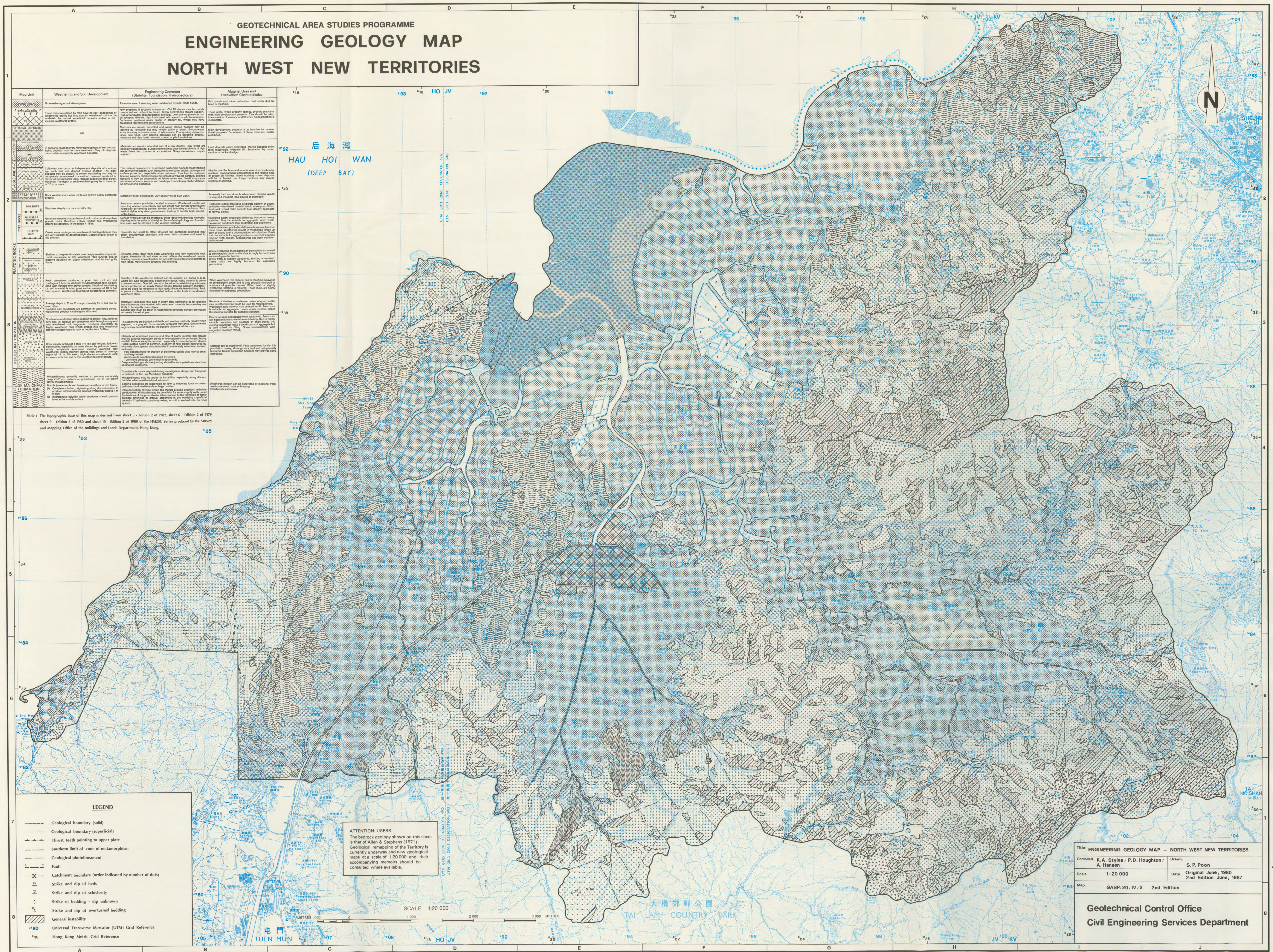
GEOTECHNICAL AREA STUDIES PROGRAMME

ENGINEERING GEOLOGY MAP
NORTH WEST NEW TERRITORIES

Map Unit	Weathering and Soil Development	Engineering Comment (Stability, Foundation, Hydrogeology)	Material Uses and Excavation Characteristics
POND AREAS	No weathering or soil development	Extensive area of standing water subdivided by man-made bunds.	Fish ponds and minor cultivation. Soil easily dug by hand or machine.
RECLAMATION / FILL	These materials placed by man have no soil (pedogenic) or weathering profile but may contain weathered rocks or be underlain by natural superficial deposits and/or a pre-existing weathered profile.	Few problems if properly compacted. Old fill slopes may be poorly compacted and subject to failure. Steep excavations require support. High groundwater requires special drainage. Low bearing pressures can be accepted directly, high loads need raft, spread or pile foundations. Settlement problems minor except in sanitary fill, which may have associated leachate and gas problems.	These areas, when properly formed, provide platforms with high development potential. Care should be taken in excavation of sanitary landfill when biodegradation is incomplete.
LITTORAL DEPOSITS	Nil	Materials are usually saturated and saline. Raised beaches may be leached by rainwater but may remain saline at depth. Groundwater extraction may induce incursion of saline water. Poor grading characteristics—low fines. Low bearing pressures can be accepted directly, moderate and high loads need raft, spread or pile foundations.	Main development potential is as beaches for recreational purposes. Excavation of these materials usually prohibited.
ALLUVIAL DEPOSITS: UNDIFFERENTIATED INCLUDING FLOODPLAIN; RAISED TERRACES	In subaerial locations very minor development of soil horizon. Relict deposits may be more weathered. Very old deposits may contain completely weathered boulders.	Materials are usually saturated and of a low density—clay layers are normally consolidated. Buried channels may pose local problems of high water flows into tunnels or excavations. Steep excavations require support.	Land deposits easily excavated. Marine deposits often form reasonable hydraulic fill. Excavation by cutter, suction or bucket dredger.
COLLUVIUM: VOLCANIC DERIVED; GRANITIC DERIVED; MIXED; METASEDIMENT DERIVED	Colluvium can occur as independent deposits of a unique age such that one deposit overlies another. The older deposits may be subject to severe weathering and may be completely decomposed to a mottled, coloured sandy silt or clayey silt similar to the insitu residual deposits of their parent materials. The depth of such weathering may be in the order of 10 m or more.	This material has moved in its geologic past and is prone to reactivation if not carefully treated by such measures as low batter angles, drainage and surface protection, especially when saturated. Has low to moderate bearing capacity characteristics but should always be carefully drained because it may be susceptible to failure when wet. Voids may cause settlement of roads, services and buildings. Tunnelling probably difficult. SI difficult and expensive.	May be used for borrow due to its ease of excavation by machine, broad grading characteristics and relative ease of access on hillsides. Some bouldary stream deposits will be of limited use. Large boulders may require blasting or splitting.
KAT O FORMATION	Rock weathers to a weak red to red-brown poorly cemented breccia.	Extremely minor distribution; very unlikely to be built upon.	Extremely hard and durable when fresh; blasting would be required. Possible local source of aggregate.
PLUTONIC ROCKS – DYKE ROCKS: DOLERITE D	Weathers deeply to a dark red silty clay.	Restricted extent precludes detailed comment. Weathered mantle will have low relative permeability and will affect near-surface groundwater hydrology by forming barriers, divides and boundary conditions. Sub-vertical dykes may dam groundwater leading to locally high ground-water levels.	Restricted extent precludes deliberate borrow or quarry activities—weathered material would make poor fill but fresh rock would make suitable high density aggregate or railway ballast.
PLUTONIC ROCKS – DYKE ROCKS: FELDSPAR PORPHYRY La	Generally weathers faster than volcanic rocks but slower than granitic rocks. Develops a thick reddish soil. Weathering depths are generally in the range 7–15 m.	Surface hydrology can be affected by these rocks with drainage networks aligning with the strike of the dykes. Subsurface hydrology and foundation levels will be affected by the variable rockhead.	Restricted extent precludes deliberate borrow or quarry activities. May be suitable as aggregate when fresh. Excavation conditions may be difficult and expensive.
PLUTONIC ROCKS – DYKE ROCKS: QUARTZ VEIN q	Quartz veins undergo only machanical disintegration as they are very resistant to decomposition. Coarse angular gravel is the product.	Generally too small to affect structure but contained sulphides may affect groundwater chemistry and react with concrete and steel in foundation.	Restricted extent precludes deliberate borrow activity for these rocks. Weathering results in mechanical break up only of quartz and a decomposition of sulphides. Fresh rock not suitable for aggregate due to potential sulphide reaction with cement. Molybdenite has been commercially mined.
PLUTONIC ROCKS – NEEDLE HILL GRANITE: FINE-GRAINED PORPHYRITIC PHASE; MEDIUM-GRAINED NHm PORPHYRITIC PHASE	Shallow to deep residual soils over deeply weathered granite. Local occurrence of less weathered rock outcrop and/or massive boulders on upper sideslopes and incised gully floors.	Unstable areas result from deep weathering and joint controlled rock slopes. Extensive rill and sheet erosion affects the weathered mantle. Bearing capacity characteristics are generally favourable for moderate to high loads. Materials are generally free draining.	When weathered, the material can be machine excavated to considerable depth and is thus strongly favoured as a source of granular borrow. When fresh or slightly weathered, blasting is required. These rocks are highly favoured for aggregate production.
PLUTONIC ROCKS: CHEUNG CHAU GRANITE; SUNG KONG GRANITE	Rock sometimes produces a poor, thin (<1 m) soil (pedogenic) horizon. At depth the decomposed rock is a silty sand with variable fine gravel content. Depth of weathering i.e. soft material, is often great and an average of 18 m has been quoted. Weathering to produce corestones is common.	Stability of the weathered material can be suspect, i.e. Zones A & B, where soil type failures may occasionally occur. Insitu material is prone to severe erosion. Special care must be taken in establishing adequate surface protection on newly formed slopes. Bearing capacity characteristics are good for moderate to high loads. Generally free draining. Rock is prone to discontinuity controlled failure in the fresh to moderately weathered state.	When weathered, the material can be machine excavated to considerable depth and is thus strongly favoured as a source of granular borrow. When fresh or slightly weathered, blasting is required. These rocks are highly favoured for aggregate production.
PLUTONIC ROCKS: TAI PO GRANODIORITE	Average depth to Zone C is approximately 15 m but can be over 40 m. Boulders and corestones are common in weathered zones. Weathering product is subangular silty sand.	Relatively unknown rock type in study area, comments as for granites but a little more care required with weathered materials because they are likely to be 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.
REPULSE BAY FORMATION: SEDIMENTARY AND WATER-LAID VOLCANICLASTIC ROCKS	Shallow to moderately deep, reddish to brown, fine, sandy to silty clay, i.e. residual soil sometimes with ferruginous gravel and weathered rock fragments, overlying completely to highly weathered rock which grades into less weathered strongly jointed volcanic rock at depths from 5–20 m.	The sediments are bedded and fissile and weather relatively rapidly when exposed, to a grey silt. Some stability problems may arise. Groundwater regime may be controlled by the bedded character of the rock.	Can be scraped and ripped when weathered. Fresh rock will need pneumatic machines or blasting. Due to highly variable properties and presence of chert bands this material would not make a good source of aggregate but is well suited for filling. Scarn mineralisation with magnetite has been mined.
REPULSE BAY FORMATION: COARSE TUFF; DOMINANTLY PYROCLASTIC ROCKS	Rock usually produces a thin (<1 m) soil horizon, followed downwards, especially on lower slopes, by yellowish brown sandy completely weathered material overlying less weathered, locally strongly jointed rock below an average depth of 11 m. On steep, high slopes considerable rock exposure with thin soil or thin weathering cover occurs.	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.	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.
LOK MA CHAU FORMATION	Metasediments generally weather to produce moderately deep (1–2 m), uniform or gradational, red to red-brown clayey metasediments. Marble (metamorphosed limestone) weathers in two forms: (i) Complete solution, originating along discontinuities, to produce interconnecting cavities which may exceed 1 m in size; (i) Intergranular solution which produces a weak granular layer at the marble surface.	Considerable care is required during investigation, design and formation in materials of the Lok Ma Chau Formation. Metasediments may be prone to instability, especially along discontinuities when weathered and saturated. Bearing capacities are reasonable for low to moderate loads on metasediments and marble without large cavities. Interconnecting cavities within the marble provide excellent hydraulic conductivity. Whilst this may be beneficial for water supply wells, rapid fluctuations of the groundwater table can lead to the formation of either collapse sinkholes or gradual settlement in the overlying superficial deposits if hydraulic continuity exists, as soil is washed into the void system.	Weathered horizon can be excavated by machine; fresh needs pneumatic tools or blasting. Possible use as borrow.

Note : The topographic base of this map is derived from sheet 5 - Edition 2 of 1982, sheet 6 - Edition 2 of 1979, sheet 9 - Edition 2 of 1980 and sheet 10 - Edition 2 of 1980 of the HM20C Series produced by the Survey and Mapping Office of the Buildings and Lands Department, Hong Kong.



LEGEND

- Geological boundary (solid)
- Geological boundary (superficial)
- Thrust, teeth pointing to upper plate
- Southern limit of zone of metamorphism
- Geological photolineament
- Fault
- Catchment boundary (order indicated by number of dots)
- Strike and dip of beds
- Strike and dip of schistosity
- Strike of bedding - dip unknown
- Strike and dip of overturned bedding
- General instability
- Universal Transverse Mercator (UTM) Grid Reference
- Hong Kong Metric Grid Reference

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.

Title:	ENGINEERING GEOLOGY MAP – NORTH WEST NEW TERRITORIES
Compiled:	K.A. Styles / P.D. Houghton / A. Hansen
Drawn:	S. P. Poon
Scale:	1:20 000
Date:	Original June, 1980 2nd Edition June, 1987
Map:	GASP/20/IV/2 2nd Edition

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Civil Engineering Services Department

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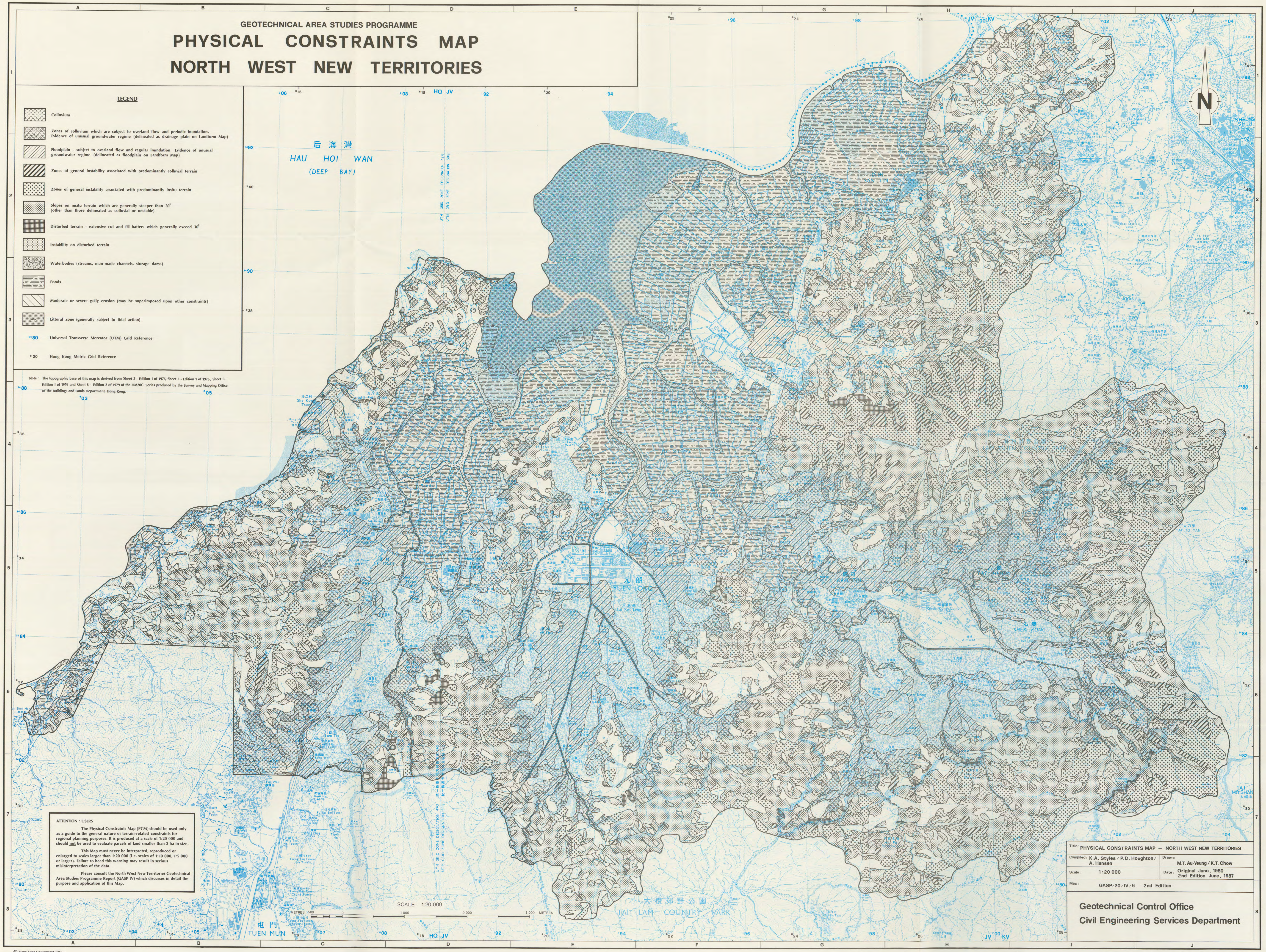
GEOTECHNICAL AREA STUDIES PROGRAMME

PHYSICAL CONSTRAINTS MAP
NORTH WEST NEW TERRITORIES



LEGEND

- Colluvium
- Zones of colluvium which are subject to overland flow and periodic inundation. Evidence of unusual groundwater regime (delineated as drainage plain on Landform Map)
- Floodplain - subject to overland flow and regular inundation. Evidence of unusual groundwater regime (delineated as floodplain on Landform Map)
- Zones of general instability associated with predominantly colluvial terrain
- Zones of general instability associated with predominantly insitu terrain
- Slopes on insitu terrain which are generally steeper than 30° (other than those delineated as colluvial or unstable)
- Disturbed terrain - extensive cut and fill batters which generally exceed 30°
- Instability on disturbed terrain
- Waterbodies (streams, man-made channels, storage dams)
- Ponds
- Moderate or severe gully erosion (may be superimposed upon other constraints)
- Littoral zone (generally subject to tidal action)
- 24 80 Universal Transverse Mercator (UTM) Grid Reference
- 8 20 Hong Kong Metric Grid Reference

Note : The topographic base of this map is derived from Sheet 2 - Edition 1 of 1976, Sheet 3 - Edition 1 of 1976, Sheet 5 - Edition 1 of 1976 and Sheet 6 - Edition 2 of 1979 of the HM20C Series produced by the Survey and Mapping Office of the Buildings and Lands Department, Hong Kong.

ATTENTION : USERS

The Physical Constraints Map (PCM) should be used only as a guide to the general nature of terrain-related constraints for regional planning purposes. It is produced at a scale of 1:20 000 and should not be used to evaluate parcels of land smaller than 3 ha in size.

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Please consult the North West New Territories Geotechnical Area Studies Programme Report (GASP IV) which discusses in detail the purpose and application of this Map.

Title: PHYSICAL CONSTRAINTS MAP — NORTH WEST NEW TERRITORIES	
Compiled: K.A. Styles / P.D. Houghton / A. Hansen	Drawn: M.T. Au-Yeung / K.T. Chow
Scale: 1:20 000	Date: Original June, 1980 2nd Edition June, 1987
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