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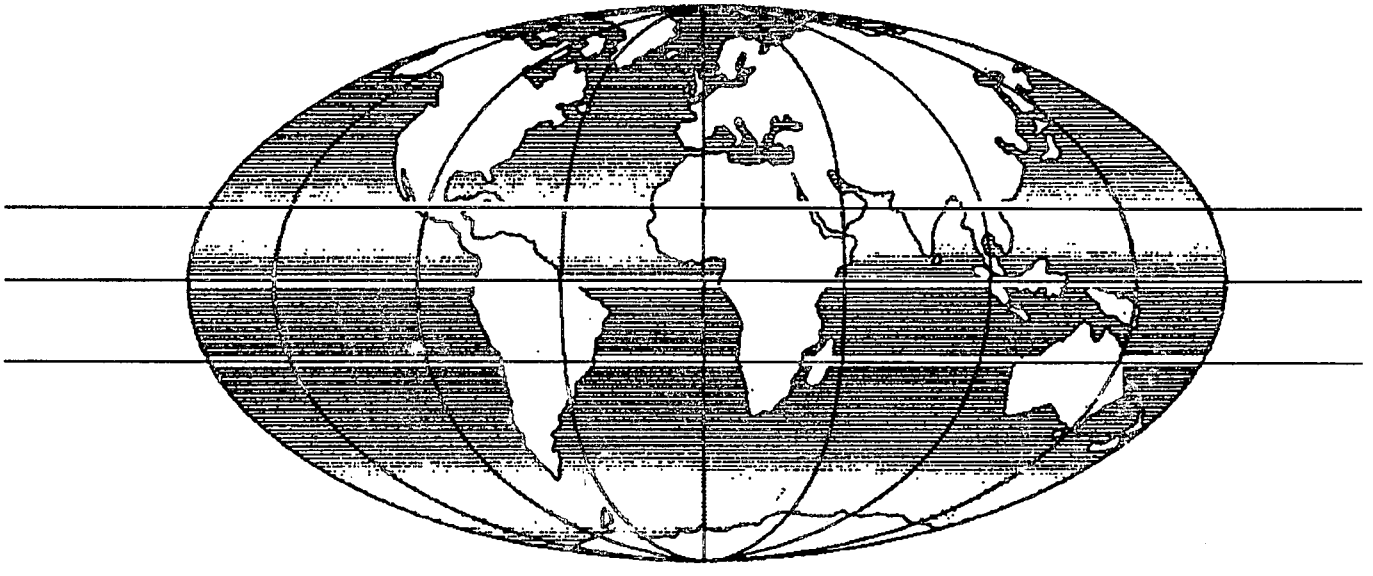

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INDONESIAN SLOPE INVENTORY STUDIES

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ABSTRACT

A slope stability research programme is currently being undertaken at the Institute of Road Engineering (IRE), Bandung. The fundamental practical objective of this programme is to develop further an understanding of the geotechnical performance of slopes. This paper outlines the initial research methodology which is based on the recovery of information from both stable and unstable slopes. The preliminary results of the IRE research is presented and discussed and examples of inventory data from Indonesia are used as an illustration of the practical usefulness of such work.

1.0 INTRODUCTION

A slope stability research project is currently part of an IBRD funded Technical Assistance and Research Training Programme (TARP) being undertaken by TRRL at the Institute of Road Engineering (IRE), Bandung. The main objective of this work is the establishment of geotechnical guidelines on the performance of natural and man-made slopes as it affects existing and proposed road links in Indonesia.

The immediate objective of the current phase of work is to collate existing information on slope stability in Indonesia, to conduct pilot studies into slope inventory methodologies relevant to Indonesian conditions and to examine the relationship between slope stability and terrain models.

This paper outlines the work undertaken so far on the development of an Indonesian slope inventory methodology and presents data recovered from a recent survey of slopes collected as part of the design studies for a proposed toll road in West Java.

2.0 SLOPE INVENTORIES

It became clear during the development phase of the TARP project that there was a need to assemble and collate basic information on Indonesian slopes. This information was available or obtainable in a number of forms:-

- in existing technical reports
- in existing slope inventories
- as potential data from existing earthworks
- as potential data from natural slopes/failures.

The use of an inventory based methodology therefore seemed a logical means by which this information could best be utilised in the pursuit of the overall project objectives. As an initial step in the development of an Indonesian inventory methodology a brief review was made of the range of existing inventories and their relevance to the Indonesian situation. The types of data recovered from these inventories was examined and it was clear that the inventories varied widely in the slopes investigated, in the detail recovered and in their particular objectives. The methodology of approach was further influenced by the geological, geomorphological and climatic terrain in which the studies took place. A representative cross section of their data sets is presented as Table 1.

From an examination of this previous work it was obvious that a clear understanding of the slope environment in combination with the project objectives was essential for the development of an effective IRE inventory methodology.

3.0 SLOPE STUDIES IN INDONESIA

In general terms, slope instability in Indonesia has a very high significance with respect to the development of infrastructure in comparison to some other countries of S.E.Asia (Brand, 1984). The variety of slope instability environments stems from the large scale natural instability problem, resulting principally from a combination of volcanic activity, seismic activity and the tropical climate, combined with the growing need to utilise available land for agriculture and infrastructure (Jibson, 1988).

Previous TRRL/IRE co-operation in slope stability research has extended over a period of ten years and has resulted in significant work being undertaken in the fields of natural slope instability processes, cut-slope monitoring and detailed investigations of particular situations (DPMJ-TRRL, 1982; Heath et al,1990). Some initial slope inventory studies were also undertaken in Java and Sumatera as part of this co-operation; information from this inventory work is included as reference 8 in Table 1.

The utilisation of terrain evaluation techniques has also been part of the above research (Saroso et al,1983) and the recently completed Land System mapping of Indonesia by Bakosurtanal was seen as providing a potentially powerful research tool for further slope work. Hence a major theme of the current TARP work is to relate existing slope information in Indonesia to the Land System mapping.

TABLE 2: PRINCIPAL INDONESIAN SLOPE INSTABILITY SITUATIONS

1	active volcanic instability
2	large scale landslide instability
3	smaller scale natural slope erosion/development
4	cut-slope failure/degradation
5	embankment failure/degradation
6	combinations of 2 to 5; eg embankment on old landslide or landslide failure initiated by cutting.

TABLE 1 TYPICAL INVENTORY DATA SETS

Recorded Features	Inventory Reference Number 1	2	3	4	5	6	7	8	9	10	11
LOCATION											
Name/number	•	•	•		•		•		•		
District				•		•	•	•	•		
Road chain.			•	•	•	•		•			•
Map Co-ord	•						•		•		
ENVIRONMENT											
Drainage basin	•										
Geomorph./terrain							•		•		•
Hydrology	•			•	•	•	•		•		
Land use							•	•			
Weather/rainfall				•			•	•			
SLOPE											
Material type	•	•	•	•	•	•	•	•	•	•	•
Material condition					•	•	•		•	•	
Material structure	•			•	•	•	•	•			•
Height above e/works											
Angle above e/works											
Slope type	•		•	•		•	•	•	•		•
Slope angle	•		•	•	•	•	•	•	•	•	•
Slope height			•	•	•	•		•		•	•
Slope width			•	•	•	•				•	
Slope shape (Vertical)	•		•		•		•		•		
Slope shape (Horizontal)			•		•						
Cross profile						•					
Vegetation	•		•	•	•		•	•		•	
FAILURE											
Erosion	•		•	•	•		•		•	•	•
Failure yes/no					•			•	•	•	•
Type	•		•	•		•	•	•	•		•
Causes	•		•			•			•		•
Movement/age	•			•		•	•		•	•	•
Stability	•	•	•							•	
Thickness	•			•			•				
Width	•	•									
Total area	•					•	•				
Length	•	•					•		•		
Foot area		•									
Scarp Height		•					•				
Scarp angle		•									
Rotation		•									
Shear plane	•										
Cracking	•										
Debris volume	•										
Debris angle	•	•							•		
Damage	•			•		•	•		•		
ENGINEERING											
Road description							•	•			
Existing measures	•		•	•		•	•	•	•		•
Proposed measures						•					
Effects											
Benching			•		•	•		•		•	
Drainage		•	•	•	•			•		•	•
GENERAL											
Notes	•			•			•	•	•		
Photos	•		•	•	•	•		•			
Sketches	•			•		•	•	•			
Desk studies									•		
Data sources							•		•		
Investigations							•		•		
Analysis											

Inventories

1 Carrara & Merenda
2 Al-Dabbagh & Cripps
3 Heath
4 Perry
5 Anderson & Kemp
6 JICA - Phillipines
7 Olarte et al
8 DPMJ - TRRL
9 GSL (UK)
10 Bulman
11 RGL (CPTR)

A general examination of stability affecting the existing road network revealed that slope instability should be considered as a number of related situations (Table 2). For the purposes of the project objective, relating to slope performance and the road network, the study has not included item (1) from Table 2. To attempt to draw-up a single data recovery procedure to cover all the remaining situations would be cumbersome and impractical. The proposed approach was seen therefore as having to consist of a variable information collecting procedure allied to a flexible database.

4.0 THE PROPOSED TARP INVENTORY METHODOLOGY

The first stage in development of the inventory methodology at IRE was to access the considerable amounts of slope information that were known to be available at the Institute. A desk study inventory was therefore initiated which first sought to identify data types and then to transfer the relevant information into a database. Figure 1 outlines the structure of this inventory.

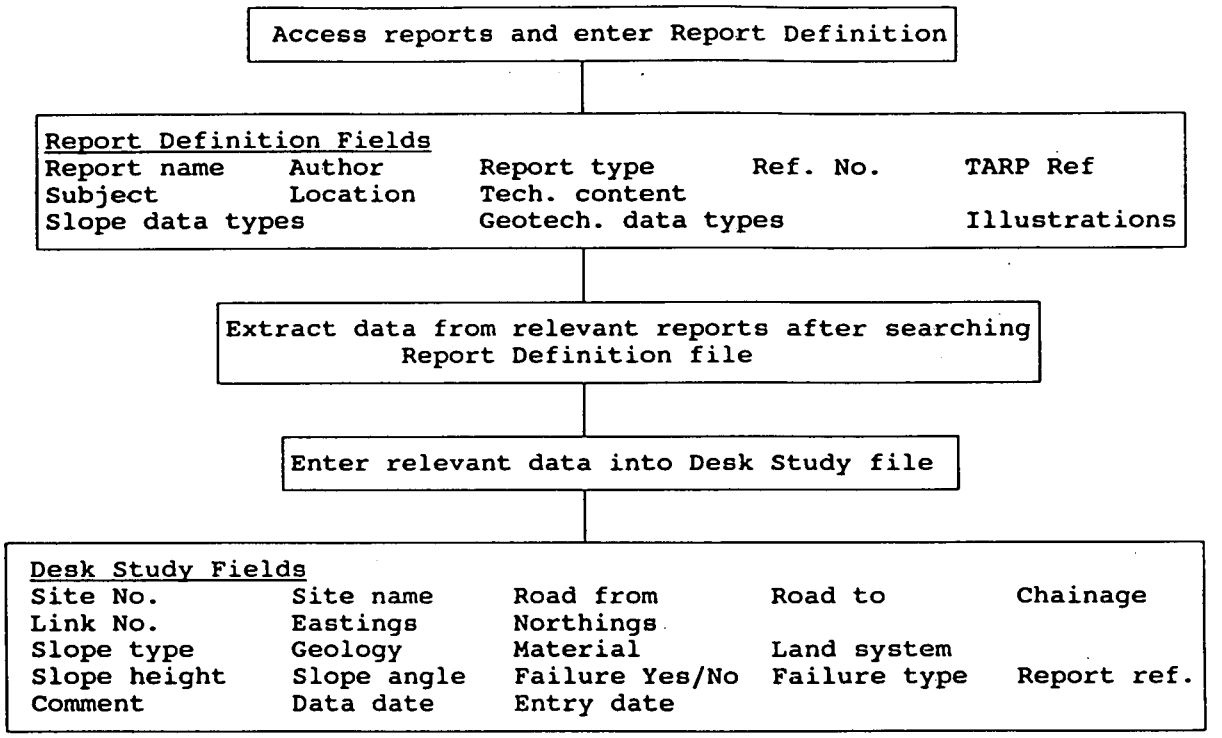

FIGURE 1 TARP INITIAL DATA EXTRACTION PROCEDURE

Previous TRRL/IRE joint research was the starting point for a data collection programme; this has now been extended to over 100 IRE reports concerning various aspects of slope stability. Preliminary data from this database, combined with information about other inventories and experience obtained from previous data gathering exercises in Indonesia, led to some basic project guidelines being drawn-up.

1 The proposed methodology should be built around a PC based database system capable of accommodating differing levels of information from a variety of sources and with different reliabilities.

2 It should be based on the existing infrastructure network and would include information on both stable and unstable slopes.

3 The procedures would be flexible enough to be adapted to variable project constraints in terms of time and manpower resources.

4 Field collection of data would be based on the completion of standard sheets designed and operated so as to reduce operator bias as much as possible.

The current TARP inventory methodology is based round the definition of "sites" ; the procedures for describing "locations" within these sites is dependant on the nature of the relationship between the site and the locations. Site, for example, may consist of the following:-

- single location, eg one large landslide
- a group of locations, eg an area of instability
- an existing road or section of road, eg earthwork inventory
- a proposed road, eg, natural slope inventory.

The data collecting procedures and field forms will be different for each major type of "site" although the general principal of utilising such forms in conjunction with lists of standard options remains the same. Locations themselves may be either natural slopes, earthwork slopes or combinations of both; they are then also subdivided on the basis of being stable or having failed.

The general data collecting procedure for the current database is outlined in Figure 2 and typical field forms are presented as Figure 3.

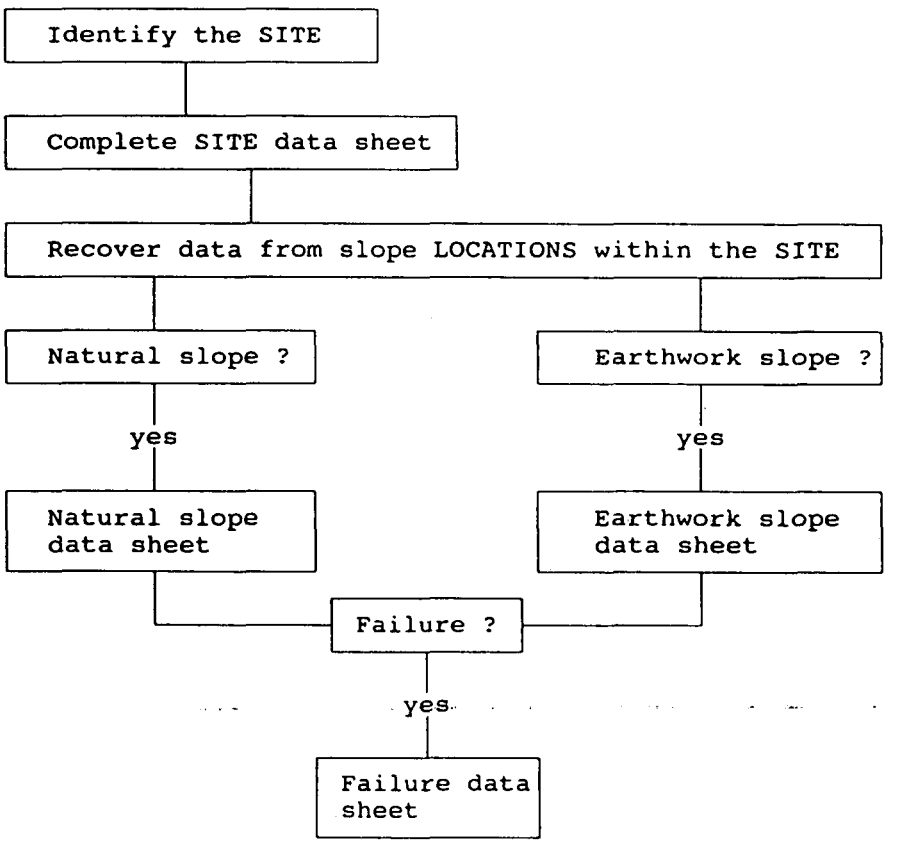

FIGURE 2 OUTLINE TARP SLOPE INVENTORY PROCEDURE

In the light of previous experience in Indonesia some data fields, not found in other similar inventories, were felt to be important.

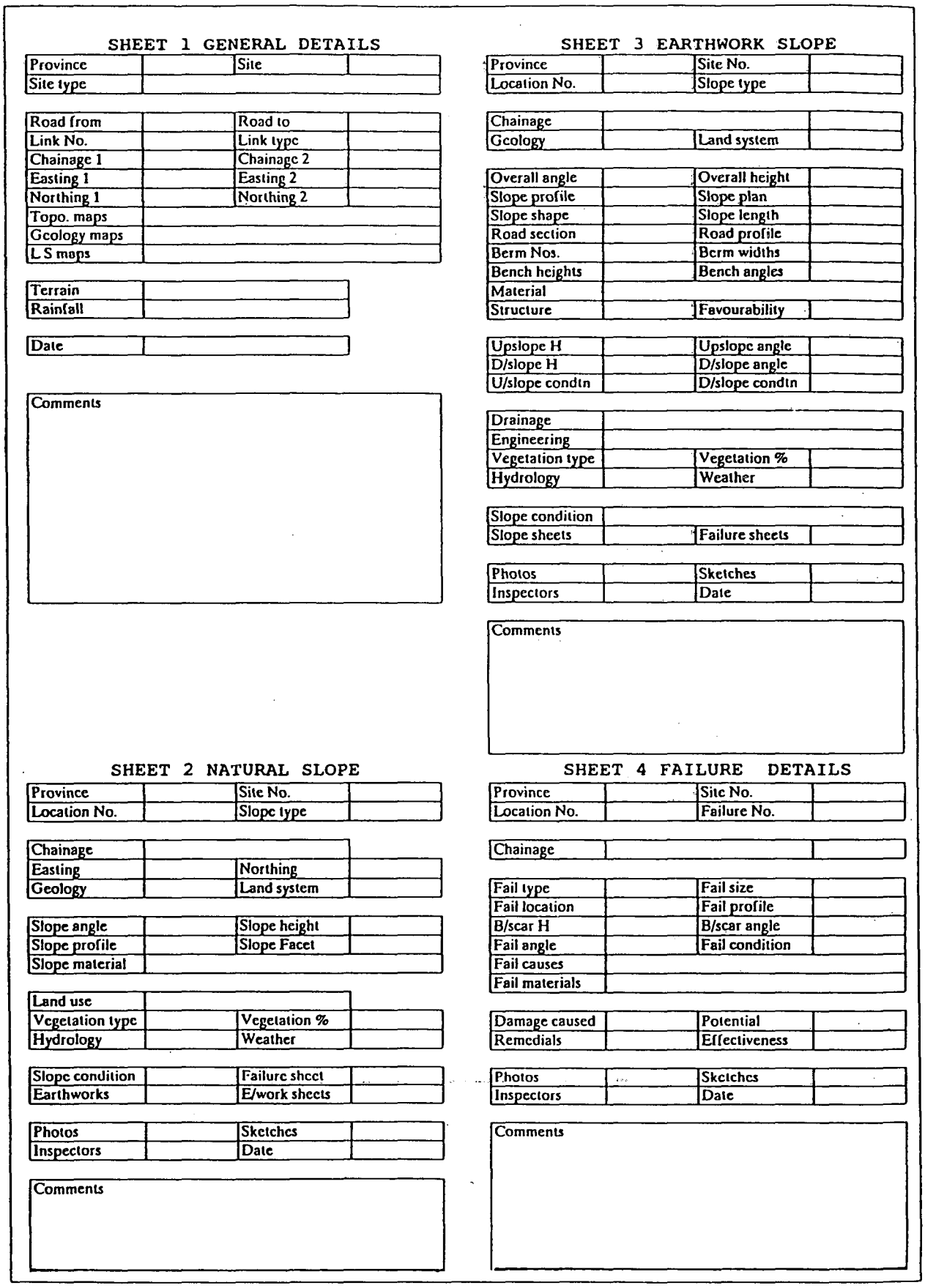

FIGURE 3 PRELIMINARY SLOPE INVENTORY FIELD FORMS

Land system: the Bakosurtanal mapping units, to form part of the basic IRE research into the relationship between terrain and slope stability.

Climate/weather: in recognition of the relationship between rainfall and slope failure in tropical environments.

Land use; to study the relevance of land use, and in particular, irrigated crops on slope stability. This is seen as particularly important in large areas of Indonesia where irrigated rice growing (paddi) may influence slope performance.

Vegetation cover: included to establish the importance of the correct vegetation, ie root pattern, on earthwork stability.

5.0 THE PRACTICAL APPLICATION OF SLOPE INVENTORY DATA

During 1990 the Principal Author of this paper was involved in the Geotechnical Studies for the proposed Cikampek-Padalarang Toll Road (CPTR) in Java (RGL, 1991). As part of this work a simple inventory was assembled of relevant slopes in the vicinity of the route corridor. The data sets for this inventory, involving both natural and man-made slopes, are summarised as reference 11 in Table 1.

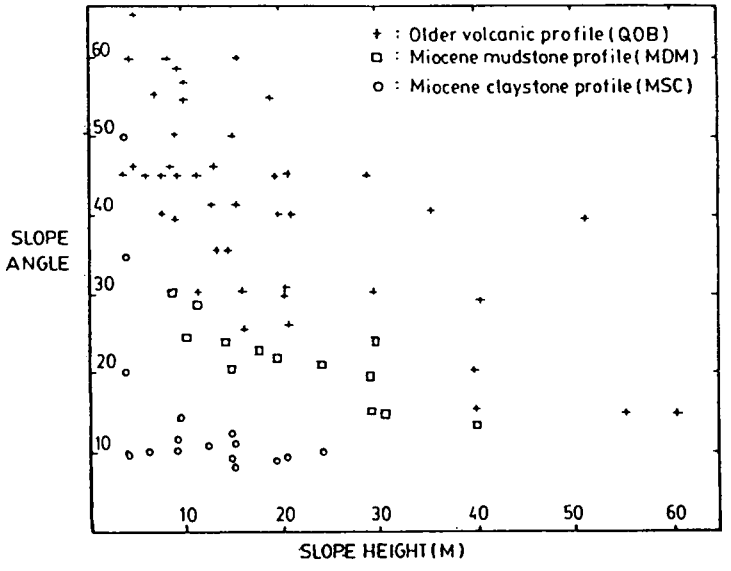

Figure 4. Slope Angles related to bedrock only

The principal objective of this inventory was to assist in the outline design of cut-slopes for the CPTR. Very distinct slope angle patterns were obtained from differing bed-rock types (Figure 4). These patterns become more applicable to slope design when considered in conjunction with terrain. Figure 5 presents the slope/height plots for the low level hilly terrain at the northern end of the route. The inventory was put to practical use in the determination of likely cut-slope designs in this problem terrain by means of the following outline procedure:

1 Ascertain typical maximum natural slope angles/height relationship.

2 Use standard slope charts (Bishop & Morgenstern or Hook & Bray) to establish a likely range of C and ϕ values - assuming for this terrain a high water table and high rainfall (saturated conditions) with a Factor of Safety (F.O.S.) equal to 1.

3 Cross check these against index tests and the strictly limited strength testing.

4 Assume an improvement in drainage of man-made slopes together with a suitable F.O.S. and again use the standard charts and the cross-checked parameters to establish outline cut-slope designs.

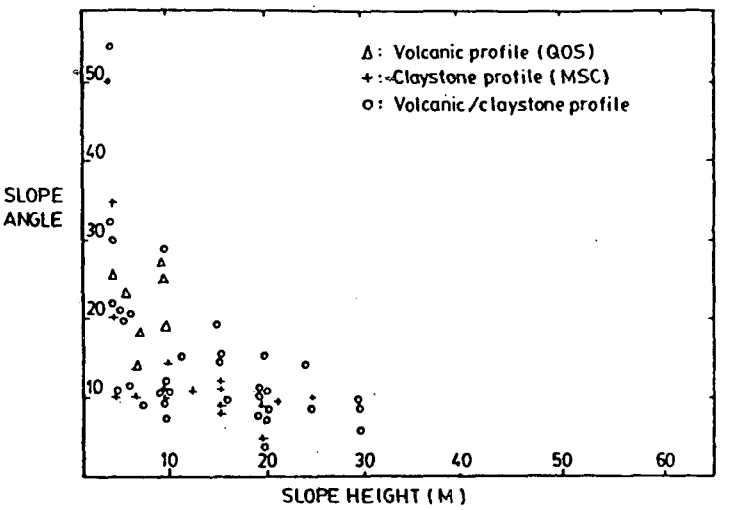

Figure 5. Slope angles related to one terrain unit

Table 4 summarises some of the results from this exercise, for the Miocene claystone soil profiles, which enabled reasonable outline slope designs to be derived. This was achieved without reliance on extensive laboratory testing which in this tropically weathered geotechnical environment would not have been cost-effective.

TABLE 4: SUMMARY DATA FROM TYPICAL SLOPE DESIGN EXERCISE

Natural H(m)	Slope Angles	Derived C'(kPa) ϕ=15	ϕ=20	Shear Box Results from limited near surface samples
5	30°	8	3	ϕ : 15 - 24°
10	13°	8	3	C': 2.5 - 10 kPa
15	10°	7	2.5	
Final Outline Design For Miocene Claystone cut-slopes; can be generally cut at 4.5h:1v with an adequate F.O.S. provided sufficient cut-off, face and toe drainage is installed.				

6.0 SUMMARY

The current slope research programme at IRE is seeking to establish firmer guidelines on the engineering performance of Indonesian slopes. As a first step in this process an inventory of existing information is being assembled which will be related to available land system mapping.

At the same time a methodology for collecting more slope data by inventory procedures has been drawn-up based on the recognition of the wide range of slope failure situations in Indonesia. This methodology is based around a microcomputer database using currently available commercial software. Data is being assembled by means of standard field forms designed to suit the relevant site and location situations.

Slope inventories may be put to a number of research and practical engineering uses. A recent road investigation in West Java exemplified the practical uses by utilising a simple slope inventory as a cost effective aid to cut-slope design in a difficult geotechnical environment.

7.0 Acknowledgements

The work described in this paper forms part of the collaborative research project being undertaken by the Indonesian Institute of Road Engineering and the Transport and Road Research Laboratory (UK). This paper is published with the permission of the Chief Executive of TRRL and the Director of IRE. The work described in Section 6.0 of this paper was supervised by the Principal Author while retained by Rendel Geotechnics Ltd who were commissioned by Rendel Palmer & Tritton, Consulting Engineers, to undertake Geotechnical Studies for the Cikampek-Padalarang Toll Road Project.

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