SOIL
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Land Resoures and Land Use Study

Hill End and Environs

August, 1981.

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SOIL CONSERVATION SERVICE OF NEW SOUTH WALES

LAND RESOURCES AND LAND USE STUDY

HILL END AND ENVIRONS

Prepared for

National Parks and Wildlife Service of New South Wales

August, 1981

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PREFACE

This report examines the development potential of the study area in terms of its physical resources and provides a guide for the management of these resources to mitigate soil erosion

While the maps are intended to assist in land use planning, it is important that information is not extracted from them at a scale larger than the scale of the originals.

The maps and the report are not a substitute for detailed investigations which may be required for a specific management plan. Rather, they provide a basis on to which other management considerations may be imposed.

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LIST OF TABLES, FIGURES AND MAPS

SUMMARY

This report provides an assessment of the physical resources of an area of 2,940 hectares at Hill End. Rural and recreational land capabilities have been derived from an evaluation of these resources and a soil conservation strategy plan formulated as the basis of controlling soil erosion within an area of major historical significance.

Soil erosion occurs throughout the study area. 79 per cent of the study area is affected by minor to moderate sheet erosion and a further 13 per cent is severely sheeted. The remaining 8 per cent, encompassing about 200 hectares, is affected by gully erosion. Of this area 148 hectares is severely gullied, with substantial sections of channel being greater than 3 metres in depth. Over a million tonnes of soil was estimated to have been lost from the main mining areas.

Potential rural and recreational land use is assessed in terms of the capability of the land to support various uses without initiating severe soil erosion.

The majority of the study area is suitable for grazing purposes but requires various conservation measures. A very high erosion hazard is associated with the steep terrain and these areas are best suited to green timber. The extreme physical limitations imposed by existing severe gully erosion render such areas unsuitable for rural production. Management should aim at minimal disturbance and encouragement of vegetation.

About half the study area is suitable for active recreation, but high intensity uses, such as camp sites, are restricted to a relatively small proportion. The other half is suited to passive recreational pursuits. However, strictly controlled access and special erosion control measures are required in areas affected by severe gully erosion. These areas include the erosional features within Hill End Historic Site and along Golden Gully.

For effective implementation of the soil conservation strategy plan co-operation is required by all interest parties to formulate a basic development plan which identifies special purpose areas. Appropriate erosion control and stabilisation measures can then be designed and implemented for special projects with the total aim being landscape stability. As part of the plan, a programme should be adopted to monitor rates of soil erosion to assist with long term erosion control and remedial measures.

This report should be used as a guide to planning and development of Hill End and its environs to ensure long term surface stability. Actual design and implementation of the proposals will require further detailed data collection and assessment for specific development plans. The Soil Conservation Service of New South Wales is available to assist with any proposals in respect of erosion control and stabilisation measures.

SUMMARY - LAND CAPABILITY

RURAL CAPABILITY

Class	Capability	Percentage Distribution
IV	Land suitable for grazing, requiring simple soil conservation practices to prevent or control soil erosion.	30
V	Land suitable for grazing, requiring intensive soil conservation measures to prevent or control soil erosion.	20
VI	Land suitable for grazing, requiring special soil conservation measures to prevent or control soil erosion.	28
VII	Land best suited to green timber because of its steepness, shallow soils and/or high erosion hazard.	17
VIII	Land unsuitable for rural production because of extreme physical limitations.	5

RECREATIONAL CAPABILITY

Class	Capability	Percentage Distribution
A	Land suitable for active recreation - high intensity use.	10
B	Land suitable for active recreation - moderate intensity use.	40
C	Land suitable for passive recreation - low intensity use.	25
D	Land suitable for passive recreation - undeveloped access.	20
E	Land suitable for passive recreation - controlled access.	5

INTRODUCTION

The 2,940 hectare study area is situated in the Central Tablelands of New South Wales, about 70 kimometres north of Bathurst. It encompasses the Village of Hill End including Hill End Historic Site, the Town of Tambaroora, and Hill End/Tambaroora Common. The northern and eastern boundaries have been extended beyond the Common to include the catchment of Tambaroora Dam (Figure 1).

This study was undertaken at the request of the National Parks and Wildlife Service of New South Wales to assist them in the development of a Plan of Management for Hill End Historic Site.

Hill End Historic Site was gazetted in October, 1967. A primary aim of its management is to maintain the overall physical "character" of Hill End. This "character" is, in part, reflected in the erosional features of the area.

Hill End's existence is due to the mining of gold. Gold mining commenced in the early 1850's. Workings continued to establish steadily, reaching a peak during the period 1870-1872. Spasmodic activity occurred after this period decreasing to the relatively low levels of the present day. The "rush" of the 1870's so disturbed the landscape that gully and sheet erosion initiated at that time continues at a significant level.

Hill End/Tambaroora Common was set aside as a temporary common in the mid 1870's and notified in June, 1903. Open grazing has been a traditional feature of the Common. Grazing stock also move relatively freely throughout other parts of the study area. This style of grazing is considered by National Parks and Wildlife Service to contribute to the "character" of Hill End.

The study involved the collection and evaluation of physical resource data to assess the extent of soil erosion problems in the area, to derive land capability classifications for rural and recreational uses, and to develop a soil conservation based strategy plan for the control and mitigation of soil erosion whilst recognising the historical significance of the area.

Climate, geology, soils, landform, land use, native vegetation, and existing soil erosion attributes have been collected for the inventory.

The capability classifications identify the limitations to the use of the land as a result of the interaction between the physical resources and a specific land use. The principle limitation recognised is the stability of the soil mantle. These capability classifications do not constitute an overall recommendation for particular forms of use or development on specific areas, as no account has been taken of other management considerations. Rather they form a basis onto which these other factors may be imposed to derive suitable land uses consistent with the need to achieve effective soil erosion control.

The soil conservation strategy plan is designed to assist planners in recognising the constraints and opportunities of available resources to permit a greater flexibility in planning. This will result in plans compatible with community needs and give full recognition to the environment.

To ensure effective use of this report, officers of the Soil Conservation Service of New South Wales should be consulted during the design and implementation of soil erosion control and stabilisation measures within Hill End and its environs.

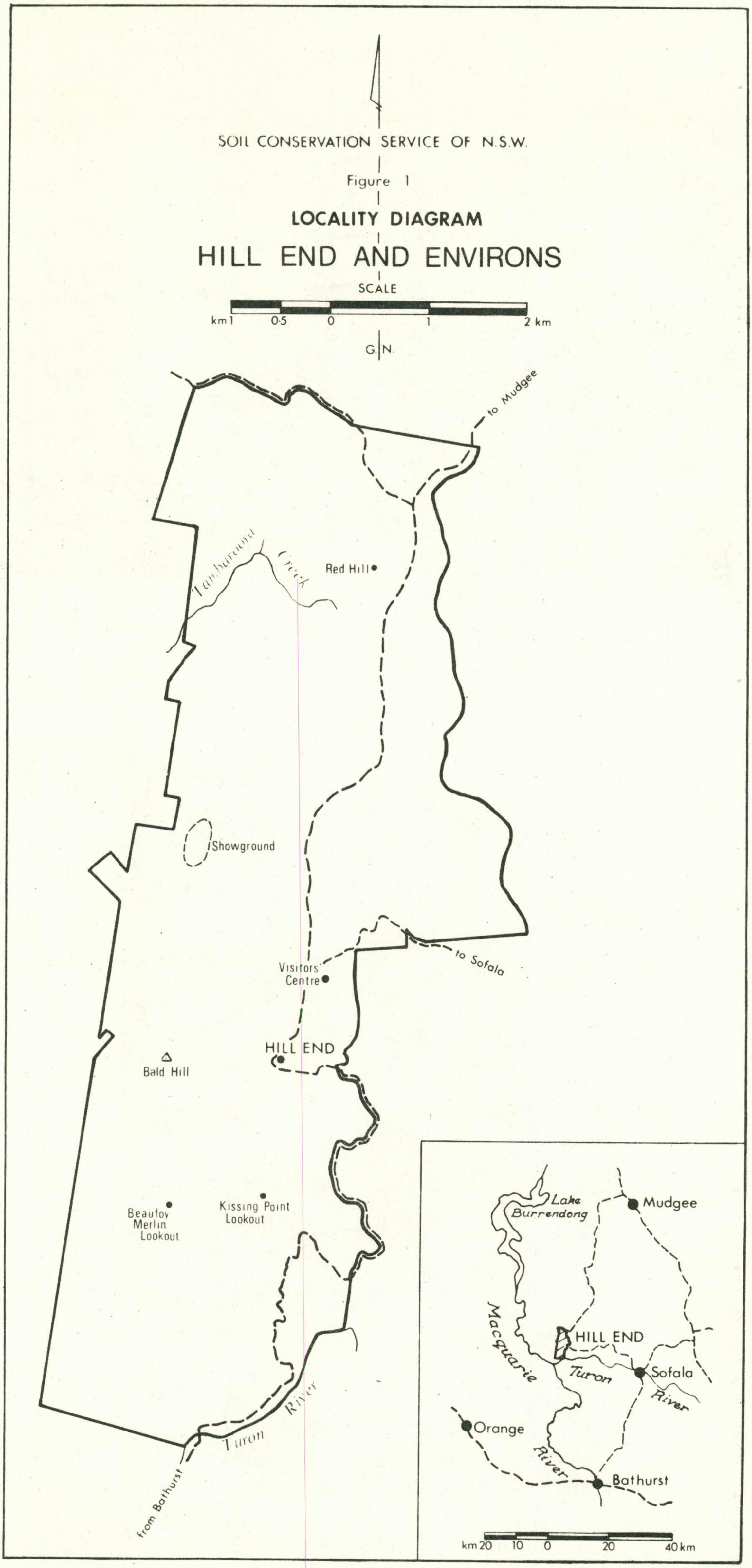

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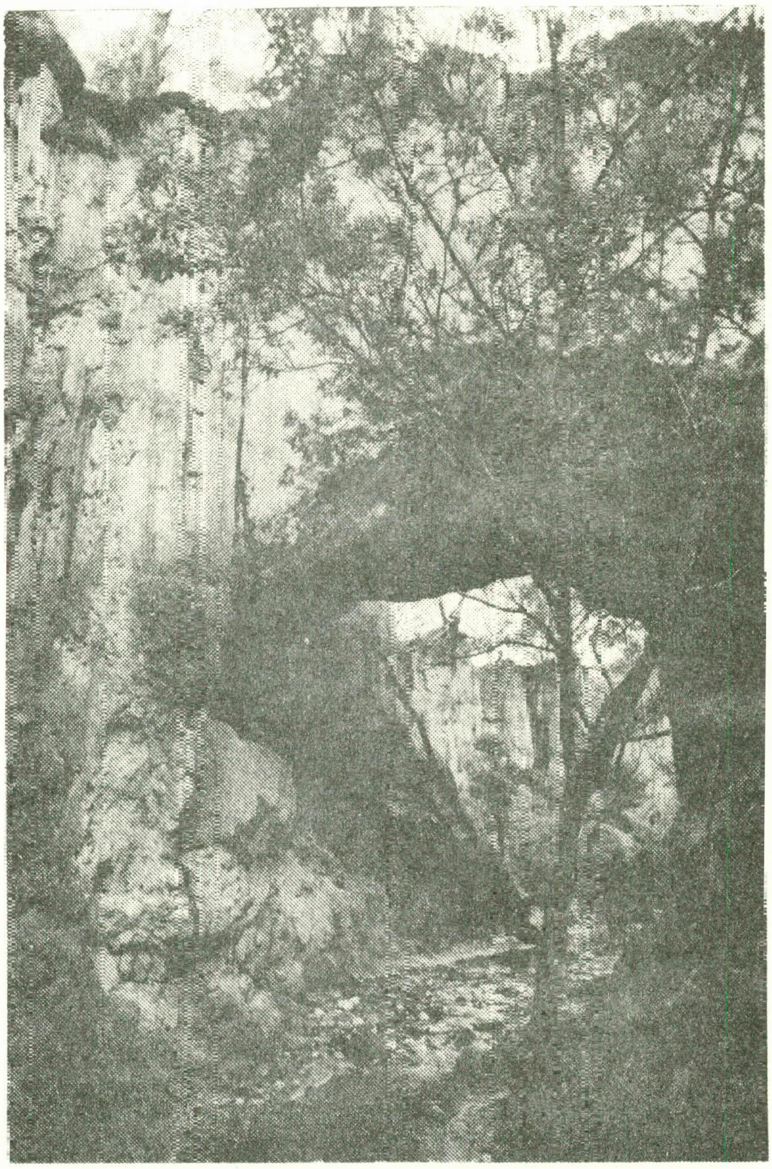
Figure 1

LOCALITY DIAGRAM

HILL END AND ENVIRONS

Reflections of Hill End's character -
Wistaria House (above) and Golden Gully Arch (below).



PART A

INVENTORY OF PHYSICAL RESOURCES

A.1 METHOD OF SURVEY

Land resource information was collected by the stereoscopic interpretation of aerial photographs, supplemented by field reconnaissance surveys to update the ground information where appropriate.

Due to the lack of suitable base maps at the time of the survey, an aerial photograph enlargement at an approximate scale of 1:20,000 was used for the base map. The final presentation of data is on maps of a similar scale and these may be viewed at the Orange Office of the Soil Conservation Service. Copies presented in this report have been reduced in scale for convenience.

A.1.1 Landform, Land Use and Erosion.

Landform, land use and the observed active erosion pattern were mapped concurrently.

Landform.

Landform is a composite resource feature comprising the two individual elements of slope and terrain. Details of the landform classification system used by the Soil Conservation Service are described by Emery (1981).

Slope intervals are selected on the basis of practicability and experience in data evaluation for land capability classification. The particular intervals chosen result from an assessment of the interrelationships between soil and erosion hazards for specific types of land use.

The terrain component describes the physical appearance of landscape segments. It is a morphological description and does not necessarily imply the geomorphological processes operating on the slope.

The following slope and terrain classes are defined:

Slope Class (per cent)	Code
0 - 1	A
1 - 5	B
5 - 10	C
10 - 15	D
15 - 20	E
20 - 30	F
30 - 50	G
Greater than 50	H

Terrain Component	Code
Hillcrest	1
Sideslope	2
Footslope	3
Floodplain	4
Drainage Plain	5
Incised Channel	6
Disturbed Terrain	7

Land Use.

Land use has been mapped as a separate attribute to record the current level of use within the area and to examine its influence upon soil erosion.

The following land uses are defined:

Land Use	Code
Orchards	1
Semi-improved pastures	2
Native pastures	3
Partially cleared timber	4
Native timber	5
Mine spoil dumps	6
Hill End town centre	7
Quarry sites	8

Soil Erosion.

A knowledge of the extent and severity of soil erosion is used to determine the types of measures required for its control. The techniques for mapping soil erosion from aerial photographs are described by Emery (1975).

The following soil erosion classes are defined:

Erosion Class	Code
Minor to moderate sheet erosion	b
Severe sheet erosion	c
Minor gully erosion	d
Moderate gully erosion	e
Severe gully erosion	f

Depth of Gullies	
Less than 1.5 metres	- 1
1.5 - 3 metres	- 2
Greater than 3 metres	- 3

A.1.2 Native Vegetation.

In conjunction with land use mapping a survey of native vegetation was undertaken. Broad vegetation patterns were delineated using aerial photograph interpretation, with tree density being the principle parameter. Any discernible change in pattern provided a point source for field verification.

A.1.3 Soils.

A soil survey was carried out to describe the dominant soil types and to identify those soils where potential instability problems are likely to occur. Soils were sampled on the basis of a geological/ terrain unit. Final soil map boundaries were drawn using landform, ground survey information and aerial photographs. Thirteen profiles were examined. Observations were also made on the amount of rock outcrop.

The identification of soil series, and their constraints to development is consistent with other soil surveys undertaken by this Service in the Central Tablelands of New South Wales, including Hannam etal (1978), Quilty etal (1978), and Houghton and Emery (1981).

A description of individual profiles and the major soil units is given in Appendix VI, Part 1 and Part 2 respectively. Northcote Codes (Northcote, 1974) are used for descriptive purposes. Laboratory analyses of soil samples are shown in Appendix VI, Part 3. A glossary of soil survey terminology is provided in Appendix VII.

A.2 CLIMATE

The climate of any area is of major importance because of its relationship to plant growth, runoff, and soil erosion.

Climatic data for Hill End are summarised in Table 1.

A.2.1 Analysis of Climatic Data.

(i) Plant Growth Model.

Probabilities of availability of unrestricted soil moisture for plant growth, for the three months following any particular month, are shown in Table 2. Soil moisture conditions are most favourable for plant growth during winter. During the period April to September there is better than a 50 per cent chance of having the three following months with adequate soil moisture for plant growth.

Table 2 also shows the likely occurrence of drought periods for three monthly intervals following any particular month. December, January and February are, on average, the driest periods with drought conditions likely about one year in five.

Using the plant growth model described by Edwards (1977), the growth curve for cool season species is depicted in Figure 2. When moisture conditions are optimum for growth, the moisture index is 1.0, and when completely limiting it is zero. The same limits apply to the temperature index. The growth index is taken as being the lower of the two indices.

The growth curve shows a prominant peak during spring and a secondary peak during autumn. Plant growth is depressed during winter owing to temperature stress, and summer owing to moisture stress.

(ii) Rainfall and Erosion.

Median annual rainfall is 771 millimetres. Although rainfall is fairly evenly distributed throughout the year (Figure 3), winter rainfall tends to be more reliable.

Intensity and duration of rainfall are important factors in causing soil erosion. High intensity storms of short duration generate sheet and rill erosion on bare areas. Long duration low intensity rainfalls tend to saturate the soil and may be a factor in the initiation and extension of gullies. In the Hill End area high intensity storms occur most frequently, on average, during the summer months, while soil saturation is common during the winter.

A.2.2 Climate and Land Use.

(i) Ground Cover Establishment.

Cool season species are recommended. Optimum sowing time would be March - April to allow establishment while warmer weather persists and soil moisture levels are moderate.

Establishment of warm season species in spring will be more risky. Allowance should be made for possible over sowing or re-sowing of such areas in autumn. Quick growing cover crops such as Japanese millet or hybrid sorghum could be sown on critical areas where protection during the summer months is essential.

(ii) Tree/Shrub Planting.

Tree/shrub planting programmes are best arranged for March - April to give seedlings the most favourable establishment conditions.

(iii) Surface Disturbance.

When installing earthworks that result in large scale surface disturbance, autumn is the preferred time. The likelihood of high intensity storms is diminished and follow up revegetation works can proceed under optimum conditions.

Construction operations and general off-road trafficking are most difficult and most damaging during the period July - October. It is during this time that soil saturation and subsurface seepage are most likely, particularly on low lying terrain such as footslopes and drainage plains.

(iv) Fire Season.

The main period of vegetative growth during the late winter to early summer period, coupled with seasonal drought conditions about one year in five, will produce intermittent high fire danger periods during the summer months. Efforts should be made to reduce surplus growth during October and November.

TABLE 1: Summary of Climate Data - Hill End*

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Median Rainfall (mm)	65	47	52	47	51	70	56	69	51	62	55	57
Per cent Deviation	41	65	48	57	52	40	35	37	35	48	52	57
Mean Evaporation (mm)	215	165	140	95	50	40	40	50	80	115	150	200
Mean Temperature (°C)	20.7	20.4	18.1	14.1	9.2	7.5	5.8	7.2	9.9	13.6	16.5	18.5

*Bureau of Meteorology

TABLE 2: Moisture Levels 3 Months following Particular Month*

Month	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Unrestricted moisture Probability for 3 months period	.05	.08	.22	.52	.89	1.0	1.0	.94	.74	.35	.12	.05
Probability of 3 months drought period	.26	.16	.03	.00	.00	.00	.00	.00	.00	.01	.07	.23

*Analyses by S.C.S. Biometry Section

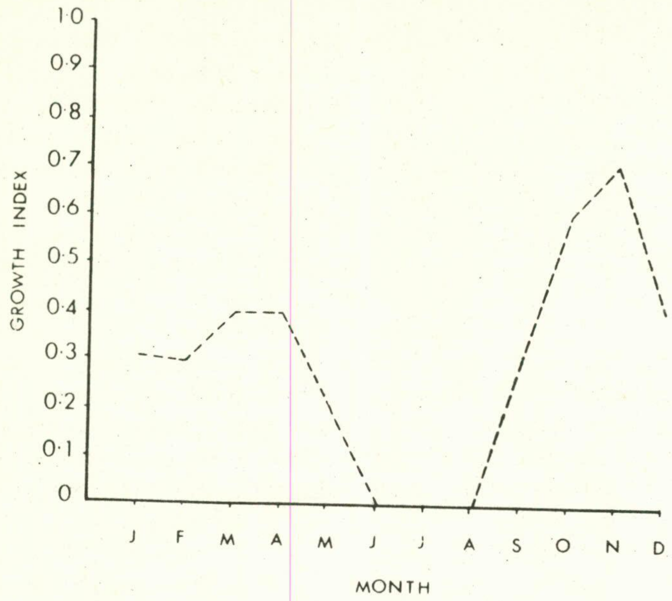


Fig. 2 : Growth Index - Cool Season Species

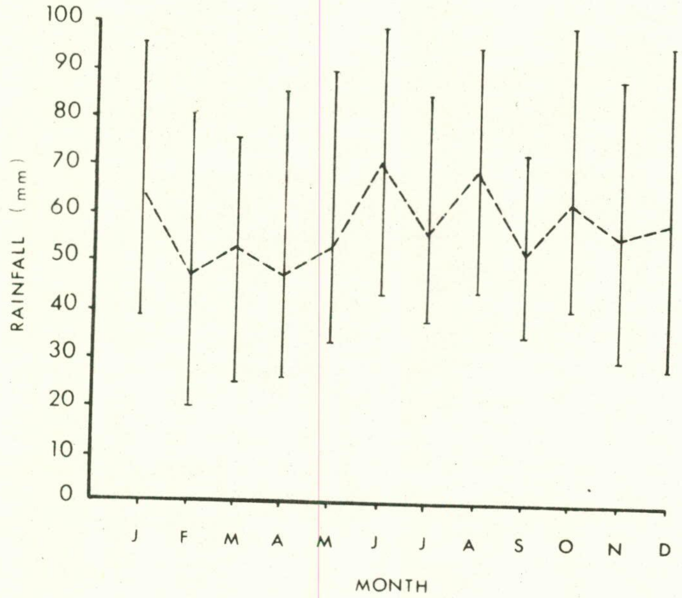


Fig. 3 : Rainfall Distribution (84 years records)

A.3 GEOLOGY

A.3.1 Regional Geology.

Hill End is located within the geological province known as the Hill End Trough. The province is a major sedimentary basin of Silurian-Devonian rocks comprising part of the Lachlan Geosyncline. It is flanked by the Molong Geanticline to the west and the Capertee Geanticline to the east. These major structures all have axes with approximate north-south orientation.

The sediments within the Hill End Trough have been deposited to a depth of six to seven kilometres (Webber and Baker, 1977).

The Silurian sequence is comprised of the Chesleigh and Cookman Formations. The Chesleigh Formation is the thicker of the two units. Its basal sections are composed of quartz-rich greywackes and slates. In contrast, the upper sections contain acid volcanic material ranging from fine tuffs to breccias with greywackes being more felspathic (Packham, 1969).

The Cookman Formation conformably overlies the Chesleigh Formation. Characteristic lithology is medium grained, quartz-rich greywacke. Packham (1969) suggests that the Chesleigh Formation may have been uplifted along the eastern edge of the Hill End Trough to provide a sedimentary source for the Cookman Formation.

The Siluro-Devonian sequence consists of the Crudine Group. The group comprises the basal Turondale Formation, largely composed of material of volcanic origin, overlain by the Waterbeach Formation which is dominated by shales and greywackes (Packham, 1969).

Merrions Tuff and the Cunningham Formation complete the Silurian-Devonian stratigraphic column, but do not outcrop within the study area.

A.3.2 Local Geology.

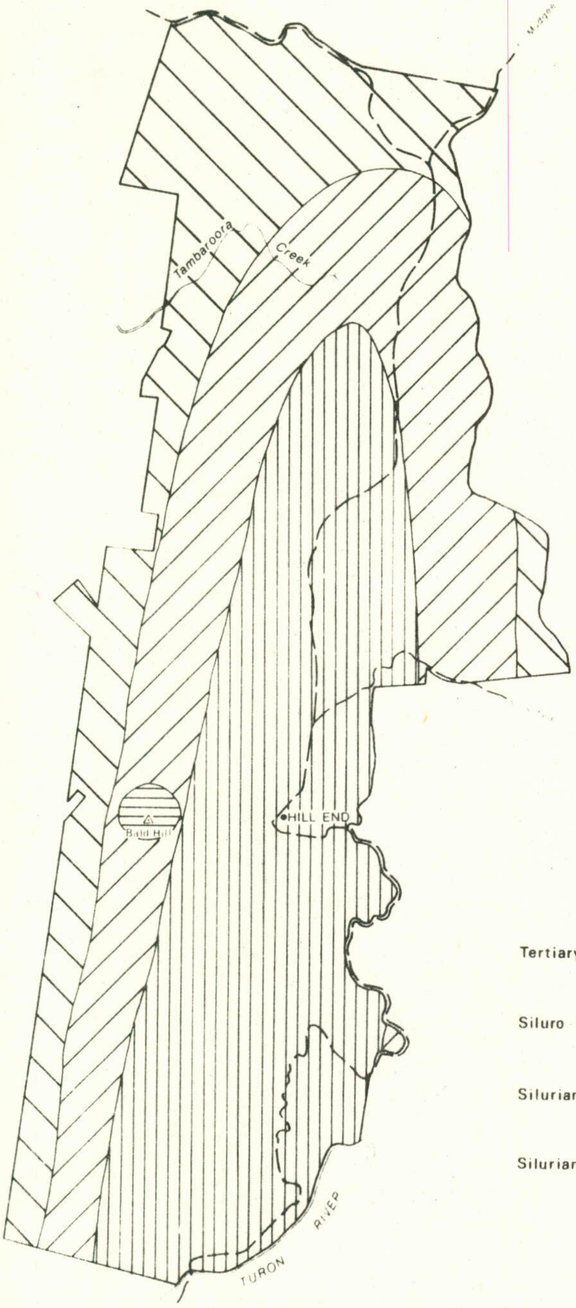
Geology of the study area is shown in Map No. S.C.S. 14739A.

The Chesleigh Formation outcrops in the centre of the study area. Its exposure has resulted from erosion of a major fold known as the Hill End Anticline. The formation includes the gold bearing deposits which run from the South Star Line Gold Reefs to Golden Gully.

A detailed description of the Chesleigh Formation, in the region south of Hill End Village, is given by Webber and Baker (1977). Grey, tuffaceous siltstones, sandstones and slates outcrop with poor sorting evident in coarse grained rocks. Characteristically, these contain angular grains of quartz and feldspar, in a matrix of quartz, white mica and chlorite. Voids commonly present in the rocks are probably relics of feldspar crystals.

The Cookman Formation outcrops adjacent to the Chesleigh Formation and is similarly dominated by quartz-rich greywacke. Tertiary basalt has intruded through these sediments at Bald Hill.

The Crudine Group forms the western and northern margins of the study area.



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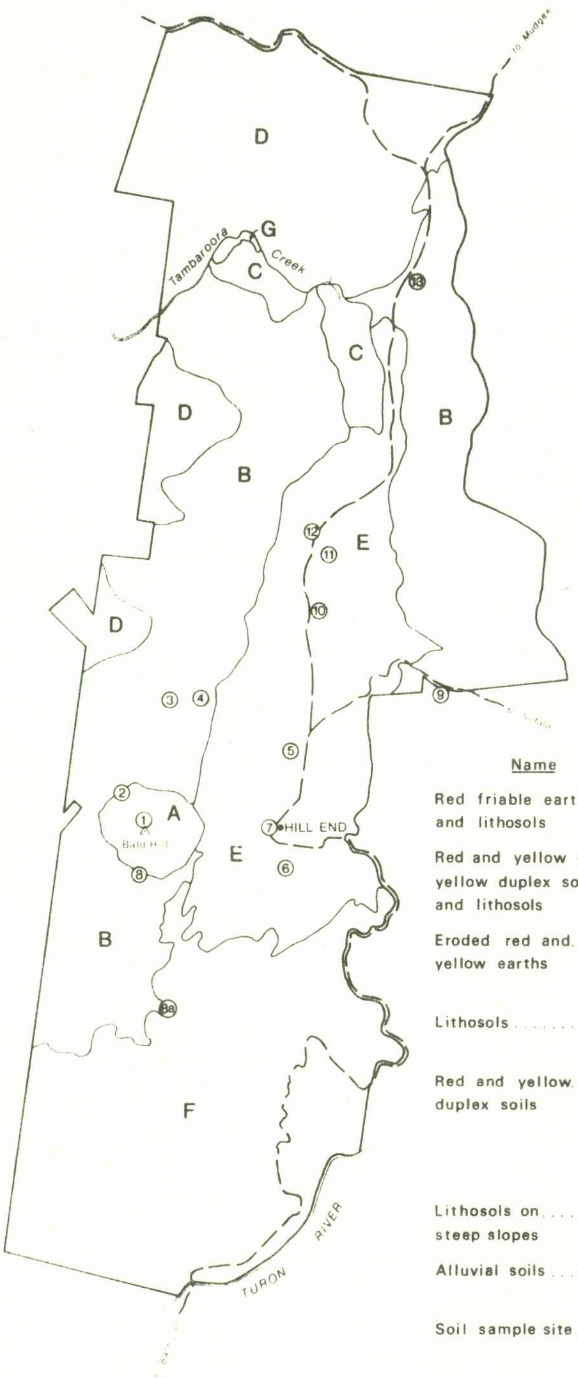
HILL END AND ENVIRONS

GEOLOGY

Tertiary		Basalt	
Siluro Devonian	Crudine Group	Slate siltstone, greywacke and tuffs and conglomerates	
Silurian	Cookman Formation	Quartzite like quartz, greywacke and slate	
Silurian	Chesleigh	Quartz rich greywacke and slate, tuffaceous at top	

S.C.S. 14739/A



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HILL END AND ENVIRONS

SCALE

kilometres 1 0.5 0 1 2 3 4 5 6 kilometres

SOILS

Name	Dominant Northcote Code	Limitations	Map Unit
Red friable earths and lithosols	Dr 4.11 Um 1.43	Shallowness on steep slopes and crests	A
Red and yellow earths, yellow duplex soils and lithosols	Gn 2.21 Gn 2.11 Dy 3.41	Very high erodibility, shallowness, poor profile drainage of lower slope soils in winter	B
Eroded red and yellow earths		Erosion pavements common, high runoff potential, difficult to revegetate	C
Lithosols	Uc 1.12 Rock outcrops	Rockiness, shallowness, very high runoff potential	D
Red and yellow duplex soils	Dr 2.41 Dy 3.41	High susceptibility to sheet and gully erosion, poor profile drainage of lower slope soils in winter, eroded areas difficult to revegetate	E
Lithosols on steep slopes	Shallow Uc soils	Steep slopes, rock outcrop	F
Alluvial soils	Uc and Um soils	Poor profile drainage in winter	G
Soil sample site			②

S.C.S. 14739/8

A.4 SOILS

A.4.1 Geology in Relation to Soils.

The controlling influence of lithology on soil types is evident in the vicinity of Bald Hill, where Tertiary basalt dominates. Red friable earths and lithosols are associated with this unit. For the remainder of the study area, where lithology of underlying rocks is basically the same, other factors, primarily topography, have a major influence on soil type.

On steep terrain in the southern and northern sectors of the study area, rock outcrop or shallow lithosol soils predominate.

Within the central portion of the study area, the landform is mainly gently sloping to undulating. Poor to very poor earth soils are found on the Crudine Group and the Crookman Formation. On the Chesleigh Formation relatively stable red duplex soils have formed on the hill crests and sideslopes, while on the footslopes and in the drainage lines unstable and infertile yellow duplex soils occur.

A.4.2 Soil Map Units.

Seven map units are defined (S.C.S. Map No. 14739B).

Descriptions of the individual profiles, the major soil units, and the laboratory analyses of soil samples are given in Appendix VI.

Map Unit A: Red Friable Earths and Lithosols.

Map Unit A is centred on Bald Hill. Soils range from stony shallow loams on the crest and steeper southern slopes, to red friable earths on the gentler slopes. They are inherently the most productive soils in the study area.

The surface soil of the red friable earth is about 10 cm deep, below which is a red friable, highly aggregated clay.

Rockiness and steep slopes are the major constraints to development of this unit.

Map Unit B: Red and Yellow Earths, Yellow Duplex Soils and Lithosols.

Within this Unit the red earths occupy the steeper slopes and better drained positions. Yellow earths occur on lower slopes, and yellow duplex soils (Peel Series) occur in drainage lines. Some lithosols may occur on steeper slopes.

The red and yellow earths are loam to clay loam soils approximately 90-100 cm deep. Surface soils are shallow (20 cm) and often stony. The yellow duplex soil of the Peel Series has a deep (40 cm) fine sandy loam A horizon over a yellow light clay.

The erodibility of the soils of this unit is very high, and they are subject to sheet erosion. The duplex yellow soils are subject to both sheet and gully erosion.

Soils are of low fertility, and revegetation programmes will require the addition of fertilizer and the retention and respreading of topsoil.

Drainage of the yellow earth and duplex yellow soils is poor in winter, and this will influence trafficability.

Map Unit C: Eroded Red and Yellow Earths.

Soil types are similar to those of Map Unit B, but they have been severely eroded, frequently to bedrock. Erosion pavements are common and revegetation is slow.

Soils within this unit are very stony.

Map Unit D: Lithosols.

Rock outcrop is the dominant feature of this unit. The occurrence of soil is patchy but where it does occur the soils are similar to those of Map Unit B.

The occurrence of rock outcrop is the main limitation to development of this unit.

Erosion hazard is generally low because of the large area of rock outcrop, but increases below the unit because of the high runoff.

Map Unit E: Red and Yellow Duplex Soils.

The red duplex soils (Worcester Series) occupy the sideslopes and crests, while the yellow duplex soils (Peel Series) occur on footslopes and in drainage lines.

The Worcester Series has a sandy loam to fine sandy loam A horizon, 25-50 cm deep, over a red clay subsoil. These soils are generally deeper than one metre. The Peel Series has a fine sandy loam to silty loam surface soil, up to 40 cm deep, over a dense yellow clay subsoil. Soil erosion has resulted in numerous variants of these two profiles. The most common are previously duplex red and yellow soils with the surface horizon eroded away, and the yellow duplex soils buried under erosion deposits.

The following limitations are associated with this map unit:

*Red Duplex Soils.

High erodibility of surface soil is associated with a high fine sand and silt component. The subsoil is less erodible, having a higher content of a relatively stable clay. As a result, the surface soil has often been removed by sheet erosion, exposing the more stable clay subsoil. However the red clay will also erode under extreme conditions as has occurred in the areas around the village and diggings.

Revegetation of the clay subsoil is difficult because of the poor physical structure and fertility for plant growth. Topsoiling of exposed subsoil is required to assist revegetation.

*Yellow Duplex Soils.

Erodibility of surface soil is high because of the high fine sand and silt component. The yellow clay subsoil also has a high erodibility, as the clay is frequently dispersible. Overall, the soil is subject to severe erosion, the surface soil to sheeting and the subsoil to gullying.

Gully erosion within the Peel Series is active at the present time. Extension of gully laterals and undercutting of gully sides is active, especially within Golden Gully.

During winter, drainage is poor, and soils will be wet for significant periods. This will affect trafficability.

Revegetation of the clay subsoil is difficult because of the poor physical structure and fertility for plant growth. Topsoiling of exposed subsoil will be required for revegetation works.

Map Unit F: Lithosols on steep slopes.

Soil development is minimal on the steep terrain of this unit and rock outcrop frequently comprises up to 90 per cent of ground cover. Soils that have developed are shallow, fine sandy loams, which are highly erodible.

Existing native vegetation and litter cover keep these sites relatively stable. Removal of this cover would cause severe erosion of these soils.

Map Unit G: Alluvial Soils.

This map unit is centred on the completely silted Tambaroora Dam. Soils are recent alluvials and include sands and some loams.

A.4.3 Soils in Relation to Land Use.

(i) Soil Erodibility.

With the exception of soils of Map Unit A, all soils are highly susceptible to sheet and gully erosion. Most soils are high in fine sand and silt and/or are dispersible.

Soils susceptible to severe sheet erosion comprise those which belong to Map Units B, C and E. A large proportion of these areas is already sheet eroded. Map Unit C (which has similar soils to Map Unit B) is the most severely affected unit. Map Unit E is severely sheeted in many areas, but the relatively stable red clay subsoil of the Worcester Series has prevented the formation of erosion pavements similar to those found in Map Unit C.

Although soils of Map Units D and F are highly susceptible to erosion, the overall level of sheet erosion is low mainly as a consequence of the high proportion of rock outcrop. However, the high percentage of rock increases the erosion hazard of land below these areas because of the increased runoff.

Soils in the drainage lines of Map Units B and E (Peel Series) are highly susceptible to gully erosion because of the high percentage of dispersible clay in the subsoil. Gully erosion is prominent in both units. Gullying is more severe in Map Unit E because of a greater depth of soil.

(ii) Soil Drainage.

Much of the area is poorly drained in winter, particularly those sites with yellow duplex soils. These soils can be expected to be at or near saturation for most of the winter months, creating problems for trafficability.

The alluvial soils are also poorly drained and likely to be waterlogged in winter.

(iii) Shrink-Swell Potential.

No areas of high or very high shrink-swell activity were observed in the study area. Soils of moderate shrink-swell activity were observed in the red duplex soils of Map Unit E.

(iv) Rockiness.

Rock outcrop is common throughout the study area. The rock is relatively hard and its outcrop is a constraint to land use and development.

Rock outcrop dominates in Map Units D and F. Within Map Unit C erosion pavements are common and bedrock is frequently exposed.

Shallow soils are a problem on the crest of Bald Hill, where depth to bedrock may be as little as 10 cm. Shallowness is also a problem in Map Unit E, where weathered or hard rock or floaters frequently occur within 90 cm of the surface.

(v) Use of Material for Earthwork Construction.

The construction of soil conservation banks and gully control structures is severely limited in parts of all mapping units.

Map Unit A: steep slopes and shallow depths to bedrock.

Map Unit B: The yellow earths and the yellow duplex soils are susceptible to tunnelling, which is most severe in the Peel Series. Shallowness may also cause problems in constructing gully control structures.

Map Unit C: has similar problems to Map Unit B, with the additional problem that weathered rock is often exposed at the surface.

Map Unit D: rockiness.

Map Unit E: red duplex soils - generally suitable for earthwork construction. Some problems of leaking because of high aggregation may restrict their use for water retention structures.

: yellow duplex soils - susceptible to tunnelling. Soil testing of individual sites is advised.

Map Units F and G - earthworks not recommended.

(vi) Problems of Vegetative Growth.

Within the study area, there is an overall deficiency of topsoil because of severe sheet and gully erosion.

A large proportion of the area, especially within Map Units C and E, has exposed subsoil or weathered rock, which provide an adverse physical and chemical environment for plant growth. Detailed investigations are required to assess the potential of revegetation programmes in these areas. Importation of topsoil may be required in some cases.

Any future development that will disturb the land surface should make provision for stockpiling of available topsoil for later respreading.

A.5 LANDFORM

The area and percentage distribution of each landform class is presented in Table 3, and on Map No. S.C.S. 14739C.

Hill End Historic Site is located within the upper reaches of Hill End Creek. The landform comprises a typical upland valley with gently sloping sideslopes and footslopes merging onto narrow drainage plains. Sideslopes generally have gradients below 10 per cent while footslope gradients are generally less than 5 per cent. Well defined incised channels have formed along many of the drainage lines as a result of severe gully erosion. These channels cover an area of approximately 18 hectares.

Much of the area adjacent to and immediately south of the Historic Site has been mined. Surface deposits of the mine spoil have created extensive areas of disturbed terrain. Approximately 58 hectares show clear signs of disturbance as a result of mine spoil deposits, 31 hectares of which occur on terrain with gradients in excess of 30 per cent.

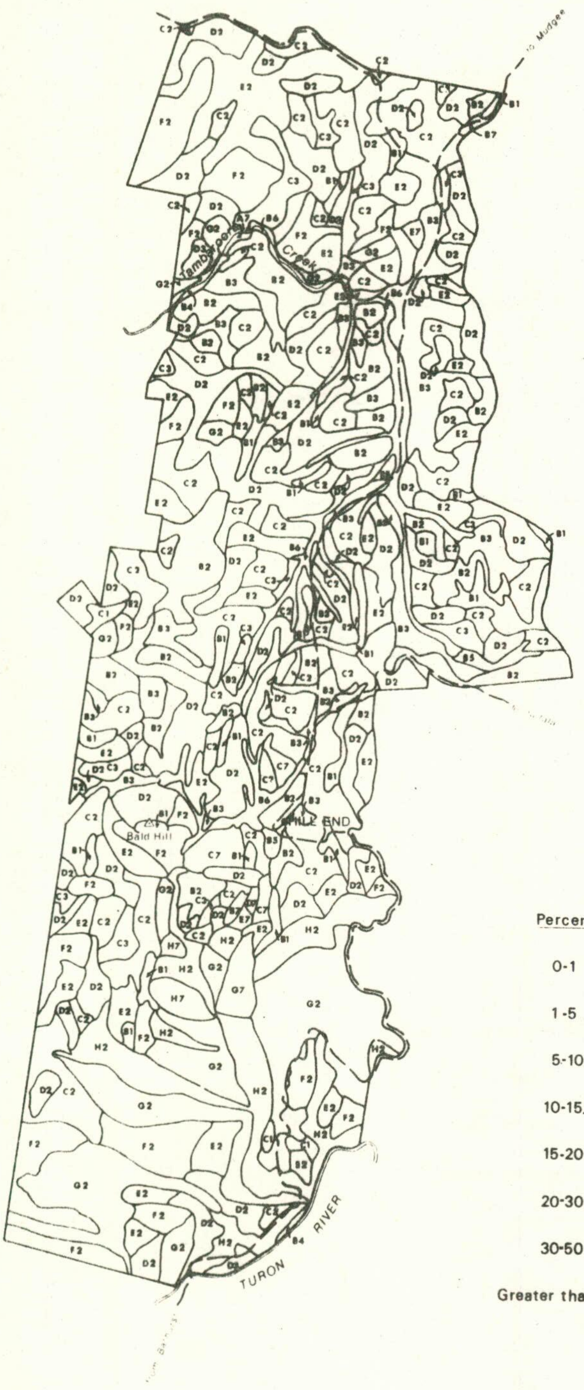
The remainder of the southern portion is characterised by narrow, deeply incised valleys. Average slope gradients exceed 20 per cent and there are substantial areas of precipitous terrain with gradients in excess of 50 per cent. Soils are typically shallow lithosols and rock outcrop is frequent.

A Tertiary basalt intrusion dominates the landscape to the west of the Historic Site. The characteristic flat plateau of the intrusion is flanked by steep slopes with gradients up to 25 per cent. Shallow soils are common and rock outcrop is frequent.

To the north of the Historic Site the majority of the study area falls within the Tambaroora Creek Catchment. Lands are predominantly undulating to hilly with average slope gradients ranging between 5 and 15 per cent. Steeper lands are scattered throughout the area, whilst in the vicinity of the showground, Tambaroora Village and Dam, and the upper reaches of Poormans Gully, the gradients rarely exceed 5 per cent. Well defined incised channels, with sections in excess of three metres deep, have formed along the creek as a result of severe gully erosion. The area covered by these channels, including Golden and Poormans Gullies, is approximately 62 hectares.

TABLE 3: Area and Percentage Distribution of Landform Classes

Class	Area (ha)	Percentage Distribution
A7	2.7	0.1
B1	102.9	3.5
B2	265.8	9.0
B3	193.2	6.6
B4	7.4	0.3
B5	11.8	0.4
B6	80.1	2.7
B7	4.7	0.2
C1	10.4	0.4
C2	550.4	18.7
C3	80.9	2.8
C7	21.5	0.7
D2	543.6	18.5
D3	11.7	0.4
D7	2.2	0.1
E2	311.2	10.6
E7	5.6	0.2
F2	239.4	8.1
G2	299.0	10.2
G7	15.9	0.5
H2	161.5	5.5
H7	15.4	0.5
Total	2,937.3	100.0



Soil Conservation Service of N.S.W.

HILL END AND ENVIRONS

SCALE

kilometres 1 0.5 0 1 2 3 4 5 6 kilometres

LANDFORM

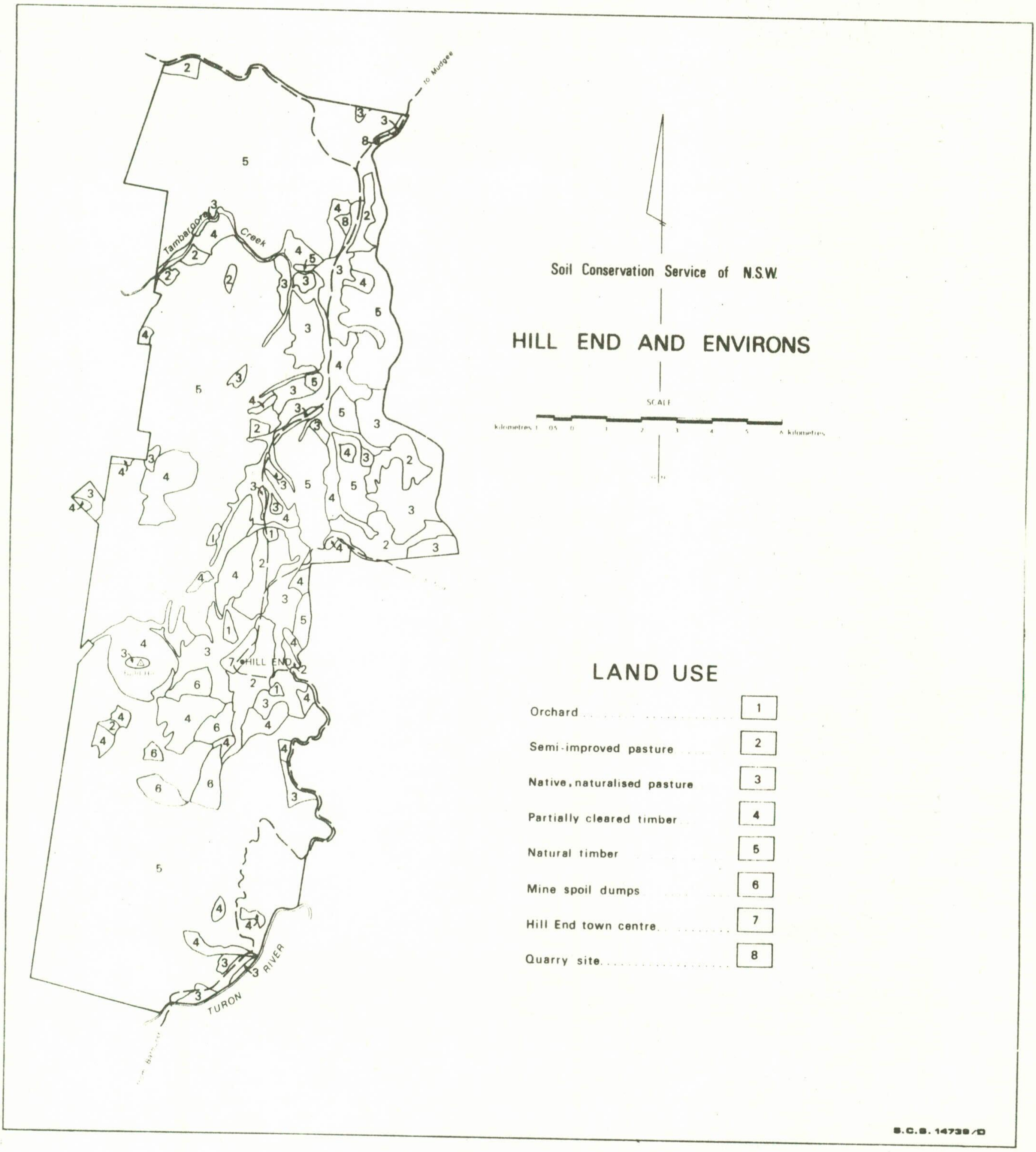
Slope

Percent	Code
0-1	A
1-5	B
5-10	C
10-15	D
15-20	E
20-30	F
30-50	G
Greater than 50	H

Terrain

Component	Code
Hillcrest	1
Sideslope	2
Footslope	3
Floodplain	4
Drainage Plain	5
Incised Channel	6
Disturbed Terrain	7

S.C.S. 14739/C



Soil Conservation Service of N.S.W.
HILL END AND ENVIRONS
LAND USE
Orchard 1
Semi-improved pasture 2
Native, naturalised pasture 3
Partially cleared timber 4
Natural timber 5
Mine spoil dumps 6
Hill End town centre 7
Quarry site 8
Tambaroora Creek
TURON RIVER
HILL END
to Mudgee
S.C.S. 14739/D

A.6 LAND USE

The area and percentage distribution of the land use classes is shown in Table 4 and on Map No. S.C.S. 14739D.

Over two-thirds (67.7 per cent) of the study area remains under native timber cover. The principal species are described in Section A.7. A further 12.7 per cent of the area has been partially cleared of timber. These timbered areas are used primarily for stock grazing under the conditions governing Hill End Common. Grazing has, in part, contributed to the depletion of under storey cover and the initiation of sheet erosion.

Within the Common, a substantial portion of the clearing activities were associated with mining.

Much of the freehold land, in the upper reaches of Poormans Gully, has been cleared for commercial grazing. Although native and naturalised pastures predominate, some pasture improvement has been carried out. Introduced species include rye grass and clover. Severe gully erosion is evident along the main drainage lines.

Four pome fruit orchards, covering about nine hectares, were identified at the mapping scale. Although other smaller orchards occur, it is apparent that the area planted to fruit trees is slowly declining.

Two quarries, encompassing about five hectares, are located in the north-east corner of the study area. Gravel extracted from these quarries is used mainly for road base.

A.6.1 Gold Mining.

Reef and alluvial gold mining have been and continue to be dominant land uses at Hill End. Although workings are found throughout the study area, they occur mainly to the west and southwest of the Historic Site, in the Golden Gully area, along Tambaroora Creek and at Hawkins Hill. Mining is restricted within the Historic Site.

The erosional features of the study area are a result of gold mining activities. Other effects of mining include heavy cutting of timber in adjacent areas for firewood and props, construction of numerous roads and access tracks, and construction of ancillary works such as dams and water races.

The large mine spoil dumps, which cover about 58 hectares, are relics of reed mining, and the need for batteries to crush the ore.

Fossicking Areas 34 and 72 (Mining Act, 1973) have been set aside at Hill End. These sites are located along a relatively stable section of Tambaroora Creek downstream of the town. If fossicking is restricted to the dedicated areas, and rules related to fossicking are observed, minimal adverse effects would result. Adequate signposting would assist in maintaining these areas.

Because of the high erosion hazard of the area generally, illegal fossicking should be actively discouraged. Unauthorised sluicing along Golden Gully is of particular concern. Deep entrenchment has created an extreme erosion hazard triggering further lateral and headward migration of the gullies.

Under the Mining Act (1973) all mining lease applications are referred to the Soil Conservation Service of New South Wales for inclusion of conditions with regard to control of erosion, and rehabilitation following mining. Conditions of Authority (1974) are summarised in Appendix IV.

A.6.2 Tourism.

Tourism has become an important facet affecting land use. Restoration of various buildings and historically significant sites, and dedication of fossicking areas, are attracting an increasing number of tourists. The main concentration of historic buildings covers an area of about 10 hectares in the vicinity of Clarke and Tambaroora Streets.

Several camping and picnic areas have been established within the Historic Site and along the roads servicing the Common. Clearing has also been carried out to enhance the views from Bald Hill, Kissing Point and Merlin's Lookouts. It is essential that erosion control measures be implemented in association with these and other recreational land uses to prevent any further deterioration of the environment.

TABLE 4: Area and Percentage Distribution of Land Use Classes

Land Use	Area (ha)	Percentage Distribution
Orchard	9.3	0.3
Semi improved pasture	162.4	5.5
Native pasture	331.8	11.3
Partially cleared timber	372.6	12.7
Native timber	1,988.7	67.7
Mine spoil dumps	57.8	2.0
Quarries	4.9	0.2
Hill End town centre	9.8	0.3
Total	2,937.3	100.0

A.7 NATIVE VEGETATION

Although dry sclerophyll forest communities dominate the study area, a small patch of savannah woodland, restricted to Bald Hill, has been identified. The spatial distribution of these forest communities is shown in Map No. S.C.S. 14739E.

The terms "sclerophyll forest", "savannah woodlands" and "association", are defined by Beadle and Costin (1952).

A.7.1 Dry Sclerophyll Forest Communities.

(i) Overstorey Vegetation.

Map Unit A: E. mannifera - E. macrorhyncha Association.

This association covers the largest part of the study area (77 per cent), and occurs at a general elevation of between 800-900 metres above sea level.

Brittle gum (*E. mannifera sub. maculosa*) is the dominant species favouring the upper slopes and broad ridges of the country north of Hill End Village. Almost pure stands of brittle gum are found, one of which is close to the village on the Bald Hill Road.

The commonest sub-dominate species is red stringybark (*E. macrorhyncha*), which in places may assume co-dominance. Other associated species include:

E. dives	broad leaved peppermint
E. rubida	candlebark gum
E. bridgesiana	butt butt
E. polyanthemos	red box
E. blakeleyi	Blakeley's red gum
E. elaesophora	long leaved box
E. dealbata	hill red gum
E. rossii	scribbly gum
E. melliodora	yellow box

Broad leaved peppermint was noted in an almost pure stand on the Bald Hill Road some two kilometres from the village, in a steep sided drainage line. Candlebark gum occurs sporadically and tends to favour higher altitudes, where it may replace or be associated with brittle gum. Butt butt occurs sporadically on more open areas of the forest.

Map Unit B: E. albens - E. blakeleyi Association.

This association is dominant to the south of Hill End Village. The topography is rugged, with highly dissected, steep sided hills. Elevation varies from about 800 metres in the north to approximately 500 metres in the vicinity of the Turon River.

White box (*E. albens*) dominates the warmer more exposed sites, especially on tuffaceous material. At lower elevation it is associated with long leaved box (*E. elaeophora*) while in upslope positions it is found in association with brittle gum. On footslopes adjacent to the Turon River, white box achieves its maximum density, and may occupy pure stands.

On hard, rocky ridges, Blakeley's red gum (*E. blakeleyi*) predominates. Sub-dominant species include white box and red stringybark (*E. macrorhyncha*). On less exposed and less rocky sites, long leaved box occurs with occasional red stringybarks.

The banks of the Turon River are lined with river oak (*Casuarina cunninghamiana*).

(ii) Understorey Vegetation.

Understorey vegetation is composed of a discontinuous layer of xeromorphic shrubs. The following is a list of species which may be found within the dry sclerophyll forests:

Dillwynia philicoides, Dillwynia retorta, Indigophora australis, Exocarpus cupressiformis, Clematis glycinoides, Hibbertia fasciculata, Melichrus procumbens, Leptospermum phylicoides, Acacia gunnii, A . lanigera, A . filicifolia, Styphelia triflora, Grevillea ramosissima, Cassytha paniculata, Davissia genistifolia, Leucopogon spp., Melichrus urceolatus, Cassytha melantha, Amyema miquelii, Hardenbergia violacea, Stypandra glauca, Heves linearis, Lissantha strigosa, Olak spp., Pultenaea subternate, A species of Helichrysum.

A.7.2 Savannah Woodland Community.

(i) Overstorey Vegetation.

Map Unit C: E. polyanthemos - E. elaeophora Association.

This association is restricted to Bald Hill, an area of Tertiary basalt, which rises some seventy metres above the surrounding terrain. The southern side of Bald Hill is steeper than elsewhere and the woodland formation is less well developed, with a discontinuous herbaceous stratum.

Almost pure stands of long leaved box (E. elaeophora) occur on the steeper southern slopes. Elsewhere, red box (E. polyanthemos) is the dominant species. Yellow box (E. melliodora) is also found in this map unit.

(ii) Understorey Vegetation.

A poorly developed shrub layer is associated with long leaved box on the southern side of Bald Hill. Species noted include:

Styphelia triflora, Rubus rubiginosa, Acacia decurrens, Rubus vulgaris, Daviesia genistifolia, Exocarpus strictus, Cassytha melantha, Acacia vestita, Hardenbergia violaceae, Lissantha strigosa, Hypericum perforatum var. angustifolium.

Originally, the common grass species of savannah woodlands in New South Wales were tall warm seasoned perennial tussock grasses. Grazing by domestic animals has drastically altered the composition of many woodland areas, and allowed the development of a disclimax population of short cool season species (Beadle and Costin, 1952). At Bald Hill, components of the origin community are still present, noteably kangaroo grass (Themeda australis) and plains grass (Stipa aristiglumis). Cool season species include wallaby grasses (Danthonia spp.) and spear grasses (Stipa spp.)

Introduced species, which have naturalised, include:

Trifolium glomeratum	ball clover
Trifolium dubium	suckling clover
Trifolium campestre	hop clover
Trifolium tomentosum	woolly clover

A.7.3 Vegetation within Hill End Historic Site (Map Unit D).

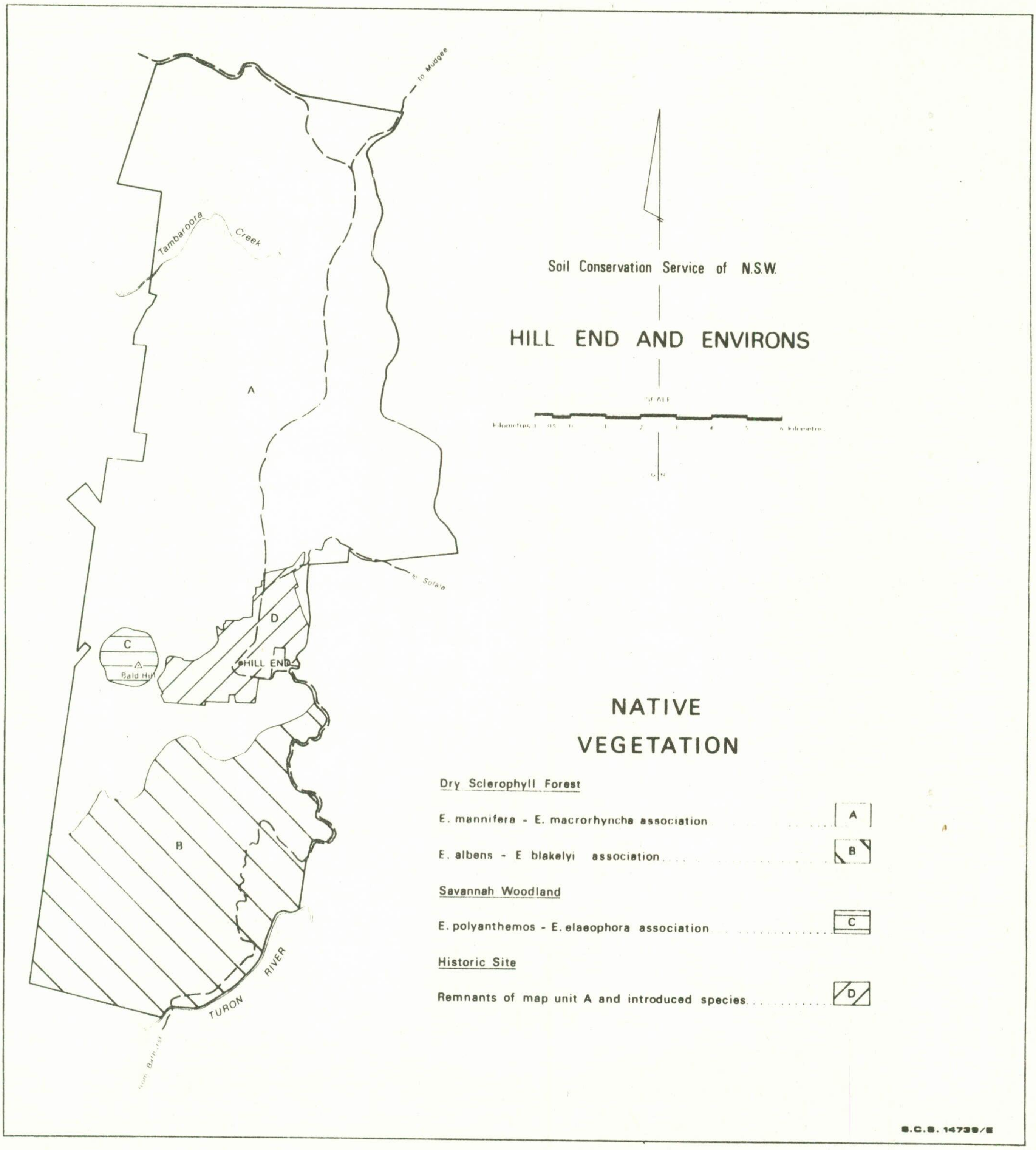
Most of the native vegetation has been disturbed as a result of settlement and mining activities. Remnants of the dry sclerophyll forest of Map Unit A are found, especially along the western margin. Brittle gum (E. mannifera sub. maculosa) is the most common species observed.

Introduced species date back to the 1870's when the main avenue was planted to imported European trees including English oaks, elms and ashs. Other species planted in the streets and domestic areas include:

Platanus orientalia	plain tree
Acer negunda	box elder
Betula alba	birch
Quercum palustris	pin oak
Allanthus altissima	tree of heaven

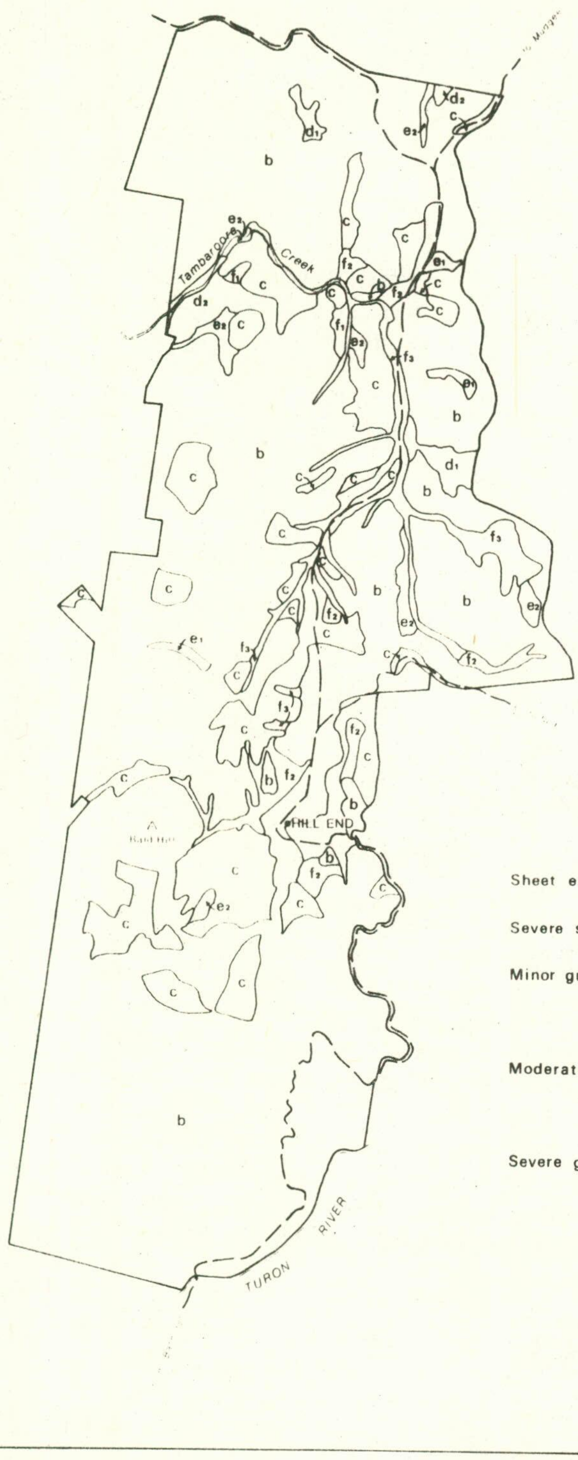
Specimens of Callitris muellari were noted along the Bathurst Road, while Acacia quadrilateralis were observed along the Mudgee Road.

Much of the denuded area south of the village is covered by a small, shrubby colonizer, a species of Cassinia. Inter-shrub areas are generally bare, although large breaks in the cover of Cassinia are dominated by poor forms of Stipa and Aristida spp.


to Mudgee
Tambaroora
Creek
A
to Sofala
D
C
Bald Hill
HILL END
B
TURON RIVER
Soil Conservation Service of N.S.W.
HILL END AND ENVIRONS
NATIVE VEGETATION
Dry Sclerophyll Forest
E. mannifera - E. macrorhyncha association A
E. albens - E blakelyi association B
Savannah Woodland
E. polyanthemos - E. elaeophora association C
Historic Site
Remnants of map unit A and introduced species D
S.C.S. 14739/E

Soil Conservation Service of N.S.W.

HILL END AND ENVIRONS



SOIL EROSION

Sheet erosion (minor to moderate)	b
Severe sheet erosion	c
Minor gully erosion: depth of less than 1½ metres	d_1
: depth of 1½ to 3 metres	d_2
Moderate gully erosion: depth of less than 1½ metres	e_1
: depth of 1½ to 3 metres	e_2
Severe gully erosion: depth of less than 1½ metres	f_1
: depth of 1½ to 3 metres	f_2
: depth of greater than 3 metres	f_3

S.C.S. 14739/F

A.8 SOIL EROSION

The area and percentage distribution of soil erosion classes is shown in Table 5, and on Map No. S.C.S. 14739F.

Various degrees of soil erosion occur throughout the study area. 79 per cent is affected by minor to moderate sheet erosion and a further 13 per cent is severely sheeted. The remaining eight per cent, encompassing about 200 hectares, is affected by gully erosion. Of this area, 148 hectares is severely gullied, with substantial sections of channel being greater than 3 metres in depth.

Many environmental factors including climate, soil type, landform and land use influence the development of erosion.

The effect of climate on the initiation and progression of soil erosion has been covered in the climate section (A.2). Similarly, the relationships between soil types and soil erosion are discussed in the soil section (A.4).

A.8.1 Soil Erosion in Relation to Landform.

Approximately 85 per cent of the terrain associated with drainage lines is severely gullied (Table 6). Most of this is related to the incised channels of Tambaroora Creek and its tributaries (62.2 ha) and the upper reaches of Hill End Creek (17.9 ha). Some 43 per cent of the low sloping footslopes (B/3) are affected by gully erosion, with approximately one-half occurring as severe gullying. The proportion of land affected by gully erosion drops substantially on steeper lands.

Sheet erosion is evident on all landform types. Its occurrence is mainly related to land use.

All areas of disturbed terrain are affected by severe forms of soil erosion, due to their poor vegetative cover. Special rehabilitation programmes will be required to control soil erosion in these areas.

A.8.2 Soil Erosion in Relation to Land Use.

Gold mining and its associated activities have been the major factors causing soil erosion at Hill End.

Historically, much of the clearing of native timber was undertaken to facilitate mining activities. The comparison of erosion levels between cleared, partially cleared and timbered areas (Table 7) reveals the substantially higher levels of soil erosion on the cleared and partially cleared areas. Within these areas the level of severe sheet erosion differs as a response to various land use factors including the degree of pasture improvement. However, severe gully erosion represents a similar proportion of each class reflecting the overriding effects of mining on soil erosion, and that any pasture improvement post dates the period of major erosion activity.

Mining has essentially been confined to the Catchments of Tambaroora Dam and Hill End Creek. For the purpose of discussion, Hill End Creek Catchment has been divided into two sub-catchments, above and below the failed structure adjacent to Merlins Lookout Road. These catchments are delineated on Map No. S.C.S. 14739G.

Tambaroora Dam Catchment.

The most noticeable effects of mining within this catchment are the deeply incised channels associated with Golden and Poormans Gullies. Severe sheet erosion, often to a depth of 100 mm and minor to moderate gullying occur on adjacent lands.

Depths along sections of Golden Gully often exceed 10 metres. Undercutting of sides and the collapse of land bridges, caused by tunnel erosion, is increasing gully width. Gully heads and gully laterals are still active due to the runoff from roads, access tracks and adjacent eroded areas. In places, active gully erosion is threatening the stability of local roads.

In the upper reaches of Poormans Gully, severe erosion is occurring on the pasture lands currently used for grazing. Soil conservation measures will be required in this area to control the erosion.

Within the northern portion of the catchment minor to moderate sheet erosion predominates. Although wild fires may have had an influence on the initiation of this erosion, communal grazing appears to be a significant influence on its continuation.

Deposition of eroded material from within this catchment has occurred in the main drainage line below Tambaroora Village and led to the complete siltation of Tambaroora Dam.

Upper Hill End Creek Sub-catchment.

The Historic Site lies within this sub-catchment. Pressure from mining, grazing and tourism are the main factors causing soil erosion in this area.

The main drainage line and its tributaries to the west of Clarke Street are severely gullied. Gully depths average between 1.5 and 3 metres but are in excess of 6 metres deep in places. Active bank undercutting is widening the gullies while gully head migration is extending them up slope.

On the western hill slopes sheet erosion is severe while deep, active gullies have developed in the drainage lines. Numerous shafts and spoil dumps dot the landscape. The extent of the underground workings is not known but their occurrence predisposes the area to instability.

Severe gully erosion threatens the camping areas adjacent to the Historic Site and below Merlins Lookout Road. Access to the gully floor, by tourists and grazing cattle, is aggravating the erosion process. The main camping area on Bald Hill Road has also been severely eroded. Severe sheeting, to a depth of 100 mm in places, has removed a substantial portion of the topsoil exposing the subsoil. Topsoiling would be essential for any revegetation programme.

Within the village, minor gullying of table drains is evident and severe sheet erosion occurs on the eastern hillslopes.

Lower Hill End Creek Sub-catchment.

This sub-catchment comprises steep terrain, the majority of which remains under native timber. Minor to moderate sheet erosion is evident over most of its area. This erosion is, in part, related to grazing activities.

Reef mining in the area bounded by the failed structure, Merlin and Kissing Point Lookouts, and Hawkins Hill has disturbed the terrain and caused severe sheet erosion. Moderate gully erosion is evident in several drainage lines. On the steep slopes to the east of Merlin Lookout and west of Kissing Point Lookout mine spoil is mainly composed of coarse rock. This spoil appears to be relatively stable.

TABLE 5: Area and Percentage Distribution of Soil Erosion Classes

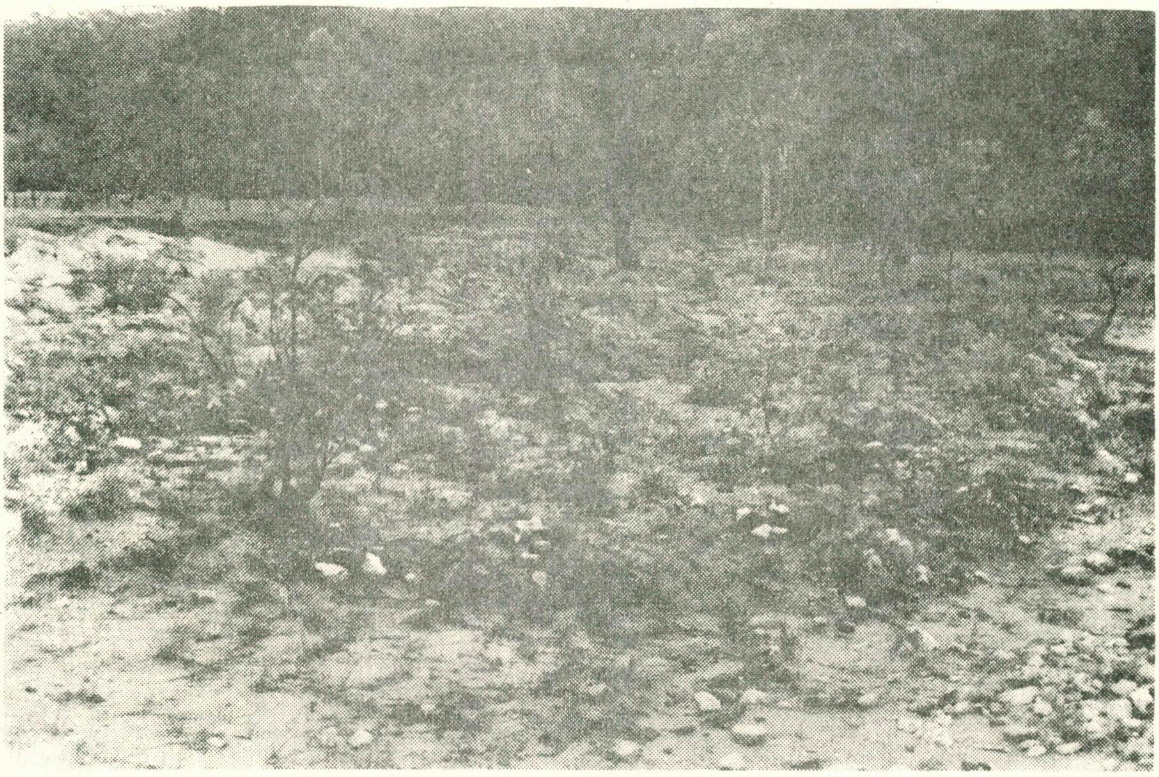
Soil Erosion Class	Area (ha)	Percentage Distribution
Minor to moderate sheeting	2,327.5	79.2
Severe sheeting	389.6	13.2
Minor gullying: gullies less than 1.5 m deep	21.5	0.7
Minor gullying: gullies 1.5 to 3 m deep	7.6	0.3
Moderate gullying: gullies less than 1.5 m deep	11.3	0.4
Moderate gullying: gullies 1.5 to 3 m deep	31.8	1.1
Severe gullying: gullies less than 1.5 m deep	5.9	0.2
Severe gullying: gullies 1.5 to 3 m deep	59.5	2.0
Severe gullying: gullies greater than 3 m deep	82.6	2.8
TOTAL	2,937.3	100.0

TABLE 6: Percentage Distribution of Soil Erosion Types within the Main Landform Types (To nearest 1 per cent).

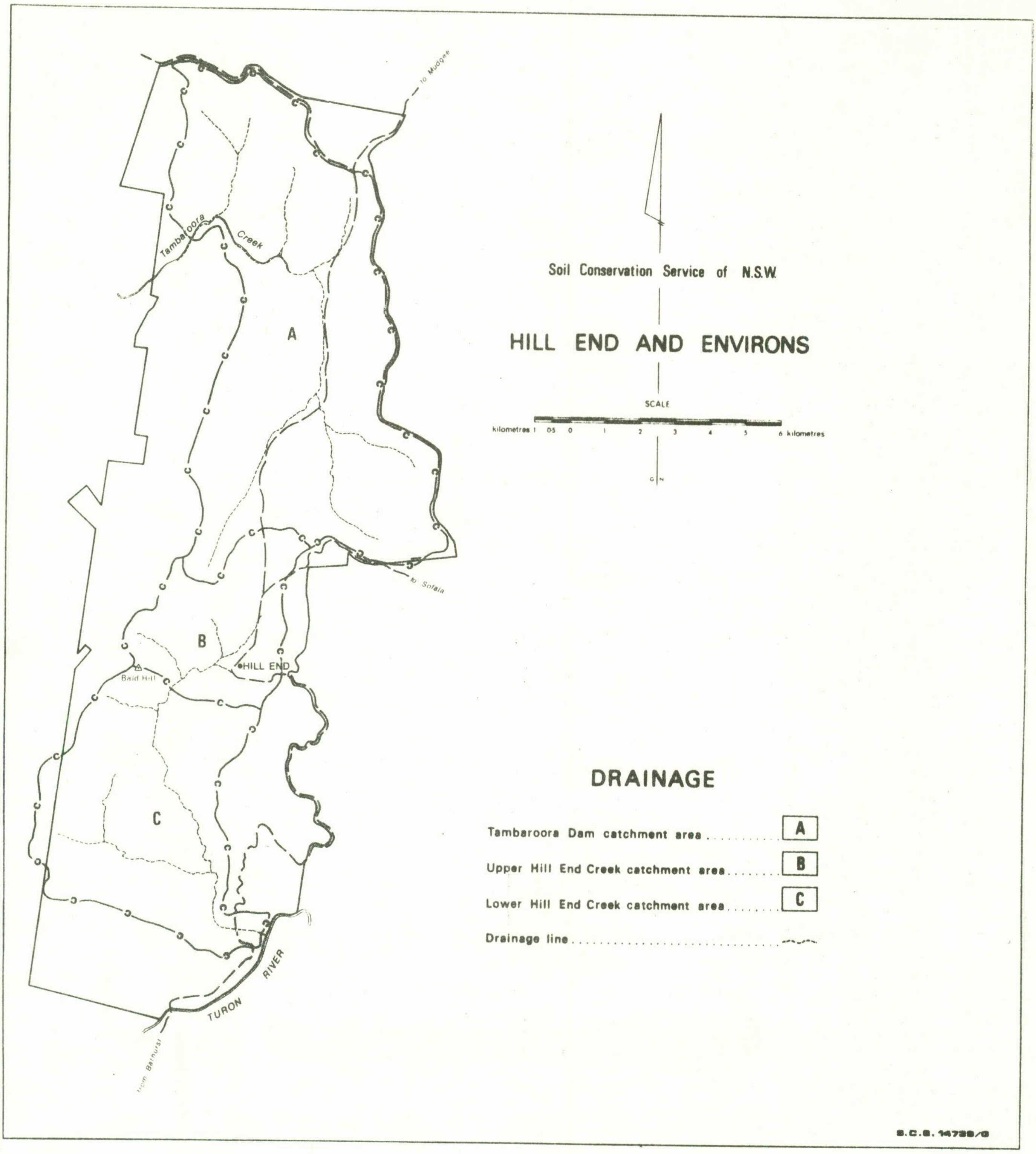
Landform Pattern	Sheet Erosion		Gully Erosion			Total
	Min. to Mod.	Sev.	Min.	Mod.	Sev.	
Land subject to inundation (drainage plains, flood-plains, incised channels)	5	2	5	3	85	100
Gentle footslopes (B/3)	45	13	4	15	23	100
Gentle sideslopes (B/2)	71	29	-	-	-	100
Undulating footslopes (C/3)	63	25	9	3	-	100
Undulating sideslopes (C/2)	75	21	1	2	1	100
Hilly lands (D/2,3)	91	8	-	-	1	100
Steep precipitous lands (E, F, G, H/2)	98	2	-	-	-	100
Hillcrests	76	24	-	-	-	100
Disturbed terrain	-	92	-	-	8	100

TABLE 7: Percentage Distribution of Soil Erosion Types within Cleared, Partially Cleared and Timbered Land Use Classes (To nearest 1 per cent).

Land Use	Sheet Erosion		Gully Erosion			Total
	Min. to	Sev.	Min.	Mod.	Sev.	
Semi-improved pastures	78	5	-	2	15	100
Native pastures	55	22	3	4	16	100
Partially cleared timber	38	37	4	3	18	100
Native timber	94	5	less than 1	less than 1	-	100



Erosion pavement typical of the Eroded Red and Yellow Earths of Soil Map Unit C.



to Mudgee
Tambaroora Creek
A
B
C
HILL END
Bald Hill
to Sofala
TURON RIVER
from Bathurst
Soil Conservation Service of N.S.W.
HILL END AND ENVIRONS
SCALE
kilometres 1 0.5 0 1 2 3 4 5 6 kilometres
G N
DRAINAGE
Tambaroora Dam catchment area .... A
Upper Hill End Creek catchment area .... B
Lower Hill End Creek catchment area C
Drainage line ....

A.8.3 Assessment of the Rates of Soil Erosion.

The estimation of soil loss at Hill End and the average rate of soil erosion are important to assess the impact that gold mining has had on both the local and downstream environments. Based on field observations and aerial photograph interpretation an estimate of total soil loss has been calculated using the following assumptions:

*Gold was discovered at Hill End in 1851. Prior to this date the study area was largely uneroded.

*Mining was essentially confined to the upper reaches of Tambaroora and Hill End Creeks. The catchments defined previously, Map No. S.C.S. 14739G are used for calculation purposes.

*That on average, 25 per cent of Tambaroora Dam Catchment, and all of upper Hill End Creek Catchment, has been sheet eroded to a depth of 100 mm.

*That on average, gully size in Tambaroora Dam and upper Hill End Creek Catchment is 6 metres wide and 4 metres deep, and that there is a total of 13,000 metres of gullying in these catchments.

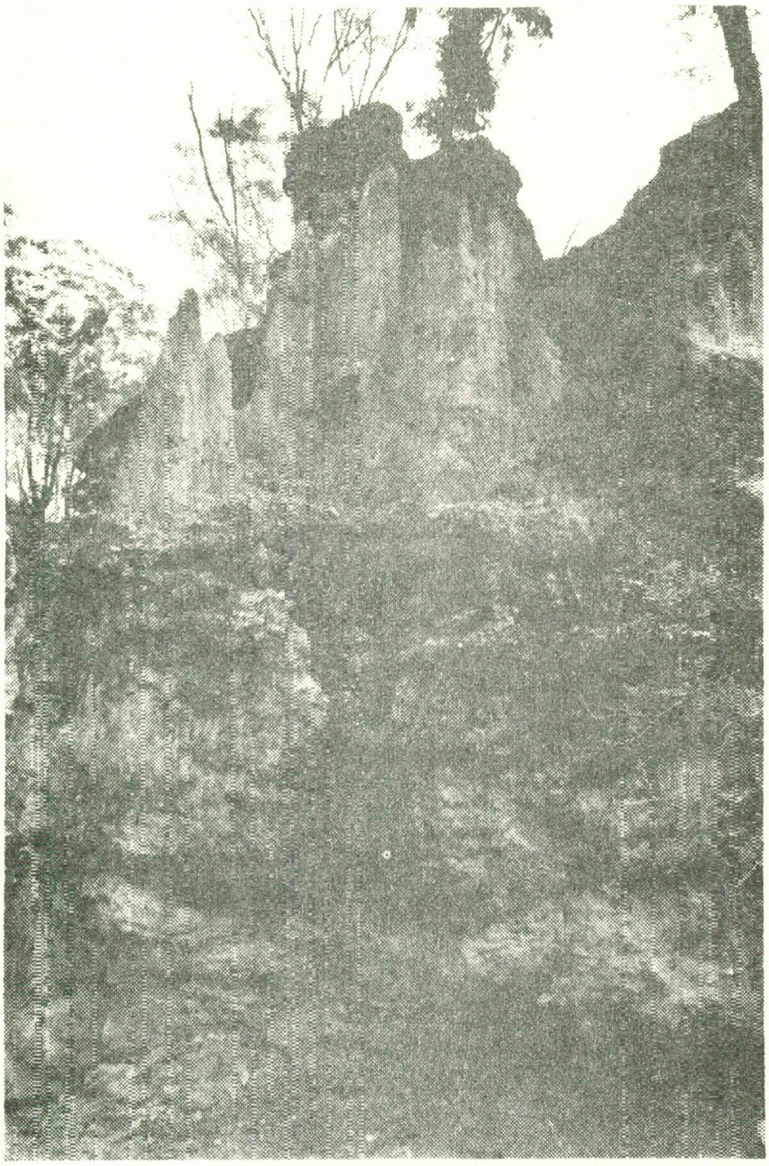
The estimated average annual rate of soil loss and the total quantity lost are shown in Table 8. Over a million tonnes of soil is estimated to have been lost from the main mining areas at Hill End. The average rate of soil loss is estimated at nearly 9,000 tonnes per year. These figures are a conservative estimate of the erosion that has occurred.

It is important to note that the figures represent average yearly losses. They do not represent the actual losses within any one year. The actual losses will be determined by the extent of land disturbance and the amount and intensity of rainfall. It is therefore likely that major portions of the total soil loss have occurred in particular years when land disturbance and/or intense rainfall occurred. This highlights the necessity to make measurements of the current rates of soil erosion so that suitable control and remedial works can be planned and implemented. Several methods for making these measurements are outlined in Section C.5.

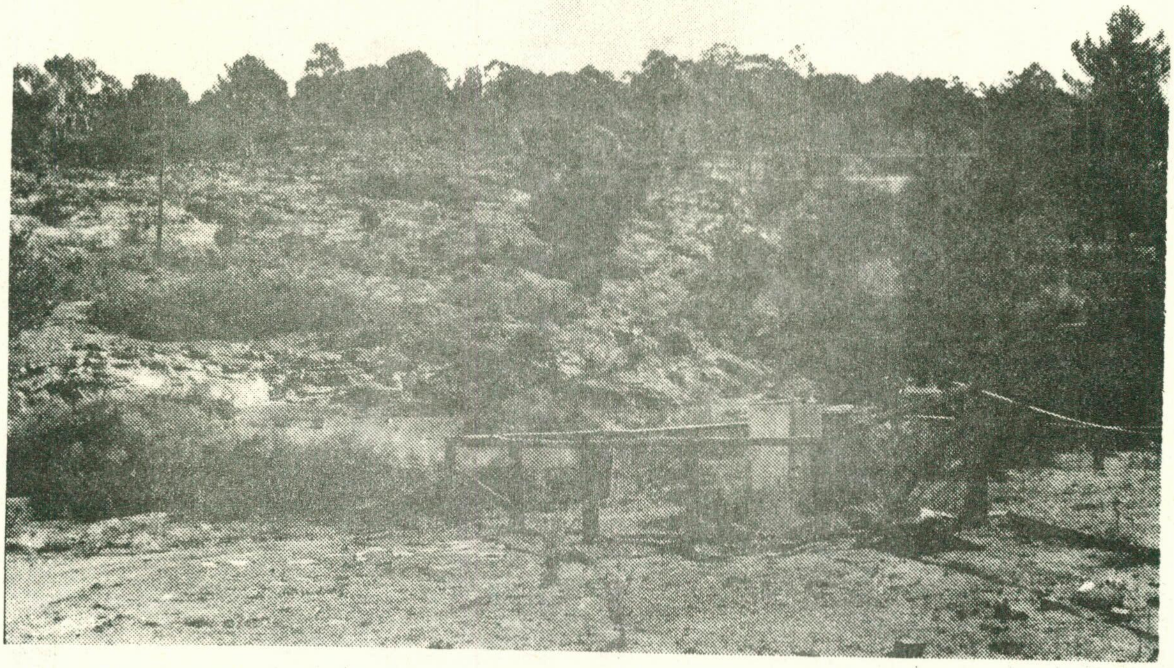
TABLE 8: Estimates of Total Soil Loss and Average Annual Rate of Soil Erosion.

Catchment	Area (ha)	Total Soil Loss (tonnes)	Average Annual Soil Loss (tonnes)
Tambaroora Dam	1,125	800,000	6,200
Upper Hill End Creek	260	350,000	2,700
Total	1,385	1,150,000	8,900

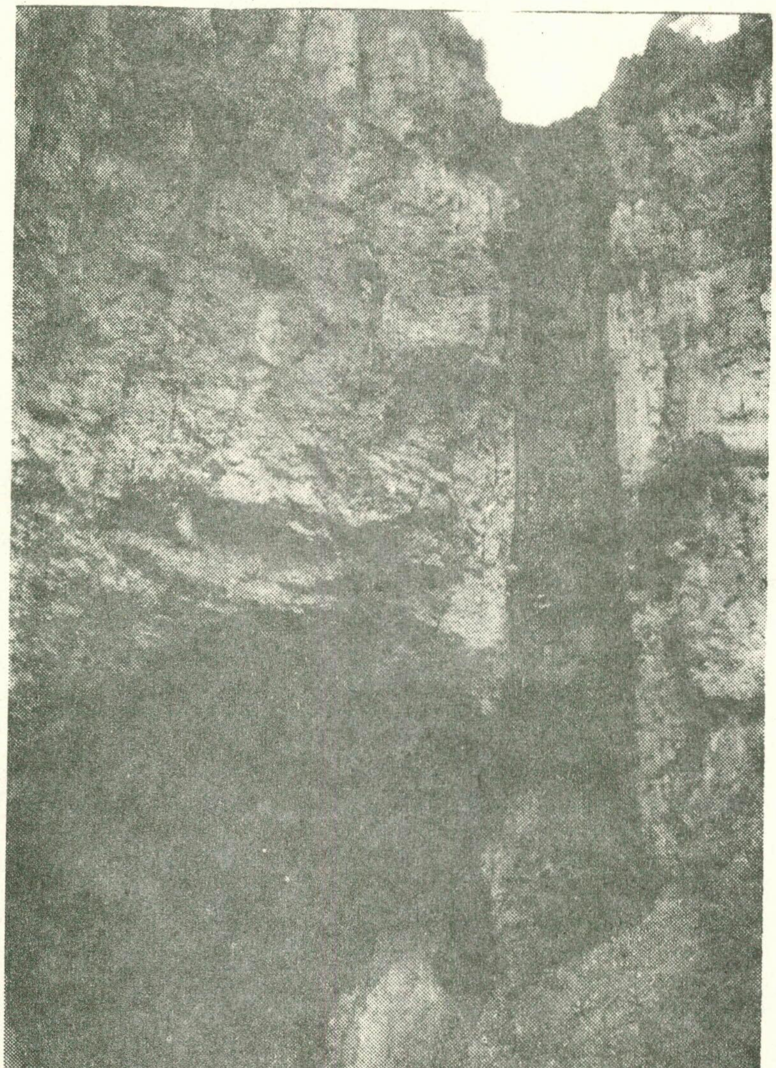
Severe gully erosion, Tambaroora Creek

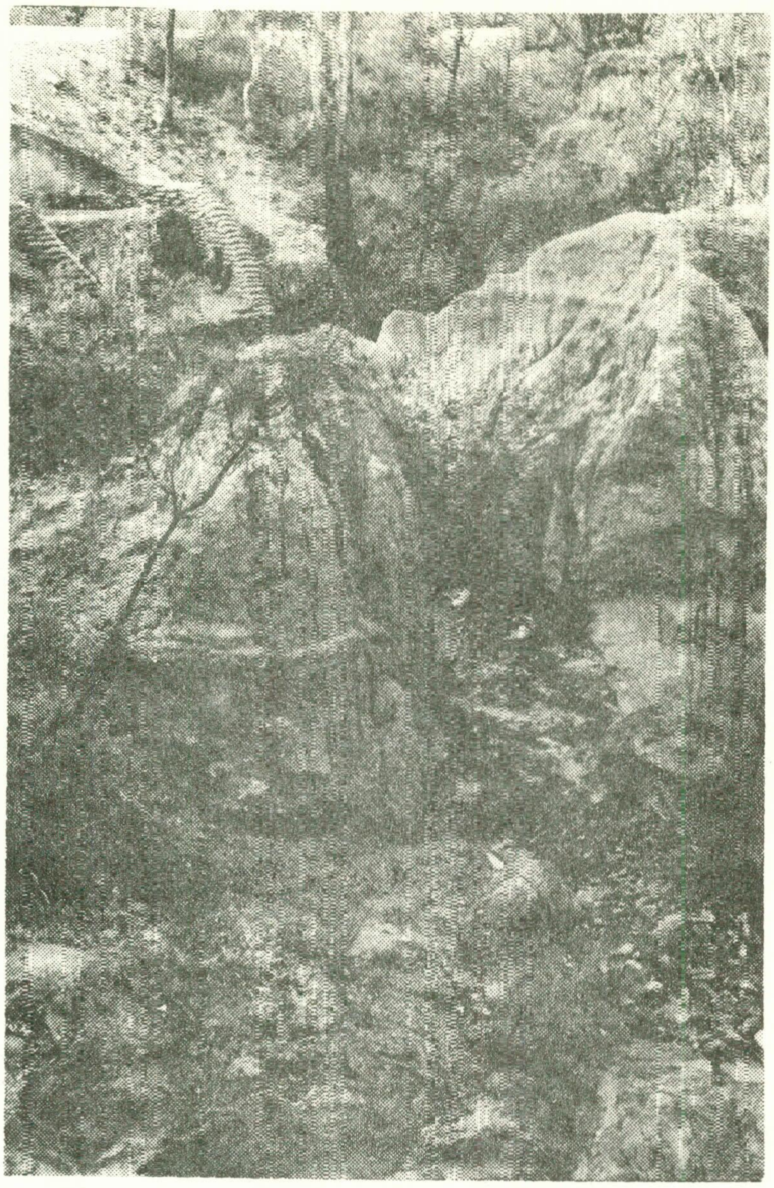


Characteristic fluting and undercutting of the banks in severely eroded gullies.

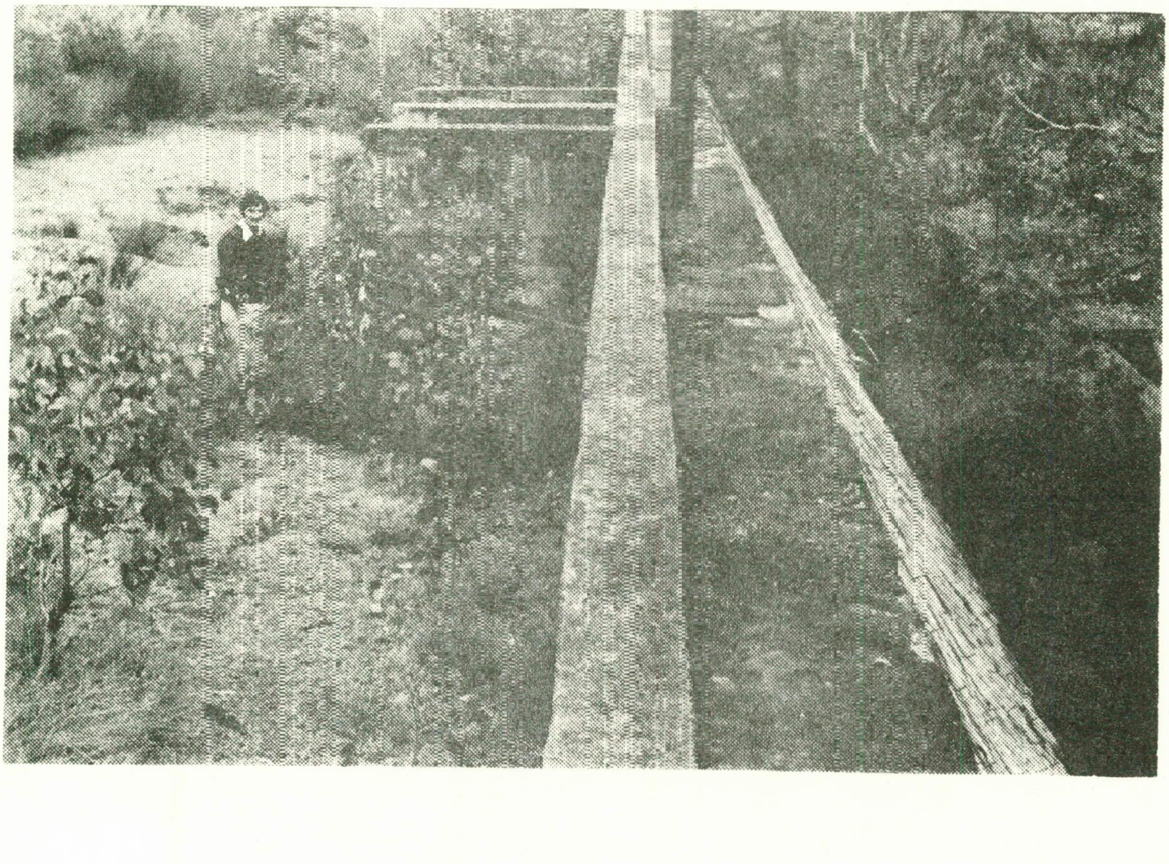


Surface disturbance within the Historic Site (above) and abandoned shafts along Golden Gully (below) indicate that past mining activities are the major causes of the severe levels of soil erosion at Hill End.





Severe erosion threatening the stability of the drop structure and adjacent road (above), and the complete sedimentation of Tambaroora Dam (below) highlight the need for appropriate landscape stabilisation measures to be implemented at Hill End.



PART B

LAND CAPABILITY ASSESSMENT

B.1 RURAL CAPABILITY

Rural capability has been determined to provide landholders and planners with a guide to the potential of the land to assist in formulating land use and land management strategies.

The rural capability classification system used state wide by the Soil Conservation Service incorporates eight standard classes (Anon, 1975), based upon the capacity of the land to sustain permanent rural production. Land within the study area has been classified according to this system and five of the eight standard classes occur. The distribution of rural capability classes is shown in Map No. S.C.S. 14739H.

While these classes may not reflect current land use, they indicate the potential of the land for such uses as pasture improvement and grazing. To achieve this potential, specific soil conservation and land management measures are required to maintain the soil resource. Land which is used beyond its capability can be expected to deteriorate rapidly, resulting in loss of production and a permanent loss of the soil resources.

Capability Class IV: Land suitable for grazing, requiring simple soil conservation practices to prevent or control soil erosion.

This class occurs on hillslopes, drainage plains and floodplains, with gradients below 10 per cent, that are only minor to moderately sheet eroded, irrespective of soil type. On soils of Unit A, Class IV includes sideslopes up to 15 per cent gradient. All hill crests also fall into Class IV.

Class IV land occupies about 30 per cent of the study area.

Management of these lands should be aimed at improving the grazing potential, using improved pasture species. Perennial ryegrass, phalaris, cocksfoot, sub-clover and white clover are suitable species.

Cultivation, for improved pasture establishment or renovation of pasture condition, is possible incorporating a maximum rotation of two consecutive fodder crops followed by six consecutive years of improved pasture. Deep, contour "chisel ploughing" or ripping on most soil types is beneficial for pasture establishment by assisting the infiltration capacity of the soil.

Stocking rates should be controlled, to maintain ground cover. Rotational grazing programmes will help to maintain year round pasture cover. Over-grazing will lead to depletion of ground cover and will result in unacceptable levels of erosion and sedimentation.

Footslopes and drainage plains are subject to run-on from areas upslope and require careful management to maintain a stable condition. Concentrated flows should be diverted to stable permanently grassed areas or to constructed grassed waterways. These areas will require fencing to exclude stock to maintain a permanent ground cover.

Capability Class V: Land suitable for grazing, requiring intensive soil conservation measures to prevent or control soil erosion.

Class V land is predominantly associated with the deeper soils of Soil Map Units B and E. It includes severely sheeted and minor to moderately gullied hillslopes with gradients below 10 per cent, and hillslopes between 10 and 15 per cent gradient irrespective of the erosion class.

Its occurrence on Soil Map Units A, D and F is restricted to footslope terrain where colluvial material generally forms deeper soils.

Class V land occupies about 20 per cent of the study area.

To achieve a stable landscape and to improve productivity of these lands, soil conservation measures such as graded banks and gully control structures are necessary. These measures are intended to reduce runoff by increasing infiltration into the soil and to reduce the velocity of runoff water.

Treatment of the gullied drainage lines should receive a high priority in the management of these lands. Such treatment would include gully filling and stabilisation measures. This will assist management of lands in the study area by allowing ready access to all sites and preventing the deposition of silt into water supplies. The catchment hydrological condition would also be improved as the amount of channelised flow would be reduced, time of concentration would be increased and infiltration increased.

Fencing should be carried out to exclude stock from critical work sites such as waterways. Similarly where extensive reclamation work has been completed, it may be necessary to exclude stock from the area for an extended period to assist with revegetation.

Classes IV and V lands require similar stock and pasture management practices.

Capability Class VI: Land suitable for grazing, requiring special soil conservation measures to prevent or control soil erosion.

Class VI lands occur on all terrain units with slope gradients between 15 and 30 per cent. Other areas of Class VI land occur on:

*sideslopes and footslopes with gradients less than 10 per cent on soils of Map Unit C and subject to severe sheet erosion. Erosion pavements are common and bedrock is frequently exposed.

*sideslopes with gradients between 10 and 15 per cent on soils of Map Units D and F. On these areas soil development is minimal and rock outcrop is frequent. This places a severe constraint on the construction of earthworks for soil erosion control.

*floodplain terrain in the vicinity of Tambaroora Dam. Streambank erosion is evident requiring special techniques to control erosion.

Class VI land occupies about 28 per cent of the study area.

To maintain surface stability, management of Class VI land must ensure the maintenance of a continuous vegetative cover. Cultivation is not recommended nor practical on the steeper slopes. Surface disturbance should be kept to a minimum. Broadcasting of seed and fertilizer is recommended as a suitable method for the establishment of improved pastures.

Judicious management techniques are necessary to maintain pastures. Low stocking rates are recommended. Eradication of rabbits or other feral animals and strict weed control are also essential.

Capability Class VII: Land best suited to green timber because of its steepness, shallow soils and/or high erosion hazard.

Class VII lands occur mainly in the southern sectors and occupy about 17 per cent of the study area. It is associated with all soil types on terrain with slopes about 30 per cent. Severely sheet eroded lands with slopes between 15 and 30 per cent gradient are also included in Class VII.

The combination of steep slope gradients and shallow soils produce a very high erosion hazard. Protection of the soil on these areas is best achieved by retaining a permanent vegetative cover including the retention and/or re-establishment of native timber. Partially cleared areas should be fenced and allowed to revert to the original climax community, or supplemented by additional plantings of native species (Refer A.7).

Control of vermin and noxious weeds is also necessary. Controlled stock grazing may be required for limited periods to control wild fire hazard.

Most of the Class VII land has been notified as protected land under Section 21 of the Soil Conservation Act, 1938 (Appendix V).

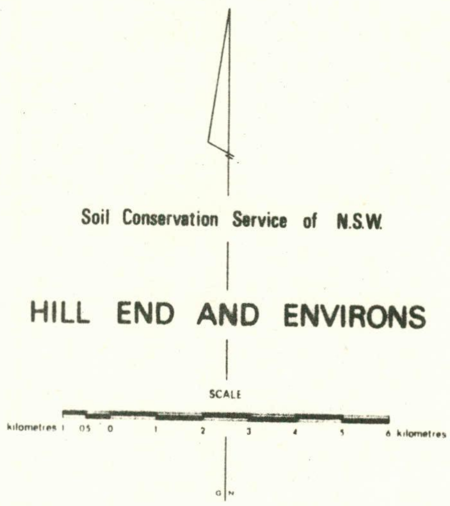
Capability Class VIII: Land unsuitable for rural production because of extreme physical limitations.

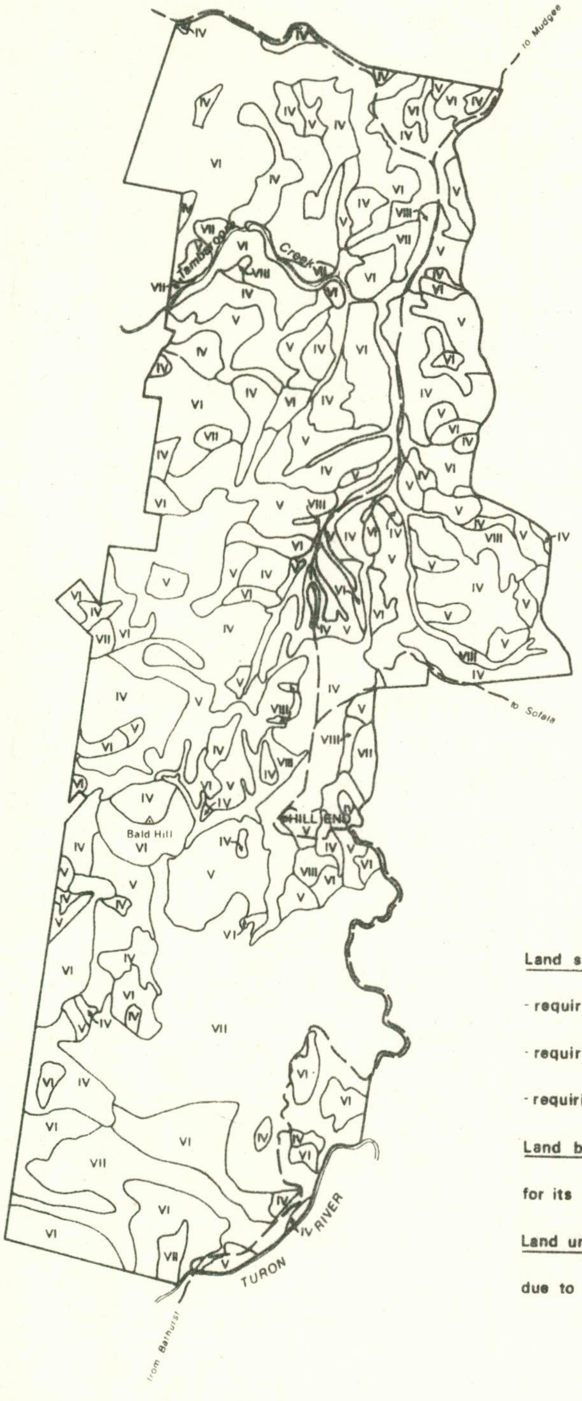
Class VIII lands comprise those areas of severe gully erosion (148 ha) along the drainage lines of Tambaroora and upper Hill End Creeks.

The combination of the highly erodible soils and deeply incised channels make these lands unsuitable for rural production. Management conditions are similar to those listed for Rural Capability Class VII with special emphasis to avoid disturbance of channel banks.

Soil Conservation Service of N.S.W.

HILL END AND ENVIRONS





RURAL CAPABILITY

<u>Land suitable for grazing</u>

- requiring simple soil conservation practices IV
- requiring intensive soil conservation practices V
- requiring special soil conservation practices VI

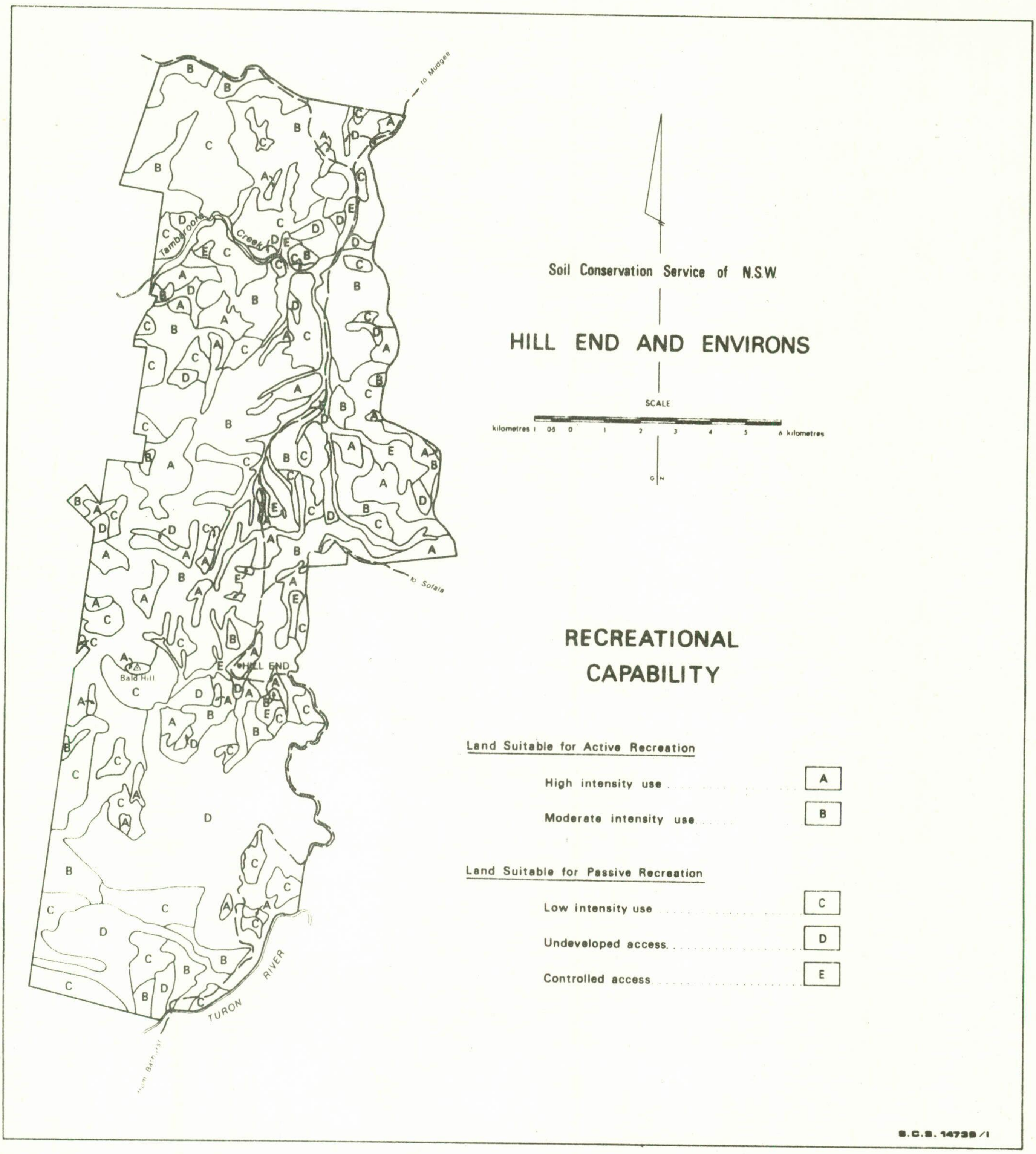
<u>Land best suited green timber</u>

for its steepness, shallow soils and/or high erosion hazard VII

<u>Land unsuitable for rural production</u>

due to extreme physical limitations VIII

S.C.S. 14788/H


Soil Conservation Service of N.S.W.
HILL END AND ENVIRONS
SCALE
kilometres 1 0.5 0 1 2 3 4 5 6 kilometres
to Mudgee
Tambaroora Creek
to Sofala
HILL END
Bald Hill
TURON RIVER
RECREATIONAL CAPABILITY
Land Suitable for Active Recreation
High intensity use A
Moderate intensity use B
Land Suitable for Passive Recreation
Low intensity use C
Undeveloped access D
Controlled access E
S.C.S. 14739/1

B.2 RECREATIONAL CAPABILITY

An objective classification of recreational capability has been derived from an assessment of soil erosion hazards. It provides a guide as to the most intensive recreational use the land will tolerate without the occurrence of serious erosion and sedimentation. Over-use of an area may subsequently require extensive site modification. In extreme cases a complete loss of a recreational facility may occur.

The recreational capability classification is designed to provide planners with information on the stability of a site, and to identify suitable alternative areas for development, when formulating management strategies. By utilising this system, any incompatibility between a proposed activity and the land capability is overcome.

When utilising the recreation capability classification planners will need to take into account the intensity of use of the site. Visitor numbers to recreational sites fluctuate widely between and during seasons. Intensive use of an area at weekends or over a summer season can cause the gradual deterioration of the grass cover, loss of topsoil, and the eventual death of established trees. In planning the development of a site the intensity of recreation visits in high demand periods should be assessed (Junor et al, 1977).

In assessing the capability the following factors have been considered:

*The stability of an area for active and passive recreational pursuits. Active recreation refers to ovals, camp sites and other activities requiring extensive clearing, levelling or modification for the provision of facilities. Passive recreation refers to walking tracks, parkland and the like, where minor shaping, clearing and replanting may be desirable to provide for a particular use, but no extensive disturbance is required.

*The intensity to which the proposed amenity is to be utilised. This may range from uses with a heavy impact on the ground surface such as playing fields, to passive uses such as viewing the landscape. Activities have not been nominated to pre-empt in any way future uses of an area, but merely to demonstrate the various levels of impact the land can sustain.

Five capability classes are shown on the recreational capability map (S.C.S. 14739 I).

Map Unit	Recreation Capability	Intensity of Use
A	Suitable for active recreation	High
B	Suitable for active recreation	Moderate
C	Suitable for passive recreation	Low
D	Suitable for passive recreation	Undeveloped access
E	Suitable for passive recreation	Controlled access

- - -

Class A: Suitable for Active Recreation - High Intensity.

Class A lands occur on hillcrests and sideslopes with gradients of less than 5 per cent on all soil types except those of Units C and G. All areas of gully erosion are excluded from this class.

Representing about 10 per cent of the study area, Class A land has the lowest erosion hazard. It is the most suitable land for intensive recreational activities, including those with a heavy surface impact, such as sporting fields, playgrounds and camp sites.

Even though these areas have a low erosion hazard, problems of site instability may arise from certain high intensity uses. Specific site investigations may be necessary for the design of facilities to locate roads and parking areas, control runoff within the area and from adjacent land, and to plan optimum conditions for establishment and maintenance of vegetative cover.

The "Trough" and group camping areas, as well as the proposed new caravan/car camp area to the northeast of the visitors centre, fall within Class A. Specific recommendations for the stabilisation of these areas is given in Appendix I.

Class B: Suitable for Active Recreation - Moderate Intensity.

Class B land includes those areas of sideslopes with gradients between 5 and 15 per cent and footslopes with gradients below 5 per cent on all soil Units except C. Gully eroded areas however, are excluded from this class.

This class covers about 40 per cent of the study area. The erosion hazard is moderate and the land can sustain intermittent heavy pressures from such activities as horse riding and picnicking.

Specific recommendations for the stabilisation of picnic areas is given in Appendix I.

Class C: Suitable for Passive Recreation - Low Intensity.

Lands in this class comprise all footslopes with gradients of 5 to 15 per cent and all sideslopes with gradients of 15 to 30 per cent irrespective of the soil type. Minor gully erosion may be present on the hillslope terrain. The unit also includes all slopes affected by sheet erosion on soils of Unit C that were excluded from Classes A and B.

Occupying about a quarter of the study area, Class C land has a high erosion hazard. It is suitable for such activities as walking trails, orienteering, etc.

Activity areas should be adequately identified and signposted. Permanent walking trails should be well defined and properly formed with provision for safe disposal of runoff. Vehicular traffic should be controlled and restricted to well formed roads and surfaced parking bays.

Class D: Suitable for Passive Recreation - Undeveloped Access.

All slopes in excess of 30 per cent gradient are included in this class. In addition floodplains, drainage plains, areas of disturbed terrain and all hillslopes with moderate gully erosion fall within Class D.

These lands, which cover about 20 per cent of the study area, have a very high erosion hazard. They are best suited to passive recreation with such activities as bushwalking and exploring. These activities have a low impact if defined trails are not provided.

Minimum disturbance of Class D land will provide the most effective erosion control. Where active erosion is occurring, general control measures cannot be recommended but would need to be assessed for each site. It is, however, recommended that defined pedestrian access paths into these areas should not be developed and that entry be prohibited in periods of extreme fire danger.

Vehicular access is a prime consideration in planning the use of these lands. If new roads are planned this Service will assist in locating stable sites and the safe disposal of runoff. Existing roads may have to be closed or upgraded by installing adequate runoff and erosion control measures.

Class E: Suitable for Passive Recreation - Controlled Access.

These lands, which are all severely gullied comprise about 5 per cent of the study area.

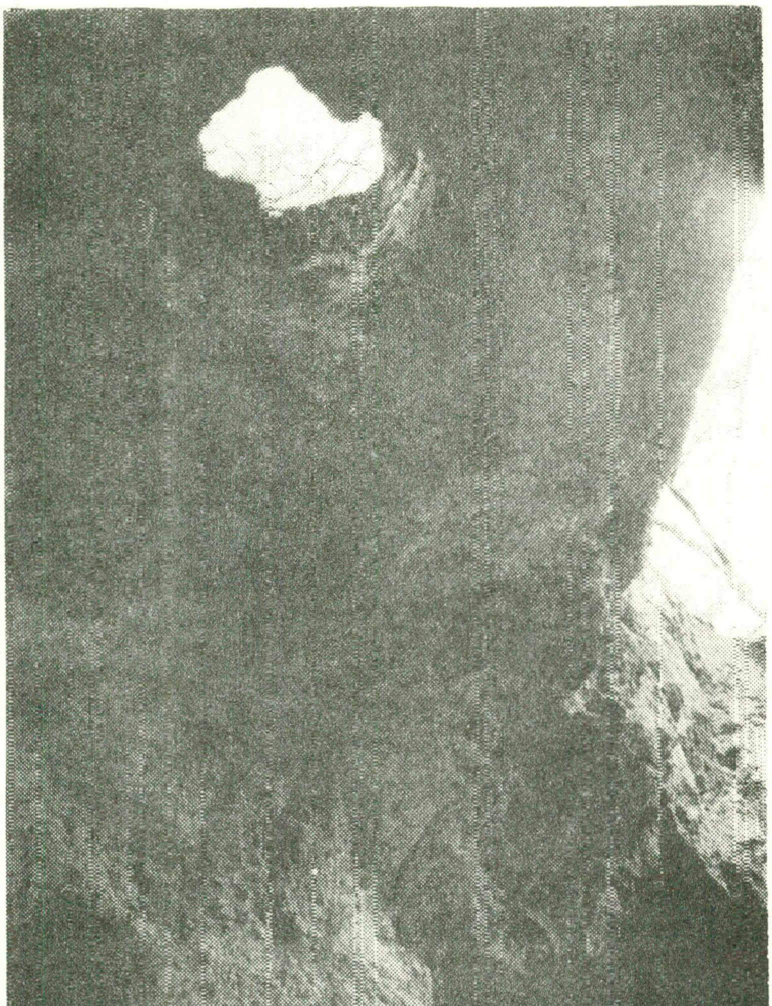
Because of the extreme erosion hazard in these areas it is recommended that recreational activities be strictly controlled. Where considerable tourist potential exists, special provisions should be made for the control and mitigation of erosion. These may include "lookout points" at safe or stable locations, and constructed walkways into the gully floors.

Erosion control measures will be costly but are required in instances where accelerated erosion is occurring or where points of interest are threatened. Any such requirements would need to be assessed on an individual site basis. Close liaison with the Soil Conservation Service is recommended during the planning and development of these areas.

The erosion features within Hill End Historic Site and along Golden Gully fall within Class E. Specific recommendations for the stabilisation of these areas are given in Appendix I.

Fossicking Areas 34 and 72 are located upstream of Tambaroora Dam. Due to the mapping scale they are included within Class E. However, the channel in this area is aggrading, and does not present the same degree of hazard as those areas of degradation.

Class A land - Group Camping Area.
Suitable for high intensity active recreation with the implementation of site specific erosion control measures.

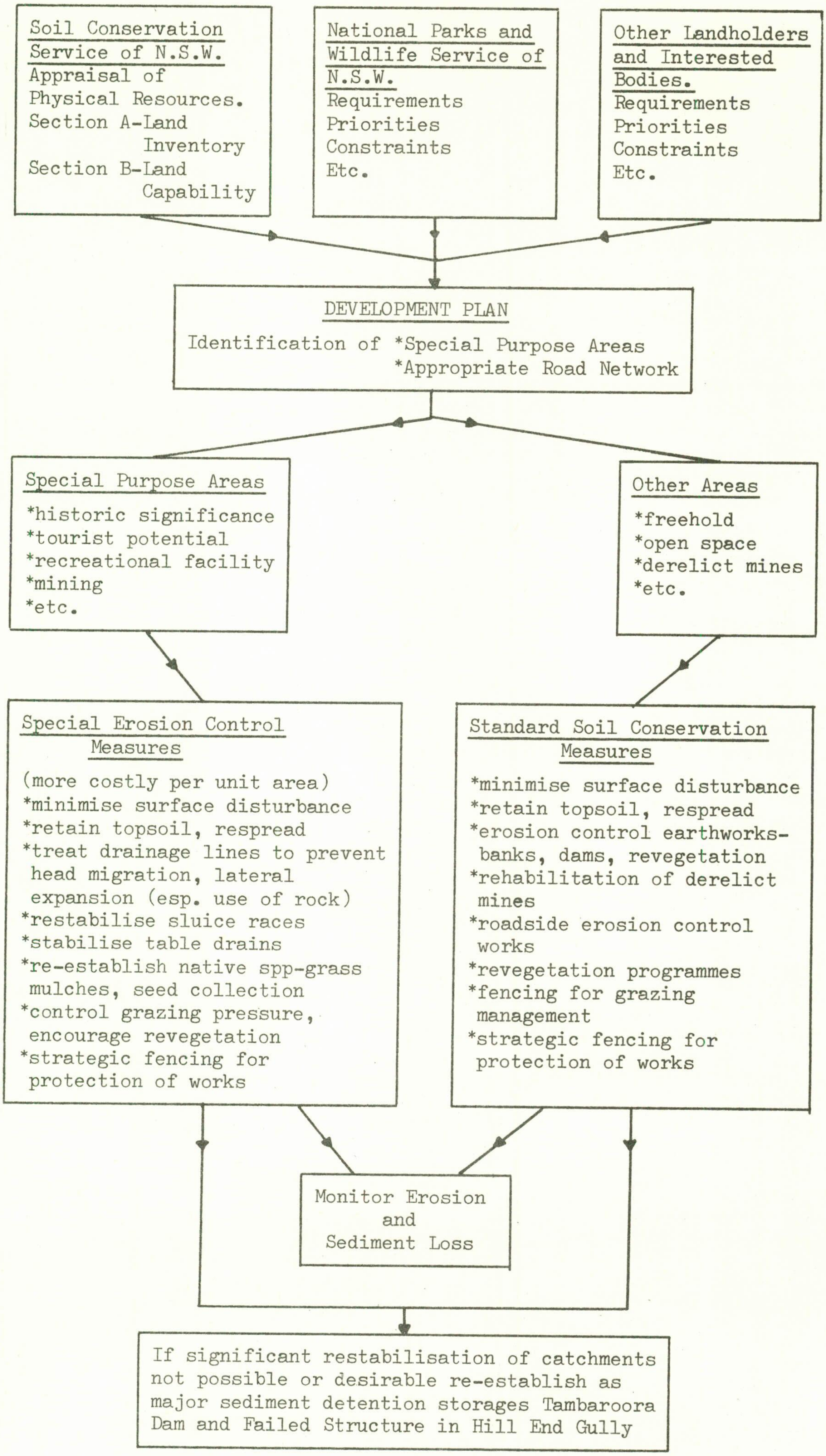


Class E land -
Erosion feature along Golden Gully.
Requires careful management including controlled access to maintain its stability.

PART C

SOIL CONSERVATION STRATEGY PLAN

FIGURE 4: Hill End and Environs - Soil Conservation Strategy Plan.



C.1 THE BASIC STRATEGY

The following soil conservation based strategy plan should be considered by the National Parks and Wildlife Service of New South Wales, and other relevant instrumentalities, as an input to the preparation of the land use and land management plans of Hill End and its environs. The plan outlines techniques to control the existing soil erosion, and to prevent future erosion problems, whilst taking into account the historical significance of the area. A diagramatic representation of the strategy is shown in Figure 4.

The first step of the strategy plan requires all landholders and interested bodies, including the appropriate state and local government bodies, to co-operate in the formulation of a basic development plan which identifies special purpose areas. To minimise the problems caused by soil erosion it is important that the development plan be based upon an objective assessment of the land's potential for development (Section B).

Appropriate erosion control measures can be designed and implemented for each specific use identified. Further detailed site investigations may be required for particular areas where the information is insufficient for planning. Details of the design, location and implementation of soil conservation aspects of the project can be arranged through the Orange Office of the Soil Conservation Service of New South Wales.

C.2 SOIL CONSERVATION MEASURES

Soil conservation measures should be implemented, as required, in all areas. In the designated special purpose areas special erosion control measures will be required to prevent the extension of the active erosion whilst maintaining significant erosional features. In other areas the standard soil conservation practices should be implemented.

The following recommendations will need to be considered in conjunction with erosion control programmes.

*Areas affected by severe sheet erosion - These areas will require protection from run-on from adjacent lands using diversion banks. Such areas may also require deep ripping, retopsoiling or mulching in conjunction with revegetation programmes. Fencing may be necessary on critical areas.

*Areas affected by gully erosion - Runoff control is essential for the stabilisation of gullied areas. The catchment of the gullies may require the implementation of a system of banks, waterways and gully control structures. Entry of runoff into the gullies by way of reshaping, flumes or drop inlet structures is essential for stabilisation of actively eroding gully heads and laterals. Grade stabilisation structures may also be required along sections of gully floors.

Critical works such as waterways, flumes and gully control structures should be fenced. Good access is also required for maintenance purposes and to allow the removal of sediment from gully control structures.

*Soil testing - Soil material should be tested for its suitability for earthworks prior to construction.

*Topsoil - Topsoiling of all disturbed sites and earthworks is recommended. Prior to surface disturbance, available topsoil should be stockpiled for later respreading.

*Revegetation - Revegetation and maintenance of adequate grass cover is necessary to maintain surface stability. A list of recommended species and sowing rates for revegetation programmes is contained in Appendix II.

Cool season species are recommended where rapid initial surface cover is required. Optimum sowing times are March-April. If sowings are delayed to spring, warm season species are recommended to provide protection during summer. However, over-sowing or resowing in autumn may be necessary to ensure the establishment of a permanent protective sward. During the initial stages of revegetation, stock should be excluded and critical areas will require fencing.

It should be noted that native species are generally not recommended in the initial stages of revegetation where rapid cover is required. This is due to their poor germination and slow growth rate, and the scarce availability of viable seed. However, native grasses have advantages in the long term as they have good persistence under drought conditions and often prefer conditions of low soil fertility.

Management techniques should be adopted to encourage native species, where appropriate. Such techniques may include the use of native grass, shrub and tree mulches, and the initial exclusion of stock followed by a restricted grazing rotation.

In areas of high traffic, native species may be unsuitable and introduced species necessary. Spelling high traffic areas may also be warranted to provide a permanent sward. Where possible, several access paths to the one site should be provided.

*Works programmes - Any Soil Conservation Service works programme should commence in the upper reaches of respective catchments and move progressively down stream to ensure the viability of works is maintained.

*Protected lands and prescribed streams - Refer Appendix V.

C.3 ROADSIDE EROSION CONTROL

Main roads, essential access tracks and fire trails should be clearly defined and all other vehicular access ways closed. The unrestricted access of off-road vehicles to the entire area will need to be assessed and a policy prepared in relation to which areas such vehicles should be permitted. Once the access ways are closed they should be deep ripped, sown to suitable species (Appendix II) and fertilized, and protected from run-on from adjacent upslope areas. Planting of native species in selected areas is also recommended.

Restricted vehicular access onto areas of severe erosion hazard, such as the upper reaches of Golden Gully, is necessary. Restrictions should also be placed on the use of unsealed access ways during periods of prolonged wet weather, especially on areas susceptible to waterlogging.

Existing roads should be upgraded and roadside erosion measures installed. Main roads should be sealed and grass allowed to grow up to the verge. Except for vertical cuts in rock, roadside batters should be reshaped to an angle not exceeding 1:3 (vertical to horizontal), topsoiled, sown to selected species and fertilized. Catch drains should be installed to prevent the movement of water over the batters. All table drains and culverts should be stabilised and discharged into stable water disposal areas.

Historically, Hill End has utilised a system of open table drains stabilised by rock rip-rap. The use of rock rip-rap in roadside and gully stabilisation programmes would therefore be in keeping with the setting of the area. Mine spoil not associated with sites designated as special purpose areas should provide suitable rock material. The use of rock rip-rap is only necessary for high expected design velocities. At runoff velocities of between 2.5 and 5 metres per second, rip-rap table drains can be expected to maintain their stability. Velocities less than 2.5 metres per second can be adequately handled by grassed drainage reserves incorporating shaped jute meshed drains.

Construction of new access tracks for purposes such as fire trails should be consistent with the specifications outlined in Appendix III.

C.4 GRAZING MANAGEMENT

Grazing management over the entire area should aim to control stocking rates to prevent depletion of vegetative cover.

Methods that can be adopted to influence grazing patterns include:

- *Strategic location of watering points.

- *Establishment of selected areas of improved/naturalised pastures. These areas should be located where there is a low erosion hazard. They will require periodic spelling to allow pastures to rejuvenate and regular applications of fertilizer. Watering points in these areas are necessary.

- *Strategic fencing to exclude stock from areas of severe erosion hazard, newly revegetated areas, and special areas such as camping sites.

C.5 MONITORING SOIL EROSION

The maintenance of the historically significant erosion features in their present form will depend upon the future rate of soil erosion. Monitoring current erosion rates will provide essential data to devise appropriate long term erosion control and remedial measures.

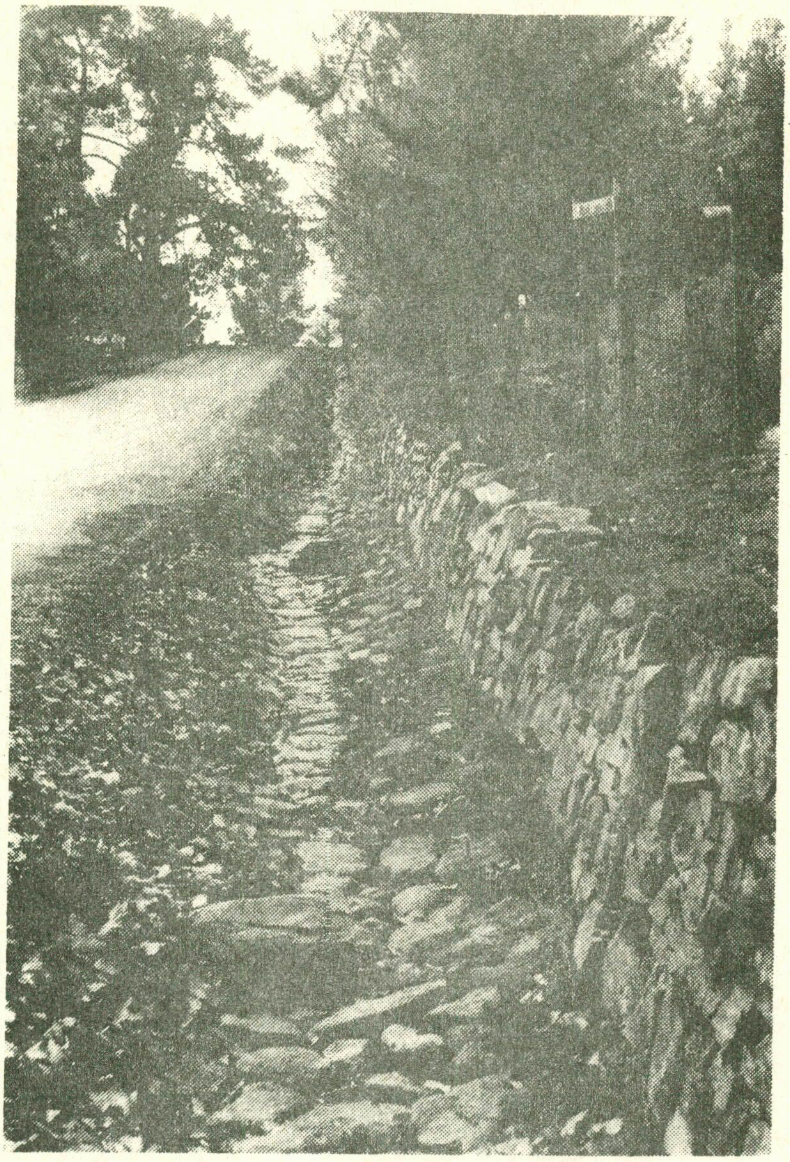
Close liaison between the Soil Conservation Service and landholders will be required before a final monitoring programme could be adopted. The level of monitoring will depend upon a number of factors including funding for instrumentation, and availability of personnel to collect the data and maintain the equipment.

Intensive monitoring of erosion rates will require detailed instrumentation of the area and will provide estimates of runoff under varying ground cover and seasonal conditions, and the volume of sediment lost. The strategic positioning of instruments plus accurate ground survey of individual gullies will provide information as to the particular sections of gullies which contribute most bedload material. Instrumentation for a detailed investigation of the two main catchments - Tambaroora Dam and Upper Hill End Creek - would require:

- *A recording rain gauge,
- *Two standard rain gauges, one in each catchment,
- *Two automatic sediment samplers, one at the outfall of each catchment,
- *Two stable hydraulic controls, e.g. a calibrated weir, one at the outfall of each catchment,
- *Two water level recording devices at the above control sites,
- *Twenty permanently located and regularly surveyed gully and sheet erosion monitoring sites.

A low intensity monitoring programme would require a large labour input for reading equipment and taking sediment samples during rainfall events. The quality of data obtained from this type of investigation is such that only general trends can be estimated. Minimum instrumentation requirements for each of the two main catchments are:

*A standard rain gauge,
*Location of maximum height gauges and staff gauges at the catchment outfall,
*The construction of a stable, natural control at the catchment outfall,
*The location of an array of bottle sediment samplers at the catchment outfall,
*A limited number of permanently located and regularly surveyed gully and sheet erosion monitoring sites.



Historically, Hill End has utilised a system of open table drains stabilised with rock rip-rap for stormwater management. Where limited access is required, a continuation of this method is recommended in place of concrete kerbing or major piping.

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The authors of the sections in this report were:

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APPENDICES

APPENDIX I

RECOMMENDATIONS FOR THE STABILISATION OF SPECIFIC SITES - HILL END AND ENVIRONS

(1) "Trough" Camping Area.

Severe gully erosion has threatened the stability of the "Trough" camping area. Recommendations for stabilising the area include:

*Reconstruction of the access track from Merlins Lookout Road. Upgrading should make provision for stable table drains (e.g. use of rock rip-rap) and sub-pavement cross drainage at selected intervals to discharge runoff onto stable water disposal areas. Topsoiling and/or straw mulching will be required on the bare areas above and below the road as part of the revegetation programme.

*Construction of a stable drain at the base of the slope below the access road to direct runoff away from the camping ground to a stable outlet. The outlet should dispose water into the floor of the drainage line by way of a drop inlet structure, rather than over the bank of the drainage line.

*Selective reshaping and straightening of Hill End Creek and Bear Gully to control bank undercutting and lateral gully migration. Banks should be battered to an angle of 1:3 - 4, re-topsoiled, grassed and fertilised. Where gully shaping is not possible a rock gabion may be installed to prevent under-cutting.

*Controlled pedestrian and stock access to the gully floor. Strategic fencing or placement of artificial barriers may be required in some areas to control access. Access ways and creek crossings should be clearly identified.

*Construction of adequately marked parking bays to keep vehicular traffic off permanently grassed areas.

*Fireplaces to be designed and installed throughout the camping area to reduce pressures at any one site.

(2) Group Camp Site on the Bald Hill Lookout Road.

This camp site is affected by severe sheet erosion, and migration of gully heads is occurring in the main drainage arteries. To aid stabilisation and revegetation of the entire area it should be fenced to exclude stock. Grids should be provided at the camp site entrances. Other recommendations include:

*Development of a system of defined individual camping sites strategically located on the hillslopes surrounding the main oval.

*Sealing the main access and trunk roads, and construction of stable table drains. At various points the roads can function as waterways to carry runoff to the drainage line at the lower end of the camping area.

*Adequately defined parking bays should be constructed to ensure grassed areas have a permanently protective sward.

*Stabilisation of the gully head on the main drainage line to stop it encroaching further into the camping area. A drop inlet structure incorporating a silt trap would be preferable. Some minor gully shaping should also be undertaken to provide stable pedestrian access into the gully floor.

*Deep ripping, topsoiling, seeding and applying fertilizer to sites that are to be permanently grassed. Stoloniferous species are recommended as they produce a dense protective sward. During the initial stage of revegetation, the camping area may have to be closed to enable adequate sward establishment.

*Subject to additional site investigations, a gully control structure may be warranted on the main drainage line below the camping area. Such a structure may provide supplementary water for irrigation as well as sediment detention.

(3) Proposed Caravan/Camp Site (Northeast of Visitors' Centre).

Plans for the proposed site include major landscape modification and the provision of full public amenities. Consequently, the following treatment may be necessary to stabilise the site.

*Runoff and site drainage control.
*Control of vehicular access.
*Well drained formed roading.
*Vehicular parking on hard areas with provision of drainage.
*Control of pedestrian access to formed or paved paths.
*Management of vegetative cover.

(4) Proposed Picnic Areas.

Development of picnic areas should include:

*Adequately defined vehicular access and parking bays, with appropriate drainage, to ensure that grassed areas are not damaged.

*Provision of permanent barbecue sites to reduce fire hazard from picnickers using unsuitable or uncleared sites.

*Constructed pedestrian access ways to the gully floor where the picnic area is adjacent to an eroded drainage line.

(5) Erosion Features within Hill End Historic Site.

The main measures necessary to stop any further erosion and retain the significant erosion features within the Historic Site include:

*Stabilisation of active gully heads and banks that threaten the stability of local roads. Gully head stabilisation structures using rock rip-rap are recommended.

Of particular importance is the stabilisation of the gully head near Moore Lane. Above this gully the drainage line is uneroded. The entire drainage line can function adequately as a stable drainage reserve for upstream areas, provided the gully head is stabilised.

*Stabilisation of actively eroding table drains and culverts using rock rip-rap.

*Stabilisation of Hill End Creek adjacent to the "Trough" camping area.

*Stabilisation and/or repair of the failed structure at the outfall of the catchment. Detailed investigations would be required prior to any works being carried out. Such investigations could also examine the possibility of utilising the structure as a sediment basin.

(6) Golden Gully.

Significant erosion features, such as the Golden Gully Arch, are currently threatened by active gullying. Uncontrolled access is also aggravating the problem. Both recreational and mining activities need to be strictly controlled, and appropriate conservation measures adopted if historical features are to be retained. The following stabilisation measures are recommended:

*Access to the upper reaches of Golden Gully should be restricted and revegetation encouraged. The high erodibility of the soils and the current land use pressures are partly responsible for active headwall retreat. The severity of erosion is increasing mainly as a result of diversion of water for unauthorised sluicing. Continuation of these practices will eventually lead to further gully incision, collapse of gully sides and undermining of Bald Hill road.

*Control of roadside and catchment runoff entering the Gully. Concentrated flows should be diverted to the Gully by way of stable natural or constructed waterways, rock races and diversion banks. Stable flumes or drop inlet structures will be required to direct flows to the gully floor. Such measures would be aimed at protecting significant land bridges and abandoned mine shafts.

*Adequate pedestrian access to the gully floor. Suitably located stable entry points should be established and adequately signposted.

*Placement of lookout points and associated parking bays at specific locations where erosion hazards will be low.

APPENDIX II

RECOMMENDED SPECIES FOR REVEGETATION PROGRAMMES AT HILL END

INTRODUCED SPECIES:

(Clover seed should be correctly inoculated and lime pelleted).

General Disturbed Areas

Autumn Sowing	kg/ha
Browntop Bent grass	10
Currie cocksfoot	6
Haifa white clover	5
Seaton Park or Woogenellup sub clover	10
Sirocco phalaris	8
Kangaroo valley perennial ryegrass	12
Cereal rye	10
Paspalum	4
Spring Sowing	
Paspalum	10
Haifa white clover	5
Couch	10
Lucerne	6
Phalaris	10
Kangaroo valley perennial ryegrass	12
Rhodes grass	10
Japanese millet	10
Drainage Lines and Wet Areas	
Paspalum dilatatum	4
Haifa white clover	6
Palestine Strawberry clover	5

NATIVE SPECIES:

Kangaroo	*Themeda australis*
Red grass	*Bothriochloa macra*
Weeping grass	*Microlaena stipoides*
Wallaby grass	*Danthonia* spps.

APPENDIX IV

MINING LEASE APPLICATIONS

The following is a summary of inclusions, specified by the Soil Conservation Service of New South Wales for incorporation in mining lease titles.

A. Conditions of Authority (1974)

35. The registered holder shall conduct operations in such a manner as not to cause or aggravate soil erosion and the registered holder shall observe and perform any instructions given or which may be given by the Minister for Mines or the Under Secretary for Mines with a view to minimising or preventing soil erosion.

56(d). The registered holder shall provide and maintain to the satisfaction of the Minister for Mines efficient means to prevent the contamination pollution or siltation of any stream or watercourse or catchment area or any undue interference to fish or their environment and shall observe any instruction given or which may be given by the Minister for Mines or the Under Secretary for Mines with a view to preventing or minimising the contamination pollution or siltation of any stream watercourse or catchment area or any undue interference to fish or their environment - with regard to Turon River and Tambaroora Creek.

B. Soil Conservation Service's Special Requirements

Where applicable, conditions related to Protected Lands (Section 21C of the Soil Conservation Act, 1938) and Prescribed Streams (Section 26D of the Water Act, 1912) have been invoked.

Additional special requirements have been included in leases at Hill End.

(a) Applicant to consult with the Soil Conservation Service prior to construction of access tracks, working benches or surface disposal of any mining residues.

(b) Drainage lines to be maintained undisturbed for water disposal. If material is to be extracted from these areas, applicant to consult with the Soil Conservation Service prior to such operations commencing.

APPENDIX V

LEGISLATION RELATED TO PROTECTED LANDS AND PRESCRIBED STREAMS

Protected Lands.

In terms of Section 21C of the Soil Conservation Act, 1938, "Protected Lands" relates to land within proclaimed catchment areas, with slopes generally in excess of 18 degrees from horizontal. Owners, occupiers or holders of timber rights are required to make application to the Catchment Areas Protection Board for an authority before destroying or injuring or causing to be destroyed or injured, trees growing on protected lands.

Generally a vigorous tree cover is recognised as the most effective control of soil erosion on steep lands. The implications of clearing these areas in relation to soil erosion has been discussed by Jones (1976).

Hill End lies within the proclaimed catchment of Burrendong Dam. Protected lands occur on much of the southern portion and in localised areas near Bald and Red Hills, Tambaroora Dam and Paling Yard Creek.

Further information relating to protected lands or the functions of the Catchment Areas Protection Board may be obtained from the Orange Office of the Soil Conservation Service.

Prescribed Streams.

Prescribed Streams are those rivers, lakes or sections of rivers which are listed as "Prescribed" within provisions of Section 26D of the Water Act, 1912. Owners, occupiers or holders of timber rights must make application to the Catchment Areas Protection Board for an authority before destroying or injuring or causing to be destroyed or injured trees growing along prescribed streams.

Unrestricted clearing of trees from the banks of streams increases the erosion hazard along the stream.

Prescribed streams within the study area include the Turon River, Tambaroora Creek and Sawpit Gully.

Further information relating to Prescribed Streams or the functions of the Catchment Areas Protection Board may be obtained from the Orange Office of the Soil Conservation Service.

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*Jones, A.J. (1976) Protected Lands in N.S.W. J. Soil Cons. 32(1), 30-33.

APPENDIX VI - PART 1

FIELD DESCRIPTIONS OF INDIVIDUAL SOIL PROFILES - HILL END AND ENVIRONS

Map Unit Name	Profile	Northcote Code	Texture A Horizon	Depth A Horizon (cm)	Depth to Bedrock (cm)
A (Red Friable Earths and Lithosols)	1	Um1.43	Loam	10	10
	2	Dr4.11	Loam	10	150
B (Red and Yellow Earths, Yellow Duplex Soils and Lithosols)	3	Gn2.21	Fine Sandy Loam	20	90
	4	Dr2.51	Fine Sandy Loam	20	90
	8	Dy3.42	Fine Sandy Loam	50	Greater than 150
	9	Dy3.81	Fine Sandy Loam	30	" 100
	13	Dy3.41	Fine Sandy Loam	30	" 150
E (Red and Yellow Duplex Soils)	5	Gn2.11 over Dy3.11	Silty Loam	30	Greater than 150
	6	Dr3.41	Sandy Loam	50	" 100
	7	Dy3.11	Silty Loam	30	" 150
	10	Dy3.81	Fine Sandy Loam	40	" 150
	11	Dr2.41	Fine Sandy Loam	25	" 150
	12	Material very mixed			

APPENDIX VI - PART 2

DESCRIPTION OF MAJOR SOIL UNITS - HILL END AND ENVIRONS

Map Unit	Name	Soil Series	Northcote Code and Variants	Description
A	Red Friable Earths and Lithosols	-	Dr4.11 Um1.43	Shallow loam lithosols (10 cm deep) occur on the crest and steeper southern slopes of Bald Hill. Basalt stones cover about 60% of the surface. On sideslopes, red friable earths occur. The surface soil is brown loam of fine granular structures and 10 cm deep. The subsoil is deep red, light medium clay with angular blocky structure. Weathered basalt is at 150 cm depth.
B	Red and Yellow Earths, Yellow Duplex Soils and Lithosols	Some Peel Series	Gn2.21 Dy3.42 Dy3.41 Dy3.81 Dr2.51 Gn2.11 Um soils	(i) Red Earths (occurring on steeper slopes and better-drained positions). Surface horizons are stony dark brown fine sandy loams about 20 cm deep, with weak structure. There is a gradual change to a yellowish red earthy silty clay loam. Depth of soil is generally 90 cm or deeper. Parent material is schist/phyllite or gneise. (ii) Yellow Earths (occurring on lower slopes). Surface horizons are stony brown to dark brown fine sandy loams 10-20 cm deep. Bleached A_2 horizons to 30 cm may occur. There is a gradual texture boundary and sharp colour boundary to mottled yellow/brown, yellowish red silt loam, fine sandy clay loam or clay loam. Structure is weak columnar, and pH 5.5 to 6.0. All soils are stony. Weathered rocks occur at about 90 to 100 cm. (iii) Yellow Duplex Soils (Peel Series). Refer Map Unit D.
C	Eroded Red and Yellow Earths	-	-	Soil types are similar to Unit B, but they have been severely eroded, frequently to bedrock.
D	Lithosols	-	Uc1.12, pockets of Gn2.11 Dr2.11 Gn2.21	Largely Lithosols and much rock outcrop. (Up to 90% rock outcrop in places). Rocks include siltstone, schist, phyllites and gneise. Soils are usually shallow fine sandy loams with pockets of shallow red earths, yellow earths, and duplex red soils.

E	Red and Yellow Duplex Soils	Worcester (Red Duplex) and Peel (Yellow Duplex)	Dy3.41, Dr2.41, Dy3.11, Gn2.21 Some Uc Lithosols	<u>Worcester Series</u> (Sideslopes and Crests). The A1 horizon is a dark yellow/brown sandy loam to fine sandy loam with weak crumb structure and 15-30 cm deep. The pH is about 6.5. Below is a pale brown to yellow brown bleached A2 horizon with sandy loam to fine sandy loam texture. This extends to a depth of 25-50 cm. There is a clear boundary to a red/brown light clay B horizon with angular blocky structure. This extends to a depth of 100 cm or more. pH of the subsoil is 5.0 to 6.0. <u>Peel Series</u> (Footslopes and Drainage Lines). The A1 horizon is a dark brown fine sandy loam to silty loam with weak crumb structure, and 5-30 cm deep. The pH is about 6.0 to 6.5. Below is usually a bleached fine sandy loam A_2 horizon about 40 cm deep. There is a clear boundary to a mottled yellow/brown and grey clay loam to light clay B horizon with coarse columnar structure. The pH is 5.5 to 6.0.
F	Lithosols on Steep Slopes	-	Shallow Uc Soils	Slopes are very steep and rocky, and there is minimal soil development. Frequently up to 90% rock outcrop.
G	Alluvial Soils	-	Uc, Um	These are the alluvial deposits of eroded material from Tambaroora Creek Catchment. They include some sand and some loam deposits.

APPENDIX VI - PART 3

LABORATORY RESULTS FOR INDIVIDUAL SOIL PROFILES - HILL END AND ENVIRONS

	Code	Depth	Grading Analysis					pH	USCS	Liquid Limit	Plasticity Index	Volume Expansion	Emerson Aggregate Test	Dispersal Index	Linear Shrinkage
			Clay %	Silt %	Fine %	Coarse %	Gravel %								
Red Friable Earths:															
Map Unit A															
Site 2	Dr4.11	100	18	14	24	44	0	8.0	SM	-	-	29	3(3)	5.3	-
		200	40	12	40	5	3	7.0	CL	-	-	43	3(4)	∞	-
		250	19	4	23	21	33	8.0	SC	-	-	22	3(1)	∞	-
Red Earths:															
Map Unit B															
Site 4	Dr2.51	20- 90	31	21	30	11	7	6.0	CL	-	-	14	5	14	-
Yellow Earths:															
Map Unit B															
Site 3	Gn2.21	30- 40	21	35	18	11	15	6.0	ML	35	13	17	3(1)	10.1	-
Site 9	Dy3.81	0- 30	16	39	19	21	5	5.5	ML	-	-	12	2(1)	∞	-
		30-100	24	48	10	13	5	6.0	ML	35	17	4	5	4.5	10
Worcester Series:															
Map Unit E															
Site 6	Dr2.41	50-100	58	12	26	4	0	5.5	CH	72	44	22	6	∞	-
Site 11	Dr2.41	0- 25	19	28	33	10	10	7.0	ML	-	-	6	3(1)	7.5	-
		25-150	47	31	20	2	0	6.0	CL	-	-	14	3(1)	4.6	-

Peel Soil Series:															
Map Unit B															
Site 8	Dy3.42	0- 50	19	57	14	10	0	5.5	ML	-	-	6	3(2)	5.0	-
		50-150	28	42	28	2	0	8.0	CL	32	15	9	1	6.3	10
Site 13	Dy3.41	0- 15	8	20	44	28	0	6.0	ML	-	-	4	3(3)	4.3	-
		30-150	41	29	29	1	0	6.0	CL	49	31	20	2(2)	2.3	15
Map Unit E															
Site 7	Dy3.11	30- 80	33	42	13	3	9	7.0	CL	46	22	18	6	∞	9
Site 10	Dy3.41	0- 40	28	50	17	5	0	5.5	ML	-	-	1	3(3)	6.8	-
		40-150	45	31	23	1	0	6.5	CL	49	28	21	6	20	14
Site 12 Sampled		150	13	46	17	8	16	6.0	ML	-	-	15	3(4)	3.2	-
from Gully Side		300	21	46	5	10	18	7.0	ML	-	-	13	3(1)	17.0	-

APPENDIX VII

GLOSSARY OF SOIL SURVEY TERMS

Atterberg Limits.

Atterberg Limits are used in conjunction with the Unified Soil Classification System as the basis for laboratory differentiation between materials of appreciable plasticity (clays) and slightly plastic or non-plastic material (silts). Two Atterberg Limits and one Index are derived:

*Liquid Limit (L.L.) - is the water content, in per cent, at which the soil passes from the liquid state into the plastic state.

*Plastic Limit (P.L.) - is the water content, in per cent, at which the soil passes from the plastic state into the solid state.

*Plasticity Index (P.I.) - is the numerical difference between the liquid limit and the plastic limit, and corresponds to the range of water contents within which the soil is plastic. Highly plastic soils have a high value for P.I., whereas in non-plastic soils, the plastic limits and liquid limits are the same and the P.I. is zero.

Dispersal Index (D.I.).

The Dispersal Index of a soil is the ratio between the total amount of very fine particles of approximately clay size, determined by chemical and mechanical dispersion and the amount of very fine particles obtained by mechanical dispersion only. Highly dispersible soils have low dispersal indices because their very fine particles are already in a dispersed state, and the ratio approaches one. Slightly dispersible soils have high dispersal indices.

The test has been shown to reflect field behaviour of soils in that dispersible soils are often highly erodible and subject to tunnelling, both *in situ* and when used in earthworks.

A full description of the Dispersal Index test and the background to it is given in "Soils of New South Wales. Their Characterisation, Classification and Conservation", edited by P.E.V. Charman (Soil Conservation Service of N.S.W., Technical Handbook No. 1, 1978).

Emerson Aggregate Test (E.A.T.).

The E.A.T. classifies soil aggregates according to their coherence in water. The interaction of clay size particles in soil aggregates with water may largely determine the structural stability of the soil.

A description of the test is given in "A Classification of Soil Aggregates Based on Their Coherence in Water", by W.W. Emerson (Aust. J. of Soil Research, Vol. 5, No. 57, 1967). However, a modification is used in this report. The Emerson classes 2 and 3 are broken up as follows:

Grade 1 - If one-quarter of the beaker or petri dish is covered by dispersed soil.

Grade 2 - If one-half of the beaker or petri dish is covered by dispersed soil.

Grade 3 - If three-quarters of the beaker or petri dish is covered by dispersed soil.

Grade 4 - If the beaker or petri dish is completely covered by dispersed soil.

The grade value is put in brackets after the class, e.g. 2(1), 3(4); which is Class 2 grade 1 and Class 3 grade 4.

On the basis of unpublished data, the following general levels of dispersibility are assigned:

Classes	Dispersibility
1 and 2(3)	High
2(2), 2(1), 3(4), 3(3)	Moderate
3(2), 3(1)	Low
4	Non-dispersible

Linear Shrinkage.

The Linear Shrinkage is the decrease in one dimension of a soil sample when oven dried (at 105°C for 24 hours) from the moisture content at the liquid limit, expressed as a percentage of the original dimension.

Shrink-swell potential is related to linear shrinkage values as follows:

Linear Shrinkage	Shrink-swell Potential
0 - 12%	Low (Non-critical)
12 - 17%	Moderate (Marginal)
17 - 21%	High (Critical)
Greater than 21%	Very High (Very Critical)

Northcote Grouping.

The Northcote Grouping represents the characteristics of a soil profile according to a system for the recognition of soils in the field. Refer - "A Factual Key for the Recognition of Australian Soils", by K.M. Northcote (Rellim Technical Publications, South Australia, Edition 4, 1974).

Particle Size Analysis.

Particle Size Analysis is the laboratory procedure for the determination of particle size distribution in a soil sample. It is used to determine the proportion of clay, silt, sand and gravel fractions in soil samples.

Rockiness.

Rockiness refers to the occurrence of outcropping rock.

Shrink-swell Potential.

Relates to significant changes in a soil's volume, in horizontal and vertical planes, with changes in moisture content. Significant swelling or shrinking in soils can be detrimental to such structures as rigid walls, roads and buildings, unless precautions are taken to allow for soil movement. Determination of shrink-swell potential is based on linear shrinkage values.

Soil Drainage.

Soil Drainage provides an indication of the period for which a profile may be wet during the year. The scale is: very poor drainage - near saturation for most of the year; to very good drainage - only saturated during or immediately after heavy rainfall.

Soil Erodibility.

The erodibility of soil material is an inherent property of that material. It is directly related to those basic properties which make the material susceptible to detachment and transportation by erosive forces. The qualitative categories for soil erodibility are low, moderate, high, very high and extreme.

Soil Profile.

The soil profile normally consists of two parts, the solum and the weathered parent material. The solum is made up of horizons which have been changed from the parent material by the processes of soil formation; they therefore have their own organisation and differ markedly from the parent material. Beneath the solum, there is usually a zone of weathered parent material which is too deep to be transformed into solum horizons, but which is weathered. This zone of weathered parent material is found even in soils derived from the underlying rock and is often much deeper than the solum. Since the weathered parent material is not sorted into horizons, it is more like the fresh rock than the solum in its properties.

Soil Series.

Represents an area of essentially homogeneous soil, which is distinguished from another series on the basis of soil morphology and the geological - geomorphological environment.

Tunnelling.

Failures in earthworks which result from post-construction deflocculation and subsequent accelerative removal of the deflocculated material. ("Investigations into the Control of Earthwork Tunnelling" by C.J. Rosewell, J. Soil Cons. 26 (3):188).

Unified Soil Classification System (USCS).

The USCS is a classification system which has been correlated with certain engineering properties of soils such as optimum moisture content, permeability, compressability and sheer strength.

Details of the system may be found in "A Handbook of Australian Soils", by H.C.T. Stace *et al*. (Rellim Technical Publications, South Australia, 1968).

Descriptions used in the soil survey for this report are:

- CL - inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays.
- CH - inorganic clays of high plasticity, fat clays.
- SM - silty sands, poorly graded sand-silt mixtures.
- SC - clayey sands, poorly graded sand-clay mixtures.