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Geological terrain mapping in Cameron Highlands district, Pahang

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Abstract: In the process of planning the landuse of an area, town planners require basic information such as the geology, topography, landform and zones which are potentially unstable. Terrain Classification Map and its derivative thematic maps such as Landform, Erosion, Physical Constraints, Engineering Geology and Construction Suitability Maps serve as useful tools for such a purpose.

Geological terrain mapping is carried out based on the evaluation of four attributes, namely, slope gradient attribute, terrain or morphology attribute, activity attribute and the erosion and instability attribute. To prepare the various derivative maps, a GIS system (using Arc Info or Arc View software) is used to analyse data from the four attributes.

Geological terrain mapping was conducted in the Cameron Highlands and the various derivative maps produced from the mapping programme are used in the planning and approval of development projects in the area.

Abstrak: Dalam proses perancangan gunatanah bagi sesuatu kawasan, perancang bandar memerlukan maklumat asas seperti geologi, topografi, bentuk muka bumi and zon-zon yang tidak stabil. Peta pengelasan terain and peta-peta tematik seperti bentuk muka bumi, hakisan, kekangan fizikal, geologi kejuruteraan dan kesesuaian pembangunan dapat berfungsi sebagai alat untuk mencapai tujuan berkenaan.

Pemetaan geologi terain yang dijalankan adalah berasaskan kepada penilaian empat atribut iaitu kecerunan cerun, terain atau morfologi, aktiviti yang dijalankan serta hakisan dan ketidakstabilan cerun. Untuk menyediakan berbagai peta tematik, sistem GIS (menggunakan perisian 'Arc Info' atau 'Arc View') digunakan untuk menganalisa data dari keempat-empat atribut tersebut.

Pemetaan geologi terain telah dilakukan di Cameron Highlands dan berbagai peta tematik yang telah dihasilkan dari program pemetaan ini sedang digunakan dalam perancangan dan kelulusan projek-projek pembangunan di kawasan berkenaan.

INTRODUCTION

Landslide hazard assessment was carried out in Malaysia for various purposes. Jasmi and Zainal (2002) carried out macro-scale landslide assessment for the state of Selangor and Penang Island. However, macro-scale landslide hazard maps only provide general information which may have some limitation for local landuse planning. Cook *et al.* (1995) developed a method of landslide hazard assessment along the East West Highway. The method requires a comprehensive site investigation at micro-scale taking into consideration, geological and geotechnical factors which contribute to slope failure. This method is used in the identification of a portion of a cut and fill slope which requires further assessment and mitigation measures.

Since 1996, the Geological Survey of Malaysia had carried out meso-scale terrain mapping in the Klang Valley and Penang Island based on the method developed by the Hong Kong Geotechnical Control Office (GCO, 1984). Subsequently, the procedure was reviewed and adopted to suit current rules and regulations relating to the development and control of highland areas in Malaysia (Chow and Zakaria, 2002). This paper describes meso-scale geological terrain mapping carried out in the Cameron Highlands.

GEOLOGY OF CAMERON HIGHLANDS

Cameron Highlands is located on the eastern side of the Main Range. The site is a premier agriculture and mountain holiday resort area. It owes its present standing to its location at a high altitude (generally between 800 m to 1,603 m above the mean sea level) and inevitably much of the terrain is steep though there are certain parts which are relatively gentle in relief. The climate of the area is of an equatorial type, which is influenced by monsoon air streams. The lowest monthly average rainfall is 93.5 mm, while the lowest annual average rainfall is not less than 2,000 mm. The relative humidity is between 70% and 90% and the mean temperature is about 18°C.

Geologically, the main range is composed of granite with scattered outliers (roof pendants) of Lower Palaeozoic schists of mainly Ordovician to Silurian Age. This portion of granite pluton had been classified as that of an undifferentiated granite though most published literatures described them as megacrystic porphyritic biotite granite (Krahenbuhl, 1991; Bignell and Snelling, 1997). Metasediments are also mapped in the area. They were listed to consist of schist, phyllite, slate and limestone. Minor intercalations of sandstone and volcanics are said to occur as well.

Table 1. Terrain classification and landuse hazards zonation attributes (Chow and Zakaria, 2002).

SLOPE GRADIENT		TERRAIN CODE			ACTIVITY CODE			EROSION AND INSTABILITY		
$0^\circ - 5^\circ$	1	Hillcrest:		A	Natural	-rock	1	No appreciable erosion:		0
					Slope:	-soil	2			
$6^\circ - 15^\circ$	2	Sideslope:	-straight	B		-soil and rock	3	Sheet erosion:	-minor	1
			-concave	C					-moderate	2
$16^\circ - 25^\circ$	3		-convex	D	Cut Slope:	-rock	4		-severe	3
						-soil	5			
$26^\circ - 35^\circ$	4	Footslope :	-straight	E		-soil and rock	6	Rill erosion:	-minor	4
			-concave	F					-moderate	5
$36^\circ - 60^\circ$	5		-convex	G	Fill:	-rock	7		-severe	6
						-soil	8			
$>60^\circ$	6	Drainage valley:		H		-soil and rock	9	Gully erosion:	-minor	7
									-moderate	8
		Flood plain:		I	Terrace:	-rock	a		-severe	9
						-soil	b			
		Coastal plain:		K		-soil and rock	c			
								Well defined recent		
		Littoral zone:		L	Reclamation:		d	landslip:		
					Mined-out:		e	(diameters)	- < 10m	a
		Alluvial plain:		X					- 10m - 50m	b
					Water bodies:				- > 50m	c
		Wave cut platform:		W		-natural stream	f			
						-man-made chann	g			
		Excavated platform:		Y		-water storage	h	Development of		
						-pond	l	general instability:	-recent	n
									-relict	r
					Colluvial:		m			
								Coastal instability:		w

COVER/VEGETATION			
Soil Slope	Dense Vegetation	No water seepage	a
		Minor water seepage	b
		Moderate water seepage	c
		High water seepage	d
	Moderate vegetation	No water seepage	e
		Minor water seepage	f
		Moderate water seepage	g
		High water seepage	h
	Sparse vegetation (Partially barren)	No water seepage	i
		Minor water seepage	j
		Moderate water seepage	k
		High water seepage	l
	Barren	No water seepage	m
		Minor water seepage	n
		Moderate water seepage	p
		High water seepage	q
Partly soil-Partly covered	Partially covered with concrete/bitumen etc. Dense vegetation in uncovered part	No water seepage	r
		Minor water seepage	s
		Moderate water seepage	t
		High water seepage	u
	Partially covered with concrete/bitumen etc. Moderate vegetation in uncovered part	No water seepage	v
		Minor water seepage	w
		Moderate water seepage	x
		High water seepage	y
	Partially covered with concrete/bitumen etc. Sparse vegetation in uncovered part	No water seepage	A
		Minor water seepage	B
		Moderate water seepage	D
		High water seepage	E
	Partially covered with concrete/bitumen etc. Barren in uncovered part	No water seepage	F
		Minor water seepage	G
		Moderate water seepage	H
		High water seepage	I
	Totally covered with concrete/bitumen etc.	No water seepage	J
		Minor water seepage	L
		Moderate water seepage	M
		High water seepage	N

GEOLOGICAL TERRAIN MAPPING

In the process of planning the landuse of an area, town planners would require basic information such as the geology, topography and landform of the area, as well as other relevant geotechnical details such as whether the area is potentially unstable due to the presence of landslides or severe erosion. Such information will assist engineers in preparing the layout plans, designing the foundation system and deciding on the most appropriate type and method of construction.

For easy assessment and utilisation of the information required, a rational evaluation of the overall terrain is conducted and the data are presented in the form of various types of thematic maps whereby the town planners and engineers may utilise them.

There are many terrain evaluation systems, each for different purpose of landuse such as the American scheme which emphasises on soil erosion and land management (Spangle *et al.*, 1976; Waynell, 1978), the British system which places priority on geology and landforms (Bibby and Mackney, 1969; Dent, 1977; Lawrance, 1972) or the Canadian method which associates with vegetation cover (Vold, 1981). The Dutch, on the other hand, is more concerned with agriculture (Gibbson and Hanns, 1976; Beek, 1978), whereas the Australians deal more with engineering geological related topics (Grant, 1972, 1982). The Geotechnical Control Office in Hong Kong (presently renamed as Geotechnical Engineering Office) in their approach to plan for the proper and safe development of Hong Kong, had also initiated a terrain mapping programme. Based on this programme, the Minerals and Geoscience Department Malaysia has produced a modified version of the Hong Kong model.

GEOLOGICAL TERRAIN MAPPING PROGRAMME IN CAMERON HIGHLANDS

Geological terrain mapping in Cameron Highlands commenced some time in 2002 and was conducted on topographical maps on a scale of 1:10,000. The base maps are available in the Survey Department in digital form. From the raw digital data, a slope gradient map was produced using the TIN Software.

Terrain classification was carried out based on four attributes (Table 1), that is the slope gradient attribute, the terrain or morphology attribute, the activity attribute and the erosion and instability attribute. Based on these four attributes, polygons were defined, reflecting on the steepness of the terrain, the morphology of the slope, the activities that were conducted on the slope and the degree of erosion or instability on that slope. Such definition of polygons was conducted in the field, but in areas which were inaccessible, recent aerial photographs were studied. Particular attention was paid to the edges of a map sheet, so that the mapped polygons match with those in the adjoining sheets.

The polygons in the Terrain Classification Maps were digitised and analysis was carried out with a GIS programme

(Arc Info or Arc View software) producing the various thematic maps as listed below:

i) Landform Map

This map summarises the broad terrain pattern in the map sheet where slope angle and terrain attributes are delineated. This map is designed for the use of technical and non-technical users who require general landform data for planning purposes.

ii) Erosion Map

This map delineates the broad pattern of erosion and instability, and is designed for technical and non-technical users who require information regarding the general nature, degree and intensity of erosion and instability for planning and engineering purposes.

iii) Physical Constraints Map

This map represents the major physical land resource constraints and is designed for technical and non-technical users who require information relating to the types of physical constraints which affect the terrain. It is designed to be used as an assessment of the physical resources for general planning and engineering purposes.

iv) Engineering Geology Map

Data from the Terrain Classification Map are used in conjunction with geological data from other sources such as geological maps, geo-hazards maps etc. This map displays the broad distribution of geological materials, based on their engineering characteristics. It is designed for technical users who require geotechnical information for strategic planning and engineering purposes.

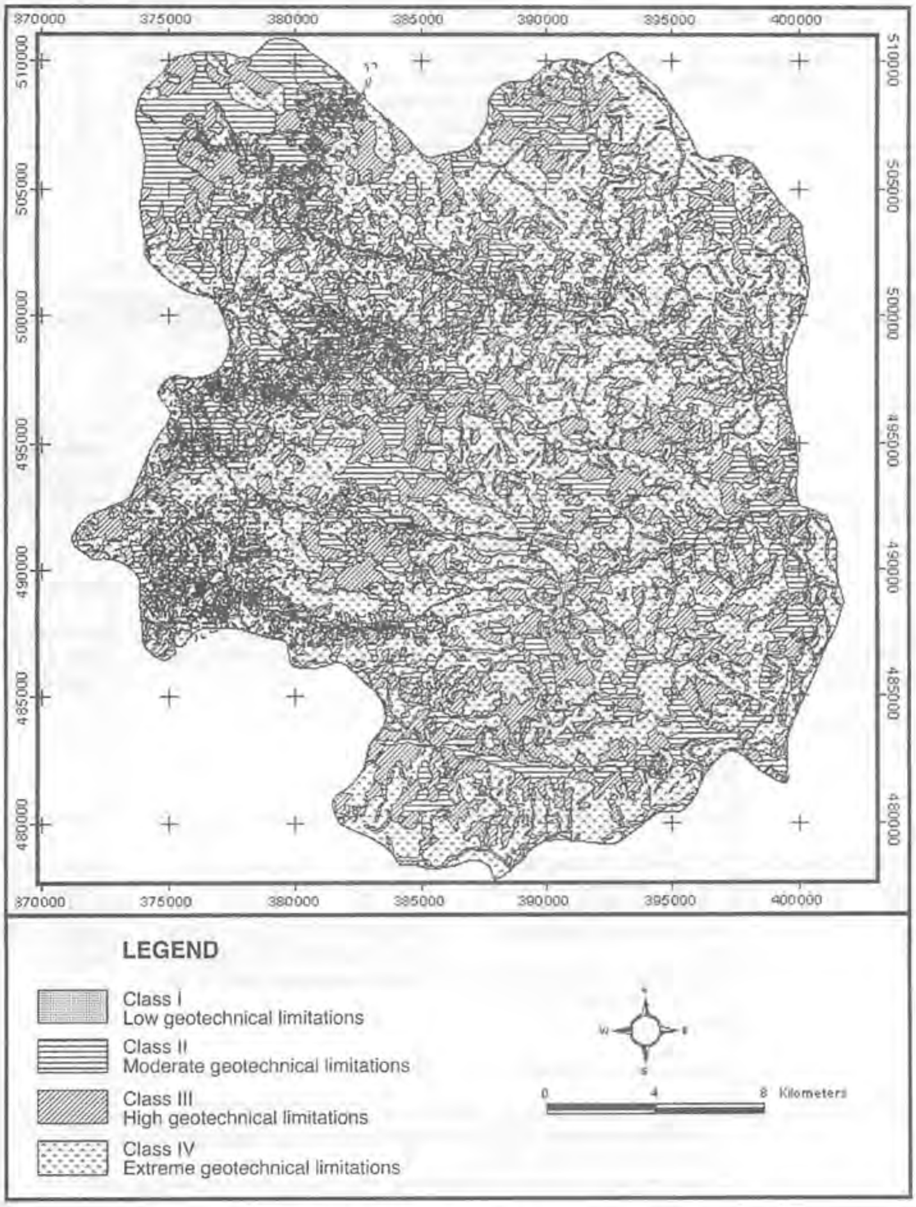

Figure 1. Construction suitability map of Cameron Highlands district.

Table 2. Implication of landuse classification system (after Brand, 1988).

GLUM Class Characteristics	Class I	Class II	Class III	Class IV
Geotechnical Limitations	Low	Moderate	High	Extreme
Suitability for Development	High	Moderate	Low	Probably Unsuitable
Engineering Costs for Development	Low	Normal	High	Very High
Intensity of Site Investigation Required	Normal	Normal	Intensive	Very Intensive
Examples of Terrain in GLUM Class	1. Insitu terrain $\leq$ 15° minor erosion 2. Cut platform in insitu terrain 3. Cut slope $\leq$ 15°, < 30 meter high insitu terrain	1. Insitu terrain 16° – 25°, no instability or severe erosion 2. Insitu terrain $\leq$ 15°, severe erosion 3. Colluvium $\leq$ 15°, no instability or severe erosion	1. Insitu terrain 26° – 35°, no instability or severe erosion 2. Insitu terrain 16° - 25° history of landslips 3. Colluvium 16° – 26°	1. Insitu terrain > 35° 2. Insitu terrain 26° - 35°, instable or severe erosion 3. Colluvium >26°

Table 3. Landuse classes and type of site investigations required (GCO, 1984).

Risk Category		Class Equivalent in Terrain Mapping		
		I, II	III	IV
Category.	a. Loss of life. b. Economic loss.		Description of Site Investigation	
Negligible.	a. None expected (no occupied premises). b. Minimal structural damage. Loss of access on minor roads	Assessment of surrounding geology and topography for indication of stability. Visual examination of soil and rock forming the site or to be used for the embankment. Specialist Advice - Requirement (A).	As for Class I & II. More detailed geology and topography survey. For the steeper slopes information on soil and rock joint strength parameters. Survey of hydrological features affecting the site. Specialist Advice - Requirement (B).	As for Class I & II. Area outside confines of site to be examinated for instability of soil, rock and boulders above the site. Specialist Advice - Requirement (B).
Low.	a. Few (only small occupied premises threatened). b. Appreciable structural damage. Loss of access on sole access roads.	Geology and topography survey of site and surrounding area. Soil and rock joint strength parameters for foundations and cut slopes. For embankments steeper than 1 on 3, recompacted strength parameters of fill. For cut, information on groundwater level. Specialist Advice - Requirement (B).	As for Class I & II. Survey of hydrological features affecting the site. Specialist Advice - Requirement (B).	As for Class I & II. Extend outside limits of site to permit analyses of slopes above and below the site. Specialist Advice - Requirement (C).
High.	a. More than a few. b. Excessive structural damage to residential and industrial structur Loss of access on regional trunk routes.	Detail geology and topography survey of site and surrounding area. Soil and rock joint strength parameters for foundation and cut slopes. Recompacted strength parameters for fill. For cut, information on ground water level. Specialist Advice - Requirement (B).	As for Class I & II. Survey of hydrological features affecting the site. Extend investigation locally outside limits of the site to permit analyses of slopes above and below the site. Specialist Advice - Requirement (C).	As for Class I & II. Extend investigation more widely outside limits of site to permit analyses of stability of slopes above and below the site. Specialist Advice - Requirement (C).

Note : Requirements for Specialist Advi A) Services for an experienced geotechnical engineer or engineering geologist not necessary.
B) Services for an experienced geotechnical engineer or engineering geologist to depend on location relative to devloped or developable land.
C) Services for an experienced geotechnical engineer or engineering geologist essential.

v) Construction Suitability Map

Based on attributes from the Terrain Classification Map, a Construction Suitability Map is produced (Fig. 1), whereby there are 4 classes, with Classes 1 and 2 having low to moderate geotechnical limitations respectively, Class 3 high geotechnical limitations, and Class 4 extreme geotechnical limitations (Table 2). The construction suitability map shown that 26% of Cameron Highlands are Class 1 and 2, 27% Class 3 and remaining 47% Class 4.

As such, Classes 1 and 2 are suitable for development and should not encounter much geotechnical problems, whereas Class 3 is not so suitable and Class 4, probably unsuitable. In terms of engineering costs for development, land under Class 1 will probably be having low development costs, Class 2 normal, Class 3 high and Class 4 very high. One of the reasons is that Classes 1 and 2 will require only normal site investigations (Table 3), whereas Class 3 will require intensive and Class 4, very intensive site investigations.

LANDSLIDE HAZARD ASSESSMENT

Landslide hazard assessment is carried out based on the similar attributes stipulated in the terrain mapping plus an extra one on vegetation cover and water seepage. However, the landslide hazard score is yet to be established and is still under study.

CONCLUSION

Terrain Classification Map and its derivative thematic maps such as Erosion Map, Landform Map, Engineering Geology Map, Physical Constraints Map and Construction Suitability Map serve as a useful guide for zoning of future development.

The Engineering Geology and Landuse Classification Maps will give a pointer to the engineers in their planning of site investigations, preliminary design of foundation systems and in the project lay-out.

Terrain mapping had just been completed in the Cameron Highlands where the rapid construction of hotels and apartments for the flourishing tourism industry and the haphazardous clearing of the jungle for farming had led to widespread erosion. The construction suitability map is presently utilised as a guide in reviewing the planning and approval of development projects in the Cameron Highlands.

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