DEPARTMENT OF CONSERVATION AND LAND MANAGEMENT

Murray-Billabong Catchments

Volume 1

Proposals for the integrated management of soil erosion and related land degradation

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MURRAY-BILLABONG CATCHMENTS (NSW)

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Acronyms and Abbreviations used

BGATF	Blue-Green Algal Task Force
CaLM	NSW Department of Conservation and Land Management
CMU	Catchment Management Unit
DWR	Department of Water Resources
EPA	Environment Protection Authority
GIS	Geographic Information System
MDBMC	Murray-Darling Basin Ministerial Council
NSCP	National Soil Conservation Program
RTA	Roads and Traffic Authority
SCS	Soil Conservation Service of NSW
SF	State Forest
SPCC	State Pollution Control Commission
SRA	State Rail Authority

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SUMMARY

Land degradation mapping projects carried out from 1989-92 by staff of the Soil Conservation Service of NSW have been used to identify the location, extent and severity of soil erosion and other forms of land degradation within the major drainage systems of the Murray-Darling Basin within New South Wales.

This report and the accompanying thirteen (13) maps, describe the results of the survey within the catchment of the New South Wales portion of the Murray River east of Howlong, including the catchment of Billabong Creek. Similar surveys have been undertaken, and reports prepared, for the catchments of the Murrumbidgee, Lachlan, Macquarie, Castlereagh, Namoi, Gwydir and Macintyre Rivers. These have been undertaken as part of the NSCP/ CaLM funded project "*The Development of Land Management Programs for the Headwaters of the Murray - Darling Basin*". The program forms part of the State's commitment to Total Catchment Management.

Mapping undertaken during the program was digitised into a Geographic Information System (GIS) which generated a range of maps and statistics on land use, land capability, soil erosion, dryland salinity, streambank erosion and mass movement. Maps are presented at a scale of 1:100 000.

The total area of the Murray-Billabong catchments above Howlong is 11,272 km^2. Land degradation issues such as dryland salinity, surface waterlogging, lack of tree cover, soil acidity, streambank erosion, soil erosion, steep lands, wind erosion sedimentation, soil structure decline and mass movement were identified in the Catchments and are discussed in this report.

The text of the report summarises data collected during mapping, and discusses the relationships between the different forms of degradation and other physical factors. A series of actions recommended by the Department of Conservation and Land Management and other government agencies for treatment of the different land degradation problems have been produced. These are presented under the headings of policy, investigations and actions.

As part of the proposals, areas of severe land degradation are identified for priority treatment on an integrated subcatchment basis using the project provisions of the Soil Conservation Act 1938. Identified subcatchments have been called Catchment Management Units (CMU's). Priorities for the treatment of problems have been based upon the types and severities of land degradation present.

This document provides comprehensive information to the government and to the community on the environmental issues in the Murray River and of the measures needed to solve these problems.

Maps and statistics for all Catchment Management Units identified in the Murray-Billabong catchments are presented in Volume 2 as a separate document.

MAJOR RECOMMENDATIONS

Five land degradation issues are of major concern across large areas of the Murray-Billabong Catchments. These are:

* waterlogging and dryland salinity associated with rising groundwater
* tree decline
* soil acidity
* streambank erosion
* soil erosion

The expression of some of these issues, particularly soil erosion, although still significant appear to have become relatively static as improved land management practices have been adopted. The major concerns are the effects of widespread rising groundwater, dryland salinity, tree decline and induced soil acidity.

The predominant cause of these problems is the lack of emphasis land managers have placed on water use. In particular, aspects needing to be addressed are groundwater recharge and nitrate leaching (soil acidity), and the balance between tree cover, cropping and perennial pastures.

The principal broad recommendations of this report are:

* an approach to land management based predominantly on vegetation utilising more soil water will address much of the land degradation in the Murray-Billabong Catchments
* joint landholder action is needed to successfully address these issues. Community activity such as Landcare facilitates this, and needs to be supported
* in areas where land degradation is widespread landholders need to prepare individual property plans of their farms, and integrate these as catchment management plans. Foreshores and immediate catchment to Hume Weir are a priority
* expand all phases of activity in the identification, recording, investigation, economic evaluation, and treatment and management of:
    . rising groundwaters, waterlogging and dryland salinity
    . soil acidity
    . tree decline
* ensure extension activity with landholders and other land management authorities addresses all aspects of land degradation
* implement a program of digitally stored land resource mapping to monitor the status and changes in:
    . groundwater
    . native vegetation cover
    . soil acidity
    . soil erosion

* assess the land degradation issues to be included under the environmentally sensitive land category of Protected Lands Legislation (Soil Conservation Act, 1938 amended), and incorporate this into the formulation of property and catchment management plans

* increase research and investigations in the following fields:

  . cropping systems to minimise groundwater recharge and soil acidification
  . pasture species and management for lands with acid soils
  . tree management, establishment and regeneration for the various landscapes and land uses across the Catchments
  . assess heritage value of retaining/enhancing landscapes and the need for planning guidelines
  . economic and environmental assessment of lower stocking rates and maintaining native perennial systems on low productivity country
  . evaluation of delivery of sediment, nutrients and salt from:
    - various forms of erosion
    - individual sub-catchments

* develop policies for the retention, use and management of Crown land through the Land Assessment Program to assist in the prevention and treatment of land degradation problems in the Catchments. Specific activities include identifying:

  . the status of all Crown land in the catchment, those Crown lands which should be retained under Crown ownership because of their importance in the prevention and control of streambank erosion, dryland salinity, tree decline and land degradation caused by extractive industries
  . those Crown lands which are important in the conservation of native flora and the maintenance of wildlife habitat
  . those Crown lands which can leased or sold

* implement a program of land rehabilitation under the project provision of Section 10 of the Soil Conservation Act, Landcare Schemes, or other appropriate funding. Priority areas, called Catchment Management Units, are identified in the report, with the highest being:

Catchment Management Unit (CMU)	**CaLM District**
Mullengandra Creek	Albury
Tabletop Creek	Albury
Native Dog Creek	Albury
Ten Mile Creek	Albury/Henty

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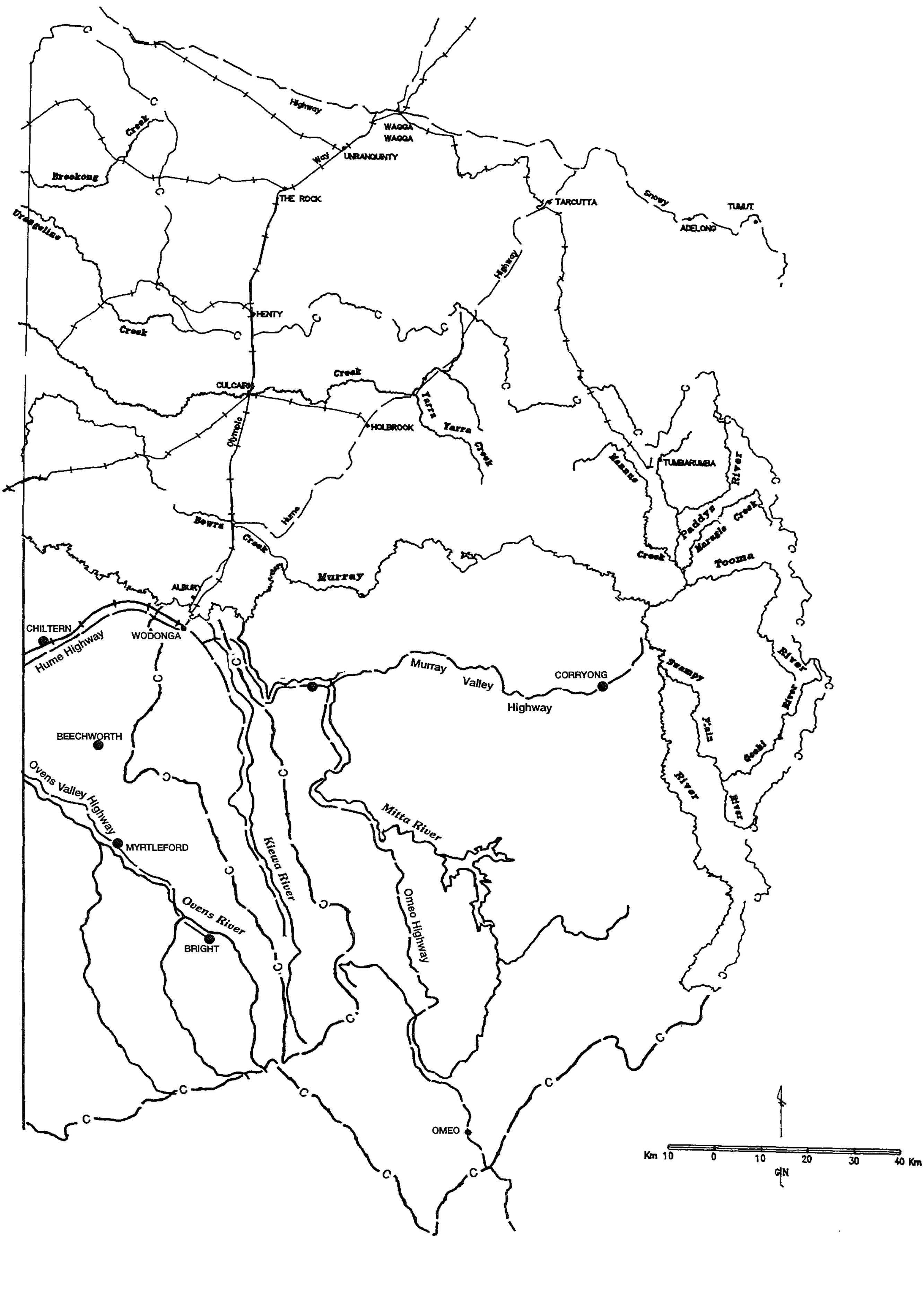
Murray-Billabong Catchments Survey Area (NSW) and Upper Murray Catchments (Vic.)



1. INTRODUCTION

1.1 BACKGROUND

Environmental issues are of increasing importance to the community worldwide. Where the concerns of thirty years ago were of increasing production and community wealth, we now have become aware of the need for greater concern about the environment and of the need to establish land use on a more sustainable basis.

The Murray-Billabong Catchments are also facing significant environmental problems which have the potential to cause major socio-economic repercussions in both rural and urban areas, and affect our quality of life. These include land degradation issues such as lower water quality, soil erosion, soil acidity, streambank erosion, rising watertables, expanding areas of salinity on agricultural lands, tree decline and the loss of native habitat and diversity.

The long term consequences of land degradation include farms becoming non-viable because of salinity, waterlogging, acidity and erosion; river water becoming unsuitable for irrigation and requiring expensive treatment prior to human consumption; and the creation of degraded rural and riparian landscapes of low aesthetic appeal.

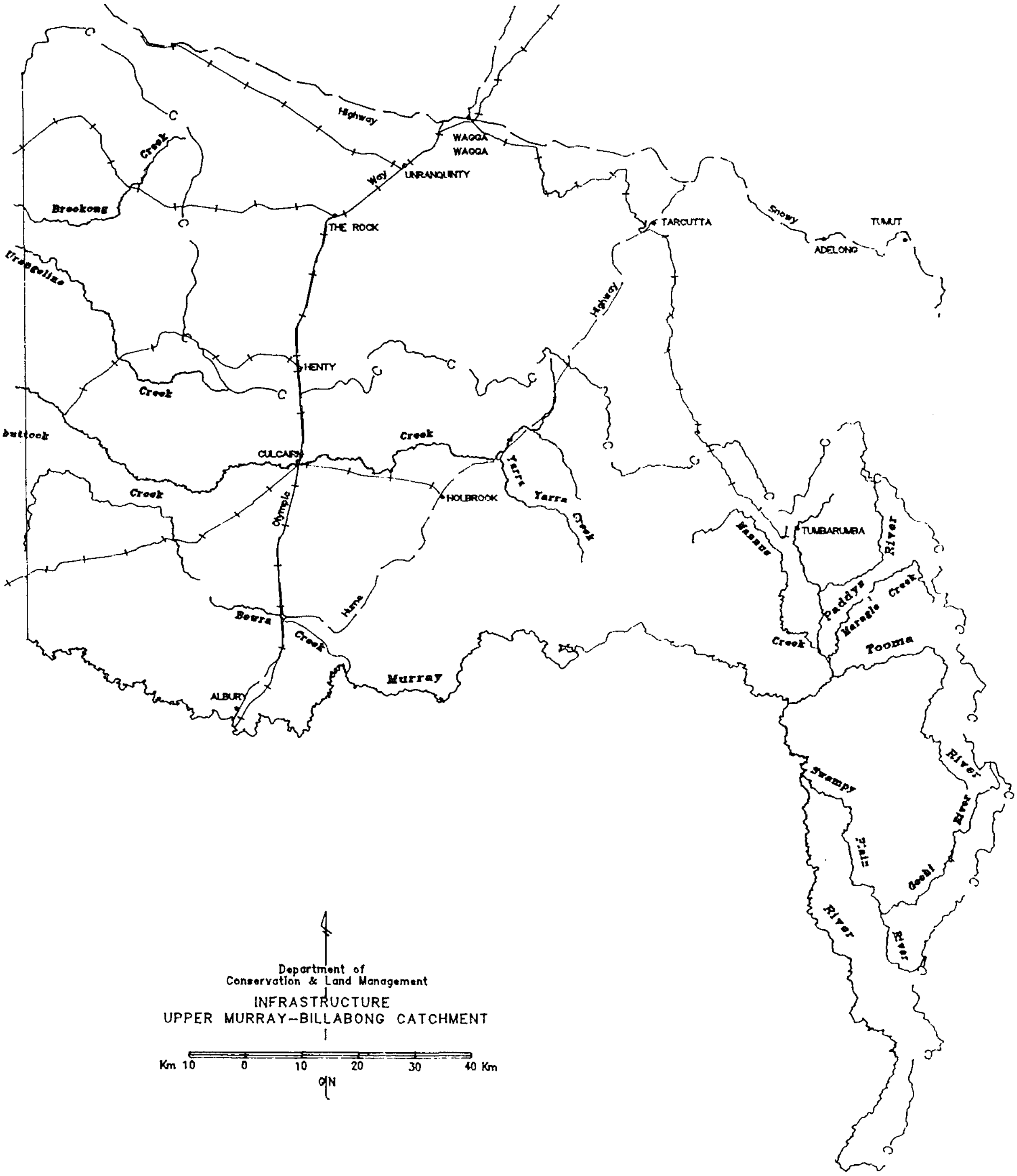
Community groups and government are already moving towards the solution of some of these problems. Within the Murray-Billabong Catchments such groups include:

* Landcare groups at
  - Redlands-Mulwala
  - West Hume
  - Bungowannah
  - Bowna Arm
  - Monument Hill
  - East Albury
  - Wagra-Fowler's Swamp
  - Mullengandra
  - Holbrook
  - Dora Dora
  - Jingellic
  - Ournie
  - Tumbarumba
  - Tooma

* Murray Catchment Management Committee
* Murray Darling Association
* Australian Trust for Volunteers
* Albury High School Environmental Unit.

Land degradation and associated problems were broadly addressed by McNamara (1990) in "Total Catchment Management in the Murray River, N.S.W: TCM Needs and Strategies". McNamara, on behalf of the Soil Conservation Service of NSW (SCS) examined the problem by means of seminars and a questionnaire circulated to government agencies, local government, local specialists and land users.

FIGURE 1: The Murray-Billabong Catchments



1.2 THE STUDY AREA

The area described in this report is the catchments of the Murray River (NSW) and Billabong Creek east of 146°30' longitude. It is covered by thirteen (13) 1:100 000 maps sheets and totals 11,272 km^2 (Figure 1). An area breakdown of the catchment on a map sheet basis is shown in Table 1.

TABLE 1: The Study Area on a 1:100 000 Map Sheet Basis

1:100 000 Map Sheet	Murray River Catchment		Billabong Creek Catchment	
	Area (km^2)	Percentage of Total	Area (km^2)	Percentage of Total
Albury	246.6	(4.0)	-	-
Walbundrie	858.7	(14.1)	1552.0	(30.0)
Lockhart	-	-	1530.7	(29.6)
Narrandera	-	-	30.3	(0.6)
Tallangatta	183.0	(3.0)	-	-
Holbrook	642.1	(10.5)	1651.1	(31.9)
Wagga Wagga	-	-	17.5	(0.3)
Corryong	45.6	(0.1)	-	-
Rosewood	1328.0	(21.8)	389.4	(7.5)
Tarcutta	-	-	2.7	(<0.1)
Jacobs River	260.8	(4.3)	-	-
Kosciusko	597.3	(26.2)	-	-
Yarrangobilly	935.9	(15.4)	-	-
Total	6097.9		5173.7	

1.3 AIMS OF THE REPORT

The aims of this report are to:

* identify the location, extent and severity of the different types of soil erosion and other land degradation issues within the Murray-Billabong Catchments

* describe each of the major land degradation issues and their local and regional significance

* identify those areas which have the highest priority for treatment based upon the types of land degradation occurring, their severity and their on-site and off-site effects

* to establish a series of actions for the treatment of the different types of land degradation in the catchment

* nominate the priorities for implementation of these.

1.4 DEFINITION OF LAND DEGRADATION

For the purpose of the survey, land degradation has been defined as the decline in the condition or quality of the land as a consequence of misuse or overuse. It can occur when the landscape is changed by developments for agriculture, mining, forestry, industry, urban settlement, tourism or by infra-structure developments such as roads, railways, dams, power stations, pipelines and transmission lines.

On agricultural lands, degradation results in a loss of sustainable productive capacity. Some degradation types also have off site effects such as sedimentation of water courses and storages, decline in water quality, and damage to roads, fences and other infrastructure.

2. DESCRIPTION OF THE STUDY AREA

2.1 LOCATION

The Murray-Billabong study area is located in the southern inland of NSW. The catchments are bounded by the Great Dividing Range to the east, the Murrumbidgee River to the north, the Victorian border (Murray River) in the south, and the 146°30' parallel to the west.

2.2 PHYSIOGRAPHY

Physiography of the catchments is strongly influenced by geology. It varies greatly and can be divided into three zones:

* Alps and Headwaters
* Southern Slopes or Upper Murray
* Riverine Plain or Lower Murray

The headwaters are the catchments of the Tooma River, Swampy Plains River and the Murray River above Khancoban. They are rugged areas with elevations generally over 1300 m and are mainly within Kosciusko National Park. They have been extensively dammed and regulated.

The Riverine Plain commences abruptly just west of Albury, and around Holbrook on the Billabong Creek.

The Southern Slopes occur between the headwaters and the plains and are characterised by undulating to steep terrain with elevation being predominantly between 100 m and 800 m. The majority of creeks in the study area occur in this zone.

2.3 CLIMATE

Considerable climatic variation exists within the catchments. Climate is mainly controlled by eastward moving low pressure cells and associated frontal systems. However, during summer convectional activity can produce local short duration high intensity storms. The climate is best described as mediterranean with warm to hot summers and cool to cold winters.

Temperature, rainfall and frost occurrence are strongly related to altitude hence it becomes cooler and wetter to the east. Frost free days vary from 249 at Albury to 58 at Pilot Hill. Rainfall is slightly winter-spring dominant with 60% of annual average falling between May and October. During this period rainfall exceeds evaporation by 138 mm (Williams, 1990). Average annual rainfall increases from 500 mm at Balldale, to 1000 mm at Tumbarumba up to over 1300 mm in the headwaters.

2.4 PLANT GROWTH

Moisture availability is the most limiting factor to plant growth across the catchments. The moisture deficit is less of a problem in the higher elevation slope areas, however low winter temperatures adversely affect winter growth. Dry summer conditions result in high fire hazard particularly in forest areas.

2.5 GEOLOGY

The geology of the catchments is a result of a complex series of erosion and deposition cycles, followed by deformation and metamorphism (SCS, 1978). The physiographic zones discussed in section 2.2 relate well with surface geology.

Geology in the headwaters is primarily low grade metamorphic rocks (slate, phyllite and low grade schist). The slopes are mainly biotite granites, granodiorites, granites and gneissic granite. The catchments of Coppabella Creek, Mannus Creek, Mullengandra Creek and Mountain Creek are predominantly low grade metasediments (slate, phyllite, greywacke and siltstone). Surrounding Albury are areas of high grade metasediments (quartz, schist), conglomerate, and residual and alluvial deposits derived from volcanics.

Extensive areas of riverine deposits of clay, silt and gravel occur adjacent the Murray River and Billabong Creek. There is some evidence of aeolian deposits in the west of the area.

2.6 SOILS

Soils of the catchments reflect the geology, relief and climate. In the Headwater areas soils on the steeper slopes are stony and shallow. On the Slopes areas, yellow and red duplex soils predominate, with siliceous sands occurring over much of the granite country. Well structured chocolate soils occur on the basalt and basalt-type areas. Yellow solodic soils occur in the drainage lines of the low undulating country around Albury and Holbrook.

The floodplains to the Billabong and Murray are a complex result of layers of deposition and changing watercourses. Soils consist of alluvials (sand, silt, gravel), red brown earths, grey and brown clays, and yellow solonetzic soils.

2.7 LAND USE

The Albury area has been a highly regarded agricultural and pastoral area since the 1850's. With the operation of paddle steamers along the Murray, by 1880, Albury was a principle wheat growing area in the State (SCS, 1978).

Land use has changed little since initial settlement over much of the Catchments. The Headwaters are used for water supply, timber production, and conservation and tourism within Kosciusko National Park. The Slopes are used for beef cattle production, and fine wool and fat lamb production. Pastures have been generally improved with introduced pasture species and superphosphate, but most are still based on annual species. In the higher rainfall and/or more rugged areas significant tracts remain as State Forest and Crown land. Increasing areas are being developed for softwood plantations, and to a lesser extent for horticulture. Some grazing properties crop small areas of oats for grazing. Dairying and grass seed production also occurs on some properties in the Tooma Valley, and the latter also around Holbrook.

On the Plains mixed farming operations are dominant, with cropping for wheat and oats, and grazing of sheep. In recent times the cropping activity has declined as a response to lower returns, waterlogging problems associated with inundation, soil structure decline and possible rising watertables. Active cropping continues on the better drained fringes to the Slopes country, where rainfall and soils also allow successful alternate crops such as canola and lupins. Small feedlots are a part of many farm operations, but there is only one large feedlot in the study area, located at Culcairn.

2.8 NATIVE VEGETATION

Particular vegetation communities have long been recognised as indicators of various agricultural uses and capabilities. The distribution of particular vegetation species relates closely to seasonal moisture availability, soil depth, drainage, soil pH, aspect, temperate and frost. The vegetation in the catchments has been altered considerably since European settlement, with only traces of native communities remaining in agricultural areas.

In the Headwaters the vegetation has been less affected and the dominant communities are Mountain Gum-Alpine Ash communities and alpine grasslands above the tree line. The elevated Slopes were covered mainly by the Peppermint community, the Red Stringbark community, and some Brittle Gum community.

On the Riverine Plain the dominant community was Grey Box. White Box communities occupied the slopes fringing the Riverine Plain. The Blakely's Red Gum community dominated the Billabong Creek Catchment above Morven, and the western Slopes country north of Albury. River Red Gums occurred along the main alluvial areas where historically there was cyclic flooding.

European settlement has transformed these communities either by clearing for crops and introduced pastures, or grazing the understorey and halting regeneration.

3. LAND RESOURCE INFORMATION

3.1 SOURCES USED IN THIS REPORT

This report draws information from a series of land resource surveys and reports prepared by the NSW Department of Conservation and Land Management (CaLM) and the Soil Conservation Service (SCS). These include the -

* Land Degradation Survey of New South Wales (1987-88)
* 1:100 000 Rural Land Capability Mapping for the Eastern and Central Divisions of NSW
* Soil Erosion and Land Use Survey of the headwaters of the Murray-Darling Basin in NSW (1989-91)
* Protected Land Mapping.

In preparing this report, a series of maps and a large amount of statistical information was produced (see Section 3.2).

3.1.1 NSW Land Degradation Survey 1987-88

A state-wide survey of land degradation in NSW was completed in July 1988. Individual maps showing the location, extent and severity of degradation and related attributes were prepared (Graham 1988).

Ten forms of land degradation were assessed on a 10 kilometre by 5 kilometre grid sampling system. They were:

Sheet and rill erosion	Irrigation salinity
Gully erosion	Scalding
Mass movement	Induced soil acidity
Wind erosion	
Soil structure breakdown	
Dryland seepage salinity	Woody shrub infestation

In addition, maps were prepared on land use, tree regrowth, and the occurrence of perennial bush (such as saltbush).

3.1.2 Rural Land Capability Mapping

The Murray-Billabong Catchments were mapped between 1981 and 1983 as part of the program to prepare maps of rural land capability for the Eastern and Central Divisions of NSW . The method used was an eight class system for evaluating rural land (Emery, 1985). It is based on an assessment of the biophysical characteristics of the land, the extent these will limit a particular land use, the need to protect the land from land degradation (erosion), and the current land management techniques which are available.

The classification determines the types of rural land uses appropriate for a particular area of land and the land management practices needed to prevent land degradation and maintain the long-term sustainability of the land.

Although National and State Parks, State Forests and urban zonings were excluded from the Land Capability assessment, area figures for these uses are presented.

A breakdown of land capability for the Murray River and Billabong Creek catchments is given in Table 2.

TABLE 2: Rural Land Capability in the Murray-Billabong Catchments [1] (Source CaLM GIS)

Land Capability	Murray River Catchment		Billabong Creek Catchment	
	km²	(%)	km²	(%)
Cultivation Land				
Class I	287	(4.2)	1307	(25.3)
Class II	579	(8.4)	1817	(35.1)
Class III	444	(6.4)	999	(19.3)
Sub Total		**(19.0)**		**(79.7)**
Grazing Land				
Class IV	671	(9.8)	356	(6.9)
Class V	536	(7.8)	287	(5.6)
Class VI	719	(10.5)	231	(4.5)
Sub Total		**(28.1)**		**(17.0)**
Best retained as timber				
Class VII	647	(9.4)	83	(1.6)
Class VIII	20	(0.3)	13	(0.3)
Sub Total		**(9.4)**		**(1.6)**
State Forests	537	(7.8)	73	(1.4)
National Park	2388	(34.8)		
Urban, water bodies	27	(0.4)	6	(<0.1)
Sub Total		**(43.5)**		**(1.7)**

1 Definitions of the eight classes and their interpretations appear in Appendix A.

3.1.3 Soil Erosion and Land Use Survey

Mapping of land degradation and land use within the Murray-Billabong catchments was undertaken in 1989-91 as part of a National Soil Conservation Program/CaLM funded project. A mapping scale of 1:100 000 was adopted to be compatible with the existing land capability maps. The various forms of land degradation were identified by interpretation of aerial photographs and verified with field checking. A list of the photography used is presented in Appendix B.

Land use was mapped to help determine its relationship to the various land degradation features and to rural land capability. The following general land use categories were mapped:

* crop land (grain, fibre or fodder)

* native or improved pasture
* native forest
* horticultural or viticultural land
* irrigated land
* softwood plantations
* softwood plantations (involved clearing of native forest between 1980-1990).
* water body, lake or swamp
* mining or quarrying
* urban.

At a mapping scale of 1:100 000 it was not possible to depict units less than 10 ha in size. Consequently small units such as groups of trees within crop and pasture lands were not able to be included. Mapped land use, is that evident on the aerial photographs used in the survey (see Appendix B).

A summary of land use in the Murray-Billabong Catchments is given in Table 3.

TABLE 3: Land Use in the Murray-Billabong Catchments

Land Use	Murray River Catchment		Billabong Creek Catchment	
	km^2	(%)	km^2	(%)
Cropping	134.4	(2.2)	876.2	(16.8)
Native or improved pasture	2739.0	(45.9)	4014.0	(77.2)
Native Forest	2731.5	(45.7)	293.6	(5.7)
Softwood plantation	231.6	(3.8)	5.0	(<0.1)
Water	101.4	(1.7)	3.0	(<0.1)
Mining or Quarrying	0.8	(<0.1)	0.9	(<0.1)
Urban	41.2	(0.6)		
Total		(100.00)		(100.0)

The soil erosion maps show the location and extent of areas affected by sheet, rill and gully erosion, salinity, streambank erosion and mass movement. The following classes were identified:

* no appreciable erosion
* sheet erosion hazard (4 classes)
* gully erosion (16 classes) differentiated on the basis of the characteristics of the gully, the degree of instability, branching characteristics and depths
* rill erosion (4 classes)
* wind erosion (4 classes)
* mass movement (4 classes)
* streambank erosion (4 classes)
* dryland salinity (7 classes)
* areas treated by soil conservation works and their status.

A description of erosion classes is presented in Appendix C.

The mapping is a pictorial representation of the ground condition. Salt outbreaks and mass movement affected lands have often been exaggerated in size to enable them to be represented. It is important to show the occurrence of these erosion forms as this information is useful when predicting erosion hazards.

The maps show the observed active erosion, except for areas of sheet, rill and wind erosion, which were mapped on a hazard basis. Actual erosion of these forms is difficult to map as they occur infrequently and are masked by land management practices and changing seasons.

Statistics relating to the erosion mapping are presented under the chapters relating to the various land degradation issues.

3.1.4 Protected Land Mapping Program

A Protected Land Map has been gazetted for the Hume Weir catchment only. A program is presently being undertaken to map remaining lands recommended for inclusion under the Protected Land legislation. This includes identifying existing and potential land degradation hazards for inclusion under the third category of Protected Land; " Land .... affected or liable to be effected by soil erosion, siltation or land degradation".

Four principal features are being identified at a scale of 1:25 000 for the third category of Protected Land. These are:

* dryland salinity - saline water seepages and the immediate contributing catchment
* mass movement
* shallow soils with moderate to high erodibility on sedimentary country
* erodible soils on granite country.

3.1.5 Land Tenure

Land tenure has major implications on land management, and has also influenced the collection of land resource data. For example, neither the Land Capability Maps nor the Protected Land Maps cover National Parks or State Forests.

Land tenure information in the Murray-Billabong Catchments is not in a form that can be readily collated. Morland (1958) presented figures for land tenure in the Murray catchment above Hume Weir (see Table 4). Advice from the Crown Lands Service Management suggests that the area of Crown land could now be 10% lower than that described by Morland (1958) following conversion of leases.

TABLE 4: Land Tenure in Hume Weir Catchment

Land Tenure	(ha)	Acre (ac)	(%)
Kosciusko National Park	161878	400000	(32)
State Forest	41279	102000	(8)
Crown land			
- longterm leasehold	21854	54000	(4)
- grazing leases	31566	78000	(6)
Travelling Stock Routes	10117	25000	(2)
Freehold	249291	616000	(48)

Table 4 shows Public Land consisting of Kosciusko National Park (about one third of the catchment), State Forest and Crown land (totalling a further 20%). Freehold land makes up less than one half of the Hume Weir catchment.

Land use controls in relation to Crown land remain much as described by Morland. *"Control (of Crown land) is vested in the Crown Lands Service (CaLM).....long term leases generally allows clearing,..... and unrestricted grazing. The remainder is..... for grazing under Annual Lease,* with Travelling Stock Reserves and Camping Reserves now administered by the Rural Land Protection Board.

3.2 MAPS AND STATISTICS

All mapped data are now digitised and stored within the Department's Geographic Information System (GIS).

In preparing this report, the following outputs were produced from the GIS:

i) a series of 1:100 000 based maps depicting
  . soil erosion
  . land use
  . land capability

ii) screen dumps - A4 size maps of identified subcatchments or catchment management units (CMU's). Three maps were produced of each area depicting
  . soil erosion
  . land use
  . land capability

iii) statistical information on a catchment basis for each set of maps listed in (i) and (ii) above.

Volume 2, a separate report, includes data for (ii) and (iii).

Maps described in (i) above are available on request. 13 sheets provide complete coverage of the NSW Murray-Billabong Catchments. An example of material described in (ii) and (iii) above is presented in Appendix D.

Funding from the Murray Catchment Management Committee (CMC) and CaLM has enabled additional data collation and map production not envisaged in the program. These are catchment maps at 1:250 000 identifying:

. sub catchments
. erosion map (simplified)
. vegetation cover
. salt outbreaks

These maps also show the extent of the eight (8) local government areas in the Murray-Billabong Catchments.

4. DATA ANALYSIS AND PRESENTATION

The large quantity of resource information for the Murray-Billabong Catchments was analysed to develop practical and workable solutions to treat the land degradation problems in the Catchment. Discussions of the results and recommendations of this program are presented in Chapter 5.

Land degradation has been associated with 10 features. They are:

* developing or expanding waterlogging and salinity
* low tree cover and tree decline
* induced soil acidity
* streambank erosion
* soil erosion (sheet, rill and gully)
* soil physical and chemical properties
* wind erosion
* steep lands
* major land use changes
* specialised land uses

4.1 INITIAL ANALYSIS

The land degradation, land use and land capability maps and supporting statistics were evaluated by district and regional staff of CaLM. Areas of severe degradation which required specific treatment or changes to land management practices to overcome the degradation were identified and the principles of Total Catchment Management employed to develop the appropriate methods for rehabilitation and management.

For each land degradation feature, the nature of the problem, its distribution, the relationships with other physical factors and the technical solutions that are available for the treatment of the problem were described. From these analyses, proposals have been developed for the treatment and/or prevention of each problem.

These treatment/prevention proposals are presented under three main headings:

* **Policies**

  Under this section, the policies needing to be adopted by all authorities responsible for land use and land management decisions are identified. This is to ensure that activities by any one group does not cause or accentuate land degradation problems.

* **Investigations**

  Where the causes or technical solutions to problems are not known or only poorly understood, specific investigation projects are proposed.

* **Actions**

  The activities or programs needing to be undertaken in the field to treat the problem or to prevent the expansion of the problem are listed. This includes activities such as catchment based land management programs under the project provisions of the Soil Conservation Act 1938, or activities that may be undertaken by Landcare groups, local government councils or individuals. The proposals for land management programs on a catchment basis have been identified for land units which are called Catchment Management Units (CMU's).

4.2 INTEGRATED TREATMENT OF LAND DEGRADATION ISSUES

Total Catchment Management (TCM) refers to the co-ordinated and balanced use of the natural resources of land, water, vegetation and soils within a catchment to maintain these resources and to achieve sustainable use of the land in the long term.

The treatment of land degradation should also be undertaken on a catchment basis so that all land degradation is treated in a planned and integrated manner. The study area was divided into 50 subcatchments (see Figure 2). Using available data, 24 priority sub-catchments, called Catchment Management Units (CMU's), have been identified with severe land degradation problems. Of these, four (4) have a series of problems, and should be treated on a priority basis under the project provisions of the Soil Conservation Act, 1938.

The advantages of the CMU descriptions are that they detail all the land degradation problems within a well defined watershed, at a scale suitable for planning and rehabilitation at the local level. Individual CMU's with similar types of problems can be grouped together and priorities set for the implementation of site treatments, investigation proposals, or policies.

All of the 24 CMU's identified have severe land degradation problems including:

* high proportions of severe to extreme sheet, rill, gullying and streambank erosion
* existing or developing salt or waterlogging problems
* soil acidity
* water disposal problems, aggravating flooding and sedimentation hazards
* tree decline
* soil structure decline on cropping lands
* wind erosion
* damage to community facilities such as water supplies, roads and public lands
* low ground cover levels and high run-off from steep lands.

As far as practicable the CMU's have been defined on the basis of the natural catchment areas of various minor streams within the Murray-Billabong Catchments. In some of the flatter areas in the western part of the catchments, roads or other features were used to define the boundaries of the CMU's whilst in a number of cases local communities which have formed Landcare groups were the basis for defining the CMU's. Figure 2 shows the location of the CMU's.

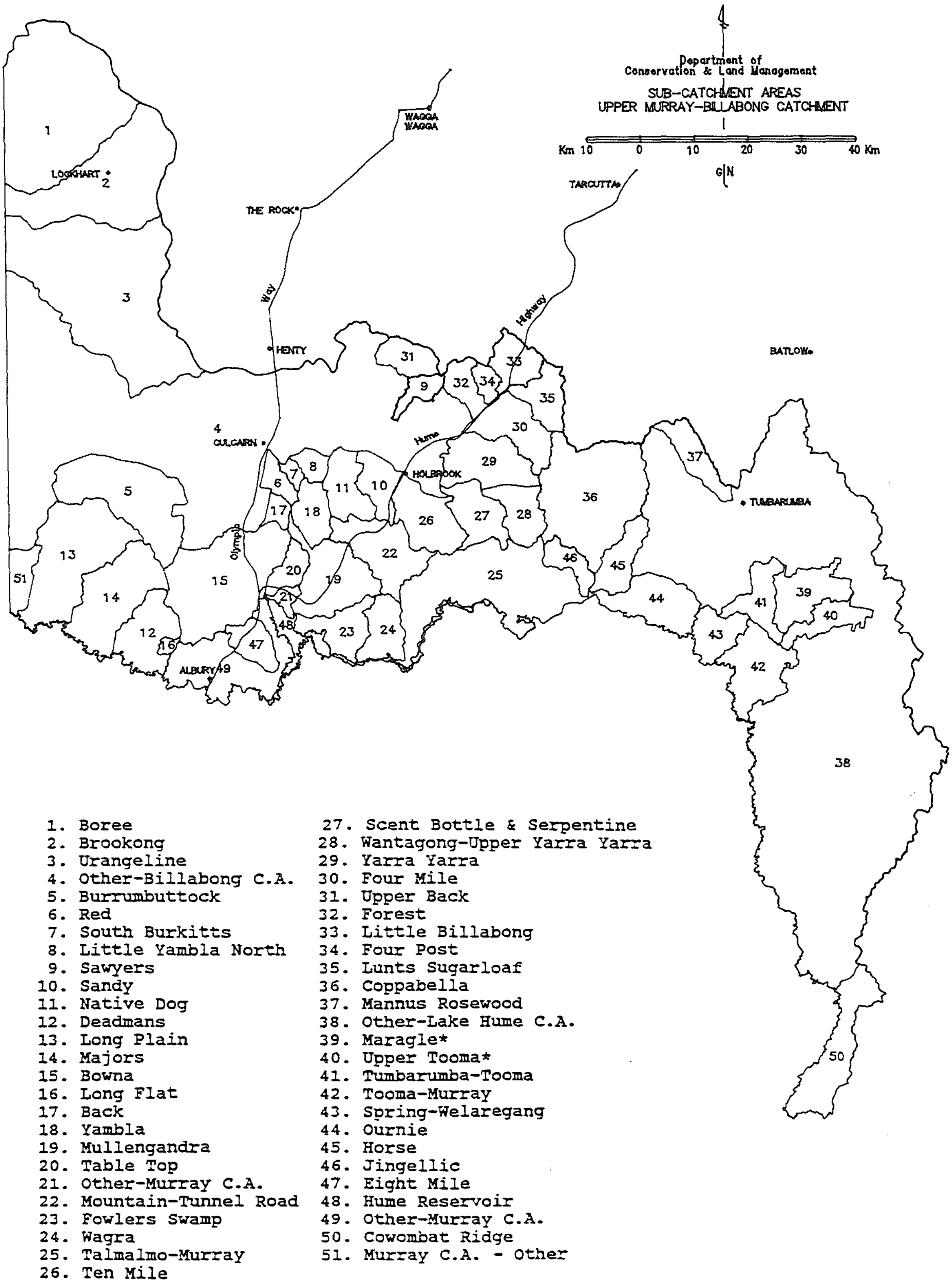
The CMU's were digitised on the GIS and a further set of statistics and maps were generated (see Volume 2).

For each 24 CMU's the following features are described:

* the subcatchment name and the CaLM District
* name of 1:100 000 topographic sheet(s) on which the catchment occurs
* area of Unit
* type, extent and severity of land degradation problems
* land use - area and percentage of each type
* land capability - area and percentage of each class
* community issues
* management requirements.

Tables 5 and 6 summarise the CMU data to show the extent and severity of land degradation problems across all Units within the Murray River and the Billabong Creek Catchments.

Figure 2: Location of Specified Subcatchments and Catchment Management Units



4.2.1 Ranking Technique and Priorities

Catchments were initially ranked using simple intensity data (ie length or area divided by the area of the CMU). This was found to be biased towards smaller CMU's and a little simplistic. A statistical ranking method (Taylor, in prep.) was applied to the CMU data. This figure called the severity *rankscore* gives a picture of the total degradation in the CMU for that particular issue. The *rank intensity* is the rankscore divided by the area of the CMU.

The two ranking figures allow direct comparison on a CMU to CMU basis, for a specific form or forms of degradation. As an example, gully erosion with a possible 16 categories, can be assessed and one CMU can be compared with any other unit. The ranking system assigns a higher ranking to the more severe forms of each of these specific degradation types, but it makes no attempt to assess the relative importance of each form of degradation.

Table 7 ranks the CMU's for the five major land degradation issues - gully erosion, streambank erosion, dryland salinity, tree decline and sheet erosion. Full descriptions of the priority CMU's are presented ranked in order in Tables 8 to 12.

From the series of tables it is obvious that the majority of the CMU's have a range of land degradation problems. Many of the causes and symptoms of the land degradation are closely inter-related, and directly related to land management. An integrated approach to their solution is required. Effectively addressing land degradation in the Murray-Billabong Catchments will involve:

* determining the inter-relationships between the different forms of land degradation where the treatment of one form of land degradation is dependent on the successful treatment of another
* development of management practices to overcome problems
* liaison and co-operation between land administration authorities and landholders
* policies required by CaLM and other agencies, to encourage a change in the land management practices.

The implementation of the recommendations of this report will be a long term process. Many of the land degradation problems have developed slowly and imperceptibly and they cannot be repaired overnight. Furthermore the solution to these problems will depend upon the co-operation and goodwill between individual landholders, rural community groups, local government and government authorities.

Changes in attitudes and practices will be required by all these groups to ensure that the land is returned to a good condition and maintained for long term sustainable production and catchment health.

It is proposed that all 24 CMU's which have been identified in this report as having severe and/or numerous interrelated forms of land degradation should be treated over time. Various means of funding will be required, including provisions of the Soil Conservation Act for Section 10 Projects.

Final priorities for the implementation of these programs will need to be set in consultation with community groups and with district and regional staff of CaLM and other agencies. Priorities will be determined according to:

* extent, severity and nature of the land degradation problems and whether the causes and solutions are known
* effects of proposed programs in controlling off site problems
* anticipated co-operation from landholders, communities and other organisations.

This report addresses the first two aspects only.

TABLE 5: Summary of Land Degradation in Murray CMU'S

CMU's	Salinity/ Waterlogging	Tree Decline	Soil † Acidity	Streambank Erosion	Soil Erosion	Structural Decline	Steep Lands	Wind Erosion	Other	Specialised Land Uses
Long Plain Creek	*	**			*	*		***		
Majors Creek	**	***	*			*		***		
Deadmans Creek	**	***	*	*	**		*	*		
Long Flat Creek		***			***		**			
Bowna Creek	**		***	*		*	*	**		*
Eight Mile Creek		**	**	***						**
Mullengandra Creek	***		**	***	***		**	*		
Table Top Creek	*	*	**	*	***		**	*		
Fowlers Swamp Creek	**	***	**	**	**		**	*		
Wagra Creek		***	**	*	**		**	*		
Talmalmo-Murray River					*		**			
Coppabella Creek			***		*		*	*		
Jingellic Creek			***							
Ournie Creek	*	**	*	*	*		***	*		
Spring Creek - Welaregang	*	**		*			**	*		
Tumbarumba Creek - Tooma				*	*		**	*		
Maragle Creek	*				*		*	*		
Upper Tooma River					*		**			
Tooma - Murray Rivers	*	***			*		**	*		
Cowombat Range					*		**			*

† estimate (NSW Agriculture, Albury)   * slight   ** moderate   *** severe

TABLE 6: Summary of Land Degradation in Billabong CMU'S

CMU's	Salinity/ Waterlogging	Tree Decline	Soil † Acidity	Streambank Erosion	Soil Erosion	Structural Decline	Steep Lands	Wind Erosion	Other	Specialised Land Uses
Boree Creek						**		***		
Brookong Creek						**		***		
Urangeline Creek				*		**		***		
Burrumbuttock Creek	**	***	**		*	**		**		
Back Creek	*		**			*		**		
Little Yambla West			**		***	*	*	***		
Little Yambla North		***	**		**	*	*	***		
South Burkitts Creek			**		**	*		***		
Yambla Creek		*	**	**	**		**	*		
Mountain - Tunnel Creeks			***	**	**		**	*		
Native Dog Creek		***	**	***	**		*	**		
Sandy Creek		**	**	***	**		*	**		
Ten Mile Creek	**		***	***	*		**	*		
Scent Bottle-Serpentine Creeks	*		***	***	*		**	*		
Lower Yarra Yarra Creek	*		***	***				*		
Wantigong Creek	**		***	*	*		**	**		
Forest Creek	**	*	**		*			*		
Four Post Creek	*	***	**		*		**	*		
Sawyers Creek	*	**	**	*	**		*	*		
Upper Back Creek		*	**		*			*		
Lunts Creek - Sugarloaf	*		**	**				*		
Little Billabong Creek	**		**		*	*	**	*		
Four Mile Creek	***		**		*	*	*	*		

† estimate (NSW Agriculture, Albury)   * slight   ** moderate   *** severe

TABLE 7: Relative Severity of Land Degradation Issues in Murray-Billabong CMU's

Gully Erosion		Streambank Erosion		Salinity		Tree Decline		Sheet Erosion	
Long Flat Creek	(M)	Mullengandra Creek	(M)	Mullengandra Creek	(M)	Wagra Creek	(M)	Long Plain Creek	(M)
Table Top Creek	(M)	Sandy Creek	(B)	Four Mile Creek	(B)	Tooma-Murray	(M)	Wagra Creek	(M)
Mullengandra Creek	(M)	Native Dog Creek	(B)	Majors Creek	(M)	Fowlers Swamp	(M)	Ournie Creek	(M)
Four Post Creek	(B)	Ten Mile Creek	(B)	Deadmans Creek	(M)	Long Flat Creek	(M)	Mullengandra Creek	(M)
Red Creek	(B)	Eight Mile Creek	(M)	Forest Creek	(B)	Four Post Creek	(B)	Ten Mile Creek	(B)
Yambla Creek	(M)	Lower Yarra Yarra Creek	(B)	Burrumbuttock Creek	(B)	Deadmans Creek	(M)	Fowlers Creek	(M)
Native Dog Creek	(B)	Scent Bottle - Serpentine Cks	(B)	Hume Foreshores	(M)	Ournie Creek	(M)		
				Little Billabong Creek	(B)	Sawyers Creek	(B)		
						Spring Creek - Welaregang	(M)		
						Table Top Creek	(M)		
						Forest Creek	(B)		
						Native Dog Creek	(B)		
						Majors Creek	(M)		
						Eight Mile Creek	(M)		
						Little Yambla North	(B)		
						Sandy Creek	(B)		
						Burrumbuttock Creek	(B)		

M = Murray Catchment

B = Billabong Creek Catchment

TABLE 8: CMU's with Expanding Salinity and Major Gully Erosion

LOCATION	1:100 000 MAP SHEET	AREA (km²)	LAND DEGRADATION PROBLEMS	LAND USE	LAND CAPABILITY (%)	COMMUNITY ISSUES	MANAGEMENT REQUIREMENTS
Mullengandra Creek (Albury ■) (Hume#)	Holbrook	165.90	Expanding dryland salinity (0.3%), scalding and waterlogging; streambank erosion to 6m; (39km) extreme gully erosion to 6m; (49km) soil acidity; tree decline (4%).	3% crop 83% pasture 14% timber	I - 3 II - 14 III - 21 IV - 6 V - 27 VI - 21 VII - 7 Other - 1	Deterioration of water quality; sedimentation of Lake Hume storage; damage to Hume Highway due to rising watertables; productivity decline; loss of remnant vegetation.	Undertake hydrogeological surveys; encourage property and whole catchment planning; treat saline discharge and recharge areas; monitor watertable movement; maintain existing trees; tree regeneration and replanting on Class VII land and other strategic locations; treatment of streambank erosion and water quality in liaison with DWR; treatment of deep gully systems; treatment and pasture management for acid soils; and management of grazing land to maintain cover and increase water use.
Deadman's Ck (Including Long Flat Ck.) (Albury ■) (Hume#)	Walbundrie Albury	121.87	Expanding dryland salinity, scalding and waterlogging; severe to extreme gully erosion to >6m; (42km) streambank erosion to 6m; (9km) tree decline; (13%) rising watertables; soil acidity.	1% crop 98% pasture 1% timber	I - 11 II - 7 III - 13 IV - 22 V - 20 VI - 25 VII - 2	Rising watertables; deterioration of water quality; sedimentation of Murray River; productivity decline; loss of remnant vegetation.	Undertake hydrogeological surveys; encourage property and whole catchment planning; treat saline discharge and recharge areas; monitor watertable movement; maintain existing trees; strategic tree regeneration and replanting; treatment of deep gully systems; treatment of streambank erosion in liaison with DWR; treatment and pasture management for acid soils; and guidelines to reduce recharge and sheet erosion.

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TABLE 9: CMU's with Expanding Salinity/Confirmed High Watertables/Waterlogging

LOCATION	1:100 000 MAP SHEET	AREA (km²)	LAND DEGRADATION PROBLEMS	LAND USE	LAND CAPABILITY (%)	COMMUNITY ISSUES	MANAGEMENT REQUIREMENTS
Four Mile Creek (Henty ▪) (Holbrook#)	Holbrook	117.30	Expanding dryland salinity (0.5%), scalding and waterlogging; soil acidity; tree decline.	3% crop 78% pasture 17% timber 2% pines	I - 4 II - 33 III - 22 IV - 9 V - 16 VI - 15 VII - 1	Wetland area gone saline; deterioration of water quality to Billabong Ck; Hume Highway damage due to rising watertables; productivity decline.	Undertake hydrogeological surveys, encourage property and whole catchment planning; treat saline discharge and recharge areas; monitor watertable movement; maintain existing trees; strategic regeneration and replanting of trees; treatment and pasture management for acid soils; management of pasture and cropped lands to maintain cover and increase water use. (Treat in association with Little Billabong Ck).
Majors Creek (Albury ▪) (Hume#)	Walbundrie	211.52	Rising watertables, developing salinity, scalding and waterlogging; (0.2%) tree decline; (7%) soil acidity; minor sheet erosion; (4%) wind erosion.	10% crop 87% pasture 1% urban 1% water <1% timber	I - 29 II - 18 III - 27 IV - 12 V - 10 VI - 3 VII - 1	Rising watertables, deterioration of Murray River water quality; inundation and poor access in winter; threat of expanding salinity; productivity decline; loss of remnant vegetation.	Undertake hydrogeological surveys, encourage property and whole catchment planning; treat saline discharge and recharge areas; monitor watertable movement; maintain existing trees; strategic regeneration and replanting of trees; treatment and pasture management for acid soils; management of pasture and cropped lands to maintain cover and increase water use; encourage reduced tillage. Integrated design for disposal of runoff water.
Forest Creek (Henty ▪) (Holbrook#)	Holbrook	51.47	Developing dryland salinity,(0.2%) scalding and waterlogging; rising watertables; tree decline; (8%) soil acidity; gully erosion to 3m (7km).	3% crop 94% pasture 3% timber	I - 6 II - 27 III - 24 IV - 9 V - 23 VI - 7 VII - 4	Rising watertables; deterioration of water quality to Billabong Ck; future pavement damage to Clifton Rd and Hume Highway; productivity decline; loss of remnant vegetation.	Undertake hydrogeological surveys; encourage property and whole catchment planning; treat saline discharge and recharge areas; monitor watertable movement; maintain existing trees; strategic regeneration and replanting of trees; treatment and pasture management for acid soils; guidelines to reduce recharge; encourage reduced tillage and direct drilling; treatment of deep gullies.

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TABLE 9: CMU's with Expanding Salinity/Confirmed High Watertables/Waterlogging (Cont.)

LOCATION	1:100 000 MAP SHEET	AREA (km²)	LAND DEGRADATION PROBLEMS	LAND USE	LAND CAPABILITY (%)	COMMUNITY ISSUES	MANAGEMENT REQUIREMENTS
Long Plain Creek (Albury ■) (Hume#)	Walbundrie	288.36	Rising watertables, waterlogging and developing salinity; (<0.1%) soil acidity; soil structural decline; tree decline; (5%) minor sheet erosion (13%).	22% crop 73% pasture 2% timber 3% water	I - 39 II - 29 III - 22 IV - 8 V - 1 VI - <1 other <1	Rising watertables, deterioration of Murray River water quality; inundation and poor access in winter; off site effects of drainage works; threat of expanding salinity; productivity decline; loss of remnant vegetation.	Undertake hydrogeological and topographic surveys; encourage property planning and whole catchment planning; monitor watertable movement; treat saline discharge areas; treatment and guidelines for pasture/crop management for acid soils; treatment of soils with structure ameliorants; encourage reduced tillage; maintain existing trees; strategic regeneration and replanting of trees; management of pasture/cropped land to maintain plant cover and increase water use; integrated design for disposal of runoff water.
Burrumbuttock Creek (Albury ■) (Hume and Culcairn#)	Walbundrie	262.63	Rising watertables, waterlogging and developing salinity; (<0.1%) soil acidity; tree decline; (5%) soil structural decline; minor sheet erosion hazard; (9%) moderate gully erosion to 6m (21km).	29% crop 69% pasture <1% timber 1% water	I - 41 II - 34 III - 19 IV - 4 V - <1 VI - 1 VII - <1	Rising watertables, deterioration of Billabong Ck. water quality; inundation and poor access in winter; off site effects of drainage works; threat of expanding salinity; productivity decline; loss of remnant vegetation.	Undertake hydrogeological and topographic surveys; encourage property planning and whole catchment planning; monitor watertable movement; treat saline discharge areas; treatment and guidelines for pasture/crop management for acid soils; treatment of soils with structure ameliorants; encourage reduced tillage; maintain existing trees; strategic regeneration and replanting of trees; management of pasture/cropped land to maintain plant cover and increase water use; integrated design for disposal of runoff water.

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TABLE 9: CMU's with Expanding Salinity/Confirmed High Watertables/Waterlogging (Cont.)

LOCATION	1:100 000 MAP SHEET	AREA (km²)	LAND DEGRADATION PROBLEMS	LAND USE	LAND CAPABILITY (%)	COMMUNITY ISSUES	MANAGEMENT REQUIREMENTS
Little Billabong Creek (Henty ▪) (Holbrook#)	Rosewood and Holbrook	72.14	Rising watertables, waterlogging and developing salinity; (0.1%)soil acidity; tree decline; minor sheet erosion hazard (10%).	3% crop 76% pasture 22% timber	II - 13 III - 18 IV - 16 V - 19 VI - 31 VII - 3	Rising watertables, deterioration of Billabong Ck water quality; threat of expanding salinity; future damage to Hume Highway pavement; productivity decline; loss of remnant vegetation.	Undertake hydrogeological surveys; encourage property planning and whole catchment planning; monitor watertable movement; treat saline discharge areas; treatment and guidelines for pasture/crop management for acid soils; encourage reduced tillage; maintain existing trees; strategic regeneration and replanting of trees on Class VII land; management of pasture and cropped land to maintain plant cover and increase water use. (Treat in association with Four Mile Creek.)

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TABLE 10: CMU's with Major Gully Erosion

LOCATION	1:100 000 MAP SHEET	AREA (km²)	LAND DEGRADATION PROBLEMS	LAND USE	LAND CAPABILITY (%)	COMMUNITY ISSUES	MANAGEMENT REQUIREMENTS
Red Creek (Albury ■) (Culcairn#)	Holbrook	262.28	Severe to extreme gully erosion to 3m; (14km) tree decline; (2%)soil acidity.	17% crop 71% pasture 12% timber	I - 20 II - 38 III - 17 IV - 0 V - 9 VI - 9 VII - 4 VIII - 2 SF - 1	Flooding and sedimentation, damage to Shire road; low catchment cover; productivity decline.	Integrated design for disposal of runoff water; treatment of deep gully systems; encourage property planning and whole catchment planning; management of grazing to maintain better cover and to reduce peak flows; treatment and pasture management for acid soils; encourage reduced tillage and direct drilling; maintain existing trees.
Table Top Creek (Albury ■) (Hume#)	Holbrook	44.97	Extreme gully erosion to 6m; (13km) streambank to 6m; (4km) developing salinity (<0.1%) and waterlogging; soil acidity; tree decline; (9%) minor sheet erosion (16%).	5% crop 85% pasture 10% timber	II - 17 III - 29 IV - 4 V - 27 VI - 13 VII - 9 VIII - 1	Deterioration of water quality, and sedimentation of Lake Hume storage; rising watertables; excessive clearing.	Encourage property planning and whole catchment planning; treatment of deep gully erosion; treatment of streambank erosion in liaison with DWR; undertake hydrogeological surveys; treat saline discharge and recharge areas; treatment and pasture management for acid soils; maintain existing trees; revegetation/replanting of trees on Class VII land and other strategic areas; management of pasture and cropped land to maintain better cover and increase water use; encourage direct drilling.

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TABLE 10 : CMU's with Major Gully Erosion (Cont.)

LOCATION	1:100 000 MAP SHEET	AREA (km²)	LAND DEGRADATION PROBLEMS	LAND USE	LAND CAPABILITY (%)	COMMUNITY ISSUES	MANAGEMENT REQUIREMENTS
Little Yambla North (Albury ■) (Culcairn#)	Holbrook	29.73	Extreme gully erosion to 3m; (9km) soil acidity; tree decline; (6%) sheet erosion hazard (12%) (soil structural decline?) wind erosion.	12% crop 87% pasture <1% timber	I - 23 II - 37 III - 25 IV - <1 V - 9 VI - 6 VII - 4 VIII - 2 SF - 1	Deterioration of water quality in Billabong Ck, excessive clearing.	Integrated design to protect cropping areas and dispose of runoff; treat deep gullies; encourage property planning and whole catchment planning; treatment and pasture management for acid soils; encourage reduced tillage and direct drilling; maintain existing trees; strategic revegetation and replanting of trees; and management of grazing lands to maintain better cover.
Yambla Creek (Albury ■) (Holbrook#)	Holbrook	66.96	Extreme gully erosion to 3m; (19km) streambank erosion to 1.5m; (12km) wind erosion.	2% crop 78% pasture 20% timber	I - 7 II - 29 III - 21 IV - 8 V - 10 VI - 8 VII - <1 SF - 17	Deterioration of water quality; sedimentation of creeks.	Treatment of deep gully erosion; treatment of streambank erosion in liaison with DWR; encourage property planning and whole catchment planning; treatment and pasture management guidelines for acid soils; maintain existing trees; strategic regeneration and replanting of trees; and management of pasture and cropped lands to maintain better cover.

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TABLE 11: CMU's with Extensive Streambank Erosion

LOCATION	1:100 000 MAP SHEET	AREA (km²)	LAND DEGRADATION PROBLEMS	LAND USE	LAND CAPABILITY (%)	COMMUNITY ISSUES	MANAGEMENT REQUIREMENTS
Ten Mile Creek (Albury ■) (Holbrook#)	Holbrook	124.30	Streambank erosion to 6m; (37km) extreme gully erosion to 6m; (7km) rising watertables and waterlogging; soil acidity; tree decline; (3%) minor sheet erosion hazard (22%).	1% crop 76% pasture 23% timber	I - 9 II - 23 III - 12 IV - 20 V - 5 VI - 13 VII - 10 VIII - 6 SF - 1 Urban <1	Sedimentation of Ten Mile Ck, and Holbrook bridge; deterioration of water quality; impending salinity, excessive clearing on Ordovician sediments; productivity decline.	Encourage property planning and whole catchment planning; treatment of streambank erosion in liaison with DWR and Holbrook Shire; treatment of deep gully erosion; undertake hydrogeological surveys; identify and treat recharge area; monitor watertable movement; treatment and pasture management guidelines for acid soils; maintain existing trees; revegetation/replanting of trees on Class VII land and other strategic areas; management of grazing land to maintain cover and increase water use; and co-ordinate fire control in timbered areas.
Sandy Creek (Albury ■) (Holbrook#)	Holbrook	67.96	Streambank erosion to 3m; (26km) extreme gully erosion to 6m; (16km) soil acidity; waterlogging; tree decline (6%).	3% crop 95% pasture 2% timber	I - 34 II - 27 III - 18 IV - 10 V - 5 VI - 5 VII - <1	Sedimentation of Sandy Ck and Ten Mile Ck, deterioration of water quality; productivity decline.	Encourage property planning and whole catchment planning; treatment of streambank erosion in liaison with DWR; treatment of deep gully erosion; undertake hydrogeological surveys; treatment and pasture management guidelines for acid soils; management of grazing land to maintain cover and increase water use; maintain existing trees; strategic revegetation and replanting of trees; and encourage direct drilling.

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TABLE 11: CMU's with Extensive Streambank Erosion (Cont.)

LOCATION	1:100 000 MAP SHEET	AREA (km²)	LAND DEGRADATION PROBLEMS	LAND USE	LAND CAPABILITY (%)	COMMUNITY ISSUES	MANAGEMENT REQUIREMENTS
Native Dog Creek (Albury ■) (Holbrook#)	Holbrook	86.48	Streambank erosion to 6m; (19km) extreme gully erosion to 3m; (20km) soil acidity; waterlogging; minor sheet erosion hazard; (9%) tree decline (7%).	8% crop 91% pasture 1% timber	I - 25 II - 25 III - 21 IV - 7 V - 12 VI - 9 VII - 1	Deterioration of water quality; sedimentation of Native Dog, Mountain and Billabong Cks; (cost to road culvert maintenance) impending salinity.	Encourage property planning and whole catchment planning; treatment of streambank erosion in liaison with DWR, Holbrook and Culcairn Shires; treatment of deep gully erosion; undertake hydrogeological surveys; monitor watertable movement; treatment and pasture management guidelines for acid soils; maintain existing trees; strategic revegetation and replanting of trees; management of pasture and cropped land to maintain cover and increase water use and encourage direct drilling.
Lower Yarra Yarra Creek (Henty ■) (Holbrook#)	Holbrook Rosewood	137.72	Streambank erosion to 6m; (28km) extreme gully erosion to 3m; (12km) soil acidity; waterlogging; tree decline.	2% crop 85% pasture 12% timber 1% pines	I - 13 II - 25 III - 17 IV - 19 V - 17 VI - 6 VII - 3 VIII - <1	Deterioration of water quality; sedimentation of Yarra Yarra and Billabong Cks; impending salinity.	Encourage property planning and whole catchment planning; treatment of streambank erosion in liaison with DWR; treatment of deep gully erosion; undertake hydrogeological surveys; monitor watertable movement; treatment and pasture management guidelines for acid soils; management of grazing land to maintain cover and increase water use; maintain existing trees; strategic revegetation and replanting of trees, and encourage direct drilling.

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TABLE 11: CMU's with Extensive Streambank Erosion (Cont.)

LOCATION	1:100 000 MAP SHEET	AREA (km²)	LAND DEGRADATION PROBLEMS	LAND USE	LAND CAPABILITY (%)	COMMUNITY ISSUES	MANAGEMENT REQUIREMENTS
Eight Mile Creek (Albury ■) (Hume#)	Holbrook, Albury, Tallangatta, Walbundrie	58.63	Streambank erosion to 3m; (16km) soil acidity; tree decline (6%).	<1% crop 95% pasture 2% timber 3% urban	II - 63 III - 21 V - 10 VI - 4 VII - 2	Runoff/discharge from major quarries, Australian Newsprint Mills plant, (and proposed irrigation project), Thurgoona urban and industrial area and Table Top rural subdivisions.	Treatment of streambank erosion in liaison with DWR, Hume Shire, ANM and AWDC; whole catchment planning; evaluate ANM proposed irrigation project in relation to streambank erosion; monitor groundwater tables; treatment and pasture management guidelines for acid soils; maintain existing trees; strategic revegetate/replanting of trees; and management of land to maintain cover and increase water use.
Scent Bottle - Serpentine Creeks (Albury ■) (Holbrook#)	Holbrook	95.75	Streambank erosion to 3m; (12km) extreme gully erosion to 3m; (10km) soil acidity; waterlogging; tree decline (3%).	<1% crop 70% pasture 30% timber	I - 2 II - 20 III - 8 IV - 28 V - 11 VI - 2 VII - 9 VIII - 1 SF - 19	Deterioration of water quality; sedimentation of creek systems causing flooding; road pavement damage due to raised watertables; productivity decline; loss of remnant vegetation.	Treatment of streambank erosion in liaison with DWR, and Holbrook Shire; property planning and whole catchment planning; treatment of deep gully erosion; undertake hydrogeological surveys; treatment and management guidelines for acid soils; management of grazing lands to maintain cover and increase water use; maintain existing trees; revegetation/replanting on Class VII land and other strategic areas; encourage direct drilling; co-ordinate fire control in timbered areas.

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TABLE 11: CMU's with Extensive Streambank Erosion (Cont.)

LOCATION	1:100 000 MAP SHEET	AREA (km²)	LAND DEGRADATION PROBLEMS	LAND USE	LAND CAPABILITY (%)	COMMUNITY ISSUES	MANAGEMENT REQUIREMENTS
Fowlers Swamp Creek (Albury ■) (Hume#)	Holbrook	59.83	Streambank erosion to 3m; (12km) extreme gully erosion to 3m; (7km) waterlogging and developing salinity; (<0.1%) tree decline; (18%) soil acidity; minor sheet erosion hazard; (20%) mass movement. (10ha)	<1% crop 97% pasture 3% timber	II - 8 III - 17 IV - 2 V - 35 VI - 30 VII - 8	Deterioration of water quality; sedimentation of Lake Hume storage; excessive clearing.	Encourage property planning and whole catchment planning; treatment of streambank erosion in liaison with DWR; treatment of deep gully erosion; undertake hydrogeological surveys; monitor watertable movement; treatment and pasture management guidelines for acid soils; maintain existing trees; regeneration and replanting of trees on Class VII land and other strategic areas; management of grazing land to maintain cover and increase water use.
Spring Creek - Welaregang (Albury ■) (Tumbarumba#)	Yarrangobilly Rosewood and Corryong	71.83	Streambank erosion to 6m; (3km) extreme gully erosion to 3m; (3km) waterlogging and developing salinity; tree decline: (10%) minor sheet erosion hazard; (12%) mass movement. (12ha).	<1% crop 80% pasture 20% timber	II - 7 III - 12 IV - 23 V - 17 VI - 22 VII - 13 SF - 6	Deterioration of water quality; sedimentation of supply to Lake Hume storage; excessive clearing.	Encourage property planning and whole catchment planning; treatment of streambank erosion in liaison with DWR; treatment of deep gully erosion; undertake hydrogeological surveys; monitor watertable movement; treatment and pasture management guidelines for acid soils; maintain existing trees; regeneration and replanting of trees on Class VII land and other strategic areas; management of grazing land to maintain cover and increase water use; co-ordinated fire control in timbered areas.

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TABLE 12: CMU's with Major Tree Decline

LOCATION	1:100 000 MAP SHEET	AREA (km²)	LAND DEGRADATION PROBLEMS	LAND USE	LAND CAPABILITY (%)	COMMUNITY ISSUES	MANAGEMENT REQUIREMENTS
Wagra Creek (Albury ■) (Hume#)	Holbrook and Tallangatta	79.64	Streambank erosion to 3m; (7km) extreme gully erosion to 6m; (6km) tree decline; (19%) minor sheet erosion hazard ;(43%) soil acidity; waterlogging; mass movement (17ha).	0% crop 76% pasture 24% timber	II - 5 III - 12 IV - 4 V - 11 VI - 38 VII - 30	Deterioration of water quality; sedimentation of Lake Hume storage; threat of salinity; slumps initiate gully heads; productivity decline.	Encourage property planning and whole catchment planning; undertake hydrogeological surveys; monitor watertable movement; treatment of streambank erosion in liaison with DWR; treatment of deep gully erosion; treatment and pasture management guidelines for acid soils; maintain existing trees; regeneration and replanting of trees on Class VII land and other strategic areas; management of grazing land to maintain cover and increase water use.
Tooma - Murray (Albury ■) (Tumbarumba#)	Kosciusko, Corryong and Yarrangobilly	144.39	Streambank erosion to 3m; (7km) tree decline; (17%) minor sheet erosion hazard (14%) ; waterlogging; developing salinity; (<0.1%) soil acidity; mass movement (2ha).	2% crop 91% pasture 6% timber 1% pines	II - 6 III - 18 IV - 21 V - 24 VI - 16 VII - 15	Deterioration of water quality; sedimentation of Tooma and Murray Rivers; threat of expanding salinity; slumps initiate gully heads; productivity decline.	Encourage property planning and whole catchment planning; undertake hydrogeological surveys; monitor watertable movement; treatment of streambank erosion in liaison with DWR; treatment of deep gully erosion; treatment and pasture management guidelines for acid soils; maintain existing trees; regeneration and replanting of trees on Class VII land and other strategic areas; management of grazing land to maintain cover and increase water use.

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TABLE 12: CMU's with Major Tree Decline (Cont.)

LOCATION	1:100 000 MAP SHEET	AREA (km²)	LAND DEGRADATION PROBLEMS	LAND USE	LAND CAPABILITY (%)	COMMUNITY ISSUES	MANAGEMENT REQUIREMENTS
Four Post Creek (Henty ■) (Holbrook#)	Holbrook and Rosewood	27.56	Extreme gully erosion to 3m; (11km) tree decline; (13%) waterlogging; soil acidity; minor sheet erosion hazard (9%); developing salinity (<0.1%).	0% crop 100% pasture <1% timber	I - 2 II - 21 III - 27 IV - <1 V - 34 VI - 11 VII - 5	Deterioration of water quality to Billabong Ck, future damage to Clifton Rd, and Hume Highway; productivity decline.	Encourage property planning and whole catchment planning; undertake hydrogeological surveys; monitor watertable movement; treatment of streambank erosion in liaison with DWR; treatment of deep gully erosion; treatment and pasture management guidelines for acid soils; maintain existing trees; regeneration and replanting of trees on Class VII land and other strategic areas; management of grazing land to maintain cover and increase water use.
Ournie Creek (Albury ■) (Tumbarumba#)	Rosewood	128.78	Streambank erosion to 1.5m; (10km) minor sheet erosion hazard; (26%) tree decline; (12%) waterlogging; soil acidity; moderate to severe gully erosion to 3m (16km).	<1% crop 71% pasture 29% timber	II - 3 III - 6 IV - 16 V - 16 VI - 28 VII - 23 SF - 7	Deterioration of water quality to Murray River; threat of expanding salinity; slumps initiate gully heads; productivity decline.	Encourage property planning and whole catchment planning; undertake hydrogeological surveys; monitor watertable movement; treatment of streambank erosion in liaison with DWR; treatment of deep gully erosion; treatment and pasture management guidelines for acid soils; maintain existing trees; regeneration and replanting of trees on Class VII land and other strategic areas; management of grazing land to maintain cover and increase water use.

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5. PROPOSALS FOR THE TREATMENT OF LAND DEGRADATION

As previously stated, the overall aim of this project, and report, has been to identify, measure and describe areas of land degradation and to develop proposals for the prevention and or treatment of these issues. In this section, eleven land degradation issues are discussed and data are presented under the following headings:

* the problem
* their extent and severity
* their relationships with other physical factors such as soils, geology, terrain and land use
* what is known about the treatment of the particular issue
* proposed actions for the treatment of the problems
    - policies required by CaLM and other agencies, to encourage changes to land management practices and attitudes
    - research and investigations required to further understand the problems and to treat them successfully
    - specific field treatments for priority areas.

5.1 DRYLAND SALINITY AND WATERLOGGING

5.1.1 Nature of Problem

Dryland salinity and waterlogging are increasing problems in the Murray-Billabong Catchments. The increase is a result mainly of rising watertables caused by increased volumes of water being added to the groundwater systems. This water is mainly from rainfall and is associated with the clearing and change of vegetation types across the catchment.

Dryland salinity occurs where the watertables approaching the ground surface are saline. Evaporation concentrates salts on or near the surface, initially causing normal vegetation to be replaced by salt tolerant species, progressing to total plant death, leaving bare surfaces (see Plate 1).

The problems associated with waterlogging and dryland salinity are:

* loss of agricultural production
* effects on management of a property

With dryland salinity the consequences can be dramatic with the added off-site effects such as:

* increasing salt loads entering watercourses and water storages, reducing water quality
* perennial trickle flows leading to flowline instability.

Related issues include groundwater accession areas, tree cover, perennial pastures, soil acidity, crop and pasture management, water quality decline and soil erosion.

5.1.2 Extent and Severity

The study showed salt outbreaks had affected 314 hectares of land in the Murray-Billabong Catchments (Table 13). A survey manual in 1993 showed a 25% increase to 393 ha of recorded salt. These figures are very low when compared to those observed in the other main river systems of southern NSW (e.g. Murrumbidgee and Lachlan Catchments). The salinity problem in the Murray-Billabong Catchments is at the early stage of development. This is evident in the statistics, as 93% of salinity (292 ha) is expressed as salt tolerant plants and small bare areas (Classes 15 and 25). The occurrence of salt affected lands in CMU's is listed in Table 14 and shown in Figure 3, respectively.

TABLE 13: Dryland Salinity in the Murray-Billabong Catchments on a Class Basis

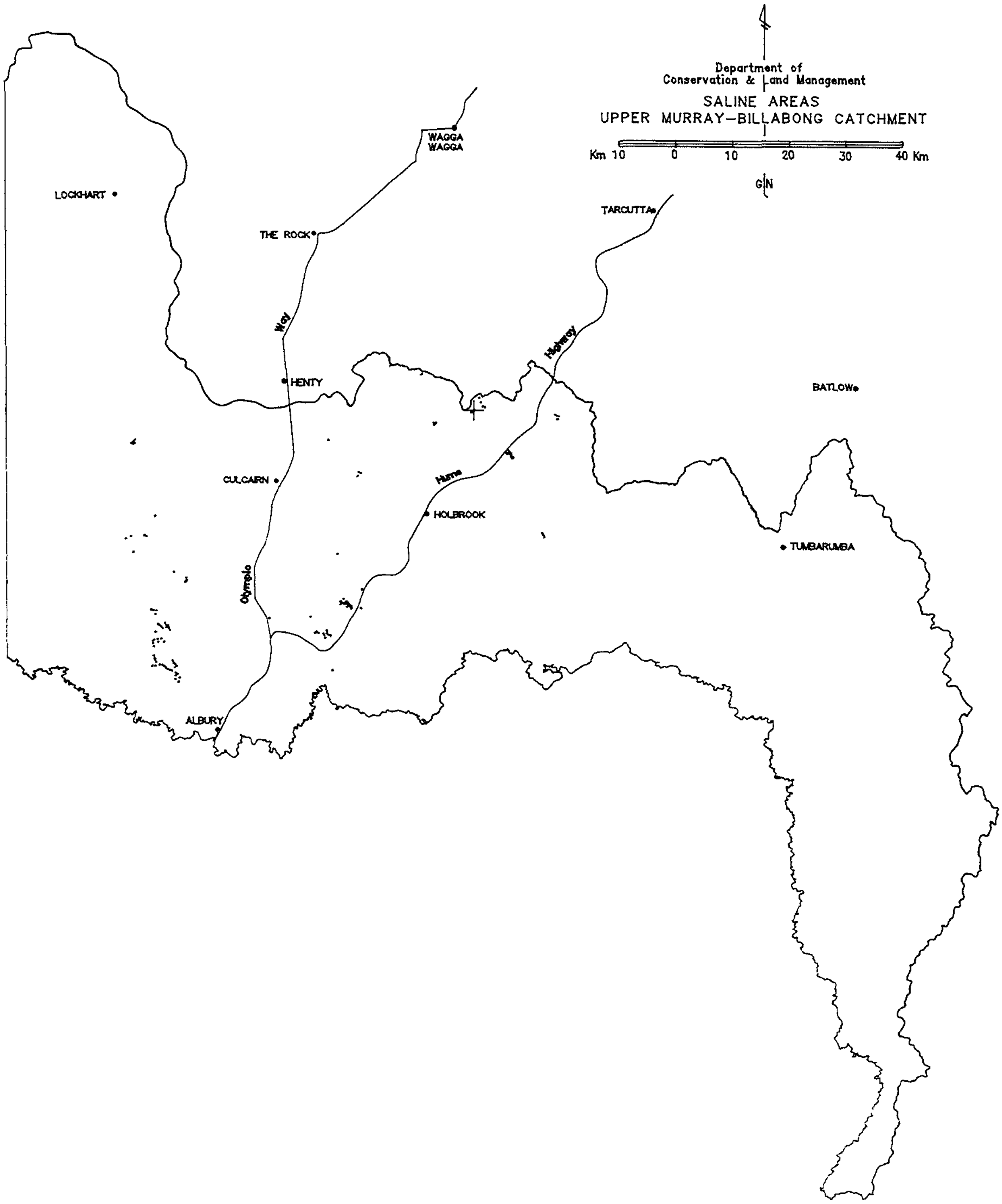
Soil Erosion Class	Area Affected (ha)		
	Murray	**Billabong**	**Total**
Vegetation change (Class 15)	148	58	206
Sheet erosion due to salinity (Class 25)	18	68	86
Rill erosion due to salinity (Class 45)	8	14	22
TOTAL	**174**	**140**	**314**
Gullies affected by salinity (km)			
Minor gully erosion (Class 55)	-	1.0	1.0
Moderate gully erosion (Class 65)	0.6	-	0.6
Severe gully erosion (Class 75)	-	-	-
Extreme gully erosion (Class 85)	-	1.1	1.1
TOTAL	**0.6**	**2.1**	**2.7**

TABLE 14: Areas of Dryland Salinity in CMU's

CMU/Subcatchment	15/25†	Soil Erosion (ha) 45‡	Total
Murray			
Mullengandra Creek			
Deadmans Creek	46°	2	48°
Majors Creek	67	-	67
Bowna Creek	36	4	40
Weir Foreshores	13	1	14
Fowlers Swamp Creek	(9)	-	(9)
Long Plain Creek	2	1	3
Table Top Creek	2	1	3
	2	-	2
Billabong			
Four Mile Creek			
Forest Creek	59	4	63
Sawyers Creek	10	-	10
Burrumbuttock Creek	5	-	5
Morven	5	-	5
Wantagong Creek	(5)	-	(5)
Upper Back Creek	(5)	-	(3)
Little Billabong	3	-	3
	4	-	4

† salt tolerant species present, may have scalds up to 1m x 1m
‡ large bare scalds
o major areas developed since mapping
( ) estimate

Figure 3: Salinity in the Murray-Billabong Catchments



At present only small areas are affected. However, observations indicate that most mapped areas have increased in size and severity, and 36 new areas have been recorded since the mapping was undertaken. Furthermore, occurrences are spread widely across the catchments. More importantly observations of rising levels of saline groundwater across large sectors of the catchment support the prediction of increasing salt outbreaks throughout the catchments within the next five years. Although several CMU's have salinity as one of a number of problems the salinity is not considered to be severe as yet. Areas with the worst salinity problems are:

Murray River	**Billabong Creek**
Mullengandra Creek	Four Mile Creek
Majors Creek	Forest Creek
Deadmans Creek	Burrumbuttock Creek
Hume Weir surrounds	Little Billabong Creek

The electrical conductivity of soil (ECe) and water samples (ECw) were measured during field checking. Some 49 soil samples and 59 water samples were tested, and results of these have been entered onto the Department's GIS. Sampling was undertaken predominantly during late spring and summer when surface water was having a negligible effect on readings. Results presented in Table 15 summarise these data and indicate "hot spots" in the catchments.

TABLE 15: Salinity Readings in the Murray-Billabong Catchments

Area	Water Source	Water Reading (ECw) - (ds/m)	Soil Reading (ECe) - (ds/m)
Walbundrie	dams	2.6 - 12.0	2.0 - 11.6
Burrumbuttock	piezometers	2.3 - 7.1	n/a
Howlong	floodplain	1.6 - 1.7	10.9
Table Top	seepage	6.0 -	1.0 - 17.3
Bowna	gully	1.4	n/a
Mullengandra	seepage	3.7	19.7
Woomargama	seepage	3.6 - 4.0	n/a
Morven	seepage	2.2 - 2.6	2.3 - 16.1
Garyowen	-	1.8 - 3.0	0.9 - 1.1
Clifton Rd	-	2.2 - 4.5	10.0 - 18.3
Black Ridge	seepage	1.8 - 5.3	1.4 - 5.5
Sawyers Ck	seepage	1.5 - 2.5	n/a
Lt. Billabong	seepage	2.0 - 6.1	0.4 - 0.5
Tooma	seepage	0.6 - 1.4	n/a

Research and observations in other parts of Australia conclude that while individual sites may fluctuate over time, the majority have become worse or at least show no improvement.

Surface waterlogging was not mapped as part of the survey as it could not be identified on the aerial photographs due to summer flying times. Feedback from landholders indicate waterlogging to be an increasing problem, and perhaps the main land degradation issue in many subcatchments (see Plate 2).

Results of recent bore surveys conducted at Howlong, Holbrook and Burrumbuttock, show that increasing waterlogging and salinity problems are likely in the future. A summary of these surveys is presented in Table 16 which shows the annual rises in bore levels being as high as 2.39 m/yr in the Howlong area, 1.38 m/yr in the Holbrook area and 1.33 m/yr at Burrumbuttock. Whilst these are maximum figures, they do show the extent of the problem.

TABLE 16: Summary of Local Bore Survey Findings

Survey	Howlong	Holbrook	Burrumbuttock
Date undertaken	1990	1992	1990-92
Average annual rise (m/yr)	0.60	0.29	0.69
Bores checked	64	33	16
Maximum annual rise (m/yr)	2.39	1.38	1.33
Area of groundwater pressure within 2m of the surface (ha/ (%))	5,000† (4.0)	8,650 (4.0)	5,200 (19.8)
Predicted area of waterlogging and salinity in 2020 (ha/ (%))	23,000 (23)		

† derived from Fig. 4.2, (Williams, 1990)

In conclusion:

* bore surveys indicate that watertables have risen dramatically and consistently over much of the productive grazing and mixed farming land in the Murray-Billabong Catchments. In many areas watertables have reached or are about to reach critical levels
* to halt rises in watertables, major changes in land management must be implemented to restore groundwater balance. These may affect profitability and land values
* the causes of changed groundwater levels and quality may be on adjacent properties and not under the control of the landholder being affected
* if nothing is done the situation will worsen significantly with large areas becoming affected by waterlogging and salinity, and increased salt loads in waterways and storages.

5.1.3 Relationships with Other Physical Factors

Predicting site specific location of salt outbreaks is extremely complicated. However, in the simplest terms, for salinity to develop anywhere, there is a requirement for a salt source and a watertable near the surface. Factors bringing about these conditions include:

* rock type
* landform
* rainfall
* land use.

Plate 1: Typical saline area (centre, left and right), also tree decline with waterlogging in foreground. Photo adjacent Hume Highway, Bowna Creek catchment.

Plate 2: Oats crop on footslope severely effected by waterlogging. Photo Bowna Creek catchment.

Plate 3: **Severe tree decline in Stringybark trees. Note ringbarking caused by cattle rubbing. Photo Mullengandra Creek catchment.**

Plate 4: **Poor tree health in Hill Red Gum on steep rocky areas. Photo Ten Mile Creek catchment.**

Rock types generally associated with salinity are the Ordovician sediments, Silurian granites and volcanic material. The Ordovician sediments are dominantly marine sediments and carry reasonable stores of salt in their profiles or in bandwidths within their profiles.

The occurrence of outbreaks at or near the contact zones of two rock types may indicate the contact zone is affecting the paths of groundwater flow.

The **landform elements** predominantly affected by dryland salinity are footslopes and drainage depressions. It is also common to have some channelling or impediment to groundwater flow, such as rock outcrops, or roads and access tracks where the soil is compacted, causing outbreaks to occur in midslope positions.

Although any soil can be affected by salinity, soils in lower catenary positions are most affected. These include podzolics, solodics, alluvials and similar soils.

So why is salinity developing at such a dramatic rate?

Rainfall is the main source of water in dryland areas. If rainfall entering the soil exceeds the amount used by vegetation then the excess water will move down beyond the root zone and eventually add to the watertable.

Land use is the major factor responsible for increased additions to groundwater and the corresponding increases in dryland salinity. Prior to European settlement rainfall input and water use by the native vegetation were in balance over the long term. The clearing of native forest, and its replacement with shallow rooted annual crops and pastures, has resulted in major changes to groundwater regimes. Reduced evapotranspiration and interception of soil water have resulted in more water reaching the watertable, causing it to rise. As the watertable rises, naturally occurring salts in rocks and the soil are dissolved and brought towards the surface. Once near the surface these saline waters are concentrated in the soil by evaporation.

Shallow watertables can be measured and monitored using piezometers. Deeper watertables are measured from bores drilled into fractured or alluvial sediments for water supplies. The Department of Water Resources (DWR), in association with Landcare groups, has been recently collecting and interpreting these data in several catchments in Southern NSW, including the Howlong, Holbrook and Burrumbuttock areas. Some of these results must be interpreted with caution as they indicate the groundwater pressure or potentiometric head, and not the actual height of the water table.

Results show these levels have risen significantly, and there is substantial pressure beneath some soils forcing water towards the surface. Generally the presence of clay under soils acts as a confining layer and water can only move upwards through weak points in the layer. These areas suffer from waterlogging and sometimes develop salinity problems when the confining layer is breached.

With pressure forcing water from beneath the soil it is logical that soil drainage is inhibited, and this is the effect landholders are seeing in their paddocks.

5.1.4 What is Known About Its Treatment?

The Soil Conservation Service (SCS) has been involved in the revegetation of salt discharge areas for almost 40 years. Until recently research has emphasised the rehabilitation of the discharge, or salt affected areas. Technically these have proven successful. The main treatment has involved:

* fencing out salt outbreaks to prevent stock from destroying remaining vegetation

* planting the affected area to salt tolerant grasses, trees and shrubs.

A recent approach has been looking at control of present and future salinity, and recommends:

* reducing the rate of recharge to the groundwater system to stop the problem from getting worse and eventually to lower the groundwater loads or pressures. This involves a whole catchment approach to the problem

* monitoring watertable levels and water quality in problem areas.

More detailed treatments are listed in Appendix E.

Recent investigations have centred on aspects such as:

* electromagnetic (EM) surveys to help identify recharge zones, groundwater movements and flowpaths

* selection of salt tolerant and high water using tree and pasture species, clones and natural phenotypes

* preferred tree planting layouts for both management practicality and effectiveness in using water in and close to discharge areas

* effects of differing surface treatments including mounding, mulching and fertilisers ("Lindfield", Mullengandra ; "Blair Athol", Brocklesby)

* natural regeneration ("Stony Park East", Jindera), tree planting, including Pinus radiata agroforestry ("Mirradong", Bungowannah), and perennial pastures in recharge areas and the effects on groundwater lower in the catchment

* direct seeding of trees.

These monitored agroforestry trials involve input from CaLM, Forestry Commission of NSW, DWR and Australian Newsprint Mills.

Waterlogging can be addressed using many of the same techniques detailed above, as salinity is often the next stage after waterlogging. The main difference being emphasised at the point of discharge is on water tolerant species rather than those being salt tolerant. Construction of diversion banks above waterlogged areas is recommended as a means of reducing the severity of waterlogging on lower areas.

Pumping, and use of the water for irrigation is extremely effective in lowering watertable levels or groundwater pressures where the water qualities are suitable (Woolley and Tuckson, pers. comm.).

5.1.5 Recommendations for Treatment

a. Policy

It is important not to treat dryland salinity outbreaks in isolation. Unless the majority of an area contributing to the recharge is treated it is unlikely that discharge areas will be fully and permanently rehabilitated. To ensure this, and to prevent further expansion of the salt outbreaks, control measures on the recharge areas of the local catchment are essential.

A whole farm and catchment approach is required by landholders and the community. Catchment and property planning are the ideal tools to foster and develop the attitude to integrated land management.
However, change will only occur if it is economically driven. If management changes are to have any widespread impact across catchments they must be profitable to the land managers.

Policies required include:

* promotion of the findings and recommendations of this report

    . encourage landholders to prepare property plans for the control and repair of the salt problems
    . in catchments where waterlogging or salt problems occur over a number of properties, encourage landholders to prepare treatment programs from a catchment viewpoint, rather than on an individual property basis

* if the economics of recommended management of recharge areas is doubtful or unprofitable, then incentive schemes need to be explored aggressively

* extension and education programs which target the effects of extensive vegetation clearing need to be maintained. Land use must be consistent with an informed and balanced understanding of land capability, land degradation, flora and fauna conservation, aesthetics, bushfire control and stocking requirements

* co-ordination between the various agencies involved (ie. Catchment Management Committees, Landcare groups, Rural Lands Protection Boards, NSW Agriculture, Forestry Commission, CaLM, Local Government, and National Parks and Wildlife Service). These must be aware of the need for this balance and incorporate the factors into the land use recommendations or programs that are developed in areas with known salt or groundwater problems

* local councils shall only consider the development of lands in catchments once there has been an assessment of potential and existing salt or groundwater problems

* clearing of native vegetation should not be permitted unless it is assessed as not having any effect on local groundwaters

* as part of the land management controls for rising groundwaters and dryland salinity, preferred tree cover levels need to be established for the whole Valley. For their roles in lowering groundwater levels and for their other uses in the landscape, tree cover densities must be based on land capability criteria (see Appendix G), and water balance

* Crown land should be managed to minimise contributing to groundwater where that is an issue. The possible effects of conversion of title to freehold with consequent changes to recharge with altered land use should be considered

* CaLM and DWR to liaise regarding priorities for investigations in particular areas

* CaLM and DWR to establish standards for recording, reporting and extension of results from hydrogeological surveys to ensure landholders can readily interpret the results

* educate officers of other extension agencies, and agribusinesses of the integrated aspects of salinity, and to promote sound land management when advising clients

* ensure research, investigations and demonstrations are undertaken in an integrated way and results and recommendations are passed onto the community

* encourage Landcare activity as a means of self help, awareness and education.

b. Investigations

* produce economic analysis detailing perennial v's annual based pasture for a range of species and management techniques including both production and environmental benefits

* record all new reports of salt outbreaks into CaLM's land resource database (GIS)

* delineate lands on which waterlogging occurs

* collate and analyse data from piezometers already installed

* undertake systematic studies of shallow groundwater in risk areas detailing past rises, future movements and expected ramifications

* evaluate new technology such as remote sensing to detect "hot spots" of salinity or early development stages of salinity

* determine rates of change of salinity in various agroclimatic/geological catchments

* identify landscapes prone to the development of salinity

* investigate methods of obtaining hydrogeological data efficiently over large areas

* determine the levels to which recharge must be reduced to halt, and reverse watertable rises

* determine the effectiveness of pasture and tree management, cropping cycles and species selection in reducing groundwater accessions, and develop recommendations for tree and pasture planting to address salinity and waterlogging

* examine economically viable agroforestry treatments for recharge and discharge areas to reduce the rates of recharge and to lower watertables

* develop methods for economically utilising suitable groundwaters, for stock water supply and/or for irrigation, to help lower and manage watertable levels

* investigate and develop salt land agronomy techniques.

c. Actions

Specific recommendations to landholders will depend upon the nature of the salinity or waterlogging problem and catchment characteristics. However the key to treatment is to integrate groundwater management and soil water use into the management of crops, pastures and trees.

A number of CMU's have salinity as their main land degradation problem, where the successful treatment of the problem would need to be a joint effort by all land users within the area. Whilst other issues of land degradation would be treated at the same time, the primary focus is the reduction of high groundwater levels and the rehabilitation of salt outbreaks.

* implement catchment management projects under Section 10 of the Soil Conservation Act 1938 on the following priorities:

  Mullengandra Creek Catchment
  Little Billabong Creek Catchment including Four Mile Creek
  Majors Creek Catchment
  Deadmans Creek Catchment
  Forest Creek Catchment including Four Post Creek
  Hume Weir foreshores including Bowna, Table Top, Fowlers Swamp and Wagra Creeks
  Burrumbuttock Creek Catchment
  Morven area (North of Billabong Creek)
  Wantagong Creek Catchment.

* carry out hydrogeological surveys for the Mullengandra/Table Top/Bowna Creeks areas and Tooma Landcare Group area. Further evaluation of results of the Holbrook survey would assist implementation of solutions

* undertake economic studies to determine cost/benefits so funding support can be directed to programs or locations which will provide the greatest community benefit.

The control and prevention of waterlogging and dryland salinity should be based around managing water use and recharge in the catchment. Principal recharge zones need to be identified and managed to reduce the amount of water being added to the groundwater systems. This involves aspects such as:

* ensuring landholders are technically informed about salinity, particularly water balance interrelations

* undertaking property planning and catchment land and water management plans in areas affected by high watertables and salinity

* tree regeneration and replanting programs on lower sloping, productive lands

* addressing soil acidity problems, and the establishment and management of perennial pastures to increase water use

* landholders selectively installing piezometers in areas with salt problems to measure groundwater levels and monitor seasonal fluctuations. This will enable landholders to assess if their treatments and management activities are working successfully.

5.2 TREE DECLINE

5.2.1 Nature of Problem

Insufficient tree cover and tree decline are major issues in sections of the Murray-Billabong Catchments. European settlement and clearing for cultivation and grazing have drastically reduced the original tree cover. In some areas trees were also cut for railway sleepers, fuel, and building materials. The consequences of excessive clearing are outlined in Appendix F.

Forest and woodland ecosystems have typically been reduced to scattered trees. Understorey components have mostly been eliminated. The resulting stresses from wind, frost, high watertables and insect defoliation on the remaining tree populations have caused dieback, loss of local ecotypes, and extinction of some species.

Broadscale dieback to date is not as extensive as is in catchments further north in NSW. However, severe damage by leaf lurp is being inflicted on *Eucalypts blakelyi,* which dominates parts of the landscape, and now started to affect other species (see Plate 3). A survey by the West Hume Landcare group (1992) showed a 2% annual death rate of trees. A survey in the Holbrook district (1994) revealed 7% of trees had died recently and 41% suffering dieback symptoms.

Ironically, tree clearing is continuing across the catchment. Restrictions on clearing are inconsistent and advisory services for land development often lack any technical basis. Whilst the benefits of retaining trees are now more widely recognised and tree planting activities are becoming common, the short-term economics of further land development can largely outweigh the opportunity costs of retaining tree cover, and benefits may be offsite.

The problems of tree decline include:

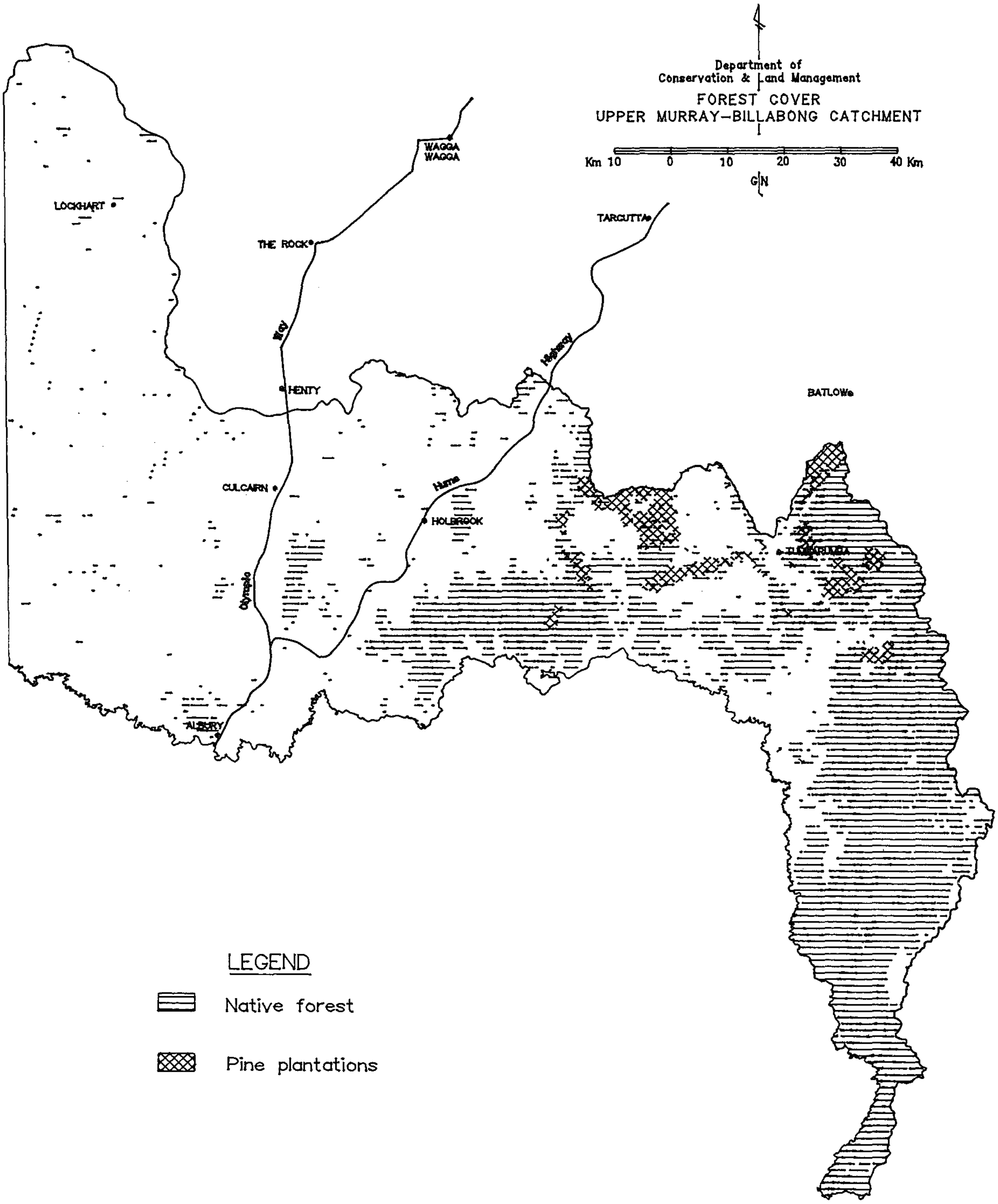
* reduced agricultural productivity (grazing and cropping), and hence viability due to exposure to the elements
* inadequate vegetation cover to protect the catchment from other land degradation such as soil erosion, streambank erosion, and dryland salinity
* poor condition, old age and imminent death of remaining trees across the catchment
* remaining trees occur as scattered clumps or individuals susceptible to insect attack and other stresses
* lack of natural regeneration due to agricultural practices
* lack of awareness of many landholders of the importance of trees to land stabilisation and the hydrological cycle.

Related issues include rising watertables, dryland salinity, water and wind erosion, and ecological diversity.

5.2.2 Where are the Main Areas of Trees?

Widespread clearing of the original native forests has occurred in the Murray-Billabong Catchments, particularly in those areas which are highly productive cropping and grazing lands. The distribution of remaining stands of native forest across the Murray-Billabong Catchments is presented in Figure 4 and Tables 17 and 18 .

Figure 4: Forest Cover in the Murray-Billabong Catchments



\# Data will soon be available from the Basincare Vegetation program which will provide a more detailed picture of woodland cover and floristic composition.

Approximately 45% of the Murray River catchment upstream of Howlong is covered by native forests. A further 4% is under pine plantations. About one-half of the area under pines (1.5%) involved clearing of forest prior to pine planting during the period 1980-1990 (see Table 38). Within the Billabong Creek Catchment less than 6% of the catchment is covered by timber (see Table 18).

TABLE 17: Forest Cover in the Murray Catchment

1:100 000 Map Sheet Name	(% of catchment)	Area of Forest km²	(%)	% of Total Catchment
Lower Murray				
Walbundrie	(14.1)	9.4	(1.1)	0.1
Albury	(4.0)	27.0	(1.1)	0.5
Upper Murray				
Holbrook	(10.5)	206.4	(32.1)	3.4
Tallangatta	(3.0)	8.5	(4.6)	0.1
Rosewood#	(21.8)	463.2	(34.9)	7.7
Corryong	(0.1)	0.3	(0.1)	<0.1
Headwaters				
Yarrangobilly°	(15.4)	579.0	(61.9)	9.7
Kosciusko^	(26.2)	1194.1	(74.8)	19.9
Jacobs River	(4.3)	243.5	(93.4)	4.1
TOTAL	**(100)**	**2731.4**		**45.7**

\# 143.2km² additional tree cover exists as softwood plantations.
° 87.1km² additional tree cover exists as softwood plantations.
^ 1.2km² additional tree cover exists as softwood plantations.

TABLE 18: Forest Cover in the Billabong Catchment

1:100 000 Map Sheet Name	(% of catchment)	Area of Forest km²	(%)	% of Total Catchment
Lower Billabong				
Narrandera	(0.6)	0.1	(0.3)	<0.1
Lockhart	(29.6)	17.9	(1.2)	0.4
Walbundrie	(30.0)	11.1	(0.7)	0.2
Upper Billabong				
Holbrook	(31.9)	166.9	(10.1)	3.2
Wagga Wagga	(0.3)	1.2	(6.8)	<0.1
Rosewood#	(7.5)	95.1	(6.1)	1.8
Tarcutta	(<0.1)	1.4	(50.0)	<0.1
TOTAL	**(100)**	**293.7**		**5.7**

\# 4.9km² additional tree cover exists as softwood plantations.

Forest cover varies dramatically between the Lower Murray, Upper Murray and Murray headwaters where tree covers are approximately 1%, 30% and 70% respectively.

Remnant timber stands on the plains and slopes occur on steeper, rocky slopes or outcrops and along roadside reserves, travelling stock routes and railway lines. They retain a reasonable tree cover, although much of the shrub layer and ground cover have been lost due to grazing, trampling and fire.

Many of the CMU's have low proportions of forest cover and of the trees remaining, large numbers are over-mature and in poor health. The health of the land in these areas is being affected by the poor condition of the tree cover.

Forest cover for a range of CMU's across the Murray-Billabong Catchments were collated. Furthermore, using land capability data, "preferred tree cover levels" were calculated and compared with existing tree cover (Table 19). The preferred tree cover levels (see Appendix G) were derived after consultation with regional and district staff of CaLM and from preferences expressed by landholders and are similar to guidelines presented elsewhere (Bird et al. 1992, Burrows 1990, Curtis 1994).

The CMU's with the largest shortfalls are:

Murray River

Wagra Creek
Tooma - Murray River
Fowlers Swamp Creek
Long Flat Creek
Deadmans Creek
Ournie Creek
Spring Creek - Welaregang
Table Top Creek
Majors Creek
Eight Mile Creek

Billabong Creek

Four Post Creek
Sawyers Creek
Forest Creek
Native Dog Creek
Little Yambla Nth
Sandy Creek
Burrumbuttock Creek

All CMU's had shortfalls in tree cover except for seven units. Of these however, five have significant areas of pine plantation. Tree distribution in catchments is typically concentrated in the steeper upper areas.

5.2.3 Relationships with Other Physical Factors

The effects of tree clearing and their replacement by annual pasture species on water quality and water yield, rising water tables, slope stability and soil erosion are well documented.

Apart from reducing land degradation, trees and shrubs have an important role to play in increasing productivity by providing shade, shelter, and habitat for predators of pest species. In the Murray Catchment, forest areas are particularly important in supplying high quality water to Hume Weir, the major storage for the Murray irrigation system. Appendix F and H outlines the consequences of clearing, and the benefits of trees in the landscape.

TABLE 19: Actual Tree Cover Compared with Preferred Cover (%)

Subcatchment	Existing Tree Cover	Tree Cover Minus National Parks and State Forests	Preferred Tree Cover	Shortfall
Murray				
Deadmans Creek	1.0	1.0	13.8	12.8
Long Flat Creek	6.8	6.8	25.0	18.2
Eight Mile Creek	1.5	1.5	7.9	6.4
Bowna Creek	5.9	5.9	10.2	4.3
Majors Creek	0.3	0.3	7.4	7.1
Long Plain Creek	1.5	0.9	5.5	4.6
Mullengandra Creek	14.6*	13.2	17.0	3.8
Table Top Creek	9.7	9.7	18.9	9.2
Fowlers Swamp Creek	2.7	2.7	21.0	18.3
Wagra Creek	23.5	23.5	42.0	18.5
Talmalmo-Murray				
Coppabella Creek	57.2*	37.8	21.8	-16.0
Lankeys Creek				
Horse Creek				
Mannus Creek				
Ournie Creek	28.9	21.7	33.4	11.7
Spring Creek - Welaregang	20.0	14.3	24.2	9.9
Tumbarumba Creek - Tooma	44.0*	44.0	47.4	3.4
Maragle Creek	30.3*	29.8	31.6	1.8
Upper Tooma River	66.0*	65.1	48.3	-16.8
Tooma - Murray Rivers	7.1*	7.1	23.8	16.7
Cowombat Ridge	97.8			
Billabong				
Burrumbuttock Creek	0.5	5.7	5.2	4.7
Urangeline Creek				
Red Creek	11.4	10.2	12.5	2.3
Little Yambla North	0.4	0.4	6.7	6.3
Yambla Creek	19.9	3.1	6.9	3.8
Mountain Creek - Tunnel Rd	32.0	11.9	14.2	2.3
Native Dog Creek	0.9	0.9	8.3	7.4
Sandy Creek	1.7	1.4	6.9	5.5
Ten Mile Creek	22.4	21.4	24.8	3.0
Scent Bottle - Serpentine Ck	29.9	11.2	14.4	3.2
Forest Creek	3.0	3.0	11.3	8.3
Four Post Creek	0.1	0.1	13.5	13.4
Sawyer's Creek	2.2	2.2	13.1	10.9
Upper Back Creek	5.8	3.8	7.7	3.9
Wantagong Creek	32.5*	21.2	18.4	-2.8
Yarra Yarra Creek	13.0*	13.0	11.5	-1.5
Lunts Creek - Sugarloaf	23.6	23.2	21.2	-2.0
Little Billabong Creek	29.1	29.1	7.5	-21.6
Four Mile Creek	19.2*	19.2	10.0	-9.2

* figures include *Pinus radiata* forest cover

The remaining areas of forest and tree cover correspond closely to the capability of the land. Trees remain on steep slopes, where soils are stony, shallow or infertile and the land has little or no agricultural potential. These areas predominate in the upland areas of the Murray River Catchment. A combination of high rainfall, and land tenure under National Park, State Forest and the Crown has assisted in retaining large tracts of relatively undisturbed or minimally disturbed forest. These lands occur in the catchments of the Murray headwaters (Murray, Swampy Plains and Tooma Rivers) on the Kosciusko and Yarrangobilly 1:100 000 map sheets, and the Murray in the Talmalmo area (Holbrook sheet). In the Billabong Catchment, apart from the Mt. Morgan area, most of the remaining stands of trees occurs on lands abutting the Murray-Billabong and Billabong-Murrumbidgee catchment divides.

Lower slopes and more fertile soils in the lower reaches of the Murray-Billabong Catchments were more suited to cultivation and were extensively cleared. For example, the Murray River floodplains near Welaregang (Corryong sheet) have only 0.1 % forest cover. A comparison of forest cover and land capability for the various portions of the catchments is presented in Table 20.

TABLE 20: Comparison of Tree Cover and Land Capability

Area	Land Capability Classes %			State Forest %	Tree Cover %
	I-III	IV-VI	VII-VIII		
Murray					
Upper Murray#	20.6	50.6	18.5	10.3*	34.0
Lower Murray!	70.9	26.2	2.6	0.3	1.5
Billabong					
Upper Billabong	59.0	33.4	4.1	3.4	11.4
Lower Billabong	93.5	6.0	0.3	<0.1	0.9

\# Holbrook and Rosewood 1:100 000 map sheets
! Walbundrie and Albury 1:100 000 map sheets
* approximately one fifth of State Forest is under pine plantation

Native forest areas continue to be cleared, mainly to be replaced by pine plantations and to a lesser extent improved pasture.

Scattered trees and small clumps of trees in the cleared farming lands are becoming increasingly at risk as they age, and are exposed to a range of stresses (see Section 5.2.4).

Habitats for insect predators have disappeared as a result of the clearing and the establishment of cropping and grazing systems. Grazing beneath remaining timber stands has removed the shrub layer and altered the species composition of the ground cover leaving no habitat for the insect predators. Grazing animals are also damaging the remaining trees by eating and rubbing the bark, effectively ringbarking the trees (See Plate 4). Improved pasture establishment has increased the habitat for insects such as the scarab beetle whilst their food source, the eucalypt, has diminished. Regeneration is rare in intensively managed areas.

5.2.4 What is Known about Maintaining Tree Cover

It is important to keep a proportion of land under timber, both at the farm level and catchment level. To prevent further degradation some means of preserving remnant timber must be implemented.

Maintaining satisfactory tree cover means managing existing timber, and in many cases increasing the area under trees. This may entail slowing the rate of tree death, planting or regeneration, or halting the clearing of existing forest and remnant trees.

Accelerated death or tree decline of eucalyptus appears to be caused by many factors. Often they act in combination with no one factor specifically identified. These include the effects of:

* insects
* fungi
* waterlogging and saline groundwater
* drought
* fire
* lightning strike, wind and hail storms
* nutrient deficiencies
* pollutants and toxic substances
* livestock on:
    - grazing of foliage and seedlings
    - soil compaction
    - alteration to the nutrient status of the soil from excreta
* unsympathetic management practices:
    - reduction of habitats for birds and other animals that prey on insects
    - use of exotic pastures and fertiliser which provide a more suitable breeding ground for some insects such as scarab beetles
    - spray drift of herbicides and other chemicals.

These factors place the eucalypts under stress making them more susceptible to insect attack and disease. Repeated defoliations eventually kill the tree. Because the way in which these factors act singly or in combination , there are difficulties in the successful management of tree decline problems.

Planting and maintenance requirements for trees are widely publicised. Many on-farm trials have been carried out, including the use of salt tolerant species, different mulching techniques and fertiliser applications. Several brochures of the 'Farm Trees' Series (Trees on Farm) also provide information on how to plan a co-ordinated farm tree establishment program. Less work has been done in the drier areas and species selection and establishment techniques for different pastures or land degradation conditions.

Successful tree establishment involves planning and commitment. Important elements are pre and post planting weed control, tree selection, planting and protection from stock.

Tree regeneration is achieved in native pastures simply by fencing to exclude stock. This has less success in improved pasture areas, particularly in drier areas, where regeneration is hindered by the effects of:

* pasture competition
* changes to the nutrient status of the soil by the use of fertilisers
* soil compaction by stock
* cultivation
* heavy grazing of young seedlings, particularly by sheep
* an overall unsuitable microclimate.

Dawson (pers. comm.) has noted that excellent regeneration has occurred during the last two years in stubble paddocks adjacent to areas with mature stands of trees. This shows another opportunity to improve tree cover. Although, it can be lost quickly due to grazing and cultivation unless the areas are fenced out.

Demonstrations have or are being carried out within the Murray-Billabong Catchments, on particular aspects of tree management. These include:

* natural regeneration
* use of residual herbicides for weed control
* direct seeding
* open rooted planting
* mounding for tree planting on discharge areas.

In catchments with groundwater and dryland salinity problems, demonstrations have been set up to:

* monitor the effects of tree planting in a recharge area on groundwater lower in the catchment

* assess the impact of natural regeneration of trees within the recharge areas.

Corridors of remnant trees and uncultivated land along paddock boundaries, roads, reserves, streams, abandoned railway lines and ridges are extremely valuable to catchments. Retaining remnant stands of trees is economically and ecologically advantageous. Natural habitat is almost impossible to recreate, and trees and corridors are expensive and time consuming to establish. Most are under consistent pressure from adjacent land uses. Remnant areas of timber must be valued as a resource and treated accordingly.

Landholders and communities can assist in the management and maintenance of remnant areas and corridors by minimising the adverse effects of adjacent land uses. This would include the following:

* increasing awareness in the community, government agencies and more particularly local government agencies of the value and significance of remnant stands of trees in the total landscape
* incorporating tree management into property planning and catchment management strategies
* minimise adverse effects of adjacent land uses, by fencing to exclude stock, ensuring chemical drift and fire damage does not occur, and creating buffer strips between cultivation and trees
* management and rehabilitation of corridors adjacent to private property
* widening existing corridors or creating new ones to link remnant stands. These could include plantings with a commercial element
* improving wildlife potential by re-seeding and replanting understorey species
* extension to raise landholder awareness of the value of trees and corridors.

An example of a corridor objective set by the Kyeamba Landcare Group is quoted in Appendix I.

Special emphasis is required for **riparian vegetation**, the corridors adjacent to streams and creeks, as these directly affect water quality. Land management practices required within the riparian zone include:

* protection of existing native vegetation to provide bank stability, wildlife and aquatic habitat without restricting flood capacities
* improve stock management by providing safe water points away from watercourses where possible, limiting grazing, and avoiding overgrazing, supplementary feeding or stock camping in these areas
* avoiding cultivation within at least the minimum distance of 20 m of stream banks
* protecting remnant and newly established vegetation by fencing and destocking.

Current legislation contributes partly in **controlling tree clearing** and protecting existing tree cover. They include:

* Protected Land (Section 21 of the Soil Conservation Act, 1938)
  . on slopes above 18° above Hume Weir Dam
  . prescribed streams as listed in Appendix M

* areas under the control of the National Parks and Wildlife Service

* Environmental Planning Act - Local Environmental Plans (LEP), Tree Preservation Orders (TPO) and Interim Development Orders (IDO)

* Crown lands including State Forests, Timber Reserves, Crown Leases, Conditional Leases, Permissive Occupancies, and vacant Crown land

* regulations relating to the destruction of trees on more than five hectares using specified herbicides

* areas considered to be part of the State's environmental heritage.

The Protected Land section of the Soil Conservation Act, and the Environmental Planning Act, are administered by CaLM, and local government, respectively. Because the Billabong Creek Catchment and the Murray River Catchment below Hume Weir have not been gazetted for Protected Land, large sections of the catchments do not have any legislative controls on tree clearing or destruction unless Shire Councils have Tree Preservation Orders in place.

5.2.5 Recommendations for Treatment of Tree Decline

a. Policies

A policy to maintain or establish adequate tree cover within catchments needs to be developed in accordance with the State Total Catchment Management Policy and the State Tree and Soil Policy. One of the policy's main aims should be the retention of existing tree cover on areas considered to be sensitive or easily prone to degradation and which are significant to maintaining the health of the catchment. Adequate tree cover, needs to be maintained or re-established both at the subcatchment and property level. The main aspects of this would be:

* promote the role and benefits of native vegetation and habitat in all departmental activities including extension visits to landholders, property management plans, and administration of Crown lands and leases

* promote the retention or re-establishment or tree cover densities dictated by land capability and water balance, and recommended tree cover figures for different climatic regions

* CaLM input into Regional and Local Environmental Plans to emphasise the importance of tree cover as part of the overall system of controlling land degradation

* a lead agency responsible for rural tree management needs to be identified and supported. Presently there are around six funding avenues and numerous term funded

positions but no central body working towards a long term objective.

The following land types require tree retention or re-establishment, in line with the preferred tree cover percentages listed in Appendix G.

* lands of Capability Classes VII and VIII
* lands which become unstable if cleared
* catchments with rising watertables or dryland salinity problems
* land of extreme soil erodibility
* riparian zones

Policies relating to extension activities include:

* property management plans, and land and water management catchment plans, should adopt the recommendations for -
  - percentage tree cover for land capability classes and water balance
  - encourage predominantly native species including understorey shrubs and ground covers

* require, as a condition of major financing under the advance loans scheme, a property plan and tree replanting or re-establishment program if tree figures are below preferred values

* provide incentives to landholders such as increased tax deductibility and/or tax credits to achieve recommended tree cover by:
  - protecting existing remnant vegetation
  - regenerating and replanting vegetation.

* promote the aims and objectives of Protected Land legislation with a well designed information package

* Protected Land controls should be developed and supported over the entire Murray-Billabong Catchments. Special emphasis should be placed on delineating lands suitable for inclusion as environmentally sensitive because of their significance to rising watertables, salinity and riverine environs.

The retention and management of Crown lands to control soil erosion, rising watertables and tree decline needs to be an integral part of CaLM policy. Crown land assessment needs to be in relation to the catchment rather than looking at the parcel of land in isolation. Recommendations to be considered include:

* encouraging Rural Lands Protection Board to play an increased environmental protection role by increasing tree and shrub cover in travelling stock and camping reserves

* retention and enhancement of vegetation on recreation reserves

* adopt various retention, exchange and revegetation strategies for Crown roads, depending on current vegetation densities

* on Crown land, agencies responsible for processing permits for clearing or agencies such as the Forestry Commission which have rights to log the Crown timber as part of the

conversion to freehold, should be required to consider site and catchment factors as part of their assessment

* retain Crown lands in areas where:
    . existing tree cover for any one type of landscape is less than 15% of the total area of the landscape
    . known land degradation problems including dryland salinity streambank erosion and soil erosion may be exacerbated
    . landscape units such as watercourses, heads of drainage lines, escarpments, steep slopes and unstable slopes which are critical for catchment protection or community use.

Closer liaison with local government is required for the protection of remnant and corridor vegetation. Relevant policies include:

* use statutory mechanisms (LEP, IDO, TPO)to control clearing and protect remnant and corridor vegetation

* all LEP's should include Tree Preservation Orders, ensuring any tree clearing requires a development application

* minimise the losses from, and degradation of, existing corridors and networks by avoiding disturbances that will reduce width or increase edge effects. Examples would be to :
    . keep all road maintenance within a defined zone
    . place all roads and utilities along one side of the corridor, leaving the other side undisturbed
    . widen roads to the most degraded side only, leaving the strip of undisturbed vegetation as wide as possible
    . encourage landholders to locate firebreaks on private land, rather than adjacent Shire roads.

b. Investigations

Demand for information on tree management and revegetation on rural lands throughout the catchment is increasing. Valuable research and investigation programs are underway, although many areas and problems are still to be investigated.

Issues that need to be investigated include:

* map the occurrence and condition of remnant native vegetation in areas where the proportions of trees are less than 10% of the total land area, or below the recommended level. Include description of their floristic and understorey quality

* survey the extent and severity of dieback and tree decline, and its causes, across the catchment

* identify areas where tree cover is critical in addressing land degradation and evaluate the

need to protect areas in particular catchments

* examine and evaluate the role of riparian vegetation in trapping nutrients, sediments and non-biodegradable materials and reducing toxic algal blooms in river systems

* water balance models to determine the proportion of catchments and farms that need to be returned to or retained under tree cover

* herbicide specifications for cropping that will not damage adjacent stands of timber

* develop methods to limit the impact of insect attack on eucalypts (eg encouraging insect predators, improving habitat, and developing effective methods of interrupting the life cycle of the insect pests)

* investigate the potential for agroforestry production including special purpose trees for stock fodder, and specialty fruit, wood and ornamental needs. The production systems, as well as the support infrastructure and some type of economic evaluation, should be part of the assessment.

State-wide dissemination of the information collected from research and investigations is vital.

c. Actions

There has been a major change in attitude in the community regarding tree cover in the last decade. There is a general awareness of the relationship between extensive clearing and land degradation. Rising watertables, salinity, repeated insect attack and dying trees have created a level of awareness of the need for replanting and regeneration of trees within the Murray-Billabong Catchments. Landcare groups are leading the way in this respect.

Substantial increases in tree cover, and care for existing trees, are required across a major part of the Murray-Billabong Catchments. Site specific treatments should be undertaken through property management planning, landcare activity, special funded projects, general extension activities and components of Section 10 Projects under the Soil Conservation Act.

Tree retention, regeneration and re-establishment are to be actively encouraged over all sectors of the Catchments with priority being given where the following degradation problems occur:

* expanding areas of dryland salinity, or where watertables are within 5m of the surface or where watertable pressures are within 2m or less of the surface (Section 5.1)

* slope instability (Ournie, Tooma Landcare area, Wagra and Fowlers Swamp Creeks - see Section 5.7)

* streambank erosion and severe to extreme gully erosion, (Mullengandra, Table Top and Fowlers Swamp Creeks - see Sections 5.4 and 5.5, respectively) and fringes to rivers, creeks, drainage lines and water storages

* areas of land capability classes VIr, VII and VIII

* tree cover is substantially below preferred figures (Section 5.2).

A series of subcatchment based rehabilitation projects which feature tree retention, re-establishment or regeneration as principal features of land management should be established under Section 10 of the Soil Conservation Act. An approach using land capability as the criteria for determining tree cover suggests priority areas would be:

Murray River Catchment	**Billabong Creek Catchment**
Wagra Creek	Four Post Creek
Tooma - Murray Rivers	Sawyer's Creek
Long Flat Creek	Forest Creek
Deadmans Creek	Native Dog Creek
Fowlers Swamp Creek	

Part of the project would involve the preparation and circulation of extension material for both rural and urban community groups detailing:

* the extent of tree decline and its effects on land degradation and long term productivity
* guidelines to assess tree cover (see Appendix J) and condition
* technical guidelines relating to tree regeneration, re-establishment and care of existing trees, including costs involved
* data gathered from research, investigations, trials and demonstrations.
* the economic costs of losing remnant vegetation.

This would be done in liaison with other groups and agencies such as Greening Australia, Trees on Farms, NSW Agriculture and the Forestry Commission.

5.3 INDUCED SOIL ACIDITY[2]

5.3.1 Nature of Problem

Acidity in soils is a major land degradation problem in southern NSW. It has a direct effect on the types of crops and pasture that can be produced, lowers production and adversely affects other forms of land degradation such as salinity and erosion.

The following ranges of pH (Ca) are used to classify soil acidity levels:

extremely acid	<3.5
strongly acid	3.6 - 4.5
moderately acid	4.6 - 5.5
slightly acid	5.6 - 6.5
neutral	6.6 - 7.5
slightly alkaline	7.6 - 8.5
moderately alkaline	8.6 - 9.5
strongly alkaline	9.6 - 10.5
extremely alkaline	>10.6

Acid soils (pH <5.5) occur naturally in higher rainfall coastal and tableland areas. Soils may be strongly acid (pH <4.5) in high rainfall zones (>1000 mm) and on sandy soils with low pH buffer capacity (Helyar et al.,1990). However, present land management practices are worsening the acidification problem on much of our agricultural lands.

If soil acidity is not addressed:

* soil pH values will continue to fall
* acidity will develop in the subsoil
* productivity and ground cover will decline and erosion is likely to increase
* other forms of land degradation, and their treatment, will be adversely affected
* in the long term the soil physical structure will collapse (Fenton pers comm.).

Related issues include pasture and crop management, groundwater accession, dryland salinity, streambank erosion, soil physical and chemical fertility, and water and wind erosion.

5.3.2 Extent and Severity of Soil Acidity

Previous mapping, as part of the 1987-88 Land Degradation Survey and by Helyar et al.(1990), identified the majority of the Southwest Slopes and irrigation areas as having acid soil problems. Chartres and Geeves (1992) estimated the extent of salinity within this area (see Table 21).

Acidification has been accelerated rapidly by the widespread use of clover dominant pastures, and in particular, the cropping/clover ley land use (Helyar et al.,1990). Consequently, the occurrence of soil acidity in the Murray-Billabong Catchments extends across the mixed farming areas down to the 500mm rainfall isohyet (Figure 5).

2 The bulk of the information used in making these recommendations has been produced by the Agricultural Research Institute, Wagga Wagga, NSW Agriculture and CSIRO

Figure 5: Soil Acidity in Relation to Rainfall (from Helyar et al., 1990)

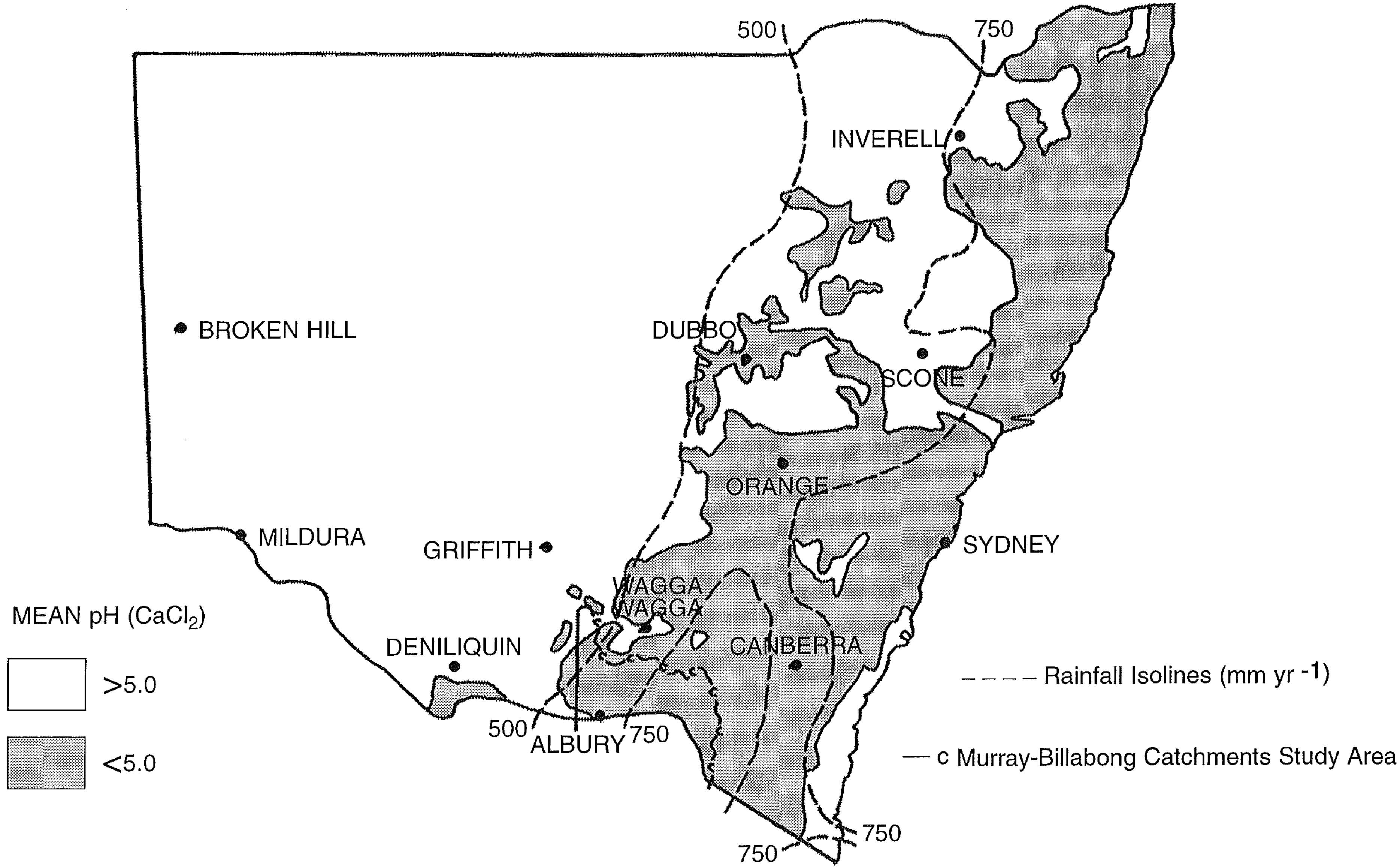


Figure 6: Acidity in Topsoil and Subsoil Layers (from Geeves and Gessler, 1991)

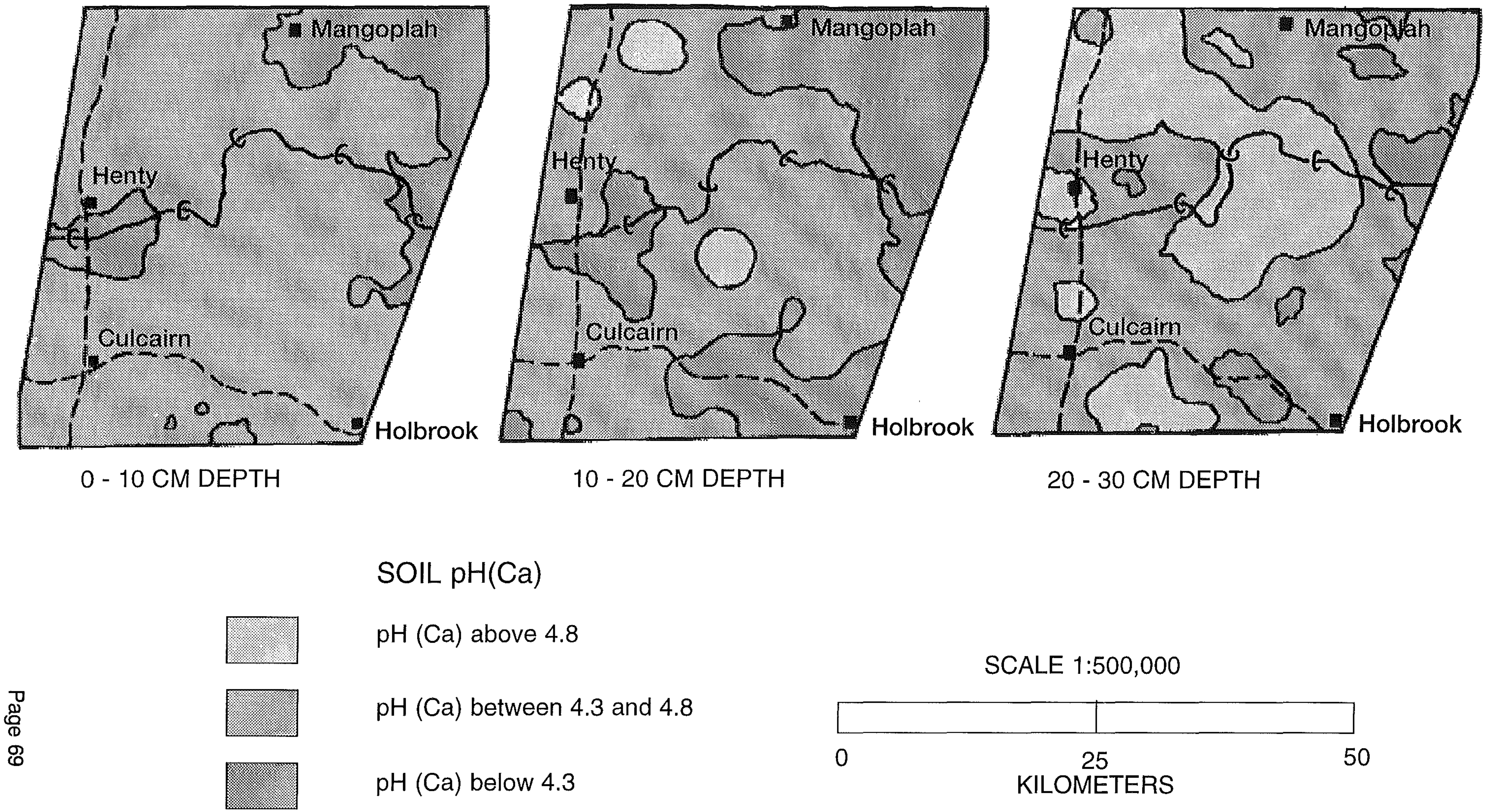


Table 21: Estimates of Soil Acidity in Southern Australia (Chartres and Geeves, in press)

Acidity Problem	Victoria Region		NSW Region		Total	
	Area (ha)	% Survey Area	Area (ha)	% Survey Area	Area (ha)	% Survey Area
Surface and sub-surface acidity (pH_{Ca} <4.8 to below 20 cm)	51,500	32	200,000	28	251,500	29
Surface acidity only (surface pH_{Ca} <4.8 pH >4.8 below 20 cm)	51,500	32	341,000	49	392,500	46
No immediate acidity problem (pH_{Ca} >4.8 to below 20 cm)	58,000	36	161,000	23	219,000	25
Total	161,000	100	702,000	100	863,000	100

When is acidity a problem?

It exists when the soil is too acid and high in Al and/or Mn, to allow a particular crop or pasture to be grown successfully.

For example, lucerne and phalaris need the soil pH to be above 5.2 and 4.8, respectively, for reliable establishment. However, subclover only incurs minor production losses down to pH 4.0 (Fenton pers comm.).

Different landholders, and the community in general, may perceive the severity of the problem differently depending on their current agricultural production. For grain cropping and many improved perennial pastures, a soil pH below 5.0 presents a major limitation.

Geeves and Gessler (1991) presented results for a survey of acidity in the Wagga Wagga Region in a series of maps showing the pH categories for three depth layers.

The Murray-Billabong Catchments were identified on these maps. Relevant portions of the maps are reproduced in Figure 6.

Within the Murray-Billabong portion, the extent and severity of acidity are:

* approximately 95% of the surface soils in the area have an acidity problem: for 10-25% of the area the acidity is severe

* approximately 65% of the subsoils have an acidity problem: for 5% of the area, the subsoil acidity is severe.

These proportions are about twice the intensity for the entire area covered by the acidity survey.

Subsoil acidity is far more demanding and expensive to rectify than topsoil acidity as lime needs to be incorporated to the depth being treated. Helyar et al.(1990) suggest once surface values become severely acid, continuing net acid additions cause pH decline in the subsoil. Geeves et.al (1990) concluded podzolic and solodic soils were particularly prone to subsoil acidity problems.

It is essential that programs be implemented as quickly as possible to treat the areas of induced soil acidity. Otherwise, the problems will worsen and the long term costs of treatment will be prohibitive.

5.3.3 Relationships with Other Physical Factors

"The pH of a soil layer is a function of the composition of the soil parent material and of the subsequent acid and alkali additions and removals from that layer" (Helyar et.al, 1990). In a natural system, surface pH values correlate well with rainfall and the pH buffering capacity of soil parent material (Helyar et.al, 1990).

Soil acidification is a natural process, as acid soils (pH <5.5) occur naturally in areas of high rainfall with light textured soils. However, acidification has been accelerated in the main agricultural areas by specific land use practices.

A major cause of soil acidification is the loss of nitrate from the surface soil. This occurs by leaching, lateral movement above some impermeable layers or in surface runoff. Factors which contribute to these losses are:

* annual legume based pastures which provide an excess of nitrate which is quickly lost from the system
* hot dry summers kill annual pasture and allow nitrates to accumulate over the summer period. With the onset of summer and early autumn rains, the nitrates are leached down the profile
* when annual plants establish, root growth generally is not able to extract the deepening nitrates
* some plants, such as subterranean clover and possibly lupins, excrete acid produced through their roots (Cregan and Helyar, 1986)
* removal of bases in products such as hay, grain, meat, etc.

Helyar et.al, (1990) investigated 10 different agricultural systems across the >500mm rainfall belt of NSW and calculated their respective acid addition rates (see Appendix K). Clearly the systems with the highest acid addition are the annual pasture and pasture/cropping rotations of southern NSW.

Large areas of southern Australia have induced acidity problems mainly as a result of land use practices. Acid sensitive crops and pastures have been replaced by more tolerant species. Examples include the replacement of barley and lucerne by wheat, triticale and subterranean clover.

Options for establishing the less acid tolerant yet more productive crops and perennial pastures are being lost. Furthermore, as the acidification process continues with time, the deferred problem is increasing in magnitude.

Other forms of land degradation and their treatment are being adversely affected by the induced acidity. This occurs through two relationships:

* lack of ground cover - when production is reduced, and/or perennials are excluded by soil acidity, overgrazing may occur. The overgrazing results in increased runoff and higher risks of sheet erosion and offsite effects such as gullying, streambank erosion and poorer water quality

*	water use - inefficient use of rainfall is itself a major component of the acidification process. Similarly, it is a determining factor in dryland salinity and it is no co-incidence that salinity and acidification are developing in areas with similar rainfall and landuse. The absence of a summer active, deep rooted pasture has resulted in rising watertables over wide areas of the Murray-Billabong Catchments. To reverse this trend, perennial pastures with extended growing seasons need to be re-established regionally.

In many cases establishment is severely hampered by low soil pH. The expense and time lag getting results from the lime and new pastures are sufficient to deter farmers from taking any positive action.

5.3.4 What is Known About Its Treatment?

The techniques and feasibility of soil acidity treatment have been well documented by several researchers and NSW Agriculture Agnotes. Management of soil acidity can be undertaken by:

*	modifying land management practices to decrease the long term rate of soil acidification
*	use of lime or other ameliorants to increase soil pH
*	use of acid tolerant species.

1. Adapting land management to slow acidification

There are several management changes that drastically reduce the rate of acidification and defer or eliminate the need for its treatment. Most involve the efficient use of soil nitrogen and water. As explained by Cregan and Helyar (1986), these are frequently the physical factors most limiting in Australian agriculture. Management techniques include:

*	the incorporation of a summer active, perennial grass species in the pasture to use the nitrates formed as a consequence of plant residue breakdown

*	pastures to have a grass component, and not to be dominated by legumes

*	cropping rotations to have a perennial pasture component

*	crops to be sown as early as possible in the season after opening rains to maximise the use of water and mineralised nitrogen

*	good pasture/crop selection, nutrition and soil physical conditions to enable maximum growth

*	strategic use of nitrogen fertiliser, careful selection of the form of nitrogen fertiliser and splitting heavy applications

*	minimise the removal of organic matter in the product

*	minimising sheep and cattle camps to stop the build up of nutrients in restricted areas.

2. Use of Lime and other pH Ameliorants

Once soil pH values fall below 4.5, there is a moderate effect on tolerant species, and a severe effect on acid sensitive species (Helyar et al.,1990). If lime or a similar product is not applied, an acid subsoil can develop in time.

NSW Agriculture has developed the "Lime it" computer program. This allows landholders to simulate particular management and lime application rates to their individual needs and to estimate future cash flows and profits. The general consensus is that lime is profitable to apply at sufficient rates to stabilise current levels of soil acidity. However, an important component of long term soil acidity management is the change from annual pastures to perennial pastures. The initial cost of this is significant, with some risk, and a return for investment being some 12 - 24 months away. Most landholders have been reluctant to take positive action, and this trend is expected to continue in the light of the present rural recession.

Technical problems exist with establishing perennial pastures on sloping lands. Lime is very insoluble, and needs to be incorporated into the soil by cultivation to allow a quick response. From a soil erosion viewpoint it is undesirable to cultivate slopes above about 15%. However if lime can not be incorporated, it may be 2 - 3 years before the soil pH rises to a level to allow perennial pastures to establish.

3. Use of Acid Tolerant Crops and Pasture

Acid tolerant plants are a method for adapting to the problem rather than treating it. NSW Agriculture's Ag Fact 1.4.1 "Liming problem acid soils" details the variations in acid tolerance both within species and between particular varieties.

However, the development and reliance on more tolerant species are not solutions in themselves. Further acidification will occur particularly if the tolerant species are annual legumes.

Acid tolerant plants need to be identified, or developed as part of the package of adopting land management to slow the rate of acidification and in time correcting pH.

A major research effort has been addressing the soil acidity problem. The NSW Department of Agriculture established the Acid Soil Research Institute at Wagga Wagga several year ago, and has also developed the "Lime it" program for farm extension. Further Federal funding has been provided to CSIRO and CaLM. The situation at present is:

* work by the Agricultural Research Institute and several NSCP funded projects have identified the problem, and given a package of recommendations to address it
* "Lime it" program has been upgraded and accepted as a good decision making tool
* preliminary mapping indicates the problem is widespread in the Murray-Billabong Catchments.

5.3.5 Recommendations for Treatment of Soil Acidity

a. Policies

Several Landcare groups have identified control of acidity as a major objective and taken this problem to the Minister for Conservation and Land Management. The Murray CMC has formed an Acid Soil Sub Committee.

Perennial pastures are required to treat a range of degradation issues in the Murray-Billabong Catchments. A limiting factor is the need for lime and the expenses associated with its application and the establishment of perennial pastures.

Policies required are:

* CaLM to make a greater commitment to recognising and treating induced soil acidity as a land degradation issues and to promote, in co-operation with NSW Agriculture, awareness of the effects of acidity on other forms of land degradation
* develop a co-ordinated extension effort with NSW Agriculture
* promote in the community the awareness of the problem and the repercussions that may arise from lack of treatment, in a similar way to which the dryland salinity problem has recently been tackled ("Acid Action")
* include liming and perennial pasture establishment programs as criteria for eligibility of concessional finance under the Department's Advance Scheme. This will assist other facets of land degradation as well as acidity
* define soil acidity land degradation at particular measurements of soil pH, exchangeable Manganese and/or exchangeable Aluminium, for each of the major soil types
* promote NSW Agriculture's "Lime it" program,
* promote the use of land management techniques as one method of combating soil acidification
* encourage all landholders and Landcare groups to undertake soil sampling and soil acidity assessment projects.

b. Investigations

* collation of all soil and survey results (SCS, NSW Agriculture, CSIRO and Agribusiness) to present an accurate picture on soil acidity problems in the Murray-Billabong Catchments
* select perennial legumes to replace subterranean clover in the cropping ley and pasture systems
* development of a method to apply lime/ameliorant effectively onto steep lands (eg worm incorporation has been trialed at Rutherglen and on the Tablelands)

* identify areas suitable for the early sowing of cereal crops

* investigate the effect of trees and agroforestry in reducing or reversing acidification

* determine the off-site effects of acidity such as its effects on rising groundwater and dryland salinity

* evaluate the onsite and offsite costs of soil acidity, and an appraisal of the cost-benefit analyses for the different treatments of soil acidity.

c. Actions

Large areas of agricultural land in the Murray-Billabong catchments require soil acidity, and the acidification process, to be addressed. To date information is not available to allow the severity of acidity to be assessed accurately or for detailed priority locations to be nominated for treatment. However, from Tables 3.1.1. and 3.1.2 the following Catchment Management Units have the highest priority for treatment:

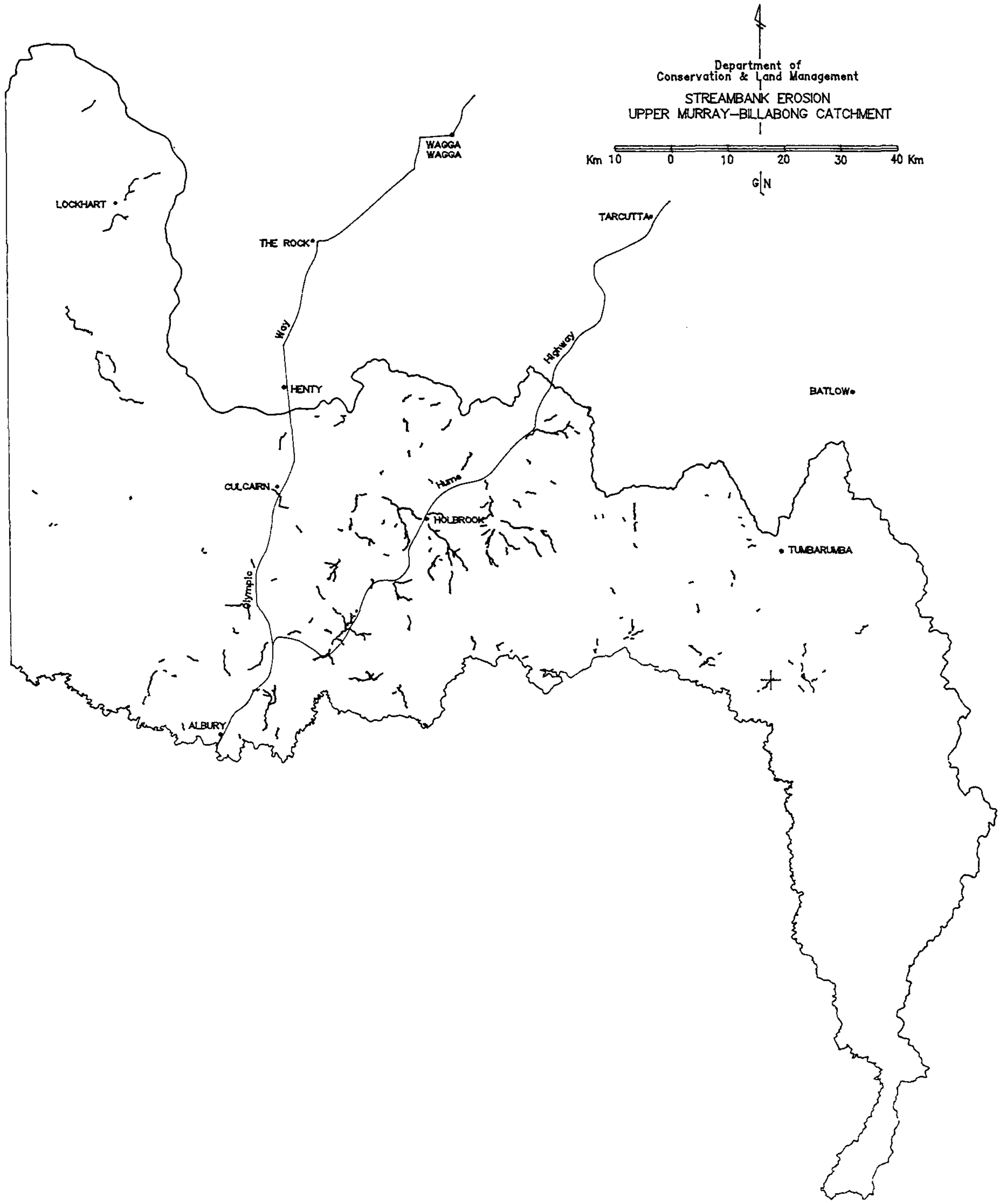
Murray Catchment

Bowna Creek
Coppabella Creek
Jingellic Creek

Billabong Catchment

Mountain-Tunnels Creek
Ten Mile Creek
Scent Bottle - Serpentine Creek
Lower Yarra Yarra Creek
Wantigong Creek

Figure 7: Streambank Erosion in the Murray-Billabong Catchments



5.4 STREAMBANK EROSION

5.4.1 Nature of Problem

Streambank erosion is a major problem in parts of the Murray-Billabong Catchments. By definition, streambank erosion is confined to incised drainage lines and results from lateral undercutting and abrasion of the streambank, rather than from flow over the edges of the channel, which causes the process of gully erosion (see Plate 5).

Major problems caused by streambank erosion include:

* increasing stream turbidity and sediment load
* loss of good quality land and soil
* damage to public roads, culverts and other infrastructure
* reduced channel capacity and changes in flood regimes
* damage to fences and farm bridges
* loss of trees and shrubs, degradation of aquatic and riparian habitat.

Related issues include tree cover, soil acidity, pasture management, altered catchment hydrology and changes to the channel.

5.4.2 Extent and Severity of Streambank Erosion

A total of 538 km of streambanks are affected by erosion in the Murray-Billabong Catchments. Much of this occurs on small creeks and their tributaries with the majority of streambank erosion less than 3 m deep. Table 22 shows the breakdown of streambank erosion in the Murray and Billabong catchments on the basis of depth of active erosion.

TABLE 22: Streambank Erosion in the Murray-Billabong Catchments

Streambank Erosion Class	Length (km)		Total
	Murray	Billabong	
< 1.5 m deep	83.6	172.4	256.0
1.5 m - 3 m deep	92.1	135.7	227.8
3 m - 6 m deep	20.3	29.5	49.8
> 6 m deep	1.4	3.0	4.4
Total	**197.4**	**340.6**	**538.0**

Table 23 lists the location of streambank erosion on a 1:100, 000 sheet basis. The majority of streambank erosion occurs on the Holbrook sheet, particularly in Billabong Creek Catchment (see Figure 7).

Appendix L shows a complete breakdown of all categories of streambank erosion on a 1:100,000 map sheet basis.

TABLE 23: **Map Sheets with Significant Streambank Erosion**

1:100 000 Map Sheet	Length (km)			Density
	Murray	Billabong	Total	(km/km^2)
Holbrook	64.7	198.3	263.0	0.11
Rosewood	44.0	84.8	128.8	0.07
Walbundrie	28.0	15.2	43.2	0.02
Lockhart	n/a	42.3	42.3	0.03
Tallangatta	21.1	n/a	21.1	0.12

n/a not applicable

All other maps sheets not listed in Table 23 contain less than 40 km of streambank erosion.

Table 24 and 25 detail the extent and severity of streambank erosion in the individual CMU's for the Murray and Billabong Creek Catchments, ordered west to east. CMU's with the most extensive streambank erosion problems are:

Murray Catchment

Mullengandra Creek
Eight Mile Creek
Fowlers Swamp Creek
Bowna Creek
Deadmans Creek

Billabong Catchment

Sandy Creek
Native Dog Creek
Ten Mile Creek
Lower Yarra Yarra Creek
Scent Bottle-Serpentine Creeks
Mountain-Tunnel Creeks
Urangeline Creek

5.4.3 Relationships with Other Physical Factors

A fundamental concept to understand streambank erosion is that each section of the watercourse is directly effected by the adjacent areas upstream and downstream.

Streambank erosion occurs as a result of several factors:

* channel grade
* runoff and storage characteristics of a catchment (landform and land use)
* rainfall pattern
* condition and type of riparian vegetation
* susceptibility of the clays in the soil to dispersion
* interference with the channel characteristics and stability
* significant storages and regulated flows.

Many of these are dynamic and can be changed quickly. Streambank erosion occurs primarily on the flatter areas of the floodplains and footslopes where the longitudinal cross sections of the drainage lines have a low gradient and the channels tend to meander.

TABLE 24: Streambank Erosion in Murray CMU's

CMU / Subcatchment	Streams Affected	Severity					
		depth (m)	Map Symbol	Length (km)	Density (km/km²)	Rankscore* (X 1,000)	Rank Intensity/ha *
Deadman's Creek	Deadman's Creek	1.5 - 3.0 3.0 - 6.0	102 103	9.2	0.08	116	9
Eight Mile Creek	Eight Mile Creek	1.5 - 3.0 3.0 - 6.0	102 103	16.4	0.27	107	18
Bowna Creek	Bowna Creek	1.5 - 3.0 3.0 - 6.0	102 103	23.0	0.07	213	7
Mullengandra Creek	Mullengandra, Yambla, Daly, Sweetwater and Waterfields Creeks	1.5 - 3.0 3.0 - 6.0	102 103	39.0	0.24	371	22
Table Top Creek	Table Top Creek	< 1.5 3.0 - 6.0	101 103	4.3	0.10	20	4
Fowler's Swamp Creek	Fowlers Swamp Creek	< 1.5 1.5 - 3.0	101 102	11.5	0.19	69	8
Wagra Creek	Wagra Creek	< 1.5 1.5 - 3.0	101 102	6.5	0.08	39	5
Coppabella Creek	Coppabella Creek	< 1.5 1.5 - 3.0	101 102	10.2	0.03	na	na
Horse Creek	Horse Creek	< 1.5	101	6.5	0.08	24	3
Ournie Creek	Ournie Creek	< 1.5	101	9.6	0.07	na	2
Spring Creek-Welaregang	Spring Creek	< 1.5 6.0	101 103	7.5	0.10	10	2
Tumbarumba Creek - Tooma	Tumbarumba Creek, and Spring Creek	< 1.5 1.5 - 3.0	101 102	7.2	0.05	na	na

* See page 25 for detailed explanation of Rank Intensity

TABLE 25: Streambank Erosion in Billabong CMU's

CMU / Subcatchment	Streams Affected	Severity					
		depth (m)	Map Symbol	Length (km)	Density (km/km^2)	Rankscore (X 1,000)	Rank Intensity/ha
Urangeline Creek	Urangeline Creek	<1.5 1.5 - 3.0 3.0 - 6.0	101 102 103	32.7	0.05	130	2
Brookong Creek	Brookong Creek	<1.5	101	16.5	0.04	na	na
Galore	Lower Bullenbung Creek	<1.5 1.5 - 3.0	101 102	15.8	0.02	na	na
Yambla Creek	Yambla Creek	<1.5	101	12.3	0.18	37	6
Mountain Creek-Tunnel Creek	Mountain, Tunnel and Wilson Creeks.	1.5 - 3.0 3.0 - 6.0	102 103	16.6	0.11	172	11
Native Dog Creek	Native Dog Creek	<1.5 1.5 - 3.0 3.0 - 6.0	101 102 103	18.7	0.22	205	24
Ten Mile Creek	Ten Mile, Sandy, Back and Devils Creeks.	<1.5 1.5 - 3.0 3.0 - 6.0	101 102 103	37.0	0.30	214	17
Sandy Creek	Sandy Creek	<1.5 1.5 - 3.0	101 102	26.1	0.38	200	29
Scent Bottle-Serpentine Creeks	Yarra Yarra, Spring, Scent Bottle and Serpentine Creeks.	<1.5 1.5 - 3.0	101 102	22.9	0.24	137	14
Wantagong Creek	Wantagong and Upper Yarra Yarra Creeks.	<1.5 1.5 - 3.0	101 102	11.8	0.14	71	9
Yarra Yarra Creek	Yarra Yarra Creek	<1.5 1.5 - 3.0 3.0 - 6.0	101 102 103	27.6	0.20	216	16
Sawyers Creek	Sawyers Creek	1.5 - 3.0	102	7.1	0.11	33	7
Lunts Creek	Lunts Creek	<1.5	101	16.6	0.15	42	5
Little Billabong Creek		1.5	101	2.7	0.04	8	1
Four Mile Creek	Four Mile Creek	<1.5 1.5 - 3.0	101 102	2.8	0.02	17	2

Inherent catchment characteristics such as soil type, rock outcrop, tree cover, slope gradient, drainage line vegetation and on farm water storages influence rainfall infiltration, detention and runoff. Changes to land use and land management and altered runoff characteristics of a catchment caused by farming, have a major effect on streambank erosion.

Aspects can be complex. For example, where native trees, understorey shrubs and perennial grasses are replaced by short season shallow rooted, exotic pastures or crops, the effects are:

* to reduce the temporary or interception storage of rainfall in the tree and shrub canopy and litter, allowing more water to reach the ground and to run off

* to raise watertables closer to the surface. Over the longterm, this reduces the water storage capacity of the soil and increases runoff. The problem is exacerbated in winter dominant rainfall areas where evaporation potentials are lower.

Poor management of pastures can contribute to streambank erosion when the surface cover of vegetation drops below 70%. This increases the runoff and soil erosion, and hence the erosive potential of streams by decreasing the times of concentration and the increasing volumes and rates of peak discharges.

Increased or intensified runoff resulting from development leads to streambank erosion. Causes of increased runoff include :

* clearing native timber to establish agriculture

* urban development

* cropping systems that cause soil structure decline, reducing the infiltration and water storage capacities of the soils

* specialised land uses such as softwood plantations and orchards in the early stages of development, and major roadworks

* wildfire

Geology has a major effect on the particle size of the soil material deposited on the floodplain and in the channel, and the chemical nature of the clay minerals therein. This relates to the susceptibility of the clays in the soil to dispersion and increased rates of weathering.

The soil type and its moisture status contribute to streambank erosion by assisting or retarding the two main processes involved. These are:

* slumping of bank material after undercutting by the stream

* direct corrosion of the bank by the stream itself (Hooke,1979).

Clay soils are more resistant to these forces than are sandy soils. One of the main factors of any soil is that when it is wet, more streambank erosion occurs. This is particularly true of low banks of silty material which are more frequently wetted over their total height. Composition of the sediments also affects the spatial distribution of erosion.

Rainfall and the seasonal variations in climate are obviously important. When drainage lines, dry for most part of the year, are subjected to high intensity rainfall, channelised flows develop quickly in the loosely bonded material. In winter, this situation is exacerbated when profiles are subject to runoff from longer duration storms causing the collapse of saturated, unsupported soil material from the channel sides.

The condition of riparian vegetation and channel stability can also be severely damaged by unlimited stock access, increasing streambank erosion. The role of the riparian zone in controlling streambank erosion and maintaining water quality is discussed in Appendix O.

Drawdown is the term used to describe a major drop in water level following a sustained level of high flow. When this occurs the weight of the saturated bank is no longer supported by the stream flows and slumping of the banks may occur. It is most common in regulated streams and rivers. Effects of river regulation on streambank erosion are discussed in Appendix P.

Interference with the channel and the floodplain is a major cause of streambank erosion. Examples include channel straightening; construction of levee banks, causeways, bridges; tree removal, removal of gravel and sand, stock access damage and obstruction by trees .

5.4.4 What is Known About Its Treatment?

The development or reactivation of streambank erosion is principally a function of changes in the hydrology of the catchment or interference with channels. The long term stabilisation of streambanks should be directed towards changes in management practices in the entire catchment, to provide more stable land conditions.

It is essential that each site, including the areas upstream and downstream, be examined for the causes of the erosion and the possible effects of any work such as reforming bed loads, the removal of obstructing trees, or alterations to stream channels, be fully assessed before any work is done.

The following points have been learnt from past practices:

* protection is a less costly alternative than repair

* there is a high inconvenience cost if the "do-nothing" option is used and infrastructure is destroyed

* piecemeal works by individuals may be outflanked by the river and are often of poor engineering standard, potentially unstable and ineffective in the long run

* major problems often arise when attempts are made to treat streambank erosion problems with apparently straightforward measures because responsibility for such works is unclear. For instance, if trees are required to be removed from the riverbank as part of the process of treating streambank erosion problems, permission must be obtained from CaLM or DWR. Furthermore CaLM and the Forestry Commission may also be involved if land mid-river is under new title and is classified Crown land

* the local cause of streambank erosion needs to be assessed very carefully to determine the effects of tree removal, alteration to bed loads and redirection of flows, on the streambanks that are presently stable and on downstream areas of streambank

* local government zonings can prevent commercial and residential locations in high risk areas.

The approach to address streambank erosion is as follows:

* stop any further clearing of trees within the riparian zones along watercourses

* exclude stock from areas of streambank erosion by fencing out and planting to trees and perennial pastures. Controlled light grazing by stock once areas are stabilised to avoid major silting and blockage problems (eg lower Mullengandra Ck.).

* limit stock access to the watercourses to areas which are stable, and prevent stock from grazing within the riparian zones

* protection of eroding banks by specialised works using simple engineering techniques, vegetation, and local materials where possible

* careful re-direction of stream flows by reforming bed shape and meanders

* removal of obstructing trees and vegetation within the stream channels

* re-establish a 'toe' of stream bed material along the actively eroding areas. This should be done in conjunction with main channel re-directions, the re-establishment of suitable vegetation and the exclusion of stock.

Technical advice on the treatment of streambank erosion should be sought from DWR. DWR have developed a range of site specific and cost effective rehabilitation methods suitable for both short and long term stability for streambanks. The DWR Catchment Manual and Riverwise pamphlets provide this is an easy to use form.

If implemented properly, **existing legislation** can contribute considerably to the prevention of streambank erosion by the controls exercised on tree clearing and soil disturbance along streams or within their catchments. This includes:

* Protected Land - Soil Conservation Act, 1938
  . Category (b) Prescribed Streams
  . Category (a) Protection of tree cover on steep slopes

* mining activities under the Mining Act

* restrictions on the removal of sand and gravel, or any work within the bed, or up to 40 metres from the top of the bank, Stream, Rivers and Foreshores Improvement Act 1948, Section 23A

* lease, licence and reservation conditions under the Crown Lands Act, 1989.

It should be noted that DWR has a statutory right under section 12 of the Water Administration Act 1986 "(e) preventing any unauthorised interference with the flow or availability of water; (f) preventing any unauthorised obstruction of a river or any change of its course; (g) preventing the unauthorised erection or use of works". Other agencies can be subject to legal action for inappropriate or failed works within the riparian zone.

5.4.5 Recommendations for Treatment of Streambank Erosion

a. Policies

The Department of Water Resources has recently developed an Interim Riparian Zone Policy which is summarised in Appendix N. Policies and extension activities by government agencies in the riparian zone and particularly on areas with streambank erosion problems should be consistent with the Interim Riparian Zone Policy.

Streambank erosion is one of the end products of changes in land use and land degradation processes throughout the catchment. Therefore policies that would assist in controlling streambank erosion are extensive, and would be relevant to every TCM program.

Policies of CaLM should reflect the primary role of vegetation in the management of the riparian zone. Aspects to be considered include the maintenance of species and structural diversity, the width and longitudinal extent of the riparian zone and land management factors.

Specific policies recommended include:

* promote the retention and good management of all existing areas of riparian vegetation along streams where streambank erosion could occur. Such a policy would support fencing to restrict stock access. The promotion would be undertaken as part of all extension activities by CaLM, DWR, NSW Agriculture, the EPA, the Forestry Commission, and the National Parks and Wildlife Service

* promote the re-establishment of riparian vegetation along streams where streambank erosion could occur. This promotion would be undertaken by officers of CaLM or DWR during visits to landholders, and in property management plans and catchment management plans

* require local government consent for all land uses that result in increased runoff or cause more uncontrolled runoff

* Crown lands which contain riparian vegetation and which are generally exempt from the leases with an automatic right to convert, shall not be sold, converted, leased or exchanged until the land is assessed as not having a significant impact on the riparian environment

* promote streambank erosion control projects in those areas where the erosion problems are of critical importance to catchment health

* promote the development and use of off-stream supply systems for stock water.

b. Investigations

* determine the contribution of streambank erosion on sediment and nutrient inputs to streams.

c. Actions

Catchment management projects need to be implemented in CMU's with high proportions of streambank erosion. Priorities are as follows:

Mullengandra Creek
Sandy Creek
Native Dog Creek
Ten Mile Creek
Eight Mile Creek
Lower Yarra Yarra Creek
Scent Bottle - Serpentine Creeks
Fowlers Swamp Creek
Bowna Creek
Mountain-Tunnel Creeks
Urangeline Creek

Funding to address some of these problems may be obtained through programs such as Rivercare (DWR) and Environment Trusts Grant Scheme (EPA).

5.5 SOIL EROSION - SHEET, RILL AND GULLY EROSION

5.5.1 Nature of Problem

Sheet, rill and gully erosion result from water flowing across the land surface and occur on all land uses where there is insufficient ground cover to provide protection to the soil. Although each form of erosion is a problem in different parts of the catchment, gully erosion is the predominant degradation issue.

i Sheet and Rill Erosion

Sheet erosion involves the removal of a fairly uniform layer of soil from the land surface by raindrop splash and/or runoff. No perceptible channels are formed.

As sheet erosion is inconspicuous and often masked, in this survey the risk or hazard of sheet erosion occurring was mapped. This hazard was assessed in five classes. These were determined using air photographs, local knowledge and the "SOILOSS" program to derive values based on the Unified Soil Loss Equation (USLE) see Appendix C.

Rill erosion is the removal of soil by runoff, with numerous small channels, up to 0.30 m deep being formed. Rill erosion typically occurs on recently cultivated or disturbed soils or in association with severe to extreme gully systems.

Sheet and rill erosion have both on-site and off-site effects. The loss of topsoil will reduce yields in crops and pastures due to loss of nutrients and organic matter. Further economic losses can be incurred by landholders and the wider community from off-site effects, such as:

* increased turbidity in streams, rivers and water storages
* sedimentation and increased flooding of fences, farm tracks, public roadways, railways, culverts and bridges (see Plate 6)
* sedimentation of waterways and water supplies
* destruction of aquatic habitat (see Plates 7 and 8)
* increased pollution from agricultural fertilisers, chemicals and animal effluent in waterways
* increased levels of gully erosion and streambank erosion lower in the catchment.

ii Gully Erosion

Gully erosion is the more obvious form of soil erosion and consists of open, incised and unstable channels generally deeper than 0.3 m. In the survey of the Murray-Billabong Catchments, major gullies are defined as gullies greater than 3 m deep and/or having multiple active heads (soil erosion classes 53, 54, 63, 64, 72, 73, 74, 81, 82, 83 and 84) (see Plates 9 and 10).

In addition to the off site effects listed for sheet and rill erosion above, gully erosion can cause:

* threats to foundations of public roads, railways, culverts, bridges and damage to

* reduction in the area of arable and other agricultural land, dividing it into smaller parcels and increasing farming costs
* increased rates of soil erosion where more erodible subsoil material is encountered.

5.5.2 Where Does Soil Erosion Occur?

i Sheet and Rill Erosion

Table 26 lists the areas of the sheet and rill erosion classes within the Murray-Billabong Catchments. Less than 0.5% and 0.1% of the Murray and Billabong catchments, respectively, have either severe or extreme sheet or rill erosion hazard. About 1.5% of the total area has a hazard of moderate or greater (see Figure 8). There are significant areas of low sheet erosion hazard in the catchments with minor sheet erosion over 28% of the Murray River Catchment and 7.4% of the Billabong Creek Catchment.

TABLE 26: Sheet and Rill Erosion in the Murray-Billabong Catchments

Erosion Class (Symbol)	Murray		Billabong		Total
	km2	(%)	km2	(%)	(%)
Not significant (11)	4105	(67.8)	4725	(91.6)	(78.3)
Minor sheet (21)	1697	(28.0)	386	(7.4)	(18.5)
Moderate sheet (22)	123	(2.0)	29	(0.6)	(1.3)
Severe sheet (23)	22	(0.4)	1	(<0.1)	(0.2)
Extreme sheet (24)	5	(<0.1)	<1	(<0.1)	<0.1
Minor rill (41)	50	(0.8)	14	(0.3)	(0.6)
Moderate rill (42)	13	(0.2)	5	(<0.1)	(0.2)
Severe rill (43)	<1	(<0.1)	<1	(<0.1)	<0.1
Extreme rill (44)	<0.1	(<0.1)	<1	(<0.1)	<0.1
Not applicable			0.8		

Sheet and rill erosion on a 1:100 000 map sheet basis are presented in Appendix Q (Tables Q1 and Q2). These show:

* the low undulating cropping lands to the west have between 6% and 8% of their total area affected by minor sheet or rill erosion, with less than 1% being moderate or severe. This is a reflection of the rotation practices on these lands, their low and short slopes, and the low intensity of the rainfall, all contributing to a low erosion hazard

* the headwaters of the catchments with steep timbered lands have between 20 and 50% of the lands with a minor sheet/rill erosion hazard and between 2 and 5% with a moderate or severe hazard. The actual levels of sheet and rill erosion increase substantially after severe wildfires

* upland areas in the Murray River Catchment comprising the steeper grazing country have some 20% of their total area affected by minor sheet or rill erosion.

Sheet and rill erosion across the catchment are not major problems mainly because of the relatively low rainfall intensities, fairly reliable rainfall and adequate ground cover conditions prevailing. However, significant amounts of soil and nutrients are lost from some areas, leading to localised on-site and off-site problems.

Sheet and rill erosion data are shown in Tables 27 and 28 for CMU's in the Murray-Billabong Catchments, ordered west to east.

CMU's with sheet erosion risks greater than 10% of the total area of the Unit are:

Murray River	**Billabong Creek**
Tumbarumba Creek - Tooma*	Ten Mile Creek*
Long Flat Creek	Scent Bottle-Serpentine Creeks*
Wagra Creek*	Mountain-Tunnel Creeks*
Upper Tooma River*	Wantagong Creek
Ournie Creek*	Lunts Creek-Sugarloaf*
Fowlers Swamp Creek	Little Yambla North c
Maragle Creek*	Little Billabong Creek*
Table Top Creek	Sawyers Creek
Mullengandra Creek	Native Dog Creek
Long Plain Creek c	
Tooma-Murray River*	
Deadmans Creek	
Cowombat Range	

* catchments with a major component of steep forested lands
c catchments with cropping lands

ii Major Gully Erosion

There are 418 km of major gully erosion in the Murray-Billabong Catchments. Almost half of this falls into the extreme class with depths between 1.5 - 3 m. The majority of this is located in the Billabong Catchment.

Lengths of the various classes of major gullies within the Murray-Billabong Catchments are shown in Table 29. A further breakdown on a 1:100 000 sheet basis, is presented in Appendix R (Tables R1 and R2).

Two-thirds of the major gully erosion (274km) occurs on the Holbrook 1:100 000 sheet alone (see Table 30) with the erosion concentrated around Bungowannah, Mullengandra, Tabletop, Little Yambla, Mountain Creek, Woomargama, Chinamans Hat, Nest Hill and Little Billabong.

Figure 8: Sheet Erosion Hazard in the Murray-Billabong Catchments

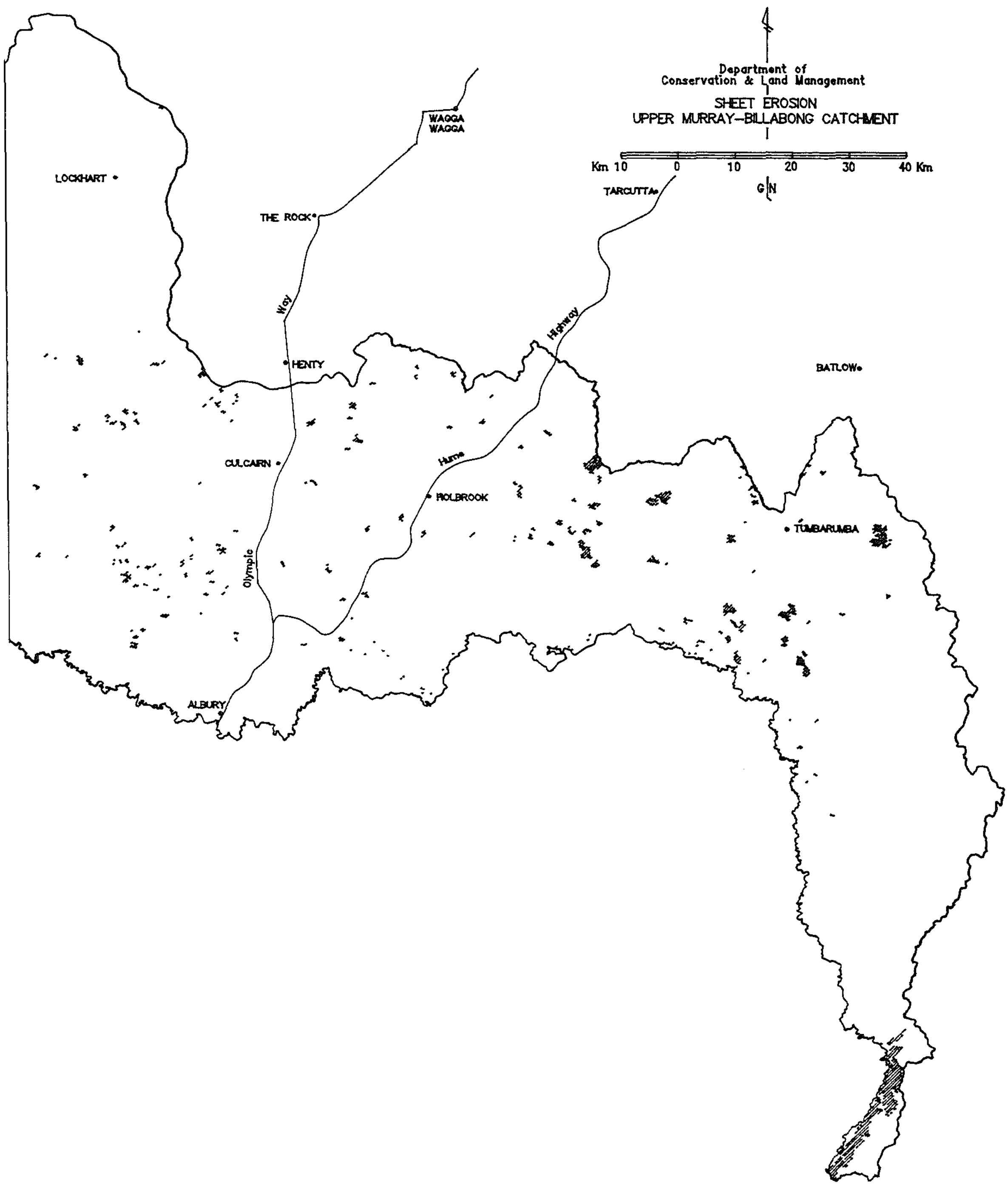


TABLE 27: Sheet and Rill Erosion in the Catchment Management Units with the Murray River Catchment

CMU/Subcatchment	CaLM District	Area Affected (ha) (% of CMU)							% pasture land use	Rankscore (X 1,000)
		Minor		Moderate		Severe		Extreme		
Long Plain Creek	Albury	3657	(12.7)	165	(0.6)	28	(0.1)	-	73.0	41
Majors Creek	Albury	749	(3.6)	204	(1.0)		-	-	87.5	7
Deadmans Creek	Albury	1319	(10.9)	-	-		-	-	97.7	13
Bowna Creek	Albury	2039	(6.3)	113	(0.4)	18	(+)	-	87.2	23
Long Flat Creek	Albury	458	(49.4)	-	-		-	-	93.2	na
Eight Mile Creek	Albury	116	(2.0)	190	(3.2)		-	-	95.0	na
Table Top Creek	Albury	714	(15.9)	-	-		-	-	85.0	7
Mullengandra Creek	Albury	2504	(15.1)	160	(1.0)		-	-	82.9	28
Fowlers Swamp Creek	Albury	1211	(20.2)	-	-		-	-	97.0	22
Wagra Creek	Albury	3769	(47.3)	-	-		-	-	75.6	38
Coppabella Creek	Albury	3227	(9.2)	936	(2.7)	891	(2.5)	-	42.0	na
Ournie Creek	Albury	3358	(26.1)	72	(0.6)		-	-	70.8	35
Spring Creek-Welaregang	Albury	696	(9.7)	135	(1.9)		-	-	79.9	9
Tooma - Murray River	Albury	1789	(12.6)	132	(0.9)	170	(1.2)	-	90.6	21
Tumbarumba Creek-Tooma	Albury	2436	(70.7)	24	(0.7)	144	(4.2)	-	53.6	na
Maragle Creek	Albury	1887	(16.8)	2	(<0.1)	15	(0.1)	-	69.6	na
Upper Tooma River	Albury	2240	(34.0)	-	-		-	-	34.0	na
Cowombat Range	Albury	1717	(10.2)	4992	(29.8)		-	-	2.2	na

TABLE 28: Sheet and Rill Erosion in the Catchment Management Units of the Billabong Creek Catchment

CMU/Subcatchment	CaLM District	Area Affected (ha) (% of CMU)				% pasture land use	Rankscore (X 1,000)
		Minor	Moderate	Severe	Extreme		
Burrumbuttock Creek	Albury	2283 (8.7)	132 (0.5)	-	-	68.8	26
Red Creek	Albury		-	-	-	71.0	2
Yambla Creek	Albury	188 (5.6)	52 (0.8)	-	-	78.1	4
Little Yambla North	Albury	315 (4.7)	21 (0.7)	-	-	87.1	4
Native Dog Creek	Albury	316 (10.6)	43 (0.5)	-	-	91.3	9
Sandy Creek	Albury	778 (9.0)	67 (1.0)	-	-	94.9	4
Mountain-Tunnel Creeks	Albury	292 (4.3)	-	-	-	68.0	28
Ten Mile Creek	Albury	2759(18.4)	78 (0.6)	-	-	76.4	29
Scent Bottle - Serpentine Creeks	Albury	2738(22.0)		-	-	69.7	20
Lower Yarra Yarra Creek	Henty	1881(19.6)	39 (0.4)	-	-		6
Four Mile Creek	Henty	404 (2.9)	112 (0.1)	25 (0.2)	-	85.1	8
Wantagong Creek	Henty	306 (2.6)	119 (0.6)	80 (1.0)	6	63.8	19
Forest Creek	Henty	1487(18.2)	101 (1.2)	-	-	94.4	3
Four Post Creek	Henty	269 (5.3)	19 (0.4)	25 (0.2)	2	78.2	3
Sawyers Creek	Henty	306 (2.6)	49 (0.4)	-	-	91.6	5
Upper Back Creek	Henty	447 (9.1)	26 (0.5)	-	-	89.5	2
Lunts Creek - Sugarloaf	Henty	250 (4.0)	90 (1.5)	-	-	73.1	11
Little Billabong Creek	Henty	1707(15.8)	21 (0.2)	-	-	69.4	10
		385 (10.3)	-				

TABLE 29: Major Gully Erosion in the Murray-Billabong Catchments

Class	Depth	Map Symbol	Length		Total
			Murray	Billabong	
Minor	> 3 m	53.54	-	8.7	8.7
Minor	salting	55	-	-	-
Moderate	> 3 m	63.64	7.3	14.0	21.3
Moderate	salting	65	-	-	-
Severe	1.5 - 3 m	72	37.8	36.5	74.3
Severe	> 3 m	73.74	4.3	5.9	10.2
Severe	salting	75	-	-	-
Extreme	< 1.5 m	81	12.8	57.0	69.8
Extreme	1.5 - 3 m	82	65.1	114.9	180.0
Extreme	3 - 6 m	83	20.2	8.6	28.8
Extreme	> 6 m	84	23.9	1.1	25.0
Extreme	salting	85	-	-	-
	Total		**171.4**	**246.7**	418.1

TABLE 30: Lengths and Densities of Major Gully Erosion for Selected Map 1:100 000 Sheets

Map Sheet	Murray Catchment		Billabong Catchment		Total	
	Length (km)	Density (km/km^2)	Length (km)	Density (km/km^2)	Length (km)	Occurrence
Walbundrie	24.1	0.03	21.1	0.01	45.2	10.8
Albury	28.5	0.12	n/a	n/a	28.5	6.8
Holbrook	82.7	0.13	191.3	0.12	274.0	65.6
Rosewood	13.7	0.01	28.5	0.07	42.2	10.1
Others			6.7			
Total					418.1	**100**

n/a not applicable

Figure 9: Gully Erosion in the Murray-Billabong Catchments

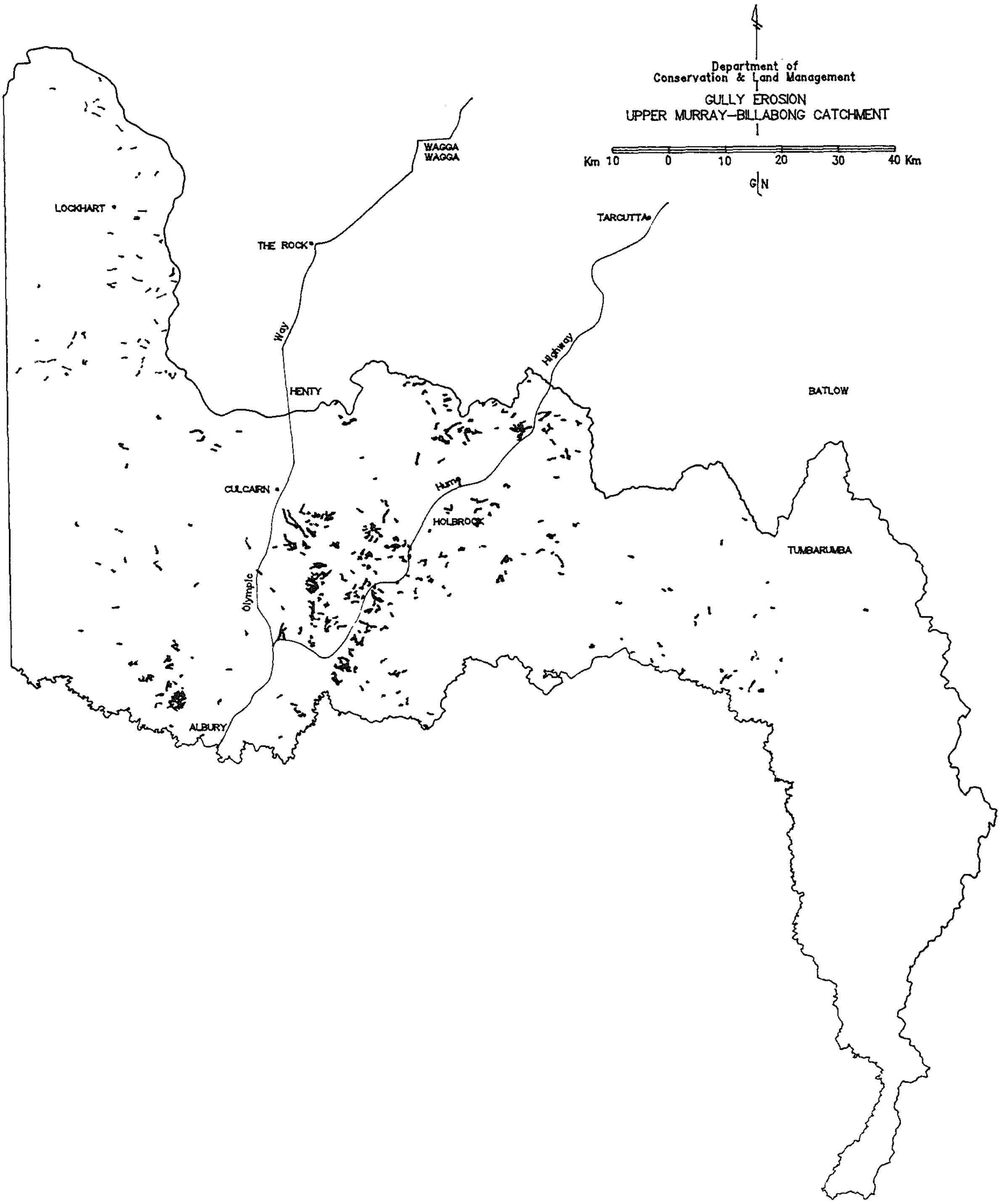


TABLE 31: Gully Erosion Data for Murray Subcatchments

Catchment	Minor Gullies length (km)	Minor Gullies density (km/km²)	Major Gullies length (km)	Major Gullies density (km/km²)	Rankscore Total (X 1,000)	Intensity (ha)
Long Plain Creek	9.6	0.03	-	-	17	1
Majors Creek	7.4	0.04	1.7	<.01	75	9
Deadmans Creek	12.7	0.10	20.9	0.17	320	26
Long Flat Creek	-	-	20.5	2.21	na	na
Bowna Creek	12.7	0.03	13.7	0.04	92	3
Eight Mile Creek	1.7	0.03	1.8	0.03	15	3
Table Top Creek	7.0	0.16	12.6	0.28	216	48
Mullengandra Creek	23.4	0.14	49.2	0.30	515	31
Fowlers Swamp Creek	7.3	0.08	7.4	0.09	77	9
Wagra Creek	4.2	0.05	5.5	0.07	44	5
Coppabella Creek	10.6	0.03	1.1	<.01	na	na
Horse Creek	0.8	0.01	1.7	0.02	14	2
Jingellic Creek	0.8	0.01	0.2	<.01	na	na
Ournie Creek	12.6	0.10	3.7	0.03	47	4
Munaroo-Rosewood	1.0	0.01	1.9	-	na	na
Spring Creek-Welaregang	9.1	0.21	3.1	0.07	40	9
Tooma-Murray River	7.9	0.06	3.1	0.02	36	2
Tumbarumba Creek-Tooma	1.8	0.05	0.7	0.02	na	na
Maragle Creek	1.4	0.01	-	-	na	na
Upper Tooma River	-	-	-	-	-	-
Cowombat Range	-	-	-	-	-	-

TABLE 32: Gully Erosion Data for Billabong Subcatchments

Catchment	Minor Gullies length (km)	Minor Gullies density (km/km²)	Major Gullies length (km)	Major Gullies density (km/km²)	Rankscore Total (X 1,000)	Intensity (ha)
Brookolong Creek	15.2	0.04	-	-	na	na
Boree Creek	18.4	0.03	-	-	na	na
Urangeline Creek	45.9	0.07	4.9	<.01	.996	1
Galore area	28.1	0.04	8.5	0.01	na	na
Bullenbong Creek	33.5	0.06	5.4	0.01	na	na
Burrumbuttock Creek	14.2	0.05	7.0	0.03	71	3
Red Creek	7.7	0.02	14.0	0.41	118	35
Yambla Creek	12.0	0.18	15.0	0.22	143	21
Little Yambla North	3.0	0.10	8.6	0.29	59	20
Native Dog Creek	5.1	0.06	19.7	0.23	161	19
Sandy Creek	4.8	0.07	16.4	0.24	124	18
Mountain-Tunnel Creeks	8.6	0.06	24.4	0.16	216	14
Ten Mile Creek	7.0	0.06	6.9	0.06	99	8
Scent Bottle-Serpentine Cks	4.3	0.04	9.3	0.10	84	9
Wantagong-Yarra Yarra Cks	4.6	0.06	5.0	0.06	na	4
Lower Yarra Yarra Creek	2.2	0.02	12.4	0.10	92	7
Upper Back Creek	1.7	0.03	10.9	0.18	148	24
Sawyers Creek	8.8	0.18	8.2	0.17	117	24
Forest Creek	5.9	0.11	6.8	0.13	71	14
Four Post Creek	8.7	0.31	11.3	0.40	101	37
Lunts Creek-Sugarloaf	13.0	0.17	5.5	0.07	46	6
Four Mile Creek	5.5	0.05	2.2	0.02	36	3
Little Billabong Creek	5.5	0.08	9.1	0.13	79	11

na not available

Descriptions of the location and extent of major gully erosion for the worst affected Catchment Management Units are presented in Table 31 and 32.
The catchments units worst affected by gully erosion (major and minor) are:

Murray Catchment	**Billabong Catchment**
Long Flat Creek †	Four Post Creek
Table Top Creek	Red Creek
Mullengandra Creek	Yambla Creek
Deadmans Creek	Native Dog Creek
Fowlers Swamp Creek	Sandy Creek
	Little Yambla North
	Upper Back Creek
	Mountain-Tunnel Creeks

† Long Flat Creek has been now treated with assistance from NRMS funding.

Localised areas of major gully erosion also occur at:

Peddles Hill	(Cookardinia)	E 515	N 6065
Groomer Hill	(Holbrook)	E 532	N 6048
Mother Wilson's Hill	(Khancoban)	E 593	N 6001
Mountain View	(Woomargama)	E 512	N 6042

5.5.3 Relationships with Other Physical Factors

Soil erosion results from excessive runoff. It begins as sheet erosion, which in severe cases initiates gully erosion on the areas below (Warburton, 1962).

i Sheet and Rill Erosion

The sheet and rill erosion hazard is related to a number of physical factors including rainfall erosivity, slope angle, slope length, the erodibility of the soil surface, the history of land use and ground cover.

Most sheet and rill erosion occurs on:

* cultivated land (see Plate 11)

* steeper grazing lands when ground cover falls below 70% (Costin, 1980, and Lang and McCaffrey, 1984)

* timbered land when the understorey is removed by grazing or destroyed by wildfires (see Plates 12 and 6)

* areas of major disturbance such as clearing, roadworks and urban developments (see Plate 13 and 5).

ii Gully Erosion

Factors involved in initiating gully erosion include:

* a history of poor ground cover due to high stocking rates, repeated cultivations, excessive clearing, fire and rabbits
* seasonal and cyclic drought
* concentrated discharge from steep lands into cleared drainage depressions
* unstable soils in drainage lines
* intense rainfall events at times when catchment cover conditions are low
* altered catchment storage - tree cover, leaf litter, soil infiltration rate.

Poor ground cover conditions on grazing land occur as a result of:

* drought
* high stocking rates based on good seasons which cause pressure on pastures when the season(s) become drier
* lack of improved perennial pastures
* soil acidity reducing opportunity for perennial pastures
* insufficient use of phosphate fertilisers to increase pasture production
* inadequate rabbit control and fire prevention measures
* insufficient subdivision fencing to provide adequate stock management
* limited water supply to allow improved grazing efficiency
* insufficient fodder reserves
* reliance on set stocking rates and inadequate adoption of annual supplementary feeding programs.

In summary, low ground cover levels are the result of poor land management and of land being used beyond its capability. European land use in Australia has a history of poor ground cover (see Appendix S).

The extensive gully systems are located on the highly dispersible soils derived from high grade metamorphic rocks in the Jindera and Bungowannah districts, and on lower grade metamorphic material in the Mullengandra to Woomargama area. Deep severe gullies also occur on deeply weathered granites at Holbrook and Tooma and on riverine deposits south of Culcairn, as a consequence of poorly designed water diversions (Albury District Manual).

5.5.4 What is Known About Treating Soil Erosion?

The most important aspect in the prevention of soil erosion is the maintenance of good ground cover. The combination of occasional heavy rainfall events and a reduced ground cover caused by cropping, fire or high stocking rates result in most erosion damage (Lang and McCaffrey 1984). Costin (1980) concluded that 70% ground cover was the critical level for runoff and soil loss. Research is currently being undertaken in NSW by Lang and Rosewell (CaLM, Gunnedah Research Centre) on critical cover levels in cropping situations. Preliminary data indicate that a minimum stubble cover of 30% is required to halve soil erosion rates in comparison to the erosion rates from a 10% stubble cover obtained after burning the stubble. This is a practical level easily achieved by landholders with current machinery and technology (Lang, pers comm.).

i. Sheet and Rill Erosion

On cropping lands the following practices will reduce sheet and rill erosion:

* management of crop and pasture residues to protect soil during fallow periods, and to improve organic matter levels and soil structure

* use of crop rotations that include a pasture ley period to improve the soil structure

* reduced or non-tillage systems involving the careful use of non-residual herbicides to control weeds and reduce the level of soil disturbance and period under bare fallow

* installation and maintenance of soil conservation structural works to:
    - reduce the velocity of surface runoff
    - allow conservation farming operations based on compatible layout of paddocks.

On grazing lands:

* adjust grazing levels and management to retain a minimum of 70% ground cover and remove stock if cover level falls below this value

* adopt a fodder/grain storage and conservation program to enable annual supplementary feeding and to reduce set stocking of hill country

* change farm layout to provide even grazing patterns through watering point design, stock shelter and shade requirements and rearranging paddock layout by taking into account soil type and terrain features

* construction and maintenance of erosion control works in areas of high erosion hazard

* retain or establish perennial pastures on more productive lands to provide a source of feed during prolonged dry periods

* increase or maintain tree cover based on land capability and other catchment requirements

* careful management of fertiliser and trace element applications where deficiencies occur.

Plate 5: Undercutting and collapse causing creek to trespass onto Hume Highway easement. Photo Mullengandra Creek catchment.

Plate 6: Sediment deposition resulting from severe sheet erosion caused by rains several months after wildfire. Photo Talmalmo area.

Plate 7: Sediment deposition degrading riparian habitat. Fence catching debris has aggravated the problem. Photo Seven Mile Creek, Talmalmo.

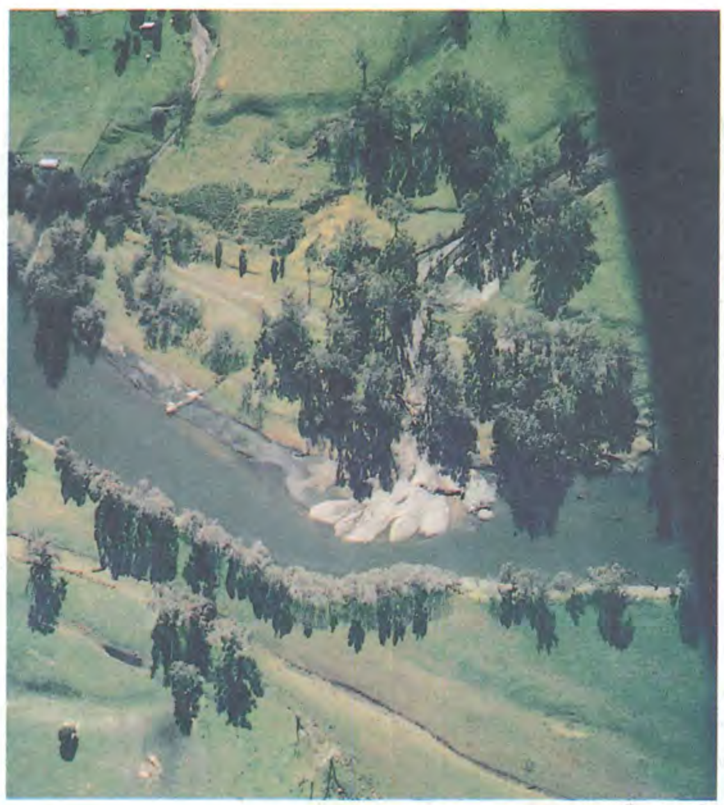


Plate 8: Sediment from a fire effected creek catchment entering the Murray River, adversely affecting aquatic habitat. Photo Seven Mile Creek, (May 1985).

Plate 9: Aerial view of severe gully erosion, and surrounding poor pasture cover. Photo Mullengandra Creek catchment.

Plate 10: Ground view of severe gully erosion. Note dispersible walls. Gully treated by fencing and planting trees. Photo Long Flat-Deadmans Creek catchment.

Plate 11: **Sheet and rill erosion on low slope cropping lands.**

Plate 12: **Overgrazed area prone to sheet erosion. Photo Ournie Creek catchment.**

Plate 11: **Sheet and rill erosion on low slope cropping lands.**

Plate 12: **Overgrazed area prone to sheet erosion. Photo Ournie Creek catchment.**

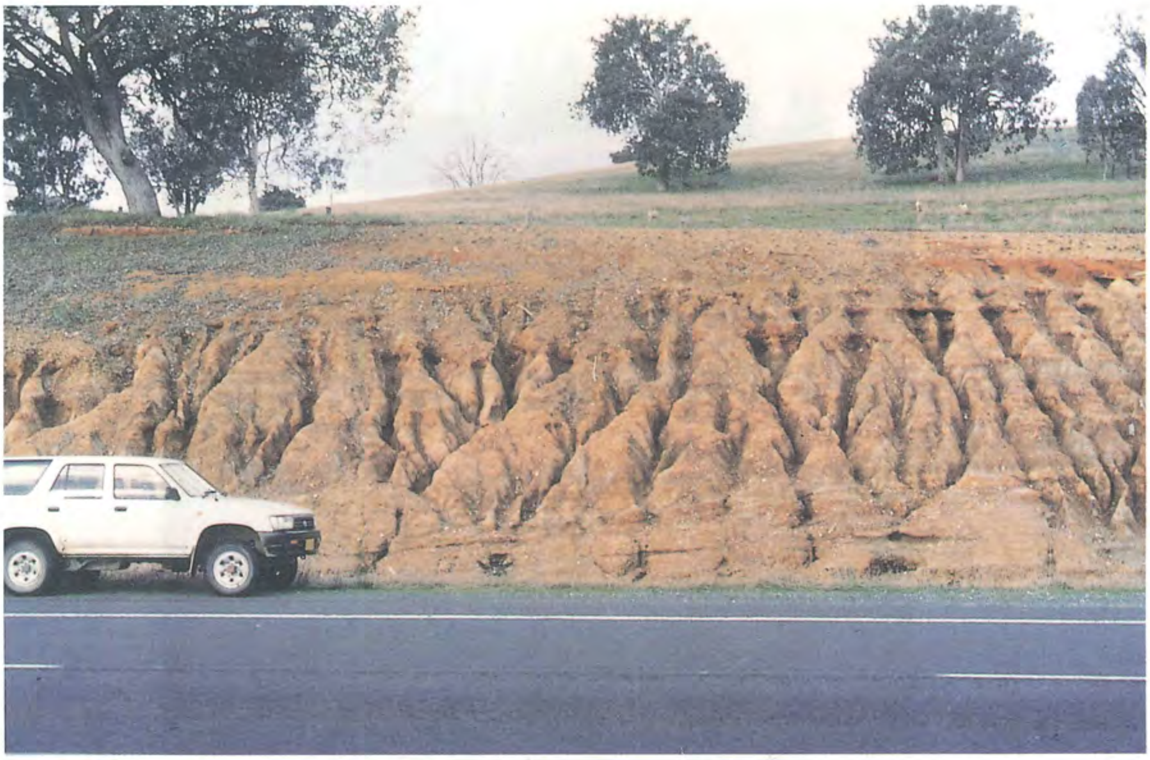


Plate 13: **Rill erosion on a steep bare batter exacerbated by saline seepage. Photo Hume Highway. Mullengandra Creek catchment.**

Plate 14: **Slumping on unstable slopes in Basalt areas can result in costly damage. Photo Tumbarumba-Tooma Road, Tumbarumba Creek catchment.**

Plate 15: **Erosion associated with roadworks required for pine harvesting and re-establishment.**

Plate 16: **Rill erosion down formed access road. Also a common problem along poorly located and designed fire trails.**

On forested lands, sheet and rill erosion can be minimised by:

* maintaining adequate ground cover as litter, grasses, herbs and shrubs

* reducing the incidence of wildfire

* removing stock from areas where the understorey is being irreparably damaged.

ii Gully Erosion

There are two components to the successful treatment of gully erosion:

* changing the catchment hydrology by-
    . reducing runoff (land management)
    . redirecting runoff (engineering works)

* stabilising gully heads, floors and walls by-
    . engineering or earthworks and/or
    . vegetative techniques.

Areas affected by extreme levels of gully erosion are best treated by changing the land use, sometimes in combination with minimal structural works. In some cases, it is essential that cropping and grazing cease in the catchment areas of gullies, and the gullies are fenced and allowed to revert to native trees. In other cases, it may be necessary to stop any further cultivation and keep the areas only for grazing.

If gullies are not fenced, unrestricted stock access reduces the chances of regeneration.

Areas affected by less extensive gully erosion can be treated with gully control earthworks. Sound crop, pasture and soil management practices are essential to complement earthworks. Techniques used in treating major gully erosion have not been well documented. Some are detailed in the Soil Conservation Service publications including "Earthmover's Training Course", and District Technical Manuals. The main aspects of these techniques are:

* catchment treatment is necessary to assist gully rehabilitation. Treatment involves reducing runoff and peak flows. On cropping lands properly designed banks and waterways are effective and economical. However, on grazing lands, due to landscape features, gully characteristics and economic factors, earthworks cannot always be used. In these circumstances catchment treatment can be provided through pasture and forest cover, grazing management and fire management

* at the heads of gullies, runoff is diverted away from active heads to a safe disposal area. Gully checks, covering the heads with water (Swadling, 1964) and diversion banks are commonly used. However the use of these techniques may be severely restricted by steepness of land, shallow or dispersible soils and the lack of a safe disposal area

* in gully floors and sidewalls use of vegetation and earthworks. Gully fill is not recommended in deep gullies with dispersible soils. Ripping and shaping gully edges, heavy fertiliser applications and revegetation of bare areas have been successful in some of these gullies. The most successful method of treating deep gullies is to erect fences exclude stock, plant trees and construct structures within the gully to encourage

deposition of sediment (SCS, 1985; Marshall, 1989 and Crouch et al. 1984)

* re-entry of runoff into drainage lines. Materials used in structures to allow safe re-entry of run-off include concrete, rock, grass and bidum cloth flumes. The cost of these structures can be high and is often prohibitive in very deep gullies with many active heads.

The implementation rate of major gully treatments can be enhanced if landholders see side benefits of such works. Such benefits include:

* using these areas for other purposes such as woodlots or agroforestry

* protection of other assets (eg reduced sedimentation of tracks and fences)

* improving stock management, their accessibility and safe movement

* improved aesthetics and resale value of the property

* improved shelter and shade

* onus for solution of off-site problems (pollution) to be directed back to the source of the problem

* where off-site effects are significant, the community benefit involved may warrant some direct subsidy.

5.5.5 Recommendations for Treatment and Prevention of Soil Erosion

a. Policies

* maintain or increase extension services to encourage the implementation of soil erosion control measures

* develop schemes for the treatment of soil erosion problems on a subcatchment basis

* encourage development of property management plans, as integrated units of catchment land and water management plans

* promote soil erosion control works by-
    . relaxing eligibility criteria for soil conservation loans
    . incentive schemes with appropriate use of concession loans and taxation concessions and credits
    . expand criteria for soil conservation loans to include recommended conservation farming and reduced tillage techniques and equipment

* make more effective use of the legislative powers which exist in existing legislation to ensure that individuals or organisations which are causing erosion and sedimentation problems are required to repair the damage they create

* promote the efficient and safe use of herbicides in conservation farming systems

minimising environmental effects (eg WASP (Weed Activated Spray System) developed by the NSW Agriculture)

* promote the adoption of control measure by public authorities such as RTA, SRA, local councils, Forestry Commission and pine plantation developers

* introduce revised Protected Land maps as quickly as possible

* encourage landholders to address soil acidity and related degraded pasture problems

* delay the conversion of forested Crown land to freehold land until Protected Land information is available in the Murray-Billabong Catchments

* undertake an education program to increase the awareness and understanding of soil erosion principles by staff of other government and local government agencies, agricultural consultants, etc

* encourage management programs to reduce the incidence of wildfires.

b. Investigations

* develop cost effective techniques and materials for stabilising very deep gully systems with dispersible soils. These would include engineering and vegetative techniques, including tree and pasture species and planting configurations to give the best results in stabilisating gully heads, floors and walls, plus cheap effective fencing

* conduct economic analysis to determine the costs and benefits of improved grazing management, lower stocking rates fodder conservation and supplementary feeding, aimed at ensuring the maintenance of good groundcover

* continued development of 'SOILOSS' to include more soil types, steep lands, new crop rotations and different pasture systems.

c. Actions

The SCS has been the lead Government Agency addressing soil erosion problems in NSW for over 50 years. It has developed a large scientific and technical base and is recognised for on farm implementation of works. Significant areas of severe gullying have been rehabilitated to full production in cropping and mixed farming areas. However, in the less productive grazing lands, the areas requiring treatment remain substantial.

The prevention of on-site and off-site effects of sheet, rill and gully erosion can be treated mostly by landholders in consultation with staff of the Soil Conservation Service. This report and the mapping upon which it is based provide a tool to inform landholders and policy makers where additional staff and resources will be required. The treatment of off site effects such as infrastructure damage will also involve local councils, SRA, RTA and possibly other departments such as DWR and NSW Agriculture.

The following actions are recommended:

* implement catchment based projects, under section 10 of the Soil Conservation Act, in CMU's in the following order of priority:

Table Top Creek	(Murray Catchment)
Mullengandra Creek	(Murray Catchment)
Four Post Creek	(Billabong Catchment)
Red Creek	(Billabong Catchment)
Yambla Creek	(Billabong Catchment)
Native Dog Creek	(Billabong Catchment)

* retain under tree cover those areas which have a high erosion hazard if cleared, including areas mapped as environmentally sensitive lands under the Protected Land provisions of the Soil Conservation Act, 1938.

* support the activity of Landcare groups in subcatchments where soil erosion is a major problem. Priorities are-

    . the Mullengandra-Table Top Creeks area
    . encourage the Holbrook Landcare Group to operate in subcatchment groups and give greater priority to dealing with soil erosion problems

* continue projects which aim to control rabbit populations.

5.6 SOIL PHYSICAL AND CHEMICAL PROBLEMS

5.6.1 Nature of Problems

Soil physical and chemical problems are those deleterious changes in soil that have occurred as a result of various land use practices. They adversely affect productivity and increase the risk of land degradation.

The main soil chemical problems are:

* soil acidity
* dryland salinity, nutrient decline, imbalances or toxicities
* dispersibility or sodicity
* hydrophobic soils,

whilst the main soil physical problems are:

* soil structure decline
* compaction

Induced soil acidity and salinity have been previously discussed in Sections 5.2 and 5.3 respectively. This section deals mainly with soil structural decline.

Soil structure decline refers to the development of:

* shattered or disaggregation of structure to a finer or single grain fabric (partial or complete)
* recurring formation of surface crusts
* a more massive condition often with a plough pan at the base of the cultivation layer
* a denser overall structure (compaction) as a result of stock movement or vehicular traffic.

Such phenomena can lead to surface crusting, poor infiltration, water ponding, and soil cloddiness when cultivated (Murphy and Allworth, 1991).

Related issues include sheet and rill erosion, wind erosion and waterlogging.

5.6.2 Where are the Major Areas with Soil Physical and Chemical Problems?

Although soil structure decline was not mapped as part of the current program, information is available from the 1987-88 Survey of Land Degradation in New South Wales.

Within the Murray-Billabong Catchments on a 1:100 000 map sheet basis, soil structure problems are as follows:

* Lockhart - severe* over most of the area
* Walbundrie - severe over much of the area
* Holbrook - moderate over part of the area

* ratings were nil to minor, moderate and severe.

These are the sheets with the highest proportions of cropping lands. Within these sheets, the CMU's are:

Boree
Brookong
Urangeline
Burrumbuttock
Long Plain
Majors
Other Billabong around Culcairn/Holbrook

The Alma Park/Pleasant Hills Landcare Group is addressing soil structure decline as one of its major areas of concern.

No information is available on the extent, location and occurrence of nutrient problems or hydrophobic soils.

5.6.3 Soil Fertility Relationships

Soil fertility is an indicator of a soil's ability to maintain the production of food and fibre. It has three major components:

* chemical - supply of nutrients to plants
* physical - condition of the soil making available an optimum supply of nutrients, water, and oxygen
* biological - microflora and microfauna activity recycling organic matter.

The organic matter content plays a critical role in enhancing the chemical and physical fertility of the soil. In particular organic matter supports the microflora and fauna in the soil and maintains a beneficial soil structure. As a consequence it:

* facilitates aeration, infiltration and soil drainage
* promotes plant establishment and root growth
* provides a supply of nutrients to plants
* improves nutrient availability and water holding capacity
* binds soil particles together making them more resistant to raindrop action, overland flow and wind erosion (Charman and Roper,1991).

Soil structure decline is caused by:

* land use factors (present and past)
* soil type
* cultivation and cropping practices
* impact of machinery
* stock management.

Most soil types are prone to soil structure decline. However, some characteristics make them more susceptible. These include:

* soil texture - lighter textured soils, particularly those high in fine sand and/or silt are affected more by cultivation than soils with higher clay contents

* clay mineralogy - sodic clays suffer from reduced porosity and permeability after cultivation as a result of dispersible clay materials blocking poor spaces
* aggregation - strongly aggregated soils are more difficult to compact, and hence resist the development of compaction and plough pans.

Cultivation often leads to the deterioration of soil structural stability. This occurs because cultivation physically shatters soil structure and speeds up the destruction of the organic matter. Heavy machinery can also cause the soils to become compacted.

Other cropping factors which affect soil structure include:

* the type of crops grown,
* the balance between organic material removed and replaced
* the past cropping history
* degree of physical disturbance
* turning or relocation of soil
* number of cultivations in any one season
* soil moisture content at the time of cultivation
* organic residue remaining on the surface
* cropping system (spray, rotations, short fallow etc).

Grazing stock can also affect soil structure. The most obvious is compaction caused by sheep and cattle trampling during wet conditions.

The effects of soil structure decline include:

* surface crusting, poor establishment and the need to resow crops
* increased runoff and soil erosion
* low infiltration and reduced water storage
* restricted root development
* surface ponding and waterlogging in lower areas
* cloddy fallows requiring additional workings or specialised equipment
* reduced time for optimal cultivation and sowing
* increased susceptibility to wind erosion.

5.6.4 What is Known About Their Treatment?

By world standards Australian soils are infertile, and the climate is harsh. To maintain long term productivity, land use and land management practices must be compatible with these limitations.

The nutrient status of soils is generally overcome by site specific soil testing and application of appropriate fertilisers, ameliorants or crop and pasture management techniques.

Physical aspects of fertility can be addressed by altering land management practices, with an emphasis on maintaining sufficient soil organic matter.

The key factors in dealing with soil structure decline in cropping areas are:

* reducing the intensity of cultivation
* retention of stubble residues.

In more detail these include:

* reducing cultivation passes during cropping cycles
* increasing retention of pasture and stubble residues by reducing the frequency of burning
* cultivating at appropriate times to avoid shattering of dry soils, and shearing and compacting wet soils
* replacing mechanical weed control with chemical control
* using direct drill sowing techniques
* avoiding continuous cropping.

Widespread adoption of these practices is indicative of their success. Where they are not adequate in reducing soil structural problems, then other actions may be required such as:

* reducing cropping intensity

* including a significant pasture phase in the rotation (and ensuring that legumes do not dominate the pasture to avoid soil acidity problems)

* adding soil ameliorants such as gypsum.

In permanent pastures these problems should not occur. However, aspects such as vehicular traffic and heavy stocking in wet conditions can cause problems, necessitating remedial action.

5.6.5 Recommendations for Treatment

a. Policies

CaLM has assessed soil structure decline to be a major form of land degradation and of economic significance to the community. Policies required to address the problem include:

* maintain the Department's program to prevent and treat **soil structure decline**

* encourage property management planning in areas identified as suffering from or being prone to soil structure decline. Encourage joint inputs from NSW Agriculture and agribusinesses

* ensure landholders are familiar with the problem, including the costs, the causes and the remedies, particularly in areas identified as having soil structure decline. Landcare is a suitable vehicle to facilitate this

* consider soil structure decline is a major issue when developing land and water management plans.

b. Investigations

CaLM has undertaken extensive research into the many aspects of addressing soil structure decline. Areas requiring further work include:

* identify and evaluate the occurrence and extent of soil structure decline in cropping lands within the Murray-Billabong Catchments

* identify soils types most prone to soil structure decline and provide maps of their distribution. Determine best preventative and reclamation strategies

* select suitable grass and legume species for use in the drier cropping areas to enhance organic matter content and improve soil structure

* develop crop agronomy and crop management to ensure the benefits of improved soil structure and productivity do not adversely affect **groundwater accession.**

c. Actions

* maintain specialist officers on the program

* train extension staff of CaLM, other government agencies and farm consultants of the benefits, costs and details of soil problems in the Murray-Billabong Catchment

* assess the economic cost to producers of different forms of soil structure decline

* provide education and assistance for landholders to be able to assess their own soil structure and monitor the impact their management has on it over time.

5.7 STEEP LANDS

The management of steep lands for individual forms of land degradation has been discussed in the respective sections. However, because of the significance of steep lands in the overall management of a catchment, it has been considered essential to discuss these lands as a separate and special unit.

5.7.1 Nature of Problem

Steep lands are affected by, or contribute to, land degradation if their land management is not sensitive to their physical features and limitations. Effects may be on or offsite. Lands in this category relate to the risk of:

* erosion
  . cleared land on slopes greater than 25%, with native and low grade annual pastures
  . forested lands, with slopes greater than 33%, where the understorey is heavily grazed
  . forested land on slopes greater than 33%, subject to frequent controlled burns and/or susceptible to wildfire. This is particularly the case on granite soils

* mass movement
  lands where slope instability is evident.

On the soil erosion maps they are delineated as soil erosion classes 21-24, 41-44 or 91-94.

Land degradation problems associated with these lands include sheet and rill erosion, gullying in drainage lines, sedimentation, increased groundwater accessions, slope instability and wildfire hazard.

Related issues include tree cover, inadequate pasture cover, streambank erosion, water quality decline in waterways and storages, dryland salinity and infrastructure damage (see Plate 14).

5.7.2 Where are the Steep Lands?

The distribution of steep lands at risk in the Murray-Billabong Catchments is shown in Figure 10. Most of the lands in the headwaters of the catchments do not fall into this category as they remain timbered and protected as National Parks, State Forests and Crown lands. Such areas include the Upper Tooma River, Geehi River, Indi, Maragle and Bago Ranges and China Walls.

In the central and upper parts of the catchments the steep lands as defined include:

* Goombargana Hill, Bungowannah - Jindera Hills, Spring Hill, Red Hill, Stringbark Hill and Cookardinia Hills
* Table Top, Great Yambla and Little Yambla Ridges, East Hill, Echina Ridge and Woomargama Hill
* Black Ridge, Clifton Hills, Kyeamba - Carabost Range and Dora Dora Forest area
* Ournie, Bald Hill, Lighthouse Mountain and Mother Wilsons Hill

The extent of land effected by mass movement is detailed on a 1:100,000 sheet basis in Table 33. Although the mapping scale has exaggerated these figure, the table reveals the overall distribution with the Rosewood and Yarrangobilly sheets having the greatest extent of instability. In more detail, most of the slumping occurs in four subcatchments abutting the Murray. These are Spring - Welegarang (13ha), Ournie (136ha), Talmalmo (na), and Fowlers Swamp/Wagra (25ha).

TABLE 33: Mass Movement in the Murray-Billabong Catchments

MURRAY CATCHMENT		BILLABONG CATCHMENT	
1:100,00 Sheet	Extent (ha)	1:100,000 Sheet	Extent (ha)
Headwaters			
Yarrangobilly	61		
Kosciusko	35		
Upper Murray		***Upper Billabong***	
Holbrook	32	Holbrook	10
Rosewood	176	Wagga Wagga	-
Corryong	2	Rosewood	-
		Tarcutta	-
TOTAL	**272**	**TOTAL**	**10**

5.7.3 Relationships with Other Physical Factors

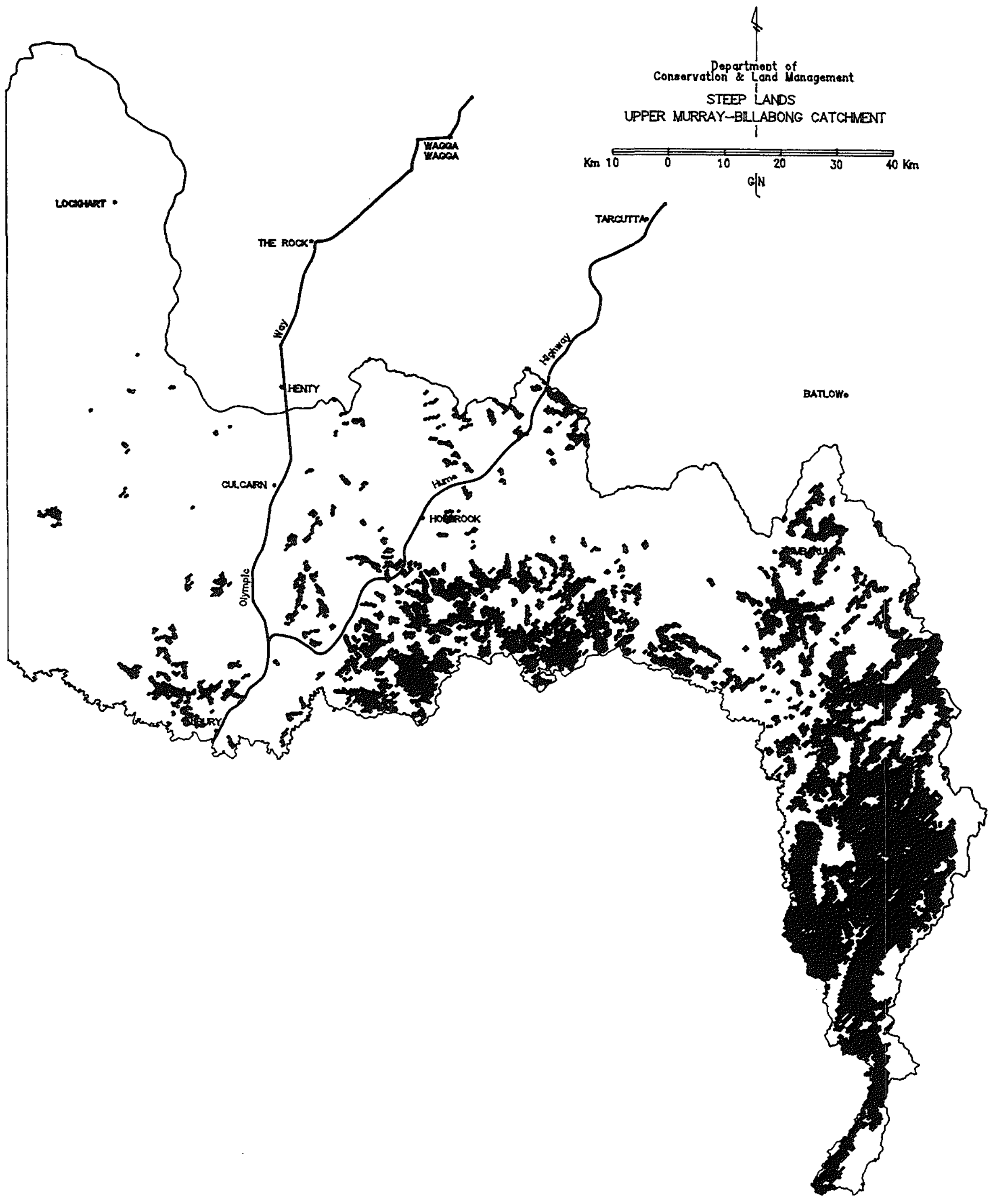
The main forms of land degradation associated with steep lands are soil erosion, sedimentation of waterways and storages, groundwater recharge and mass movement. These have significant off-site effects particularly in lowering water quality.

Sheet erosion stems from accelerated runoff as a result of low levels of groundcover. On steep lands maintaining an adequate groundcover is critical. Groundcover problems have been discussed extensively in Section 5.5.3, but usually exist where:

* excessive clearing has occurred
* pastures are depleted by high stocking rates
* pastures are dominated by annual species
* rabbit control is not practised
* fire removes ground cover including litter
* soils have severe acidity or other nutrient problems.

Groundwater recharge is receiving increased attention due to the recent expansion of areas being affected by rising watertables and dryland salinity (see Section 5.1).

Figure 10: Steep Lands in the Murray-Billabong Catchments



In steep timbered terrain the soil erosion hazard is mainly related to the incidence of wildfires. The destruction of groundcover, including understorey and leaf litter, leaves these lands prone to high rates of soil loss until the groundcover is re-established. Erosion occurs mainly as sheet and rill wash and sedimentation of roads and watercourses can be substantial.

A good local example of this followed the Talmalmo fires of 1985. A severe fire scorched the area leaving it completely bare. The fire apparently killed seed stock and grasses, as the area stayed bare until rains occurred 6 months later in May. These moderate rains caused major soil erosion and sediment blocked road culverts and covered the main Jingellic access road to depths of 0.3m. The area was declared a Project under Section 10 of the Soil Conservation Act to stop the movement of sediment into the Murray River.

In 1983, the SCS submitted a comprehensive document titled "The Environmental Impact of Bushfires" to the House of Representatives Standing Committee on Environment and Conservation. Information in that report, and research, relevant to the Murray, are summarised below:

* large areas of forest have fuel reduction burns on a irregular basis about each 5-7 years

* low intensity burns have little effect on hydrology or water quality, but may affect habitat

* dramatic increases in runoff, peak discharges and velocities may occur after major fires

* erosion may be up to 1,000 times the natural rate (Brown, 1972), and it may take 1 - 3 years to return to base levels

* big storms (single events) do most of the erosion damage, although a wide range of factors determine soil loss

* the effect is most dramatic in dry sclerophyll and alpine areas

* low standard fire trails may cause serious erosion (White, 1978; Marshall, 1982) but this can be substantially reduced with planning and by educating plant operators (SCS 1990a and 1990b).

Erosion and wildfire in the Kosciusko National Park has been discussed widely, (Good, 1973; Brown 1972; Unger 1985), particularly before grazing leases were restricted (Costin, 1960; Newman 1954 and 1955).

The NSW National Parks and Wildlife Service (NPWS) and the Forestry Commission actively manage fire on their respective lands. NPWS has developed a computer model (FIREPLAN) to assist in decision making for fire management. To support FIREPLAN, detailed information on tree species, fuel, slope, soils and past fire history has been compiled. Using the soils data, and assuming a wildfire on average every 30 years, and the CaLM SOILOSS program, the erosion hazard for forest country was assessed and shown on the soil erosion maps.

Heavy grazing in steep timbered areas leads to the shrub layer and groundcover being eaten out. It has a similar effect to wildfire, but the condition is maintained because the understorey is not allowed to recover.

Morland (1959) extensively documented the resources of the Hume Weir catchment. He considered the stringybark dry sclerophyll country to be particularly erosion prone, stating:

* *"the easily formed impression that because an area is timbered it is therefore erosion stable, is most unsound and can be dangerously misleading"*

* *"it* (stringybark country) *accounts for practically all the 40,000 acres of non-alpine, cleared country in the catchment classed as severely sheeted, and for most of the 90,000 acres of such country classed as moderately sheeted".*

He also spoke of landslips *"on steep, cleared, south and east aspects slopes of deeper granite soils* "and that they *"often initiate gullies"*. Further *"so long as they remain under pasture these slopes are a permanent serious erosion hazard"*. *"Moreover, grass alone is not sufficient to prevent mass movement of soil in landslips".* (see Plate 14)

Mass movement (slumps) occur when soil can no longer support itself, usually as a result of becoming saturated. Other factors involved include:

* shallowness of soil (small storage)
* rock types and fracture patterns
* clearing decreasing support and increasing water infiltration.

Slumps are common on the wetter south eastern aspect on steep cleared slopes. The occur on mainly granitic Siliceous Sands, and to a lesser extent on Basaltic like Chocolate Soils. They can also occur on the steep side plateau where Basalt overlays Granite or Serpentine (Spiers pers.comm.).

5.7.4 What is Known About Managing Steep Lands?

Steep lands are a problem where they have been used beyond their capability. The problem can be rectified by addressing the causes; excessive tree clearing and ground cover levels being reduced below 70%, often by the pressures of grazing.

Clearing of the original forest communities has occurred on lands that have a low agricultural potential. These lands are classified as Rural Land Capability Classes VII and VIII, and parts of Class VI under CaLM's Rural Land Capability classification.

Morland (1959) saw the solution to erosion control as requiring *"in the first instance establishment of adequate pasture. However, eventual stabilisation requires reafforestation of all cleared steep country of* (greater than) *30% slope, together with restriction of any future clearing to land well under 30% slope"*. A similar view remains today. The benefits of trees in minimising land degradation are discussed in Section 5.3.

The preferred use of these areas involves the retention of the trees and their shrub communities in critical areas, with limited grazing only to reduce wildfire hazards.

Other mechanisms of maintaining an adequate cover on the steep lands would be to reduce the risk and spread of wildfire, establish perennial pastures to replace annual species, and run very low stocking rates particularly in forested lands to maintain shrub, grass and litter cover.

5.7.5 Recommendation for Treatment of Steep Lands

a. Policies

CaLM has policies to :

* ensure all lands are utilised within their assessed capability

* ensure that land management practices are adopted to minimise soil erosion and other forms of land degradation and maintain the productive capacity of the soils

* management of land on a TCM basis (Soils and Trees Policy).

More specific local policy recommendations regarding ground cover are as follows :

* no further clearing, poisoning, or destruction of trees should occur on slopes above 33%, or on other types of land where tree cover densities are below catchment guidelines

* implement Protected Land legislation in the Billabong Catchment, and Murray Catchment

* encourage and support the establishment of Landcare groups in areas with steep lands

* encourage the use of land management practices to control soil erosion after wildfires

* Crown land, other than those lessees having statutory rights to convert to freehold under existing Perpetual and Term Lease arrangements, shall not be sold, converted, leased or exchanged until a management plan has been completed and the use of that land is assessed as not having an impact on land degradation. Specific considerations will be given to:
    - known land degradation problems including dryland salinity, streambank erosion and soil erosion requiring good tree cover stands as part of the control practices
    - landscape units, such as watercourses, heads of drainage lines, escarpments, steep slopes, and unstable slopes which are critical for catchment protection
    - areas of significant remnant native vegetation

* no approval should be given for small lot subdivision in steep lands involving major tree clearing

* maintain infrastructure in good condition to minimise the spread of wildfire

* reduce fire hazard by controlling fuel load build up in an environmentally responsible manner.

b. Investigations

* determine tree cover densities required on steep lands to minimise runoff and soil erosion, to stabilise slopes with mass movement problems

* determine preferred levels of tree cover on an individual catchment basis required to address dryland salinity and waterlogging problems

* identify zones where fires develop, or are ignited, and manage these areas to lower the fire risk

* update information to allow assessment of soil loss from steep lands associated with wildfires, grazing, clear felling and logging activities

* identify areas susceptible to slope failure.

c. Actions

Management of steep lands is best achieved through general extension activities. Particular avenues include land and water management plans on a catchment basis involving the community, Landcare, property management planning, NSW Agriculture and media and field extension. Specific programs include:

* establish demonstration sites to address particular land management problems in:
    - Tooma Landcare area
    - Holbrook Landcare area
    - Wagra - Fowler's Swamp Landcare area
    - Mullengandra Landcare area

* identify areas being used beyond their potential and requiring reafforestation or improved pasture management

* prepare extension information for rural community, detailing:
    - land degradation problems occurring on steep lands
    - off site effects of land degradation
    - land management recommendations for specific problems.

5.8 WIND EROSION

5.8.1 Nature of Problem

Wind erosion can be severe in parts of the Murray-Billabong Catchments.

Wind erosion is the detachment and transport of soil by wind. It is a significant form of soil degradation in the drier cropping areas, and on lands with more sandy soils, where topsoil can be blown away if it is not protected by sufficient vegetative cover. The continued cropping or overstocking of susceptible soils breaks down soil aggregates into sizes which make them more susceptible to wind erosion. Like other forms of erosion most damage occurs as a result of a small number of infrequent major events.

The loss of the finer soil particles, also reduces soil nutrient levels and its ability to retain moisture for plant growth.

Related issues include soil structure decline, tree cover, inadequate pasture cover, and conservation farming.

5.8.2 Where Does Wind Erosion Occur?

Wind erosion hazard was assessed in the 1987-88 Land Degradation Survey of NSW based upon information of the texture of the soil surface, vegetation cover and land use. The cultivated areas of the Plains and South Western Slopes of NSW were found to have the most severe wind erosion problems.

In the Murray-Billabong Catchments, the 1:100 000 map sheets with a severe wind erosion hazard were:

* Lockhart - severe* hazard over most of the area
* Walbundrie - severe hazard over most of the area
* Holbrook - severe hazard west of Holbrook.

(* severe was the third highest rating in a four class system)

To a lesser extent, the traditional grazing lands in the upper parts of the catchment are prone to wind erosion. However, during dry periods the risk increases, particularly on granite soils that have been cultivated or have only a thin covering of annual based pastures.

Just to the west of the survey area numerous sand hills exist which require special land management treatment.

5.8.3 Relationships with Other Physical Factors

Wind erosion in the Murray-Billabong Catchments occurs mostly during dry periods on land which is cultivated or on grassland which has been grazed bare of vegetation.

The following factors play a determining role in wind erosion:

* erosivity of the wind
* ground cover
* soil moisture content
* soil type
* surface roughness
* topography.

Long fallows and frequent cultivations reduce soil structure and increase its susceptibility to wind erosion.

5.8.4 What is Known About Managing Wind Erosion?

The key to minimising wind erosion is maintaining an adequate ground cover particularly during those periods when the soils are dry and at greatest risk. The erosivity of the wind can be reduced by planting multiple row windbreaks, perpendicular to the direction of the prevailing problem winds.

Land that has a severe to extreme wind erosion hazard is best left in its natural condition with stocking rates adjusted according to seasonal and ground cover conditions.

Land that has a moderate or severe wind erosion hazard, and is cropped, should be managed by:

* use of reduced tillage systems and
    - retaining stubble for as long as possible after harvest
    - controlling weeds with herbicides rather than by cultivation
    - direct drilling of crops and pastures
    - sowing successive crops into stubble residues and not allowing soil surface to be exposed
* in row crops, strip cropping with alternate strips of a protective crop
* sowing crops across the direction of the prevailing wind.

Land that has a moderate or severe wind erosion hazard and is under pasture, should be managed to ensure sufficient ground cover levels in dry periods. This involves:

* establishing a perennial pasture preferably with a native grass included
* light grazing of annual based pastures during dry periods to maintain adequate cover levels.

Treatments for severely wind eroded areas include:

* retention of tree cover where possible to reduce the effects of the wind
* planting windbreaks of multiple rows around block boundaries, especially on the sides of the prevailing winds
* stopping or reducing the frequency of cropping
* removing stock
* deep ripping to roughen the soil surface to allow seed capture and reduce surface wind velocities
* repositioning fences to separate different soil types with different vulnerabilities to wind erosion
* structural works such as water ponding to rehabilitate bare scalded lands.

5.8.5 Recommendations for Treatment of Wind Erosion

a. Policies

* prevent any further clearing of trees on lands that have a severe to extreme wind erosion hazard, such as areas with light, sandy soils

* promote wind erosion as a land degradation issue through Landcare groups

* encourage landholders to undertake property management planning, and establish windbreaks

* the sale or conversion of Crown lands in areas of severe to extreme wind erosion hazards should provide for timbered areas to be set aside and maintained as windbreaks. Appropriate conditions will need to be included within any license or lease

* require development consent for cropping on areas of severe to extreme wind erosion hazard

* implement guidelines for drought management as set out by Walker (1992) and summarised in Appendix T.

b. Investigations

* identify soil and land use associations most prone to wind erosion

* identify areas with inadequate windbreak protection

* undertake field trials on different windbreak designs. The theoretical engineering and wind mechanics data exist to design correct windbreaks, but further investigation and field applications are needed to work with local species and conditions.

c. Actions

* encourage conservation farming techniques and other management systems based on maintaining adequate ground cover levels at all times (eg stubble retention during dry periods, establishing perennial pastures)

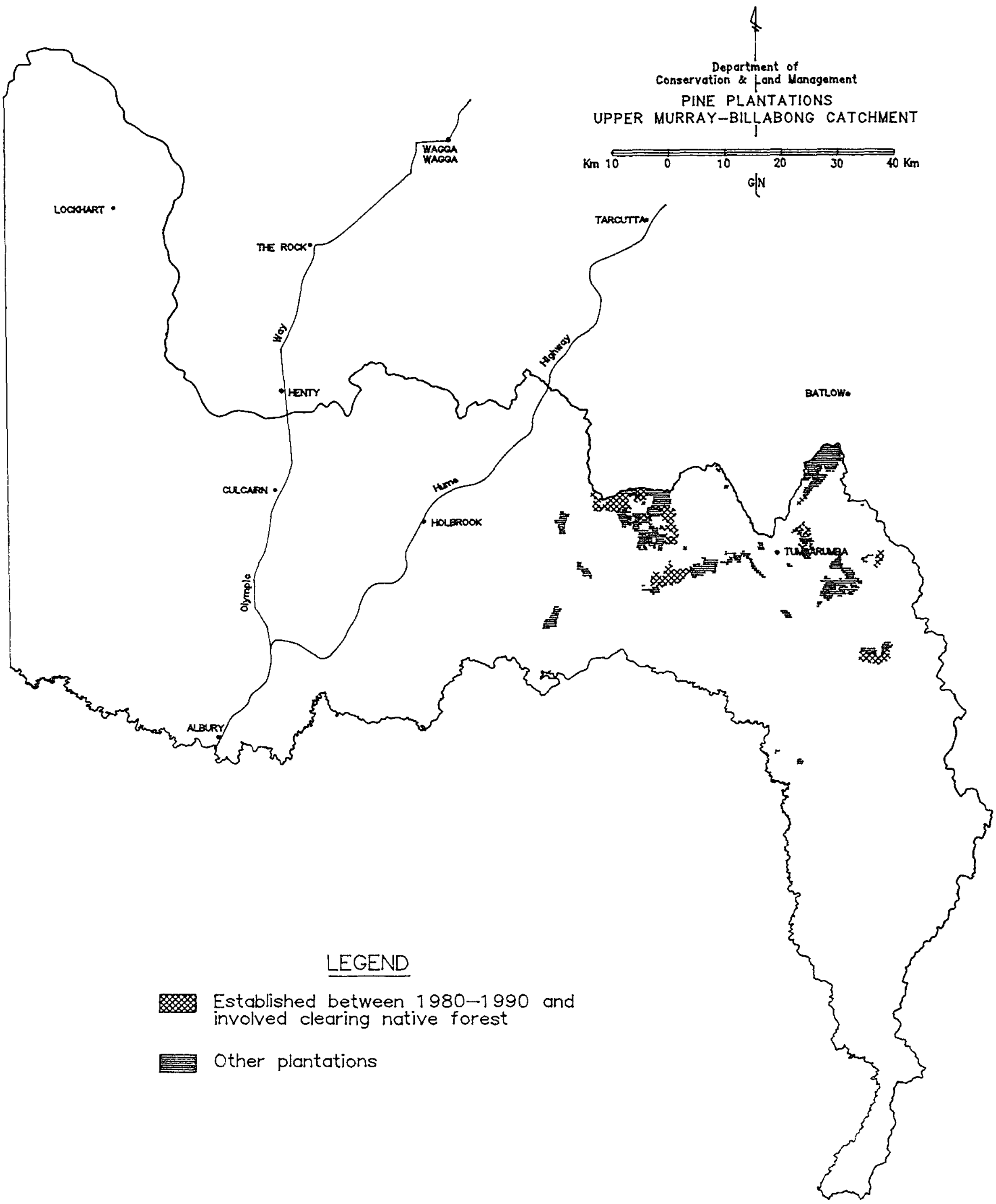
* encourage landholders to retain, maintain and enhance existing windbreaks

* encourage landholders to adopt guidelines for drought management as outlined by Walker (1992) and summarised in Appendix T

* establish group schemes for windbreak establishment programs in critical areas. Priority would be given to the following localities:

  . Lockhart area
  . Walbundrie area
  . Culcairn area.

Figure 11: Pine Plantations in the Murray-Billabong Catchments



5.9 MAJOR LAND USE CHANGES

Previous sections discussed the degradation issues caused by altered land use. However this section discusses the impact of major land use changes, particularly clearing of native forests, to allow the issues to be considered jointly.

Major land use changes discussed in this section are:

* pine plantation development
* pasture development
* vineyard and orchard development.

5.9.1 Nature of Problem

Major disturbance is involved with land development, particularly where the operation involves clearing native forests. The major land use change in the Catchment during last 20 years has been the rapid expansion of pine plantation development in the Upper Murray. Activity has been concentrated around Rosewood-Tumbarumba. Small pockets continue to be developed for pasture establishment and more recently for vineyards/orchards also around Rosewood and Tumbarumba.

Concerns have been expressed about soil erosion, altered hydrology, streambank erosion, loss of wildlife habitat and a range of other environmental issues.

5.9.2 Where are Major Land Use Changes Occurring?

The survey identified over 12,300 ha of native forest which was cleared between 1980-90 on the Rosewood and Yarrangobilly 1:100,000 map sheet areas.

(i) Pine Plantations

Because the Forestry Commission has been the main developer, large areas of pine plantations are located on the State Forest lands. Private operators often establish plantations on adjacent freehold lands.

The locations of pine plantations within the catchment, and those areas which involved clearing native forests between 1980-90, are shown in Figure 11. Area counts are provided in Table 34 At the time of mapping, there were over 23,000 ha of pines in the NSW Murray River Catchment, and just under 500 ha in the Billabong Creek Catchment. Most of this occurred west of Rosewood and the remainder in the Bago areas. Of this, a minimum of almost 10,000 ha was developed between 1980-1990 and involved clearing native forest.

Pine plantation developments tend to be concentrated in areas which are suited to pine cultivation. Furthermore, private operators tend to locate their operations adjacent to State Forest plantations, taking advantage of existing road and firefighting infrastructure, and future sale potential. Consequently, some subcatchments can have significant areas being developed at any one time. For example, almost 30% of Coppabella Creek subcatchment is under pines, and more than one-half of these plantings (16% of the total area of subcatchment) has involved clearing of native forest between 1980-90 (see Table 35).

TABLE 34: Pine Plantations in the Murray-Billabong Catchments (ha)

1:100 000 Map Sheet	Plantings * 1981-1990	Other Plantings	Catchment Total	Grand Total
Walbundrie	0	0	0	0
Albury	0	0	0	0
Lockhart	(0)	(0)	(0)	0
Holbrook	0	11	11	11
	(0)	(0)	(0)	
Tallangatta	0	0	0	0
Wagga Wagga	(0)	(0)	(0)	0
Rosewood	7403	6919	14322	14821
	(39)	(460)	(496)	
Corryong	0	0	0	0
Yarrangobilly	2402	6312	8714	8714
Kosciusko	0	117	117	117
Jacobs River	0	0	0	0
Total	**9844**	**13808**		**23652**

* pine plantations which replaced native forest
( ) Billabong Creek catchment

As an example statistics for land use and various forms of erosion in the Coppabella Creek subcatchment are presented in Tables 39 and 40.

TABLE 35: Land Use in the Coppabella Creek Subcatchment

Attribute	Area (ha)	%
Crop	295	0.8
Pasture	14805	41.7
Pasture#	117	0.3
Timber	10201	28.7
Pines	4359	12.3
Pines#	5754	16.2

\# development involved clearing forested areas in the last 10 years *(ii) Pasture Development and Vineyards/Orchards*

Areas cleared for the development of pasture and vineyards/orchards are small and sporadic across the landscape. The survey did not determine the exact areas concerned, but rather 2633ha of clearing was undertaken by landholders other than the Forestry Commission and the main private pine plantation developers (See Table 36). It is estimated that the clearing for pasture and vineyard/orchards was less than 500ha and the remaining 2133ha were areas being prepared for pines, but at the time of the survey, had not been established.

TABLE 36: Unaccounted Clearing in the Murray-Billabong Catchments 1981-1990 (ha)

1:100 000 Map Sheet	MURRAY	BILLABONG
Walbundrie	na	na
Albury	na	na
Lockhart	-	na
Holbrook	na	na
Tallangatta	na	-
Wagga Wagga	-	na
Rosewood	1518	360
Corryong	na	-
Yarrangobilly	755	-
Kosciusko	na	-
Jacobs River	na	-
Total	2273	360

5.9.3 Relationships with Other Physical Factors

The major factor determining the siting of pine plantations, and to a lesser extent vineyards/orchards, is rainfall. Localities are preferred with the following features:

* rainfall greater than 800 mm
* good road access
* elevation below 1200 m to avoid risk of snow damage
* specific soil types (pines-granodiorite/or shaley soils, horticulture-chocolate soils)

Areas cleared for pasture establishment are generally specific to individual landholder's priorities.

i Soil Erosion

The problem times are those which lead to the removal of groundcover and soil disturbance. These are:

* between the clearing of the forest cover and the establishment of the pines, orchard or pasture

* road construction (Plate 15)
* harvesting
* after major fires (pines only).

The risk of erosion is greatest if development or harvesting is undertaken in particular areas. Data for erosion in the Coppabella Creek subcatchment is presented below.

TABLE 37: Soil Erosion in the Coppabella Creek Subcatchment (1990)

Attribute	Length (km)	Area (ha)	(%)
Streambank	10.2		
Major gully	1.1		
Sheet			
- not significant		30005	85.6
- minor		3227	9.2
- moderate		936	2.7
- severe		891	2.5

The erosion risk is determined by local factors such as slope and soil type. However, poor design and poor management aggravate the erosion problems. Problems have been experienced with:

* windrowed areas left for extended periods
* excessive clearing of steep areas
* clearing within or too close to drainage lines
* poorly located roads and poor design of road drainage (Plate 16)
* harvesting and working during wet conditions
* unsuitable cultivation practices
* extremely erodible soil types.

Some of the older plantations are now being harvested and re-established, and these areas will require attention to avoid reactivating problems inherent in the older designs.

ii Surface Hydrology

Concerns have been expressed that widespread pine plantation developments have altered hydrology and caused streambank erosion.

During the establishment phases of pine plantations, when ground cover conditions are drastically changed, significant changes in runoff and stream flows may occur. These changes may cause instability in waterways leading to streambank erosion, turbid water supplies and sedimentation downstream .

Some streambank erosion is present in higher rainfall catchments where pine plantations are located. However, this survey shows the vast majority of streambank erosion located in catchments devoid of pine plantations. As discussed in Section 5.4.3, the causes of streambank erosion are complex. Erosion present today may have been activated by events of the past (eg. the 1952 fires and 1982 drought).

Nowadays, there are much greater resources available to control fires in and around pine plantations and the risk of major fires is very low. However, if a fire was to burn out a large proportion of a mature plantation area, the lack of regeneration canopy and ground cover would leave large proportions of catchments susceptible to severe soil erosion and high peak discharges aggravating streambank stability. Intensive activities to salvage the merchantable timber would exacerbate the erosion hazard. Retention of buffer strips retaining native species in the drainage lines would largely overcome this problem.

iv Environmental

Major changes in land use frequently attract community concern. Such is the case when large areas of native hardwood forest were felled and burnt. Objections from community interest groups relevant to this report include:

* sedimentation and streambank erosion
* reduced native hardwood forest and natural habitat
* reduced flora and fauna diversity
* major barriers to the movement of fauna and flora
* degraded skyline and landscape aesthetics
* harbour for weeds and vermin

Some concern has been expressed that *Pinus radiata* lowers soil pH. Forestry Commission research indicates pines have a minor effect on soil acidity, which is insignificant when compared to improved clover pastures (Ryan, pers comm.)

5.9.4 What is Known About Managing Major Land Use Change?

Problems, or potential problems, associated with major land use change such as pine plantation development can be greatly reduced by good planning and liaison. This applies during the design, development and operation phases.

Where sound soil conservation practices have been incorporated into the site design and the development phase problems associated with major land use change have been dramatically reduced. These practices include:

* locating roads away from drainage lines, preferably on ridges

* providing adequate road drainage works using table drains, culverts, broad based dips and sediment traps

* avoid disturbing vegetation adjacent and within drainage lines

* not developing highly erodible soils

* avoid clearing or disturbing slopes greater than 18°

* areas cleared to have windrows following the contour

* cleared areas on sloping land to be ripped (pines only) and planted as quickly as possible

* pastures to be established using direct drill

* areas suffering soil erosion problems to be treated

* plantings to follow the contour.

Water quality problems have occurred because of turbid water flowing off harvesting areas during wet conditions. In response to this, the industry has produced a series of guidelines to regulate operations. These include:

* enforcing contractors to halt operations in wet conditions

* developing and implementing new techniques and technology such as covering tracks with slash and using wide, low pressure tyres.

Heavy traffic at dump sites and along haul tracks pulverises the surface leaving it susceptible to erosion. There is a need to provide:

* adequate design and maintenance of drains and sediment traps, to minimise off-site effects of intense heavy vehicle use

* sites of intense use are to be kept out of, and away from, drainage lines.

5.9.5 Recommendations for Treatment

a. Policies

On site problems have been considerably reduced in recent years as a result of Council regulations and developers placing greater emphasis on erosion aspects of their operations. Further improvements, particularly from the catchment viewpoint, require the implementation of the following policies:

* identify and develop catchment based policy on native timber and pine plantations, with part of the criteria being catchment habitat, fauna and flora values and their movement

* development plans lodged under a Local Environmental Plans by private and government developers need to be assessed on the basis of on-site and overall effects on catchment policy

* evaluate applications to change land use according to catchment policy (for example; where not already in place, development plans be required for commercial developments larger than say 50 ha in one year and cumulatively say more than 200 ha in 5 years)

* referral of all development applications to the Soil Conservationist Service to ensure appropriate management requirements are included as conditions of consent

* changes in land use to be monitored

* discourage continuous plantations across the landscape by ensuring a reasonable mix of native and exotic forests to guarantee habitat and opportunity for fauna/flora movement

* encourage the use of wood resulting from land use change to be utilised for sawlogs, pallets, firewood or wood chips.

b. Investigations

* determine the amount of native forest and habitat that needs to be left in catchments to support flora and fauna diversity

* identify the effects, if any, of high proportions of pine plantations in a catchment on the catchment hydrology, groundwater, flora and fauna

* develop practical designs to spread various aged planting and harvesting operations around catchments

* develop techniques to improve the design and location of pine plantations to take into account visual and aesthetic factors at both a site and catchment level.

c. Actions

Many of the issues associated with major land use change relate to aspects of catchment management. These are best addressed through liaison and extension and opportunities exist during:

* district soil conservationist's activities

* CaLM input into LEP's and Council Development Approval Applications

* Murray CMC activity

It is also recommended CaLM and the Forestry Commission

* develop and install sediment control measures on plantations to demonstrate their effectiveness in controlling sedimentation.

5.10 SPECIALISED LAND USES

5.10.1 Nature of Problem

Several other special land uses contribute to land degradation problems. These are:

* mining and quarrying including derelict mines
* feedlots
* urban activities
* effluent disposal
* recreation.

The major problems associated with these are sedimentation or nutrient contamination of watercourses, increased turbidity and lower water qualities, algal blooms, and corresponding costs to infrastructure. Landscape aesthetics can also be affected. Increased levels of recreation use can lead to increased erosion and wildfire risk.

5.10.2 Where Do They Occur?

Although these land uses affect very small areas, the intensity of the activity can have major consequences, on and off site, and for long periods after the activity has ceased.

i Mining and Quarrying Sites

Current mining activities relate to extraction of gravel, sand and clay. They are widespread, mainly near roads and the larger urban centres, such as Albury. Strict conditions now regulate this industry, including the requirement to undertake an Environmental Impact Statement.

Abandoned and unrehabilitated mines are a problem on some areas in the upper reaches of the Murray catchment. These are a result of alluvial and shaft gold mining last century. Major disturbance occurred in the sensitive alpine environment and significant areas have not naturally rehabilitated.

ii Feedlots

Lot feeding animals has become a common and integral part of many farming operations in recent years. A large operation exists at Culcairn with an anticipated capacity of 2000 animals. If poorly located or managed, a concentration of animals can lead to offsite water quality and odour problems.

iii Urban Activities

In urban and peri-urban areas the main problems are associated with:

* soil disturbance, soil erosion and sedimentation associated with the development of housing and industrial estates

* hobby blocks fringing small towns and urban areas which are seriously overstocked, particularly with horses.

These areas are generally very small and isolated and have not been mapped in this study. However, within major urban areas, it is common to have major subdivision and building occurring at one or more locations, which can generate major problems, particularly on sloping land. The amount of urban development can generate is substantial, and may be many times greater than rural areas. At the time of mapping 165ha and 133ha were identified as having moderate and severe sheet and rill erosion risk, respectively.

iv Effluent Disposal

Almost all towns and urban centres within the catchment are located on the Murray River, Billabong Creek or their tributaries. In the light of the increased importance on water quality, and recently the blue-green algae problem, effluent disposal must meet stringent standards. This generally is administered by the Environment Protection Authority (EPA).

Two major effluent disposal issues are Albury's wastewater disposal and the Australian Newsprint Mills (ANM) irrigation proposal at Ettamogah. A determined effort is being made to develop land utilisation programs to reduce the need to dispose of any effluent into the Murray River but care is critical to avoid creating a range of new land based problems .

v Recreation

Recreation activities with potential to cause land degradation are identified below.

Use	Problem	Location
4WD and trail bikes	Erosion	Upper Murray
Bush walkers	Track erosion	Kosciusko N.P.
Snow skiing	Run and track erosion	Kosciusko N.P.
Speed boats/jet skies	Bank/foreshore erosion	Murray, Hume Weir

5.10.3 Relationships with Other Physical Factors

Physical factors influencing these problems include:

* rainfall frequencies and intensities
* slope gradient
* ground cover
* soil type
* intensity of the operation
* proximity to drainage lines, waterways and waterbodies.

Planning, due care and supervision can significantly reduce problems.

5.10.4 What is Known About Treating These Problems?

i Mining and Quarrying sites

Controls exist for these operations, and Environmental Impact Statements are usually required for commercial operations. Guidelines for operations and rehabilitation are available from the EPA. Treatment of derelict mines usually involves:

* reshaping and stabilising mine material
* installing adequate erosion control and drainage works
* topsoiling and revegetation of affected areas.

ii Feedlots

Feedlots housing over 999 head of cattle require the preparation of an EIS under the Environmental Planning and Assessment Act. Appropriate conditions have been established to regulate such operations (SPCC, 1979). Any feedlotting requires development consent from Council under the same Act. Farmers need to be made aware of this fact, and of guidelines including:

* locate on well drained sites
* locate well away from drainage lines
* control of runoff, and minimising effluent and nutrients leaving the property.

iii Urban activities

Land degradation associated with urban areas is best addressed by preventing poor practices. Methods of minimising erosion in urban areas are documented in "Urban Erosion and Sediment Control" (SCS, 1978).

Common practices are:

* small silt traps to control runoff velocity and retain sediment onsite
* retaining wetlands or dams in suburbs to filter urban water
* planting cover crops on large areas which are likely to remain bare for sometime.

Liaison between the Soil Conservationist, local councils and developers, prior to and during major urban developments can greatly reduce the soil erosion problems. The early review by CaLM of major development proposals also assists in the early identification of likely problem areas.

Small blocks on the fringe of urban areas and small towns, can be a major erosion hazard, relative to their size. Although some are no more than a few vacant house blocks in size they often maintain several livestock or horses year round. Rarely is any action taken to address soil erosion or water quality problems.

iv Recreation

The most effective methods of treating land degradation induced by recreational activities is by planning the location and management of such areas. Controlled access to suitable areas can be used to minimise potential problems. When access is concentrated in certain areas, structural works can be put in place to redirect or reduce the pressures on more sensitive sites.

5.10.5 Recommendations for Treatment

a. Policies

i Mining and Quarrying sites

- continue to require operators to rehabilitate all extraction sites to the satisfaction of

- develop a program to record and rehabilitate untreated and abandoned quarry sites, particular in catchments experiencing rising watertable problems

- CaLM continue to support the State Abandoned Mines Program by preparing proposals for future rehabilitation projects.

ii Feedlots

- incorporate the guidelines for feedlot management prepared by the NSW Government inter-departmental committee into all feedlot proposals

- small operations to be made aware of potential problems of their operations and of the requirements to obtain any necessary licences from the EPA.

iii Urban activities

- CaLM continue to have Council circulate all major development proposals for comment

- CaLM officers to liaise with developers onsite at an early stage of all housing and industrial estate developments

- require owners or lessees of small urban blocks where land degradation is occurring to treat all such problem sites.

iv Effluent disposal

- stringent standards to continue to be applied to wastewater being returned to the Murray River and its tributaries

- support TCM State Soil Policy.

5.11 WATER QUALITY DECLINE

5.11.1 Nature of Problem

"The water resources of the Murray-Darling Basin are one of its most important assets..." (MDBMC 1987).

Water quality has declined worldwide and this is a reflection on past land use and natural resource management practices. The major water quality problems in the Murray River are salinity and turbidity, with nutrients and bacterial pollution a problem at times (MDBMC, 1987).

This problem was highlighted in the Darling-Barwon River System in November and December 1991, with the occurrence of the world's largest recorded riverine algal bloom, extending over 1,000 km (BGATF, 1992). During 1991-92, 37 waterways throughout NSW had algal bloom reports, 22 being regarded as having a serious potential to cause problems with water use (BGATF,1992).

There are increasing demands for water for various uses in the Murray-Billabong Catchments including:

* agriculture (livestock and irrigation)
* industry
* natural habitat
* recreation
* human consumption.

The most critical use of water is that intended for human consumption. Contamination must be kept at low levels and relatively large volumes are required to be processed. Treatment for turbidity and sedimentation are major costs in the supply of water to urban communities. Water for all uses is usually drawn from the same source, and often waste waters are returned to that source.

Related issues include rising groundwater levels, dryland salinity, soil erosion; and nutrients, chemicals, pollutants and wastes from industry, urban areas and agriculture.

5.11.2 Occurrence and Severity

Major urban centres and the extensive irrigation lands in New South Wales, Victoria and South Australia rely entirely on the Murray River for water supply. Water quality decreases in the western parts of the Murray and has been accelerated by land use changes.

There is significant fear of further water quality decline in the Murray. This is most dramatic in the lower reaches of the Murray where water supplies are reaching levels close to the maximum desirable limit for human consumption, and at times, are too saline for irrigation. Water quality is the main issue behind the emphasis of the need to manage the total catchment (TCM).

Salinity and turbidity levels in the Upper Murray, and particularly above Hume Weir, must be kept to an absolute minimum. Mapping programs by CaLM show that a significant number of salt outbreaks and a high concentration of major gully and streambank erosion have developed in the immediate catchment to the Hume Weir.

Serious algal blooms occurred locally in the Murray River in the autumn of 1992. These were at Wodonga and Echuca but were attributed to sources in Victoria outside the area documented in this report. There are major cost implications for water treatment works if upgrading is required to handle increasing taste and odour problems, toxins and organic loads ensuing from algal blooms (BGATF, 1992). A "State of Emergency" was declared during the summer of 1991/92 to deal with the Darling-Barwon outbreak, at a cost yet unknown to the Government.

5.11.3 Relationship with Other Physical Factors

Water quality decline is associated with:

* soil erosion
* rising groundwater levels and dryland salinity
* nutrient lost from agricultural systems
* point source of pollutants from abattoirs, manufacturing industry and urban effluent treatment systems.

In the simplest terms, water quality is determined by:

* soil types
* terrain
* rock types with high inherent salt levels
* rising groundwater systems bring salt close to or at the surface
* land use and land management practices. These influence the sediment content, turbidity, salinity, chemical toxicity, nutrient levels, biological materials, quantity and even the temperatures of surface water supplies
* quality of waste water being returned to the river.

The latter two are factors that can be controlled. Point source pollutants can be identified and treated relatively easily. Land use has a major effect on water quality, but because it is spread over such large areas it is difficult to identify and monitor at any one site or time.

5.11.4 What is Known About Maintaining Water Quality?

Water quality has historically been maintained by treatment at the point of end use, primarily for town water supply and local governments acting individually. Local government minimises the problem of water supply contamination, from both sediment and salinity by:

* drawing water from less contaminated areas

* using bores as well as surface water

* drawing water at times of low contamination of storages

* reticulating water rather than allowing overland flows.

However, removal of sediment and reduction in turbidity can be major costs to these institutions. For example, the annual cost of chemicals alone to the Bathurst Council is around $247,000 (Taylor, pers comm.). The cost of treating Yass town water supply for salt is estimated at $150,000 per annum (Carlos, 1992).

There are direct relationships between land use, land degradation and water quality. Larger councils can process tens of megalitres of water every day, so there is substantial scope for reducing costs by improving the quality of raw water. Escalating costs mean that improvements to land management will be required to improve the quality of raw water and therefore reduce the use of extremely costly chemical treatments.

Councils have not yet had to deal with costly desalination procedures in the Murray-Billabong Catchments due to the avoidance mechanisms practised, as well as the fact that the majority of surface waters are still below the maximum limits set for human consumption. Such as in the Murray-Billabong.

The current relatively low costs of water treatment in the Murray Catchment will be one of the first effects of a decline in quality of our water sources. In addition, the fact that a large number of towns along the Murray River and the wider Murray-Darling Basin depend on the rivers for their water, emphasises the necessity to treat water quality as a catchment wide issue.

Diffuse contamination from sediment and salinity can be offset by improved land management practices. Point source pollution can be targeted and pollution from urban sources can be reduced or treated.

There will always be a need to treat water at a municipal level for pathogens, turbidity, chemicals and other contaminants. CaLM however, can play an important role in promoting land management practices to combat the long term problems of sedimentation, nutrient contamination and salinity.

5.11.5 Recommendations for Treatment of Water Quality Decline

a. Policies

* increase community education to highlight the role all land uses and land users play in the determination of water quality and its effects on downstream users

* promote water sampling and testing as part of the response to the developing dryland salinity problems in the region.

c. **Actions**

* in co-operation with local Landcare groups, develop and implement integrated property management plans and catchment land and water management plans, with special emphasis on **foreshore** management and water quality. The plans should be co-ordinated with the management of adjoining State Forests, Crown lands and recreational areas. The plans would consider:

. gully and streambank erosion
. rising watertables and salinity
. sediment flush after bushfires.

Resource data collation would include:

- location of subdivision fencing
- distribution of stock watering points
- grazing requirements
- tree regrowth and clearing
- bushfire prevention
- wildlife preservation
- soil erosion control
- vermin and noxious weed control
- vegetation cover
- access.

Priority locations for treatment would be:

. Mullengandra Creek
. Table Top Creek
. Fowler's Swamp Creek
. Wagra Creek
. Talmalmo foreshores
. Bowna Creek
. Eight and Nine Mile Creeks.

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APPENDIX A : RURAL LAND CAPABILITY

		Interpretations and Implications
I	No special soil conservation works or practices.	Land suitable for a wide variety of uses. Where soils are fertile, this is land with the highest potential for agriculture, and may be cultivated for vegetation and fruit production, cereal and other grain crops, energy crops, fodder and forage crops, and sugar cane in specific areas. Includes "prime agricultural land".
II	Soil conservation practices such as strip cropping, conservation tillage and adequate crop rotation.	Usually gently sloping land suitable for a wide variety of agricultural uses. Has a high potential for production of crops on fertile soils similar to Class I, but increasing limitations to production due to site conditions. Includes "prime agricultural land".
III	Structural soil conservation works such as graded banks, waterways and diversion banks, together with soil conservation practices such as conservation tillage and adequate crop rotation.	Sloping land suitable for cropping on a rotational basis. Generally used for the production of the same type of crops as listed for Class I, although productivity will vary depending upon soil fertility. Individual yields may be the same as for Classes I and II, but increasing restrictions due to the erosion hazard will reduce the total yield over time. Soil erosion problems are often severe. Generally fair to good agricultural land.
IV	Soil conservation practices such as pasture improvement, stock control, application of fertiliser and minimal cultivation for the establishment or re-establishment of permanent pasture.	Land not suitable for cultivation on a regular basis owing to limitations of slope gradient, soil erosion, shallowness or rockiness, climate, or a combination of these factors. Comprises the better classes of grazing land of the State and can be cultivated for an occasional crop, particularly a fodder crop or for pasture renewal. Not suited to the range of agricultural uses listed for Classes I to III. If used for "hobby farms" adequate provision should be made for water supply, effluent disposal, and selection of safe building sites and access roads.
V	Structural soil conservation works such as absorption banks, diversion banks and contour ripping, together with the practices as in Class IV.	Land not suitable for cultivation on a regular basis owing to considerable limitations of slope gradient, soil erosion, shallowness or rockiness, climate, or a combination of these factors. Soil erosion problems are often severe. Production is generally lower than for grazing lands in Class IV. Can be cultivated for an occasional crop, particularly a fodder crop or for pasture renewal. Not suited to the range of agricultural uses listed for Classes I to III. If used for "hobby farms" adequate provision should be made for water supply, effluent disposal, and selection of safe building sites and access roads.
VI	Soil conservation practices including limitation of stock, broadcasting of seed and fertiliser, prevention of fire and destruction of vermin. May include some isolated structural works.	Productivity will vary due to the soil depth and the soil fertility. Comprises the less productive grazing lands. If used for "hobby farms" adequate provision should be made for water supply, effluent disposal, and selection of safe building sites and access roads.
VII	Land best protected by green timber.	Generally comprises areas of steep slopes, shallow soils and/or rock outcrop. Adequate ground protection must be maintained by limiting grazing and minimising damage by fire. Destruction of trees is not generally recommended, but partial clearing for grazing purposes under strict management controls can be practised on small areas of low erosion hazard. Where clearing of these lands occurred in the past, unstable soil and terrain sites should be returned to timber cover.
VIII	Cliffs, lakes or swamps and other lands unsuitable for agricultural and pastoral production.	Land unusable for agricultural or pastoral uses. Recommended uses are those compatible with the preservation of the natural vegetation namely: water supply catchments, wildlife refuges, national and state parks, and scenic areas.

APPENDIX B: AERIAL PHOTOGRAPHS USED IN THE SURVEY

1:100 000 Sheet	Date	Scale	Lens	Print
Narrandera	9/88	1:50 000	153.10	Black & White
Lockhart	9/85	1:50 000	151.45	Black & White
Walbundrie	2/87	1:50 000	153.10	Black & White
Albury	12/87	1:25 000		Black & White
Wagga Wagga	80	1:40 000	87.80	Black & White
Holbrook	83-84	1:40 000	87.80	Black & White
Tallangatta	12/87	1:25 000		Black & White
Rosewood	5/80	1:25 000	151.45	Black & White
	2/90	1:25 000	153.10	Colour
Yarrangobilly	1/80	1:25 000	151.45	Black & White
	2/90	1:25 000	153.10	Colour
Kosciusko	3/88	1:40 000	153.10	Black & White
Jacobs River	2/88	1:40 000	153.10	Black & White

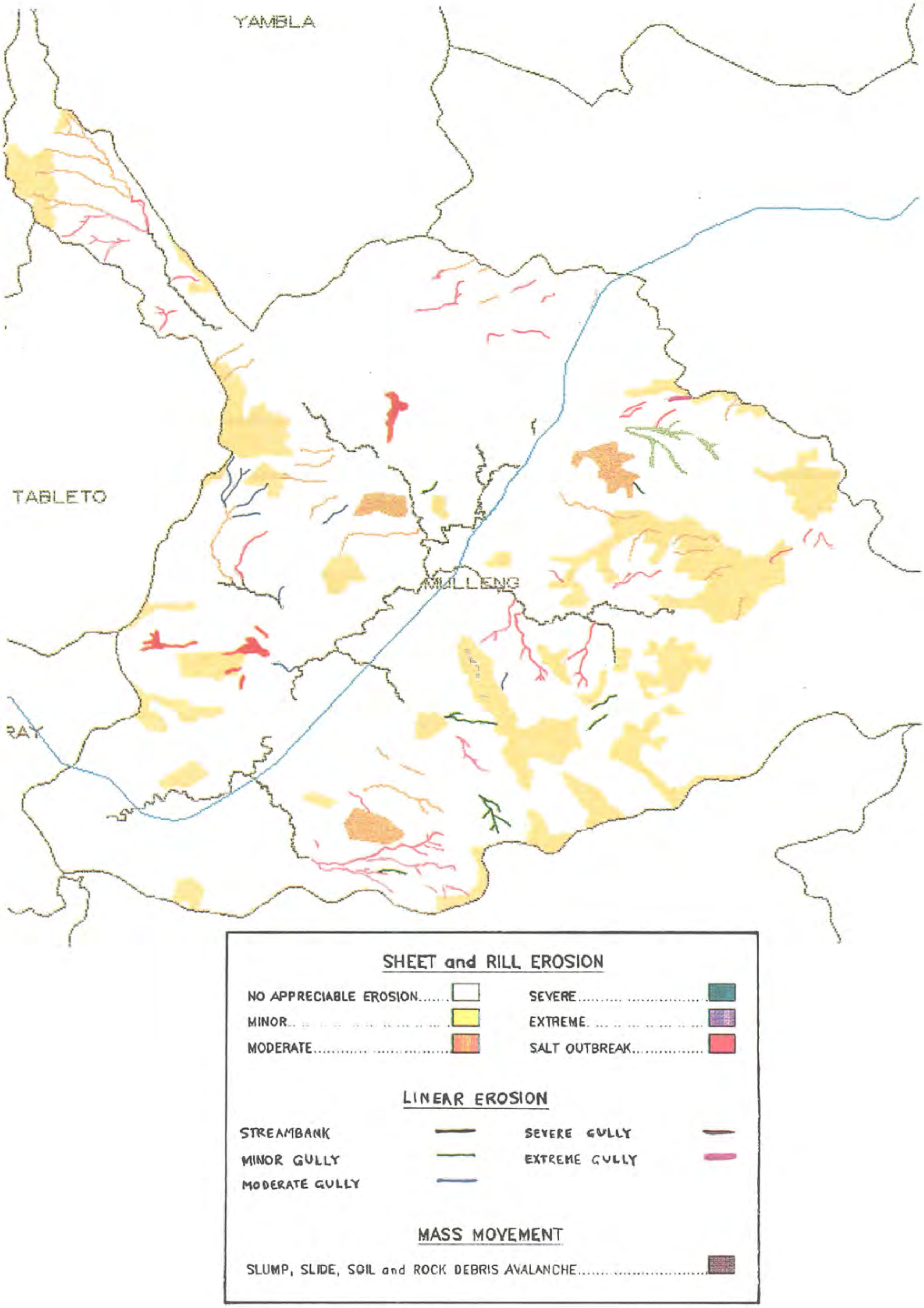
APPENDIX C: SOIL EROSION MAPPING ATTRIBUTES

AREAL FEATURES			
Code	**Erosion Class**	**Sub-Class**	**SOILOSS (tonnes/ha/yr)**
11	No appreciable sheet		< 1
21		Minor	1-5
22		Moderate	5-10
23		Severe	10-25
24		Extreme	> 25
25		Salting	
31	Wind	Minor	1-10
32		Moderate	10-20
33		Severe	20-40
34		Extreme	> 40
41	Rill	Minor	1-5
42		Moderate	5-10
43		Severe	10-25
44		Extreme	> 25
45		Salting	
91	Mass movement	Slumps	
92		Slides	
93		Soil debris avalanche	
94		Rock debris avalanche	

LINEAR FEATURES			
Code	**Erosion Class**	**Description**	**Depth**
51	Minor gully	Isolated discontinuous linear	< 1.5 m
52		gullies, confined to primary or	1.5-3.0 m
53		minor drainage lines	3.0-6.0 m
54			> 6.0 m
55		Salting	-
61	Moderate gully	Continuous linear gullies	< 1.5 m
62		confined to primary or drainage	1.5-3.0 m
63		lines	3.0-6.0 m
64			> 6.0
65		Salting	-
71	Severe gully	Discontinuous or continuous	< 1.5 m
72		gullies branching into minor	1.5-3.0 m
73		drainage lines or multiple	3.0-6.0 m
74		branching within primary	> 6.0
75		drainage lines Salting	
81	Extreme	Discontinuous or continuous	< 1.5 m
82		branching gullies or sub-parallel	1.5-3.0 m
83		gullies	3.0-6.0 m
84			> 6.0 m
85		Salting	-
101	Streambank		> 1.5 m
102			1.5-3.0 m
103			3.0-6.0 m
104			> 6.0 m

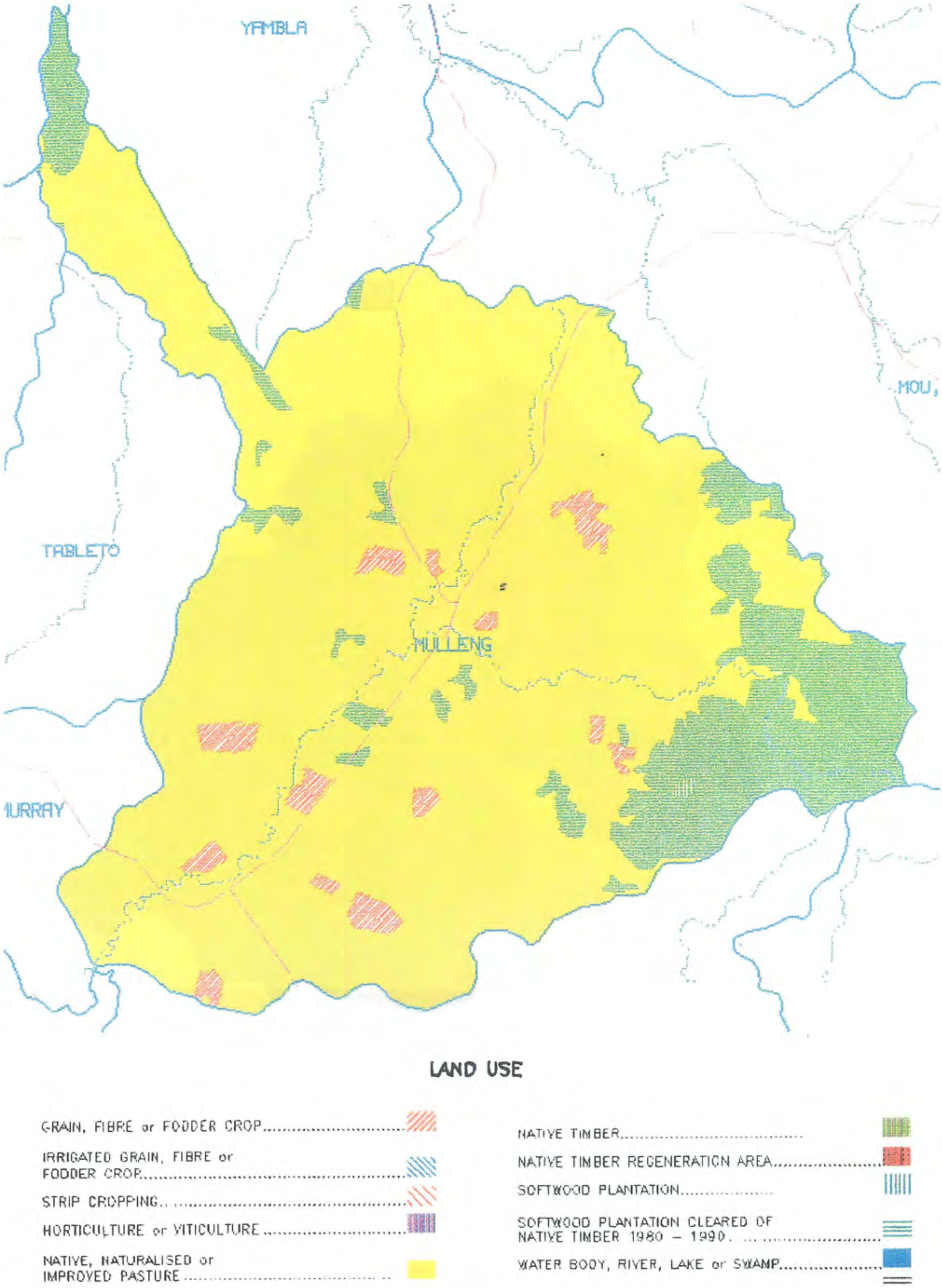
APPENDIX D: EXAMPLE - OUTPUT AVAILABLE FOR CATCHMENT MANAGEMENT UNITS

(i) Erosion



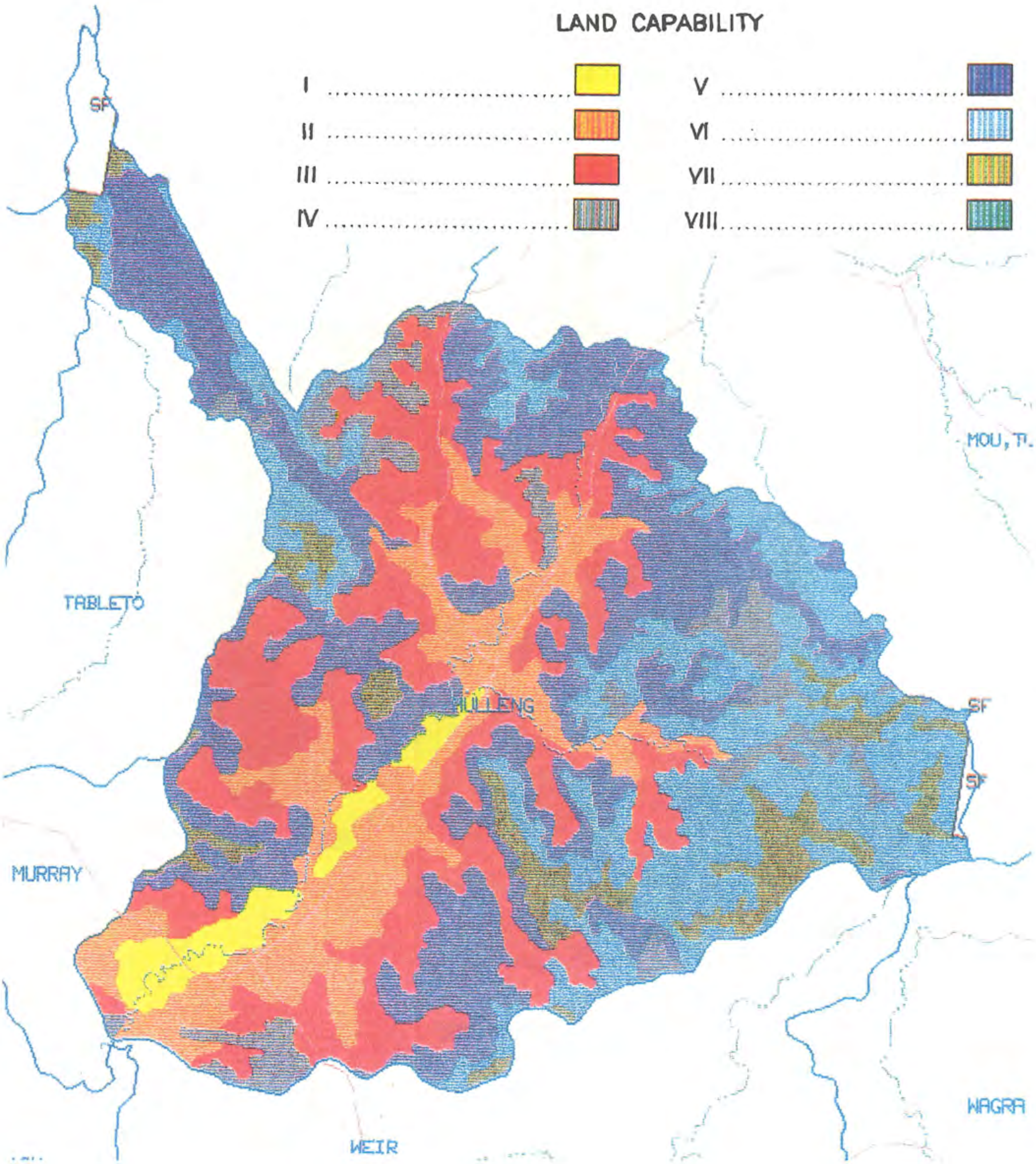
APPENDIX D: EXAMPLE - OUTPUT AVAILABLE FOR CATCHMENT MANAGEMENT UNITS

(ii) Land Use



APPENDIX D: EXAMPLE - OUTPUT AVAILABLE FOR CATCHMENT MANAGEMENT UNITS

(iii) Land Capability



APPENDIX D: EXAMPLE - OUTPUT AVAILABLE FOR CATCHMENT MANAGEMENT UNITS

(iv) Detailed Statistics

MULLENGANDRA CREEK SUBCATCHMENT - MAPSHEET NUMBERS - 8326

RILL AND SHEET EROSION AND MASS MOVEMENT

CODE	AREA	FREQUENCY	PERCENT
MULLENG.11	13829.45	33	83.36
MULLENG.15	40.40	4	0.24
MULLENG.21	2504.44	34	15.10
MULLENG.22	160.14	3	0.97
MULLENG.25	4.12	2	0.02
MULLENG.41	1.16	1	0.01
MULLENG.42	13.14	8	0.08
MULLENG.43	30.13	1	0.18
MULLENG.44	0.49	1	0.00
MULLENG.45	1.52	1	0.01
MULLENG.91	4.91	2	0.03
TOTAL IN HECTARES	16589.88	90	100.00

STREAMBANK AND GULLY EROSION

CODE	LENGTH	FREQUENCY	PERCENT
MULLENG.101	8056.75	4	6.98
MULLENG.102	23523.06	19	20.39
MULLENG.103	7526.32	13	6.52
MULLENG.51	856.47	2	0.74
MULLENG.51F	1360.86	1	1.18
MULLENG.52	2577.09	7	2.23
MULLENG.52F	2312.24	9	2.00
MULLENG.61	5275.63	12	4.57
MULLENG.65	629.95	1	0.55
MULLENG.71	14074.36	30	12.20
MULLENG.72	13231.11	16	11.47
MULLENG.81	5312.32	18	4.60
MULLENG.82	23523.17	84	20.39
MULLENG.83	7123.30	25	6.17
TOTAL IN METERS	115382.64	241	100.00

LANDUSE

CODE	AREA	FREQUENCY	PERCENT
MULLENG.C	415.09	14	2.50
MULLENG.M	0.85	1	0.01
MULLENG.P	13756.31	48	82.92
MULLENG.T	2406.17	26	14.50
MULLENG.TS	11.46	1	0.07
TOTAL IN HECTARES	16589.88	90	100.00

RURAL LAND CAPABILITY

CODE	AREA	FREQUENCY	PERCENT
MULLENG.1	497.97	3	3.00
MULLENG.2	2271.63	1	13.69
MULLENG.3	3503.41	13	21.12
MULLENG.4	1052.46	18	6.34
MULLENG.5	4542.12	20	27.38
MULLENG.6	3402.34	22	20.51
MULLENG.7	1087.95	18	6.56
MULLENG.S.F.	232.00	3	1.40
TOTAL IN HECTARES	16589.88	98	100.00

APPENDIX D: EXAMPLE - OUTPUT AVAILABLE FOR CATCHMENT MANAGEMENT UNITS

(v) Summary Statistics

MULLENGANDRA CREEK SUMMARY - AREA = 16589.9 Hectares

GULLY/STREAMBANK EROSION

	Length(Km)	Frequency	Percent
Minor Gully Erosion (51,52,55,61,62,65,71)	23.4	52	21.0
Major Gully Erosion (53-4,63-4,72-5,81-5)	49.2	143	44.0
Streambank Erosion (101-4)	39.1	36	35.0
TOTAL	111.7	231	100.0

INTENSITY ANALYSIS

	Minor Gully	Major Gully	Streambank
Density (Km/Sq.Km)	0.141	0.297	0.236

OTHER EROSION

	Area(Ha)	Frequency	Percent
No Appreciable Erosion (11)	13829.5	33	83.4
Sheet Erosion (21-24)	2664.6	37	16.1
Rill Erosion (41-44)	44.9	11	0.3
Wind Erosion (31-34)	0.0	0	0.0
Saline Areas (15,25 & 45)	46.0	7	0.3
Mass Movement (91-94)	4.9	2	0.0

LANDUSE

	Area(Ha)	Frequency	Percent
Cultivation	415.1	14	2.5
Mining	0.8	1	0.0
Grassland (sown/native pasture)	13756.3	48	82.9
Timbered land	2406.2	26	14.5
Other Landuses	11.5	1	

RURAL LAND CAPABILITY

	Area(Ha)	Frequency	Percent
Class (1,2 & 3)	6273.0	17	37.8
Class (4 & 5)	5594.6	38	33.7
Class (6)	3402.3	22	20.5
Class (7 & 8)	1088.0	18	6.6
Other	232.0	3	1.4

APPENDIX E: TREATMENT OF SALINITY AND RISING WATERTABLES

Current treatments for discharge areas include -

* fence to exclude livestock as soon as salting becomes obvious, ensuring fence is a reasonable distance from bare areas to allow for some expansion of affected area

* area to be sown should be sprayed with herbicide or cultivated with a tyned implement for weed control

* sow salt tolerant grasses, tree and shrub species, and use surface mulches on severely scalded areas

* apply phosphorus and nitrogen fertilisers

* construct graded banks immediately above the affected area to prevent surface run on, and erosion on severely effected areas.

Current treatments for recharge areas include -

* undertake property planning and be aware of the surrounding catchment characteristics of the outbreak and property in general

* install piezometers to monitor the depth and quality of ground water at strategic locations

* prior to tree planting, and establishment of perennial pastures, assess soils, slope, rainfall, water logging and select species suitable

* plant suitable trees on ridge lines, toe slopes, mid slopes, along drainage lines and in windbreaks and road reserves, where possible

* plant high water using perennial pastures, such as lucerne, in mid slope positions

* minimise cultivation, the period under fallow and winter cropping in general

* manage grazing to maintain pasture cover and therefore maximise water use

* consider agroforestry plantings to offset yield or stock reductions.

APPENDIX F - OVERCLEARING: PROCESSES AND AFFECTS

* accelerated erosion occurs as a consequence of higher rainfall runoff. Destabilisation of soil and stream banks leads to increased risk of gully and streambank erosion

* long term consequences of tree decline in specific areas may result in rising watertables and dryland salinity

* loss of shelter for birds and parasitic insects means reduces effectiveness of natural control of insects. Tree grazing insect numbers therefore remain high, concentrating their attack on remaining trees

* shade and shelter for stock and pasture are lost, placing more stress on stock during times of extreme temperatures (both hot and cold), thereby reducing productivity

* less trees for timber and fuel

* natural beauty of the region is reduced

* native plant species may disappear locally. Genetic diversity of both plant and animals is reduced

* trees are an integral component of the riparian vegetation associations, assisting in water quality. Reduced water quality, due to erosion of bare banks and insufficient vegetation to trap sediments and nutrients in runoff either singly or in combination down grade natural values including fish and wildlife habitats with a subsequent decline in ecological, recreational and aesthetic values.

* increasing wind velocities accelerate soil moisture loss and soil erosion.

Brown (in prep.)

APPENDIX G: PREFERRED TREE COVER IN RELATION TO LAND CAPABILITY

Land Capability	Preferred Minimum Tree Cover (%)
Class I - III	5 -10%
Class IV - V	10 - 15%
Class VI	25 - 50%
Class VII - VIII	100%
Whole catchment minimum	10 -15%

APPENDIX H - BENEFITS OF RETAINING TREES

Retention of native tree cover on the landscape is important both from an ecological and an economic point of view. Productivity in agriculture ultimately will depend on the retention and replacement of trees and shrubs in the landscape.

Remnants of native tree/vegetation will assist in ensuring the long-term viability of the various agricultural systems, as well as greatly enhancing the quality of life for those living in the valley.

The clearing of country for broadacre dryland and irrigation farming has proceeded rapidly over recent decades to the benefit of farmers and the wealth of the nation as a whole. In hindsight, it is now apparent that too much of the clearing was indiscriminate, without any aim of preserving effective windbreaks or effective size clumps of trees for stock shelter and wildlife habitat. There has been no consideration of the fact that very few farming systems in the world have sustained continuous cropping. Rather, most rely on an integration of animals and plants, and the benefit of trees for shade and shelter.

Effective windbreaks through reduction in wind movement can increase the yield of crops over any losses caused by land remaining uncultivated in the windbreaks. Windbreaks reduce wind movement to a distance downwind up to 28 times the break height, producing a positive crop yield response for nearly half that distance. By reducing wind velocity, moisture loss is reduced downwind of the break. The other benefits of windbreaks include retardation of bushfires and reduction in wind erosion. Trees in general add to the beauty and genetic diversity of the landscape, the latter providing some scope for biological control of the pests and diseases which affect monocultural systems.

There is a need therefore for effective windbreaks to assist in protecting soils from wind erosion during dry periods.

Peasley (1992)

APPENDIX I - CORRIDOR OBJECTIVE

"establishing a sustainable network of tree core areas and corridors throughout the area using Crown mapping areas and Crown roads. The trees should ideally be mixed with shrubs. This strategy will ensure that at least some new tree establishment occurs, as well as helping to reverse the process of dieback by providing a linked network of habitat for insect eating birds."

Kyeamba Draft Soil and Water Management. *Section 4, p 2.*
November 1991.

Table 17

Conversion of crown separation ratios (crown gap:crown size) to percentage crown cover

	Overlap			*Touching*	*Crowns separate*																				
Crown separation ratio	−.1	−.05	−.02	0	.05	.1	.15	.2	.25	.3	.4	.5	.6	.75	1.0	1.25	1.5	2.0	3.0	4.0	8.0	10	15	20	30
Percentage crown cover (%)	100	89	84	81	73	67	60	56	52	48	41	34	31	26	20	16	13	9	5	3	1	.6	.3	.2	.1

When crowns are touching the ratio is zero; when the crowns are separated by half the size of the crowns the ratio is 0.5.
When tree crowns are touching the percentage crown cover is 81%; when the ratio is 0.5 the percentage crown cover is 34%.
Overlapping cover can also be estimated; in this case the fraction of overlap is recorded and the ratio recorded as a negative number.

APPENDIX K - ACID ADDITION RATES FOR AGRICULTURAL SYSTEMS (Helyar, et al. 1990)

Location/Rainfall	Land Use	Fertiliser (kg.element/ha/yr)	Acid addition (kmgl H^+/ha/yr)
North Coast (1600 mm)	Perennial pasture	0-300 (NH_4NO_3) 700 (NH_4NO_3) 340 ($(NH_4)_2SO_4$)	0 8 21
North Coast (1200 mm)	Perennial pasture	0 45P (Superphosphate)	0 3.6
Northern Tablelands (850 mm)	Perennial pasture	0 35P (Superphosphate)	0 2.5
Coleambally Irrigation Area	Irrigated rice	some N ($(NH_4)_2SO_4$)	8 - 10
South West Slopes (600 mm)	Annual pasture and cropping	10P (Superphosphate)	4.8 - 7.4
Southern Tablelands (750 mm)	Annual pasture	10P (Superphosphate)	3.5 - 4.2
North East Victoria (600 mm)	Annual pasture and cropping	10P (Superphosphate)	4.0 - 5.0
	Wheat/fallow	10P (Superphosphate)	0.4

APPENDIX L: Streambank Erosion in the Murray Catchment on a 1:100 000 Sheet Basis (km)

1:100 000 Sheet	101 (<1.5m deep)	102 (1.5-3m deep)	103 (3-6m deep)	104 (>6m deep)	Total	Density (km/km²)
Lower Murray						
Walbundrie	6.9	13.5	7.6	-	28.0	0.03
Albury	1.2	7.1	1.3	1.4	11.0	0.04
Upper Murray						
Holbrook	20.9	34.6	9.2	-	64.7	0.10
Tallangatta	9.7	11.4	-	-	21.1	0.12
Rosewood	34.7	9.3	-	-	44.0	0.03
Corryong	0.8	1.1	2.2	-	4.1	0.09
Headwaters						
Yarrangobilly	8.3	8.8	-	-	17.1	0.02
Kosciusko	1.2	6.2	-	-	7.4	<0.01
Jacobs River	-	-	-	-	-	-
Total	**83.5**	**92.1**	**20.3**	**1.4**	**197.4**	**0.03**
Lower Billabong						
Walbundrie	0.9	3.5	10.8	-	15.2	0.10
Narrandera	-	-	-	-	-	-
Lockhart	32.0	10.3	-	-	42.3	0.03
Upper Billabong						
Holbrook	86.3	93.3	18.7	-	198.3	0.12
Wagga Wagga	-	-	-	-	-	-
Rosewood	53.2	28.6	-	3.0	84.8	0.08
Tarcutta	-	-	-	-	-	-
Total	**172.4**	**135.7**	**29.5**	**3.0**	**340.6**	**0.66**

APPENDIX M - PRESCRIBED STREAMS IN THE MURRAY-BILLABONG CATCHMENT

Murray River and the following tributaries:

Billabong Creek
Bowna Creek
Coppabella Creek
Eight Mile Creek
Geehi River
Horse Creek
Jingellic Creek
Khancoban Creek
Lankeys Creek
Majors Creek
Mannus Creek
Maragle Creek
Munderoo Creek
Native Creek
Paddys River
Spring Creek
Swampy Plain River
Ten Mile Creek
Tooma River
Tumbarumba Creek
Urangeline Creek
Wantagong Creek
Mountain Creek
Yarra Yarra Creek

APPENDIX N - INTERIM RIPARIAN ZONE POLICY (DWR)

> "1. All developments requiring DWR approval or consent should give consideration to the maintenance and rehabilitation of the full range of biophysical functions of the zone within the catchment and, where appropriate, have conditions pertaining to the retention of effective riparian protection zones (based on site specific consideration of soil types, landform, vegetation, development type, etc.). This would apply to all natural drainage lines.
>
> 2. All DWR works, should, in the investigation and planning phases, give consideration to the maintenance and rehabilitation of the full range of biophysical functions of the zone within the catchment."

The review document stresses the need to treat the riparian-stream system as a single ecosystem. The protection of this ecosystem is dominantly effected by -

> "...the retention of effective riparian protection zones (based on site specific consideration of soil types, landform, vegetation, development type, etc.)."

Interim Policy Riparian Protection Zones (1992)

APPENDIX O - ROLE OF THE RIPARIAN ZONE

This buffer zone has been shown to be a dynamic system. The required characteristics of this zone (morphology and width) are influenced by the role that it is intended to play. For example, different characteristics are required to protect the stream from diffuse rural pollutants to those required to protect it from high volumes of sediment produced by nearby roadworks or forestry activities. Where a particular form of degradation exists, for example streambank erosion, buffer zones will need to be "upgraded" to offset these specific effects.

Buffer zone characteristics and therefore policies to offset streambank erosion should address -

* changes to **resistance to streamflow** (increased channel "roughness")

* changes to **bank strength** (sediment binding in root systems)

* bank **vegetation disturbances** (such as unrestricted stock access causing destabilisation, low levels of streambank flora, soil compaction and higher overbank flow velocities) which can lead to exacerbation of natural flooding effects

  Vegetation in the riparian zone assists:-
  - water interception
  - soil stabilisation
  - infiltration enhancement
  - restraint and filtering of soil particles
  - usage of soil water.

* high level **sediment loads** from nearby activities such as forest operations.

These recommendations are aimed at offsetting river channel changes attributed to alteration of climate, land use or human modification of channel and water regimes.

APPENDIX P - EFFECTS OF RIVER REGULATION

Levels of streambank erosion are affected by river regulation. Apart from direct erosion caused by increased velocities and discharges this occurs primarily in relation to the effects of regulation on the accelerated lowering of the river bed (not that lowering caused naturally over geological time).

The relevant effects of regulation are -

* realignment of the channel during periods of altered flow
* fast drawdowns which destabilise the materials of the bank initiating mass movements by saturating banks and then retreating
* undermining of banks and infrastructure by altered flow regime
* damaging vegetation that binds the bank materials during flow increases and during alteration to natural flow cycles, eg. the release of water during summer for irrigation and flow retardance in winter
* alteration of depths of flow directly affecting banks at varying levels
* alteration of groundwater levels in the adjacent floodplain and resultant lateral water movements
* enhancement of alterations to sedimentation regime
* reduction in sediment content of water allowing further entrainment of bank materials
* increase in bed slope and velocity, with related changes to width of channel
* marked changes to stream ecology through temperature and flow variations which impacts on bank stability via vegetation/wildlife interactions.

APPENDIX Q: SHEET AND RILL EROSION BREAKDOWN

TABLE 1: Sheet and Rill Erosion Breakdown for the Murray Catchment[#]

Sheet/Rill Erosion	Albury Walbundrie	Tallangatta Holbrook	Rosewood	Yarrangobilly	Kosciusko Jacobs River	Total Area
Not significant	984.55 (89.1)	569.82 (69.1)	1090.89 (82.1)	695.95 (74.3)	763.71 (41.1)	4104.92 (67.8)
Minor	94.19 (8.5)	178.73 (21.7)	200.70 (15.1)	224.70 (24.0)	999.14 (53.8)	1697.46 (28.0)
Moderate	6.04 (0.6)	3.64 (0.4)	19.21 (1.4)	7.54 (0.8)	86.51 (4.7)	122.94 (2.0)
Severe	2.92 (0.2)	0.57 (*)	9.96 (0.8)	8.19 (0.9)	0.39 (*)	22.03 (0.4)
Extreme	- (-)	<0.1 (*)	4.67 (0.4)	- -	<0.1 (*)	4.78 (*)
Other	17.50 (1.6)	72.32 (8.8)	2.57 (0.2)	- -	8.26 (0.4)	100.65 (1.7)

areas in km^2
( ) % of catchment on particular 1:100 000 sheet
* less than 0.01

TABLE 2: Sheet and Rill Erosion Breakdown for the Billabong Catchment[#]

Sheet/Rill Erosion	Narrandera Lockhart	Walbundrie	Holbrook Wagga Wagga	Tarcutta Rosewood	Total Area
Not significant	1428.50 (93.1)	1422.63 (91.8)	1532.91 (91.2)	342.05 (87.3)	4725.43 (91.6)
Minor	103.36 (6.7)	100.52 (6.5)	134.91 (8.0)	47.00 (12.0)	385.77 (7.4)
Moderate	2.74 (0.2)	11.96 (0.6)	12.2 (0.7)	2.05 (0.5)	28.95 (0.6)
Severe	-	<0.1 (*)	<0.1 (*)	0.84 (0.2)	1.09 (*)
Extreme	-	<0.1 (*)	<0.1 (*)	<0.1 (*)	<0.1 (*)
Other	-	14.42 (0.9)	2.07 <0.1	-	16.49 (0.3)

areas in km^2
( ) % of catchment on particular 1:100 000 sheet
* less than 0.01

APPENDIX R - MAJOR GULLY EROSION

TABLE R1 : Major Gully Erosion on a 1:100 000 Sheet Basis

1:100 000 Map Sheet	Length of Gullies (km)									Density (km/km²)
	Minor gullies > 3m 53/54	Moderate gullies > 3m 63/64	Severe gullies 1.5-3m 72	Severe gullies > 3m 73/74	Extreme gullies < 1.5 81	Extreme gullies 1.5-3m 82	Extreme gullies 3m-6m 83	Extreme gullies > 6m 84	Total	
Walbundrie	-	7.3	9.7	1.5	-	0.5	4.9	0.2	24.1	0.03
Albury	-	-	-	2.2	0.7	3.7	-	21.9	28.5	0.12
Holbrook	-	-	15.3	0.6	9.5	46.4	9.1	1.8	82.7	0.13
Tallangatta	-	-	4.3	-	-	1.0	0.7	-	6.0	0.03
Rosewood	-	-	3.2	-	2.6	7.7	0.2	-	13.7	0.01
Corryong	-	-	1.9	-	-	-	-	-	1.9	0.04
Yarrangobilly	-	-	1.1	-	-	0.8	1.3	-	3.2	<0.01
Kosciusko	-	-	2.3	-	-	5.0	4.0	-	11.3	<0.01
Jacobs River	-	-	-	-	-	-	-	-	-	-
Total	-	**7.3**	**37.8**	**4.3**	**12.8**	**65.1**	**20.2**	**23.9**	**171.3**	**.03**
Walbundrie	3.2	12.2	1.7	1.1	2.0	0.9	-	-	21.1	0.01
Narrandera	-	-	-	-	-	-	-	-	-	-
Lockhart	-	-	4.7	-	0.2	0.9	-	-	5.8	<0.01
Holbrook	5.5	1.8	29.6	4.8	42.1	98.9	8.6	-	191.3	0.12
Wagga Wagga	-	-	-	-	-	-	-	-	-	-
Rosewood	-	-	0.5	-	12.7	15.3	-	-	28.5	0.07
Total	**8.7**	**14.0**	**37.8**	**5.9**	**57.0**	**116.0**	**8.6**		**246.7**	**0.05**

* less than 0.01

APPENDIX S - A HISTORY OF POOR GROUNDCOVER

Early settlers were unfamiliar with the climate and soils, and indiscriminately cleared and cultivated large areas (Earthmover notes). Repeated burning was an integral component in the clearing process. Major gully erosion was probably initiated when the early squatters moved west and grazed out the shrub understorey (Eyles pers.comm.) A succession of rabbit plaques and drought ensured severe grazing pressure and widespread severe soil erosion. An extreme example being the drought between 1892 and 1902, when sheep numbers fell from 106.4 million to just 18.4 million (Mullen 1983).

The widespread use of subterranean clover and superphosphate, and control of rabbits in the post W.W.II period dramatically reduced the poor ground cover problem and hence erosion. Bigger machinery, improved wheat varieties and the use of chemicals has considerably reduced the time cropping land is under bare fallow. With the recent run of good seasons and reduced cereal crop plantings, active erosion is probably at the lowest levels since European settlement of inland Australia.

However problems exist in the steeper grazing lands of the and Southwest Slopes. These relate to the reliance on annual pastures in a climate that experiences a seasonal summer/autumn drought, as well as periodic drought. Extreme erosion risks (wind and water) occur extensively during severe drought, particularly when crop failure and inadequate or delayed destocking leaves large areas with very poor groundcover.

APPENDIX T - DROUGHT MANAGEMENT

Guidelines for Drought Management - Mixed Farming and Grazing and Tableland Zones

Before Drought

- maintain a cash reserve
- monitor rainfall prospects
- monitor groundcover, feed supply, and needs for coming months
- monitor stock market prices
- monitor cost and availability of agistment
- monitor grain, hay and other fodder prices
- continually assess mix of enterprises
- stock so as to strike a balance between maximising profit and reducing damage to pasture and soils
- control feral and native animals and weeds
- identify genetically superior animals to be retained in drought and categories of stock for staged destocking
- develop or set aside areas of drought resistant pastures
- identify land which should be destocked first
- determine special animal husbandry needs
- ensure water supplies are adequate
- set dates for staged destocking if rains fail
- identify possibilities for irrigation to produce feed or fodder
- produce or purchase and store fodder supplies
- assess crop rotation possibilities
- use reduced tillage and retain stubbles and other groundcover on cropping paddocks, in order to retain cropping options for as long as possible
- seek advice on technical matters, financial matters and sources of assistance

During Drought

- monitor rainfall prospects
- monitor feed supply and groundcover levels
- monitor stock and fodder prices
- commence destocking according to plan
- remove stock from erodible land types (e.g. shallow soils, some granite soils, saline areas)
- commence feeding well before pasture runs out
- prevent grass butts or lucerne from being eaten to the ground
- maintain control of feral animals
- protect water supplies
- act to reduce stock diseases and suffering
- manage cash flow according to chosen strategy
- keep stubble or other cover on cropping paddocks
- restrict or cease stocking of cultivated paddocks
- keep soil surface in cropping paddocks in a cloddy, uneven state
- assess crop yield prospects
- determine optimum use of already growing crops
- defer further cultivation (except where required to roughen surface)
- reconsider crop or pasture sowing plans
- carry out emergency soil conservation measures where necessary
- seek advice on technical matters, financial matters, sources of assistance and, if

required, rural counselling

After Drought

- allow pastures (especially native perennials) to recover before restocking
- compare costs of breeding back with buying stock
- maintain feral animal control to prevent rebuilding of numbers and damage to new pasture growth
- control weeds resulting from imported fodder or stock
- watch out for poisonous plants
- spell paddocks used for intensive feeding
- rehabilitate eroded or otherwise damaged lands
- keep an eye out for germinating woody weed seedlings such as sifton bush
- reap the benefits of a well planned and carefully executed drought strategy personal, environmental, and economic