HILLSLOPE ANALYSIS AT TEMPLEHILL, CORK

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1. GENERAL INTRODUCTION

"Geomorphology is the Science of Landscapes" (Weyman 1977;10).

As a science, Geomorphology includes both a description of landscape and the analysis of the processes which create that landscape. A hillslope analysis must therefore include an insight into the original genesis of the area and any subsequent processes causing changes in the landscape thereafter.

The area covered in this Hillslope Analysis is approximately one square kilometer. The area is situated south west of Blarney and Tower villages and lies five miles west of Cork City. The area under examination incorporates parts of the following townlands; Coolatanavally, Currabeha, Coolatubrid, Moneyflugh and Coolyduff. The area is drained by the Owennagearagh and Shournagh river which in turn is a tributary of the River Lee.

The landscape of the earth's surface is largely the creation of two sets of indigenous forces acting constantly against one another. Firstly, there are processes within the earth such as volcanic activity, and folding of the earth's crust. Secondly, arrayed against these internal forces of creation are the external forces of weather, water and ice which modify and destroy these landforms. This second group of forces is referred to as the denudation process.

Denudation forms part of the geological cycle and consists of a number of seperate operations namely; weathering, mass movement, erosion and deposition. Hillslope analysis may be seen as analysing the interaction between denudational forces and the underlying geological structure and the time during which the interaction has been taking place.

2. ORIGIN OF THE LAND SCAPE AND EARLY DENUDATIONAL PROCESSES

The character of the region analysed was entirely determined by the presence of the well developed Armorican fold system of Southern Ireland. Three basic rock types are involved in this folding. Firstly, there is Old Red Sandstone whose strata include sandstones, mudstones, slates and conglomerates. The thickness of this layer increases from 1200m over most to a maximum thickness of 6700m in parts of Co. Kerry.

Secondly, resting on the Old Red Sandstone there are Carboniferous strata consisting of thin basal beds of Tower Limestone Shales followed by a thick sequence of Carboniferous Limestone. Thirdly, to the south of a line from Cork Harbour to Kenmare, the Old Red Sandstone is overlain by a thick series of Arenaceous and Argillaceous rocks known as the Cork Beds. "There can be no doubt that the folds control both the pattern of the region's geological outcrops and the distribution of its uplands and lowlands" (Bruck P.M. et al 1984; 28). The region is like a large sheet of corrugated Old Red Sandstone exposed by the widespread removal of the former Carboniferous mantle. However, Lower Limestone Shales and the Limestone survive on the floor of linear valleys in the regions deepest Old Red Sandstones synclines. In Templehill the rock outcrops on the ridges are characterised by the prevalence of brown and purplish tints in it's Sandstone.

The glacial history of the region is somewhat uncertain. The greater Cork/Kerry Ice Sheet extended to cover most of the east Cork region, depositing extensive amounts of Till. The Drift Sheet is however discontinuous and in many places it has been removed by later erosion. The eastern boundary of the lesser Cork/Kerry glaciation is marked by a large gravel moraine at Killumney and to the west of Templehill, although some experts believe it may have extented further west (Davies G. - H.L. and Stephens N. 1978;10).

Considered as a whole, the accumulation of glacial drift is not as great in the Cork region as in areas further north such as Dublin or Belfast. Glaciation in this part of the country has been less effective both in terms of the quantities of material transportated and also in terms of the level of erosion of solid rock.

The most wide-spread type of drift in the Cork region is a red stony loam or clay for the most part composed of debris of the local Old Red Sandstone and Carboniferous rocks, and the occurrence of any extranaeous material is quite exceptional.

The Templehill area lacks any typical glacial features such as moraines or drumlins and there is no evidence of striations on exposed rock faces. The area appears to have experienced a diminished, almost stagnant glaciation. The subsequent topography of the area has been dominantly influenced by surface water impedence.

3. HILLSLOPES IN THE TEMPLEHILL AREA

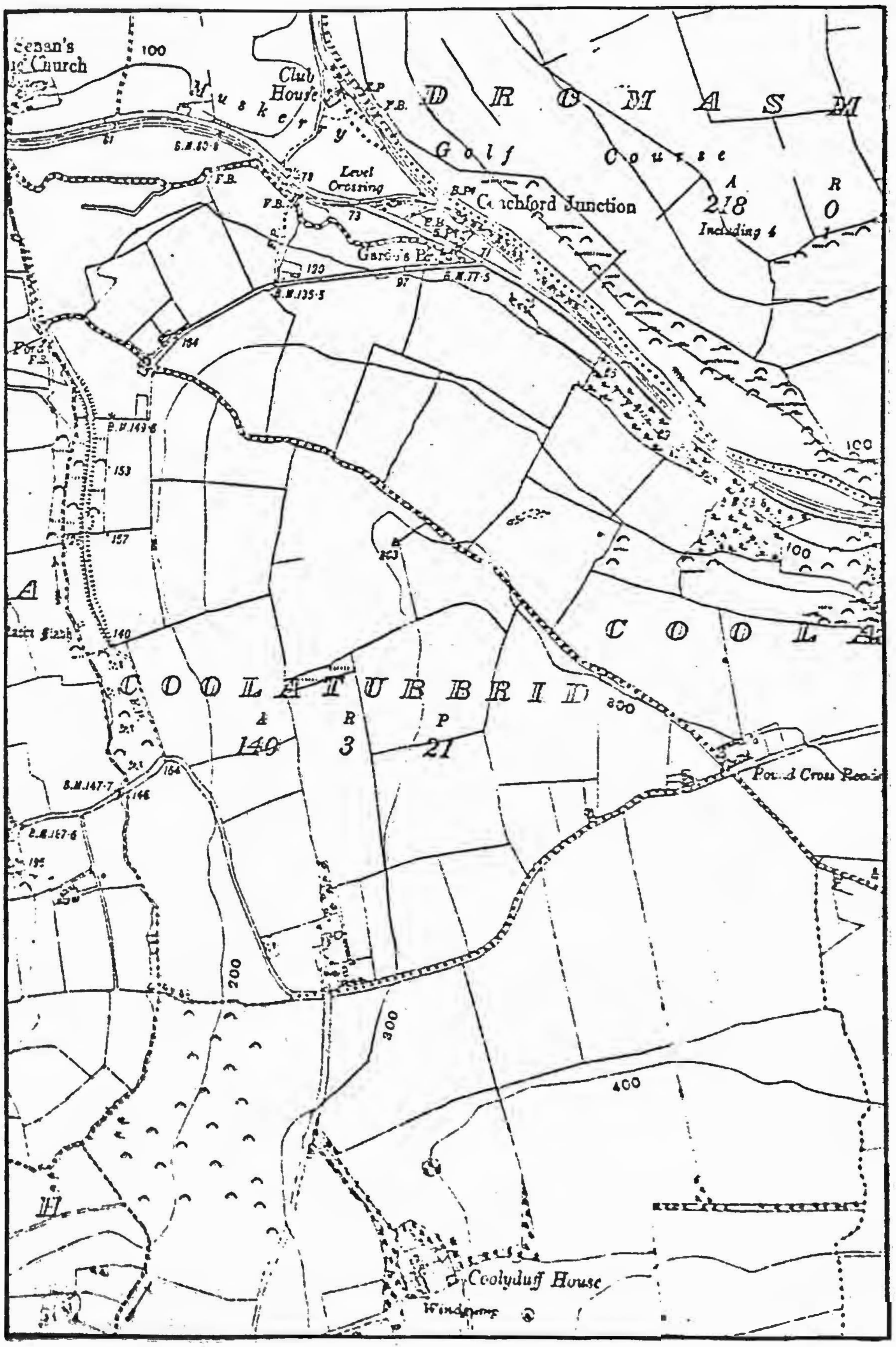
The Templehill area is bounded on three sides by valleys (see fig 1). The highest point in the area lies east of Coolyduff house at an elevation of 158m. O.D. South of this ridge lies the Lee Valley from where the river Lee flows eastward towards Cork City.

On the western side of the highest point, the ground falls away into a valley, containing a stream flowing in a south to north direction, eventually joining the Owennagearagh river. On the northern side of the highest point the ground level falls away to the Shournagh River, which has been joined by the Owennagearagh river The Shournagh flows west to join the Lee at Carrigrohane.

The steepness of the hillslopes in the region range from one degree to thirty degrees with the steepest slopes occurring in western and northern sides of the area. These slopes were measured with a Abney hand level in order to construct a morphological base map.

HILLSLOPE ANALYSIS:COOLYDUFF:General Location

Fig. 1



Scale 1:10,560

Old Red Sandstone outcrops appear in many areas from the 100m contour downwards. In the valley on the western side of the region the hills fall rapidly to a poorly drained marshy area. In the northern part of the region the hillslopes end abruptly at a cliff adjacent to the Carrigrohane/Cloghroe road north of which there is a flat area extending a short distance to the Shournagh river.

The dominant land use in the Templehill region is dairy production. Many fields in the area are so steep that they could onl be categorised as rough pasture, whereas fields above the 60m contour are of superior quality as the slope is generally less severe (see fig 2).

In conjunction with an examination of the general hillslope trends in the Templehill region, a more detailed study of a smaller area was also undertaken. For this purpose a 28 acre field in Coolyduff was selected (see fig 3). The field lies between elevations 25m and 70m O.D. and is situated in the general Templehill area. The field is bounded on the west by a stream rising from a spring which drains the area into the Owennagearagh river. The eastern boundary of the field is defined by a public road. The levels fall from 70m O.D. on the road to 25m at the stream. Slope angles range from 6-10 degrees from the road to an area of up to 25 degrees before levelling out to 1 degree or less near the stream.

The upper area of the field is characterised by hollows of coarse grained soil over Old Sandstone rock. The rock in this upper area appears at the surface in places. A horse-shoe shaped area of land overgrown with gorse and small trees dominate the central steepest section of the field. Again in this area Old Red Sandstone outcrops are a feature. The soils in the relatively flat area of the field are smooth and fine grained in texture and this area is generally poorly drained.

4. FIELD WORK

The field work undertaken in this analysis consisted of the following.

1. Contour Survey.
2. Longitudinal Sections A-B, and A-C.
3. Soil Samples No. 1-7.
4. Percolation Tests No. 1-3.
5. Stream flow measurements No. 1-2.

1. Contour Survey. (fig 4)

This survey was undertaken to provide a picture of the topography of the field. A theodolite was used to accurately establish four instrument station points at certain positions in the field from which the total area of the field could be observed. By setting up the theodolite on each of these instrument stations three hundred and fifty points were then surveyed with respect to their elevation and location in the field.

A computer was then employed to establish the co-ordinates and levels of the 350 points. The points were then drawn by the computer using a plotter. The computer then had to be told which

Fig.2 HILLSLOPE ANALYSIS at COOLYDUFF,TEMPLEHILL:MORPHOLOGY

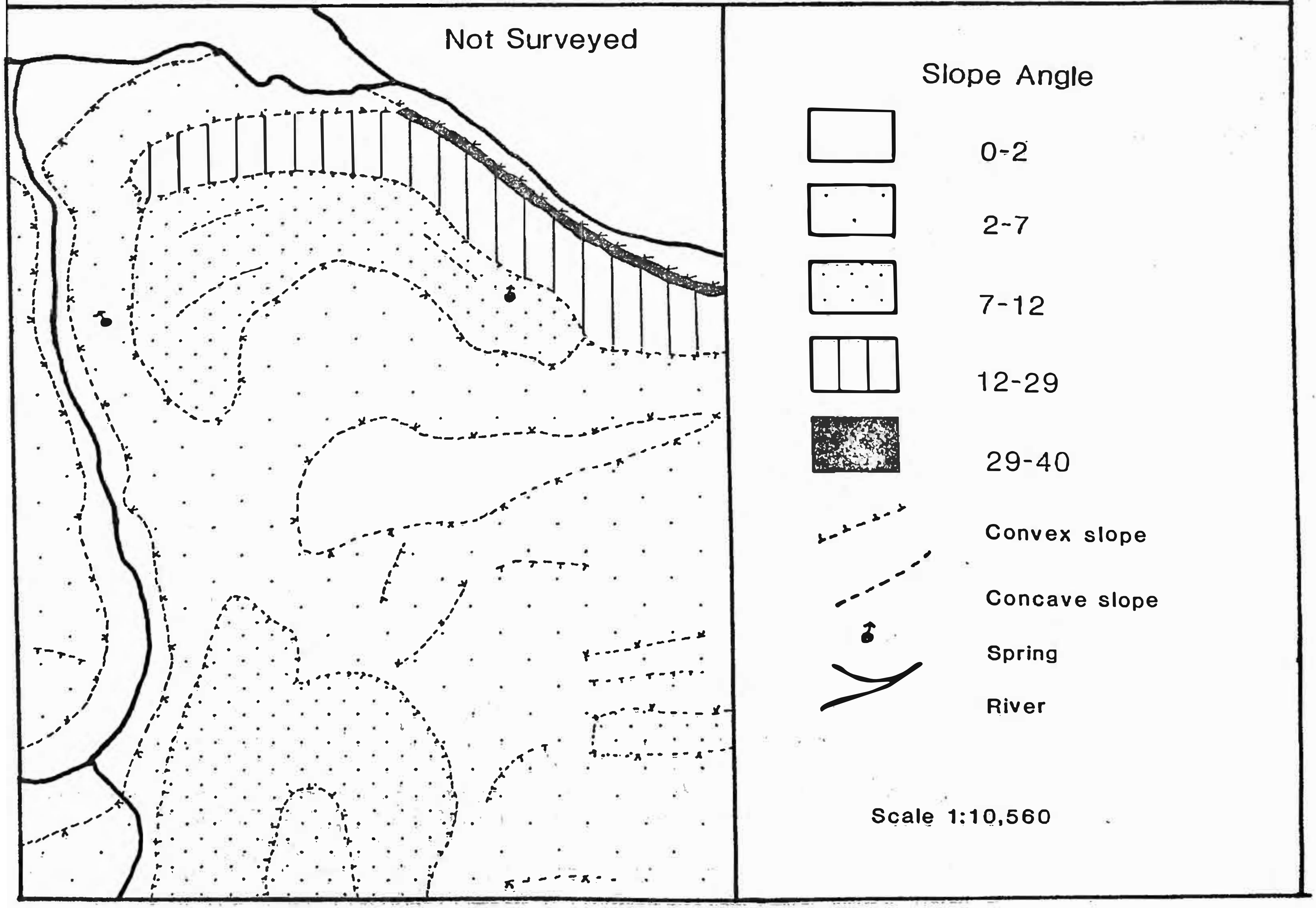


Fig.3. HILLSLOPE ANALYSIS at COOLYDUFF:Site of Detailed Analysis

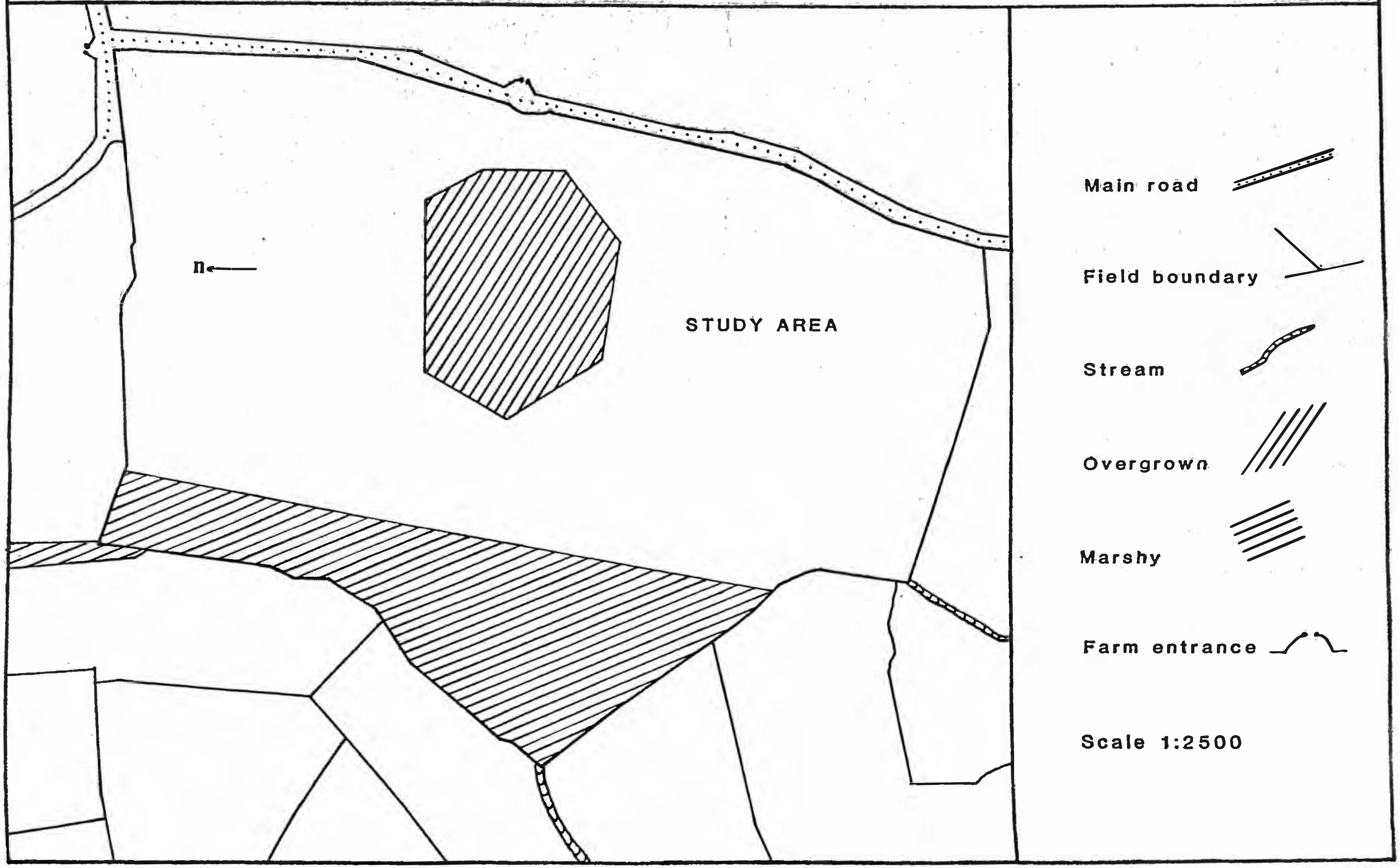


Fig. 4 HILLSLOPE ANALYSIS-AT COOLYDUFF TEMPLEHILL

points to contour between and the plotter plotted a grid pattern of lines to be contoured. The computer and plotter produced symbols indicating levels along these grid lines. Identical symbols were then joined together by dotted lines to give the finished contour map (see fig.4). One objective of the contour survey was to indicate any areas where mud flows or soil creep may have occurred. For this reason it was necessary to use as small a contour interval as possible namely 0.5m. Ninety contour lines were drawn which necessitated increasing the scale of the survey to 1:500 contour map.

2. Sections A-B and A-C. (fig 5)

These sections were surveyed independently of the contour survey. They were taken from a high level in the middle of the eastern boundary down to the north west and western corners of the field. Levels were taken at points where the slope changed or where a break in slope occurred. This survey was undertaken to establish the convex/concave relationship in operation on the slopes in the area. These sections were plotted at a scale of 1:500 horizontally and 1:100 vertically. The Contour Survey and Sections A-B and A-C drawings have been reduced in size for this publication and therefore do not scale as shown.

3. Soil Samples (Table 1)

Seven soil samples were taken along section lines at points where it appeared that the soil characteristics might change. These samples were taken at depths ranging from 225mm to 450mm depending on the ground conditions. The following laboratory tests were carried out on the sample.

A. The determination of the moisture content for all the samples.
B. The determination of the plastic limit for all the samples.
C. The determination of liquid limits for samples 1, 3, and 5.
D The determination of the percentage of organic matter in all the samples.
E. The modified pipette method for measuring silt and cla sized material in samples 1, 3, and
F. Sieve analysis of all samples.

4. Percolation tests

Flow measurements were taken in both streams on the western side of the field using a current meter. The flow at point F1. (see fig 3) was calculated at 0.0317 cub.m/s. and F2 at 0.110 cub. m/s. These measurements should be taken repeatedly at intervals over a period of at least one year and used together with relevant rainfall data for the area in order to evaluate runoff and drainage characteristics.

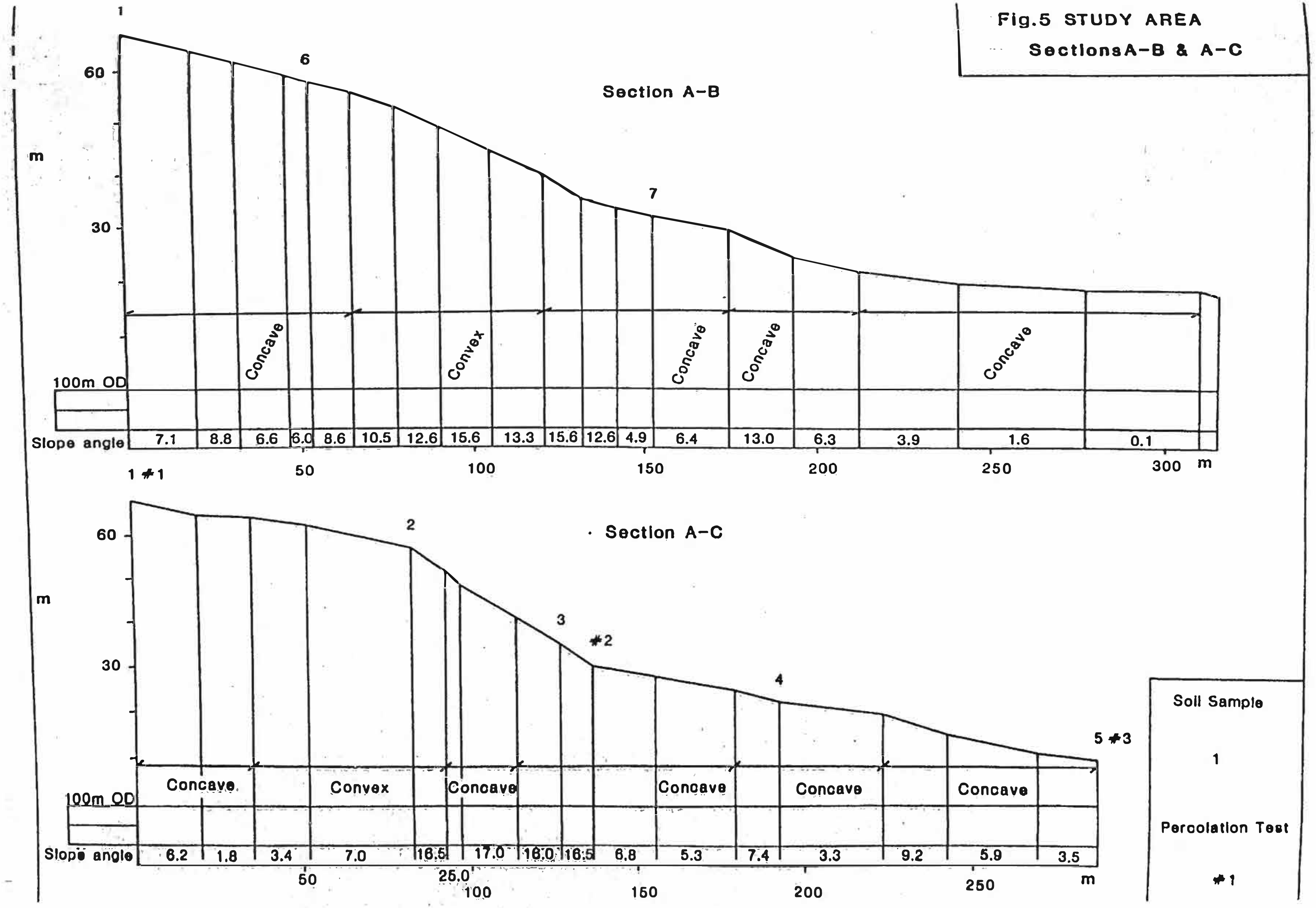


Fig.5 STUDY AREA

Sections A-B & A-C

TABLE 1

HILLSLOPE ANALYSIS AT TEMPLEHILL.

SOIL SAMPLE TEST RESULTS.

SAMPLE NO.	ORGANIC MATTER CONTENT (A)	MOISTURE CONTENT (B)	PLASTIC LIMITS (C)	PLASTIC INDEX (D)	LIQUID INDEX (E)
1.	7.80	40.29	36.72	5.78	0.61
2.	5.28	31.49	36.71	———	———
3.	5.23	23.62	34.00	-4.00	2.59
4.	———	36.03	45.38	———	———
5.	6.74	40.57	56.77	-3.52	4.05
6.	8.43	31.52	50.53	———	———
7.	9.68	37.30	56.52	———	———

LIQUID LIMITS (F)

SOIL SAMPLE	MOISTURE CONTENT TEST "A"	MOISTURE CONTENT TEST "B"	MOISTURE CONTENT TEST "C"	MOISTURE CONTENT TEST "D"	LIQUID LIMITS
1.	49.15	38.32	39.66	40.49	42.50
3.	26.45	30.88	25.46	22.92	30.00
5.	45.47	53.90	51.81	52.86	53.00

MEASUREMENT OF SILT, CLAY AND SAND CONTENT OF SAMPLES (G)

SOIL SAMPLE NO.	COARSE SILT %	MEDIUM SILT %	FINE SILT %	CLAY %	SAND %
1.	07.50	07.50	00.00	10.00	75.00
3.	07.50	07.50	00.00	07.50	77.50
5.	22.50	07.50	02.50	05.00	62.50

5. ANALYSIS OF DATA

"Slope profiles commonly possess rounded upslope elements and lower basal concavities" (King 1966;124). Inspection of both sections A-B and A-C show this to be divided into three main categories. The first of these is Denudation slope, which is one where material loss is occurrring. The second category of slope is a Transportation slope where there is neither a gain or loss of material. The third type of slope is an Accumulation slope where there is a build up of material. The Denudation type slope may be further subidivided according to those caused by weathering and according to those caused by erosion.

In the case of weathering, the rate at which weathered material can be removed from the slope exceeds the rate of weathering. Thus the denudation is controlled by weathering. Control by removal occurs when the rate at which weathering produces debris exceeds the rate of removal on the slope. In the case of a weathered controlled slope, the relative resistance of different rock types to weathering controls the slope form, whereas in the case of a removal controlled slope, the slope form is determined by the nature of the regolith that is produced.

The fundamental distinction between erosional and constructional slopes is essential for understanding the nature of slope components. As water removes material and carries it down a slope, it tends to erode the upper section but, if the amount of material removed at the base of the slope is not equal to the supply from above, deposits of material at the foot of the slope may result.

Variations in lithology will, however, complicate the above analysis of slope form. To overcome this Dalrymple, Blang and Connacher have developed a hypothetical 9 unit land surface model (Douglas 1978 ;37). In unit 1 pedological processes involving the area where throughflow is important. The convex unit 3 is dominated by soil creep while unit 4 is a free face of rock outcrop affected by rockfalls. Unit 5, the transport mid slope zone is similiar to but not equivalent to the straight or constant slope mentioned previously. The dominant process is the transportation of material across the unit. The deposition of colluvial material dominates the straight or concave unit 6, while unit 7, the equivalent of a flood plain is dominated by the deposition of alluvial material brought down the valley by the river. The erosive and transport action of the river dominate the channel wall, unit 8, and the channel bed, unit 9.

Such an analysis of slope forms may be applied reasonably accurately to the slope profiles surveyed in this study. On section A-B, units 1 and 2 may be thought of as operating between chainage 0 and 66.40. Between chainage 66.4 and 122.80 unit 3 is in operation. Unit 5,the transport mid slope zone,lies between chainage 122.80 and 178.80. Unit 6, the deposition of colluvial material zone lies between chainage 178.50 and 216.70, while the equivalent of Unit 7, the river flood plain,operates between chainage 216.70 and 316.80.

Unit 8, the steep channel wall lies between chainage 316.80 and 321.20, while unit 9, the channel bed, operates at chainage 312.20. Thus while all of the units may not be in operation on any one slope profile, nevertheless the analysis gives a clearer understanding of slope form. A similar analysis may be applied to section A-C.

The soil samples analysed in the laboratory revealed the following results. The moisture contents of the soil samples show the highest moisture content coming from sample no.1. The lowest value was obtained from sample no. 3, but the moisture content values rise again for samples no. 5 and 7. The high moisture content for sample no. 1 can be explained by the fact that the samples were taken on a wet day after several days rainfall. The low porosity and high permeability of coarser grained soils would allow for a temporary high moisture content. This high moisture content would facilitate transportation of smaller soil particles. Sample no. 3 was taken from an overgrown area thus accounting for its low value. The siltier clayish soil samples 5 and 7 would be expected to have a high porosity. The moisture content remains constant for samples taken from similiar elevations resulting in the moisture content of samples 2 and 6 and 5 and 7 being similar.

The plastic limits are again indicative of finer grained soils being present at lower elevations in the field. Sample nos. 2 and 3 taken from the steepest slopes have the lowest plastic limits. Highest values are again obtained for samples taken from the lowest elevations in the field.

The natural water content of a soil when expressed as a function of the plastic range (or plasticity index, P.I. = (L.L.-P.L.) is known as the liquidity index (L.I.) and is defined as:

$$L.I. = \frac{(W - P.L.)}{(L.L. - P.L.)}$$

Where W - moisture conte

Thus at their liquid limit all soils have a liquidity index of 1.0, at their plastic limit a liquidity index of 0.0, while negative values apply at water contents below the plastic limit. These index tests work well for soils with a high clay content. The liquidity indices of the three samples analysed are above their liquid limits and these indices increase from samples no. 1 to no. 5 as one moves down the slope. These tests however can be unreliable as they are carried out on disturbed samples that might well behave differently in situ. In this case, however, a comparison can be made between samples from different areas of the field.

The percentage of organic matter contained in the soil samples again follows the same basic trends as in the moisture content and plastic limit tests. A greater percentage weight loss after ignition occurs in the lower elevations indicating a greater amount of organic matter in these soils. This may be also indicative of a clay presence in the lower areas, as an increased proportion of weight loss could be due to destruction of the lattice and other minerals. The high percentage weight loss for sample no. 1 may be due to the fact that this section of the field contains the most abundant vegetation.

Sieve analysis and the modified pipette method of particle size analysis, while not indicating any great differences in particle size composition between samples, do however substantiate trends found in the previous tests. Taking for example the sieve analysis for soil sample nos. 1, 3 and 5, it is clear that sample no. 5 contains a higher percentage of smaller particles than sample no. 3 which in turn contains a higher percentage than sample no. 1.

In summarising the results of the soil tests it is apparent that, though all the samples appear to be reasonably graded, samples taken from the lower elevations contain a higher percentage of finer grained particles of fine silt particles. Samples from the higher elevations also contain a reasonable percentage of fine particles but this percentage decreases on steep sections of the slope.

The results tend to support the argument that a percentage of fine particles has been removed from the steepest slopes by hill-wash and deposited in the poorly drained lower elevations.

> "Water is of vital importance to the denudational process of the landscape" (Weyman 1977;13).

Water moves in a cycle, entering the landscape as precipitation and leaving it either as runoff or evaporation and transportation. Water enters the soil by infiltration at varying rates depending on vegetation or the permeability and porosity of the soil. During periods of intense rainfall a certain amount of overland flow may occur depending on the soil's ability to allow water to percolate through it. The results of three percolation tests carried out in the analysis are as follows:

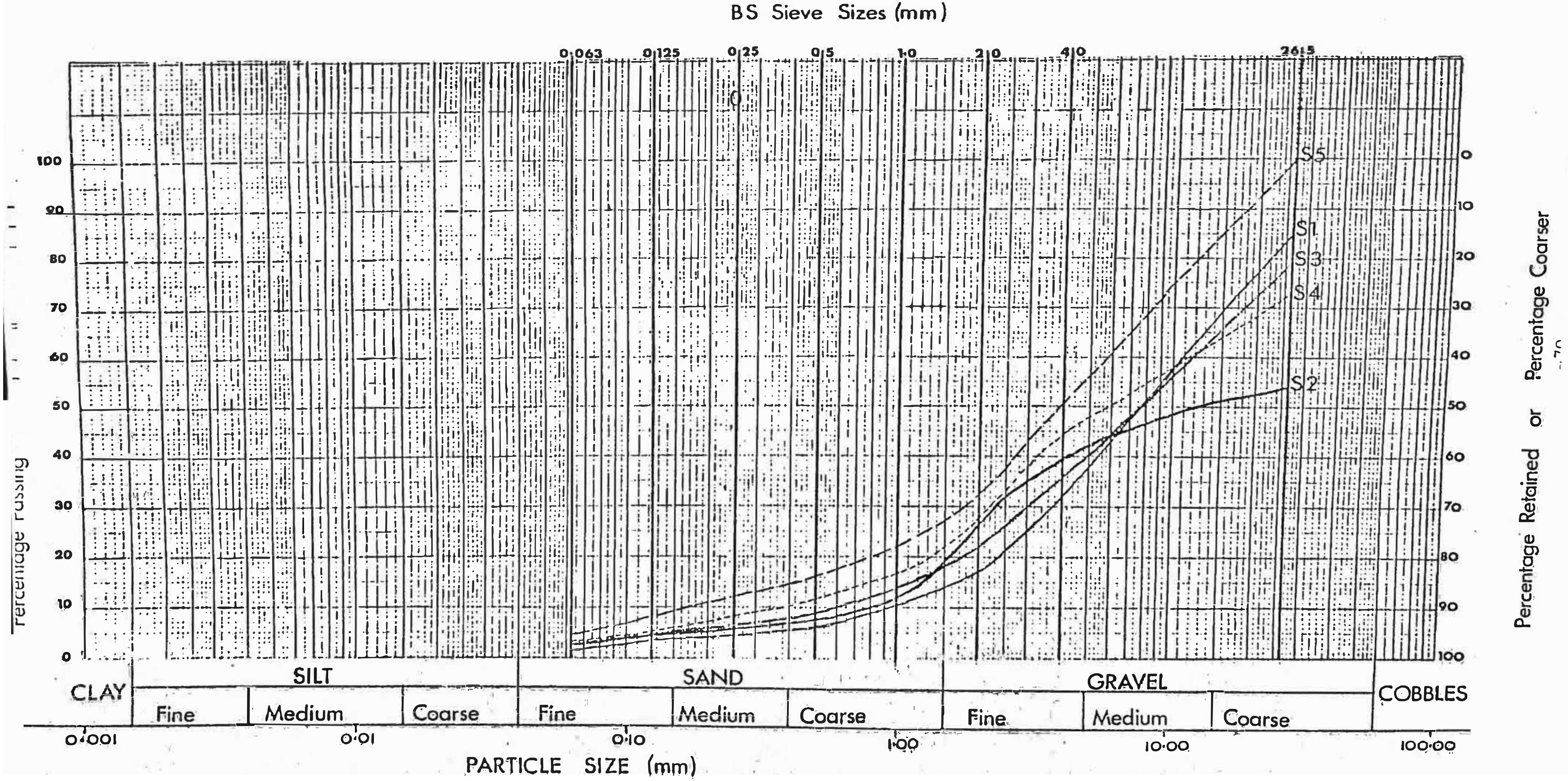
Test No.	Time T.
1.	6.06 mins.
2.	12.70 mins.
3.	over 60 mins (test failed)

The time T is the time taken for 25mm. depth of water to percolate through soil. The percolation rate decreases down the slope implying higher moisture content and less permeability. At the higher elevations in the field, rock is found near the surface. As this Red Sandstone is less permeable than the soil, most water moves downslope either over the soil or within the soil as throughflow. This causes an increase in the moisture content of the soil and increases the possibility of erosion by transportation. Water entering the more permeable and fractured rock nearer the surface forms the ground water zone. Ground water usually emerges along the beds of streams but this is very hard to detect. The springs in the area could be a result of ground water in the permeable rock being forced to emerge on the surface of hills due to the presence of an impermeable layer of rock below it.

Fig.6 SIEVE ANALYSIS GRAPHS

Showing results obtained from sample Nos 1, 2, 3, 4, & 5

Samples taken from Section A–C



The amount of water flowing in a river depends mainly upon the size of its catchment area and secondly upon the level of precipitation. The drainage basin for a stream is the total area supplying water to the stream. Water enters the drainage basin as precipitation and leaves it again as evapotranspiration or river discharge. During the course of one year a drainage basin usually becomes neither increasingly wet or increasingly dry. The basin will remain in roughly the same moisture state. In other words the amount of water entering the basin will be very close to the amount leaving it.

The water balance equation states:

Precipitation = Runoff + Evapotranspiration.

Two flow measurements were taken in streams bounding the site as part of this analysis. However, to obtain a clear picture of the drainage characteristics of this area, records of flow and precipitation would need to be taken over a period of at least one year. A rating curve, storm hydrograph and flow duration curve for the streams would reveal information on the storage capacity of the soils and bedrock.

In areas of temperate climate chemical erosion powered by the presence of water varies with three main factors.

1. The type of minerals present in the rock.
2. The availability of natural acids.
3. Temperature.

Chemical weathering may be more effective beneath some soil covers, where the carbon dioxide content is increased by biological activity. Organic acids derived directly from the decomposition of chemical weathering consequently on hillslopes such as the one being analysed in this project. Chemical weathering is certainly more effective than physical weathering in areas of temperate climate. Physical weathering normally leaves a larger sized residue and the residue from this type of erosion is not normally chemically altered. Chemical weathering on the other hand usually produces a residue consisting of clay particles. If this material is colonised by vegetation, a soil develops that has a higher quantity of organic matter. This fact would also enhance earlier points made from the result of the percentage organic matter test showing samples at lower elevations having a higher weight loss on ignition.

If water content increases greatly in a soil containing a high percentage of smaller sized or clay sized particles, mass movement can take place in the form of mud flows. The samples analysed in this project would appear to be clayish enough on the steeper sections to flow considering the amount of rainfall and the amount of vegetation present. However it can be seen from the contour survey that many horse shoe shaped areas and terracettes are identifiable on an at the bottom of the steeper sections. These features are indicative of mud flows that may have occurred during earlier periods in different conditions with respect to climate and vegetation

Although mud flows are rare on normal slopes, a slower form of the same process takes place almost everywhere. Soil creep is the very slow movement of soil down a hillslope. Factors such as wetting and drying or heating and cooling of particles, plant activity or just animal grazing will allow gravity to pull the soil particles farther down the slope. The rate of creep rarely exceeds 1mm. per year and is therefore too minimal to measure. In the steep horse shoe shaped overgrown area of the field being examined, soil can be seen piled up behind some of the tree trunks and small terracettes can be seen on the down slope side.

6. CONCLUSION

The subject of hillslope analysis is very complex. At the simplest level, hillslope shape appears to be the product of differing rates of weathering and mass movement at various points on the slope.

On any hillslope there is a relationship between the rate of weathering and the rate of transportation. In the two sections surveyed for this project a convex - concave hillslope shape can be identified. The upper convex part of the slopes appear to be the areas most prone to creep. Since more weathered material is added progressively downslope, it follows that either soil depth or velocity of soil creep must increase in a downslope direction. However since soil depth controls the rate of weathering, the effect of increasing downslope soil depth is to produce a convex slope. Once a convex slope is established, the velocity of soil creep increases downslope, leading to a more constant soil depth and a more uniform rate of weathering. A convex slope is therefore self perpetuating. The above hypothesis would account for the slope profiles existing in Coolyduff.

Over time the topography of the field will change. Forces of denudation acting on the area over time could expose large areas of rock on the top of the hill and the flat area on the bottom may become more clayish and swampy. The lower area of the field could be drained by the use of "French drains" and also by filling the low area below the 25m. contour. Drainage would also be improved in this area by planting trees.

The fact that this project examines the area at one point in time is important. To gain a clearer understanding of the rates of denudational processes, in action on the area, further investigation would be required over a longer period. The contour survey and sections could be redrawn at a later date as the four instrument points have been fixed points on the landscape.

In other words it would be possible to set up the theodolite at any one of the four stations again and resurvey any one of the original points surveyed, by referring to the computer print-out for their locations. In this way rates of mud flow and soil creep could be monitored in conjunction with other field tests such as the placing of tubes in the ground to measure creep at different levels.

In conclusion, the results of this project point to the validity of a convex-concave type slope development process being at work at this site. This is emphasised both by the results of the topographic surveys carried out and also by higher percentage of fines found in the soil analyses at lower elevations. Slope evolution in the future is likely to proceed by means of a process of slope replacement where the maximum angle decreases through replacement from below by gentler slopes causing a greater part of the slope to be occupied by concavity.

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