

technical bulletin

No. 53

**ISSN 0038-8675
AGDEX-570**

**AN ASSESSMENT OF RECOVERY
AND LAND CAPABILITY OF PART OF
THE ORD RIVER CATCHMENT
REGENERATION PROJECT**

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by W. J. Ryan

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Manuscript received June 1980

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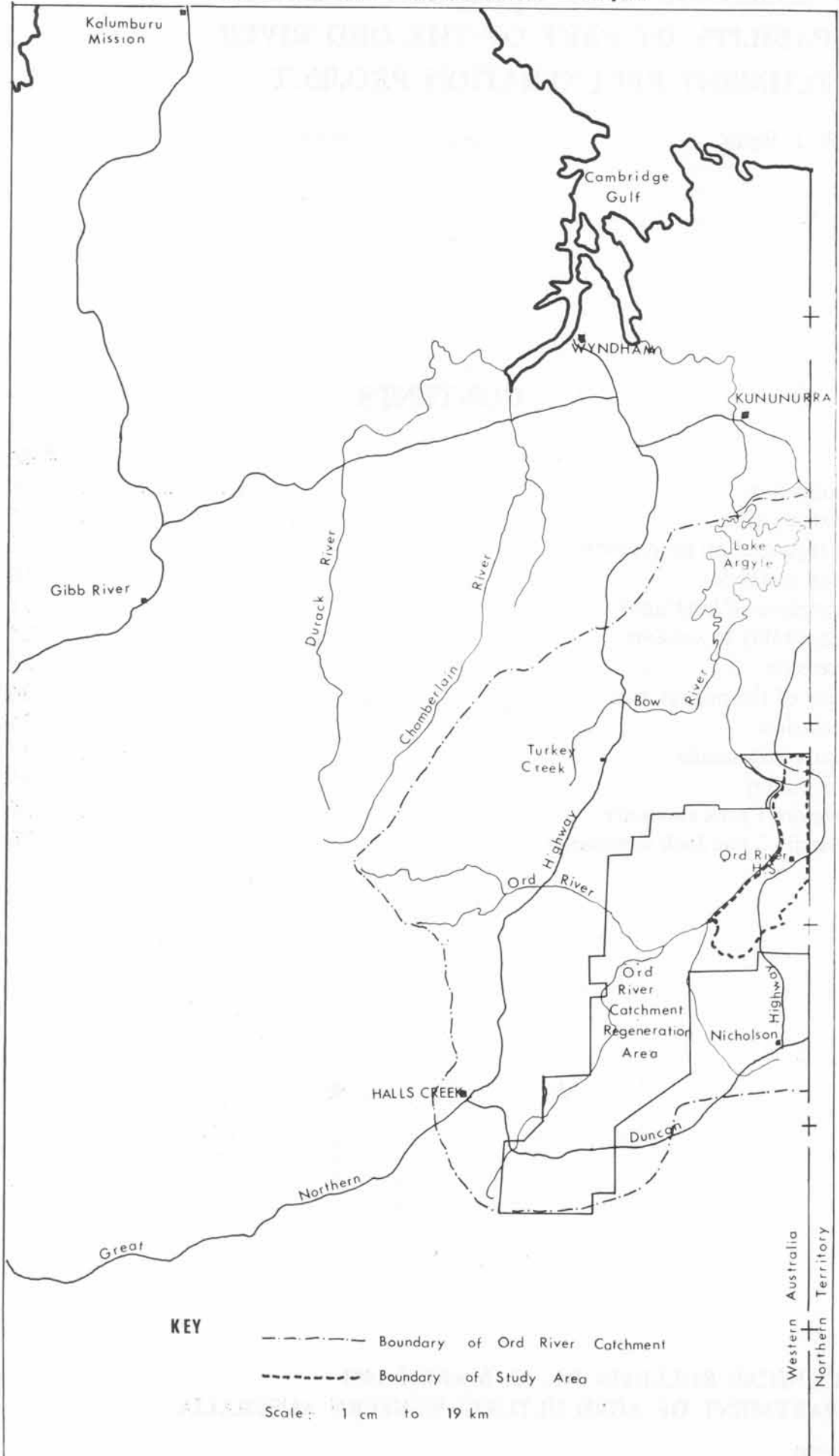
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TECHNICAL BULLETIN No. 53, MARCH 1981
DEPARTMENT OF AGRICULTURE, WESTERN AUSTRALIA

**Figure 1 : Location of Study Area on part of the
Ord River Catchment Regeneration Project**



INTRODUCTION

The area covered by this study forms part of the Ord River Regeneration Project which in turn forms part of the catchment area for the Ord River Dam (Lake Argyle). The Ord River Regeneration Project is situated approximately 190 km south of Kununurra adjacent to the Northern Territory border (see Figure 1) and extends over 910 750 ha.

The area was taken up about 1890 when the first settlers arrived from Queensland. The abundance of surface water, the gentle terrain and excellent pastures made it a favoured area and it was one of the earliest settled. It was subjected to continuous grazing by large numbers of cattle which led to severe degradation and erosion.

The problem of erosion was recognised early and was the subject of a number of reports commissioned by Government. While the problem was recognised early it was not until the Ord River Irrigation Project was commenced that attempts were made to remedy the situation. It was recognised that the silt load of the Ord River had to be reduced in order that the dam's life should not be shortened. The Department of Agriculture of Western Australia was assigned the task of catchment regeneration.

The object of the study reported here was to discuss the progress of the regeneration pro-

gramme, map the area on a land unit basis, evaluate the project and provide priorities and direction for future work.

For the purposes of this study, land units which were repeatable small areas of land that could be defined by soils, topography and vegetation, were convenient mapping units. A number of land units go together to make up a land system as defined by Stewart *et al* (1970).

The erosion of the area was first described by Medcalf (1944). Medcalf found that overgrazing had resulted in widespread pasture deterioration and this had led to widespread erosion. He recorded deep gully erosion, particularly where slopes were in excess of 2°. Sheet erosion was also recorded for the first time in this report.

The pastures of the area were described by R. A. Perry (1970) as arid short grass pastures (*Enneapogon polyphyllus* and *Aristida contorta*). Perry considers that the original pastures were probably Mitchell (*Astrelba* spp.) grass pastures.

Robinson (1970) also described the pastures as arid short grass. However, Robinson considered that the original pastures were a number of *Triodia* associations and that the arid short grass pastures were a subclimax of the original hummock grasses.

THE STUDY AREA

The area covered by this study does not include the whole of the regeneration project, but covers approximately 119 000 ha extending from the southern boundary of Linnekar paddock to the northern boundary of the R. B. paddock. It is bounded in the east in part by the W.A./N.T. border and bounded in the west by the Ord River. (Fig. 2) The main rivers of the area are the Negri, the Forrest and the Linnekar Rivers, all of which drain into the Ord River. The fieldwork for the study was undertaken in 1976.

GEOLOGY

The largest part of the area under study is based upon Upper Cambrian sediments of the Negri group (Traves 1956) which consist of interdispersed layers of limestone and shale lying in a conformable sequence. A stylised section is shown in Fig. 3. For the most part of the study area the formation strikes approximately north-east to south-west and dips at between 30° to 60°

to the south-east. The sequence of the group is as follows:

1. Headleys Limestone: It is defined as the limestone that overlies the Antrim Volcanics to the east. The typical sequence of the formation is 20 metres of thickly bedded grey, crystalline limestone overlain by 15 to 20 metres of thinly bedded limestone.
2. Nelson Shale: This is the first of the shale units and lies conformably between the Headleys Limestone and the Linnekar Limestone. The thickness of this formation is approximately 185 metres and its dip ranges from 45° to 60°.
3. Linnekar Limestone: Is the second of the limestones in the group. It is approximately 18 to 22 metres thick and dips at between 45° to 30°. This unit outcrops just to the north of the Ord River Homestead.

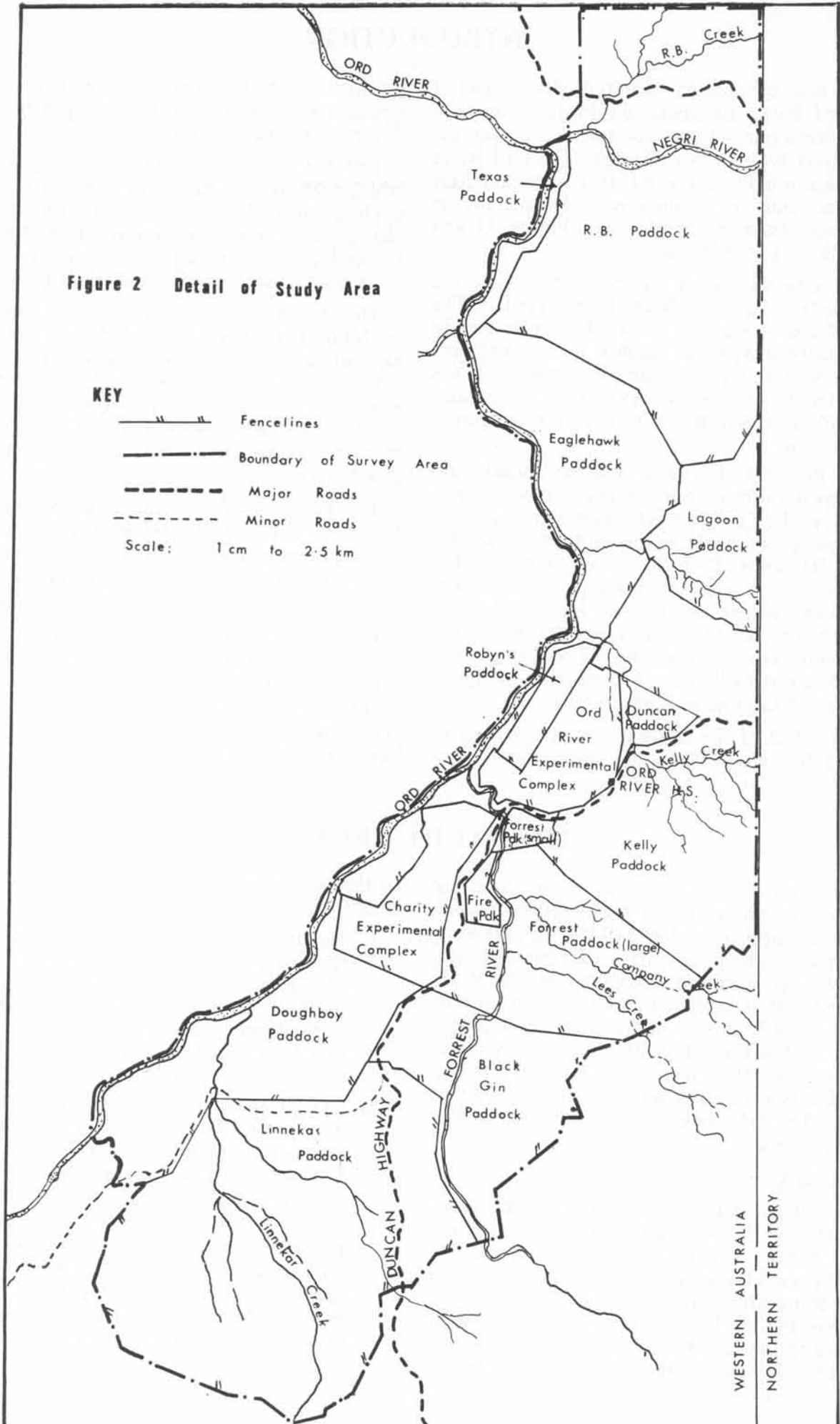






Figure 2 Detail of Study Area

KEY

-  Fencelines
-  Boundary of Survey Area
-  Major Roads
-  Minor Roads
- Scale: 1 cm to 2.5 km

WESTERN AUSTRALIA
NORTHERN TERRITORY

4. Panton Shale: Is the second of the Shale units and lies conformably between Linnekar Limestone and Shady Camp Limestone. Approximate thickness of this unit is 60 metres making it the smallest of the shale units.
5. Shady Camp Limestone: Is the third limestone unit and conformably overlies the Panton Shale. The estimated thickness of this unit is 40 to 45 metres.
6. Negri River Shale: Is the third shale unit of the Negri Group and lies conformably between Shady Camp Limestone and Corby Limestone. The estimated thickness of this unit has been listed as 20 to 70 metres.
7. Corby Limestone: This is the last of the limestone units. The thickness of this unit is approximately three metres.
8. Hudson Shale: This is the last of the shale units. This unit is approximately 200 metres thick and conformably overlies the Corby Limestone.

The geology of the remaining area under study is Elder Sandstone which overlies the Negri group.

Geomorphology

The area is an inland erosional plain (Fig. 3) consisting of:—

- Crests and low scarps of limestone.
- Moderately sloping interfluvial soils of fine textured calcareous soils derived from shale.
- Lower slopes and shallow depressions of cracking clays of depositional derivation.
- Massive outcrops of sandstone.
- Large moderately sloping sand plains.

Soils

In general those soils derived from the shale materials are very fine textured and calcareous, while those derived from the limestone formations tend to be skeletal, containing rocks throughout. Those soils derived from the sandstone are sandy in nature. The relationship between parent material and the resulting soil and land unit for the Negri Group and the Elder Sandstone is also shown in Fig. 3.

THE REGENERATION PROGRAMME

A two phase approach was adopted in the programme of regeneration. The two phases can be most conveniently described as:—

- Protection from grazing by removal of stock.
- Cultivation and reseedling.

These phases were not mutually exclusive though cultivation and reseedling was carried out only on part of the area as described below.

Fencing and cattle control

The removal of cattle was considered to be essential to the establishment of durable plant material. To achieve this over 800 km of fencing was erected so that successive areas could be mustered and kept free of stock. The fencing on the study area is shown in Fig. 2.

Many areas showed recovery quickly following destocking. This occurred on all units that had not suffered from erosion and was particularly evident on the heavy clay soils of Unit 3 (Black soil plains). Here there was still an adequate seed supply in the soil. Destocking allowed seedlings to develop into mature plants which quickly re-established the original community.

Cultivation and reseedling

Areas which had been badly eroded (Units 4a, 4b and 6), required cultural operations in addition to the fencing and cattle control in order to restore vegetative cover.

The removal of much of the topsoil had left the soil in these units with a smooth, hard surface which effectively prevented the infiltration of water. This surface seal was broken with cultivation enabling water penetration. The small furrows and depressions created by the workings acted as water traps.

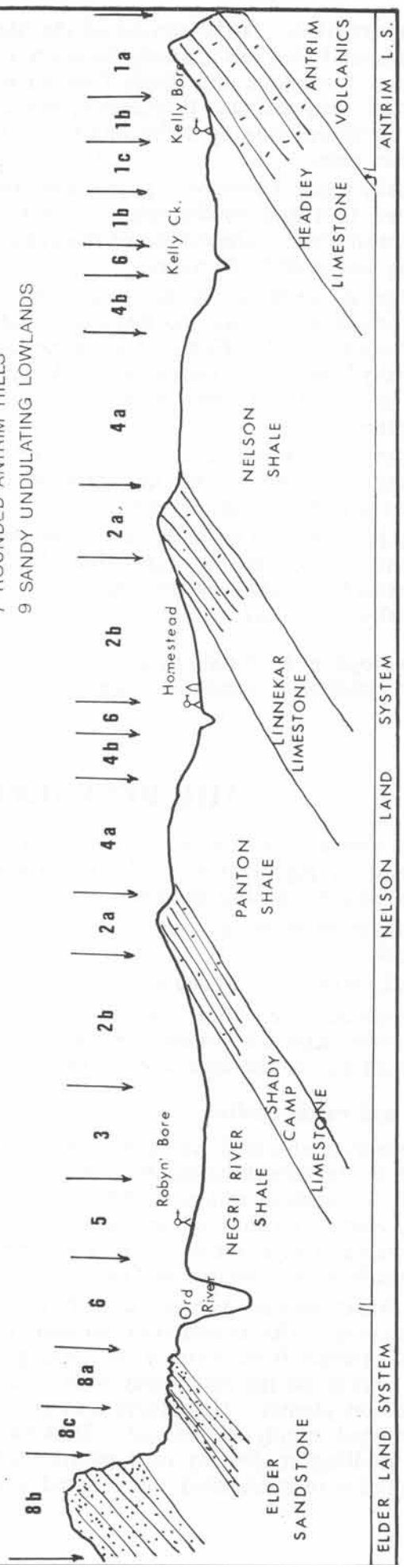
The seed reserves of most of these areas were extremely low and new supplies of seed were required. Three perennial species were introduced in the seeding operations, *Cenchrus setiger* (Birdwood grass), *Cenchrus ciliaris* (Buffel grass) and *Aerva javanica* (Kapok bush). Thus those areas which were treated culturally were also seeded at the same time.

Two cultural implements were used. These were a pair of opposed discs with a centrally mounted ripper which was used to throw up a small bank and a five or seven tined chisel plough used immediately above the bank.

Figure 3 : Schematic Cross - Section of Kelly Paddock showing the relationship between Parent Material and the resulting Land Unit

- 1a** LIMESTONE OUTCROP (Headley's)
- 1b** BACKSLOPE - Short grasses
- 1c** BACKSLOPE - Spinifex
- 2a** CUESTA OUTCROP } Linnekar and
- 2b** CUESTA BACKSLOPE } Shady Camp Limestone
- 3** BLACK SOIL PLAIN
- 4a** UNDULATING INTERFLUVES - upper slopes
- 4b** UNDULATING INTERFLUVES - lower slopes
- 5** LEVEE BACKSLOPE
- 6** LEVEES, BANKS and STREAMLINES
- 8a** STONY LOWLANDS
- 8b** SANDSTONE HILLS
- 8c** SANDY LOWER SLOPES

NOT SHOWN IN FIGURE
 7 ROUNDED ANTRIM HILLS
 9 SANDY UNDULATING LOWLANDS



ELDER LAND SYSTEM

NELSON LAND SYSTEM

ANTRIM L. S.



Plate 1. Strip cultivation used for regeneration.

The opposed disc unit was a three point linkage implement and threw up a small bank about 30 to 40 cm high and about one metre wide at the base. The discs generally cut to a depth of

10 to 14 cm. The chisel plough was either five or seven tyned and was also three point linkage mounted. It worked to a depth of about 10 to 15 cm and was approximately two metres wide.



Plate 2. Initial establishment of kapok bush along chisel plough workings.

Seed boxes were mounted either on the implement or on the back of the tractor and were chain driven from a sprocket on the rear wheel of the tractor. The seeding rate was about 0.5 kg per km of furrow.

The distance between the furrows varied according to the severity of degradation of the area being treated. It was as little as five or six metres on very bare areas, and up to 20 metres apart on less degraded areas.

All workings were done on the contour. The contours were marked with a mobile hose level and although the accuracy was acceptable for broadscale workings, the cultivations were made discontinuous to safeguard against errors. Workings were usually 20 metres long with about six metres of untreated ground between. The cultivated strips were staggered down slope.

In the area of the catchment covered by this study, cultural works have virtually been completed. Small areas between bad gully erosion are being treated with a spiked roller to improve water infiltration rates into the soil and to collect seed.

Although three units, the upper and lower slopes of the undulating interfluvies on Pantan Shale (Units 4a and 4b) and the streamline margins (Unit 6) required cultural regeneration the major effort was concentrated on Unit 4a for two reasons.

Firstly, of the three units, Unit 4a was the only one which was well suited for large scale mechanical operations. The upper slopes of the interfluvies had a smooth gently sloping surface and were up to 18 km long in places. This enabled the cultivating units long, uninterrupted runs which could be covered at speeds up to six to seven km per hour. In excess of 80 000 km of strip contouring and ploughing was done on the whole of the project area, somewhat less of course in the study area. Both the lower slopes of the interfluvies (Unit 4b) and the streamlines (Unit 6) by contrast were deeply incised by massive gully systems and these areas were not suited to cultivation.

Secondly the upper slopes (Unit 4a) were the source of most of the run-off. It was considered that the run-off had to be reduced and the gully systems starved if any stabilisation was to be achieved.

SURVEY METHODS

As a first step, land systems and their units were identified on 1:85 000 scale aerial photographs which were subsequently verified by ground traverse. Plant species lists and full landscape descriptions were made at several points in each of the repeatable patterns delineated on the aerial photographs. The boundaries of the land unit patterns were transferred to a controlled transparency sheet and a map was compiled at approximately photo scale. The land units were numbered for ease of referral. The area of each unit was calculated as shown in Appendix 1.

Representative samples of each unit were examined for evidence of soil loss through a series of check sites. Two types of erosion were found to have occurred.

- Gullying: which was assessed on a simple presence or absence basis.
- Sheeting: which was assessed using parameters such as exposed tree roots and/or hummocks around obstacles.

Erosion sites were further examined to ascertain whether the erosion had been halted or was still active. Vegetation degradation was

assessed in conjunction with erosion at each check site. The assumption was made that areas with a vegetation composition similar to the original situation had suffered the least degradation, and that those areas where the vegetation composition had changed markedly had suffered the greatest degradation.

On the units which were culturally treated, traverse recordings were made every 0.5 km to determine the composition of the vegetation. The species present were classified into three classes; either original species, introduced species, or pioneer species. Each 0.5 km section of the traverse was characterised on the basis of the dominant plant class occurring in the preceding 0.5 km.

Stocking levels were calculated for the land units using data from Payne *et al.* (1974). Paddock capability statements for the fenced portion of the survey area were compiled and are presented in Appendix 2.

The response of each unit to the regeneration treatments imposed on it was also assessed and included in the land unit description.

DESCRIPTION OF LAND UNITS

For ease of description each land unit has been considered under the following headings:

- Land system
- Geology
- Landform
- Soils
- Vegetation
- Erosion
- Stability
- Condition
- Response
- Capability assessment

Land system

The area of this study falls into the "Lands of Ord-Victoria Area, W.A. and N.T." (Stewart *et al* 1970) and the units described are part of the various land systems. This description enables the land units to be related back to its parent land system.

Geology

Provides a brief description of the parental material of the soil of a particular unit along with an approximate age.

Erosion

This describes any accelerated or non-geological erosion that may or may not have taken place on a particular unit.

Stability

Many units which have suffered accelerated erosion are still unstable and some mention of present stability is required. A stability index from 1 to 5 was used on the investigation and is shown below:

Stability Indices

Stability Index	Land Description
1	Whole area extremely stable.
2	Majority of area stable, odd pockets unstable.
3	Equal areas of stable, unstable land.
4	Majority of area unstable, some stable pockets.
5	Whole area extremely unstable.

Condition

A number of range condition assessment systems notably that of Deming (1957) are based on the estimation of the relative proportions of desirable species and undesirable species in the vegetation stand. An adaptation of this

approach was used in the assessment of those areas which were not subject to cultural treatment.

In the assessment of Units 4a and 4b two further criteria were used.

- It was considered that in the degraded areas of units 4a and 4b any increase in in vegetative cover was desirable and that the bare soil represented the lowest stage of degeneration. Therefore in the assessment of the vegetation on these units the presence of pioneer species was not considered as the lowest limit of condition as it would have been under normal circumstances, but rather one step on the way to recovery.
- The introduced species were also considered in any assessment of condition as they were regarded as an integral part of the vegetation of these units. A strong pasture stand of either introduced species and/or original species was assessed as good condition.

The effectiveness of the cultural treatment for Unit 4a was assessed in terms of:

- The relative proportions of the species present either original, introduced or pioneer, and
- A condition assessment made by detailed ground traverses.

Recordings (class of vegetation, condition) were made of the vegetation in 0.5 km intervals on the traverse. The dominant vegetation type was estimated as: Original (O); Introduced (I); Pioneer (P).

The condition assessment was a subjective rating which depended upon the percentage cover estimated for each 0.5 km of traverse. The vegetation was scored for condition in the following manner:

Class	Condition	Cover
1	Very good	Dense cover
2	Good	Good cover, a few bare patches
3	Fair	Fair cover, about half bare.
4	Poor	Sparse cover, mostly bare patches
5	Very poor	Virtually no cover.

Response

Response on units that were not subjected to cultural seeding was assessed on the condition of the native pastures present using the criteria outlined above.

Response on areas which were seeded was assessed by both the condition of the pastures and the ratio of original species to introduce species to pioneer species.

Capability assessment

This provides a statement of the approximate level of stock numbers which can be carried.

Stocking rates are expressed in cattle units (c.u.) per square kilometre. A cattle unit is defined as an adult animal in excess of two years of age such as a steer or dry cow (Payne *et al* 1974).

DESCRIPTION OF LAND SYSTEM UNITS

UNIT	1a. Limestone Uplands (30·22 km², 3·26% of the area).
Land system	Headley
Geology	Limestone, and minor shale Lower Cambrian or basal Middle Cambrian.
Landform	Steep low hills up to 40 metres high.
Soils	Limestone outcrops with small pockets of shallow skeletal soils.
Vegetation	Present vegetation consists of sparse low woodland with an understorey of <i>Triodia wiseana</i> (limestone spinifex) and <i>Enneapogon polyphyllus</i> (limestone grass).
Erosion	Virtually nil.
Stability	Inherently stable. Stability index 1.
Condition	Very good.
Regeneration work	Nil.
Response	Not applicable.
Capability assessment	Now: Low stocking rate because of unattractive pastures 1·2 c.u. km ⁻² . Potential: Low stocking rate of 1·2 c.u. km ⁻² .
UNIT	1b. Limestone Backslopes (136 km², 11·4% of the area)
Land system	Headley
Geology	Uncertain complex between Headley Limestone and Nelson Shale, both lower Middle Cambrian.
Landform	Gently sloping depositional backslopes of limestone cuestas.
Soils	Generally shallow skeletal soils. Some inclusions of soils derived from shales (fine textured calcareous soils) and of brown cracking clays.
Vegetation	Low open woodland of <i>Eucalyptus dichromophloia</i> (variable barked bloodwood), <i>Terminalia arostrata</i> (nutwood) and some <i>Lysiphyllum cunninghamii</i> (bauhinia) occurring above a ground storey of <i>Enneapogon polyphyllus</i> (limestone grass), <i>Aristida contorta</i> (wind grass) and <i>Triodia wiseana</i> (limestone spinifex). In the small inclusions of heavy clay soils <i>Chrysopogon fallax</i> (ribbon grass) is found in association with <i>Astrebla pectinata</i> (Mitchell grass)

Dichanthium fecundum (blue grass), *Aristida latifolia* (feather top) and *Iseilema vaginiflorum* (Flinders grass). *Triodia wiseana* is prominent on the rocky outcrops.

Erosion	....	....	....	Small pockets of sheet erosion are present in some areas. No gully erosion.
Stability	....	....	....	This unit is quite stable due to good vegetation cover and low slope which minimises run-off, and the shallow stony soil which is resistant to erosion. Stability index 2.
Condition	....	....	....	Very good.
Regeneration work	....	....	....	Stock were excluded. No other remedial treatments were made.
Response	....	....	....	Good. Condition prior to treatment was fair with vegetation degradation but little erosion—condition has improved to very good.
Capability assessment	....	....	....	Now: Condition is considered to be very close to the best that can be expected. Stocking level for arid short grasses five to ten c.u. km ⁻² . Potential: As for present condition. This stocking level may be conservative for this type of pasture; higher levels would need to be carefully monitored to ensure no degradation occurred. More waters will need to be provided to ensure an even grazing of the pasture.



Plate 3. Limestone backslopes of Headley's Limestone showing arid short grass pastures.

UNIT	1c. Limestone Spinifex Rises. (30·42 km², 2·5% of area).
Land system	Headley.
Geology	Limestone with some Nelson Shale. Age approximately lower Middle Cambrian.
Landform	Small rises or mounds more resistant than those of Unit 1b which surround it.
Soils	Very shallow skeletal soils and rock outcrops.
Vegetation	Low open woodland of <i>Eucalyptus dichromophloia</i> (variable barked bloodwood) with a dense ground storey of <i>Triodia wiseana</i> (limestone spinifex). Small patches of <i>Enneapogon polyphyllus</i> (limestone grass) and <i>Eragrostis falcata</i> are present.
Erosion	Nil, due to the very rocky nature.
Stability	Extremely stable. Stability index 1.
Condition	Very good.
Regeneration work	Exclusion of stock. No seeding or cultivation treatments. Because of the unattractive nature to livestock and inherent stability of the hard spinifex pastures this unit was not degraded and was in good condition prior to treatment.
Capability assessment	Now: Very low stocking rate because of the low palatability of the pasture. 1·2 c.u. km ⁻² . Potential: Low capability, maximum stocking rate about 1·2 c.u. km ⁻² .



Plate 4. Low rise of Headley's Limestone showing hard limestone spinifex pastures.

UNIT	....	....	....	2a. Limestone Cuestas (37·7 km², 3·16% of area).
Land system	....	....	....	Nelson.
Geology	....	....	....	Limestone (Linnekar limestone or Shady Camp limestone.) The age of both Linnekar limestone and Shady Camp limestone has been put as lower Middle Cambrian.
Landform	....	....	....	Cuesta outcrops up to 15 metres high in places.
Vegetation	....	....	....	Low open woodland of <i>Eucalyptus argillacea</i> (southern box) <i>Lysiophyllum cunninghamii</i> (bauhinia) and <i>Gyrocarpus americanus</i> (white wood) with an under storey of <i>Triodia wiseana</i> (limestone spinifex) with small pockets of <i>Enneapogon polyphyllus</i> (limestone grass), <i>Aristida contorta</i> (wind grass) and <i>Aerva javanica</i> (kapok bush).
Erosion	....	....	....	Nil.
Stability	....	....	....	This unit is very stable because of the very resistant nature of the limestone outcrop and skeletal soils. Stability index 1
Condition	....	....	....	Very good.
Regeneration work	....	....	....	Exclusion of stock. No cultural or seeding treatments.
Response	....	....	....	Not applicable. Hard spinifex pastures are unpalatable and the unit is inherently stable, condition prior to treatment was good.
Capability assessment	....	....	....	Now: Capability moderate. Condition at present is close to the best that can be expected. Stocking rate moderate to low because of the high proportion of unpalatable species in the pasture. Stocking rate about 4 c.u. km ⁻² . Potential: Moderate capability stocking rate about the same (4 c.u. km ⁻²) as that recommended for present condition.



Plate 5. Cuesta outcrop of Linnekar or Shady Camp Limestone, kapok bush in foreground and limestone spinifex on background outcrop.

UNIT	2b. Cuesta Backslope (107.7 km², 9.0% of area).
Land system	Nelson.
Geology	Linnekar and Shady Camp limestone of lower Middle Cambrian age.
Landform	Gently sloping backslopes of cuestas.
Soils	Generally skeletal soils with pockets of cracking clay and calcareous soils.
Vegetation	Low open woodland of <i>Eucalyptus dichromophloia</i> (variable barked bloodwood) <i>Terminalia arostrata</i> (nutwood), <i>Eucalyptus argillacea</i> (southern box) and <i>Lysiphyllum cunninghamii</i> (Bauhinia). The under storey is a short grassland of <i>Enneapogon polyphyllus</i> (limestone grass) <i>Sporobolus australasicus</i> (fairy grass), <i>Aerva javanica</i> (kapok bush) and <i>Eragrostis falcata</i> . Pockets of <i>Chrysopogon fallax</i> (ribbon grass) <i>Panicum decompositum</i> (panic) and <i>Sehima nervosum</i> (white grass) exist in the areas of clay soil.
Erosion	Very little erosion. Some sheeting, but no gully erosion.
Stability	Because of its stony nature and gentle slope this unit is very stable. Stability index 2 to 3.
Condition	Very good.
Regeneration work	Exclusion of stock. No cultural or seeding operations.
Response	Very good. Pastures were initially degraded with some minor erosion. Recovery after exclusion of stock was rapid and condition has improved to very good.
Capability assessment	Now: This unit has a moderate production capability in its present condition and capability is unlikely to increase in the future. Provided stock control is adequate it could be grazed at about five to six c.u. km ⁻² on a year long basis. Potential: Moderate capability, stocking rate of five to six c.u. km ⁻² .



Plate 6. Cuesta backslope on Linnekar or Shady Camp Limestone showing mixed pastures.

UNIT	....	....	3. Black Soil Plains (108·5 km², 9·1 % of area).
Land system	....	....	Nelson.
Geology	....	....	Black soil plains in this area are frequently upper Tertiary lacustrine deposits.
Landform	....	....	Depositional plains of heavy cracking clays of the Argyle family.
Vegetation	....	....	Perennial grasslands of <i>Astrebala pectinata</i> (barley Mitchell grass), <i>Chrysopogon fallax</i> (ribbon grass), <i>Dichanthium fecundum</i> (bundle bundle), <i>Iseilema vaginiflorum</i> (Flinders grass), <i>Aristida latifolia</i> (feather top), with minor components of <i>Astrebala squarrosa</i> (bull Mitchell grass) and <i>Panicum decompositum</i> (panic).
Erosion	....	....	Very little erosion evident, isolated gullies along the banks of the larger creeks and rivers.
Stability	....	....	Because of the heavy nature of the soil and lack of slope this unit is very stable. Stability index 2.
Condition	....	....	This unit is in very good condition.
Regeneration work	....	....	Exclusion of stock. No cultural or seeding work.
Response	....	....	Very good. The stable nature of the soil prevented much erosion even under extreme grazing pressure. Following destocking vegetation recovery was dramatic.
Capability assessment	....	....	Now: High capability; at the present time a stocking level of up to 11 c.u. km ⁻² , could be applied. Potential: High capability. A stocking level of 11 c.u. km ⁻² could be maintained without pasture deterioration provided that adequate fences and waters are available for stock control.



Plate 7. Black soil plain showing very good stand of barley Mitchell grass and ribbon grass perennial pastures.

Units 4a. and 4b. Upper and Lower Slopes of Interfluves (collectively 305.5 km², 25.6% of area).

The long moderately sloping interfluves formed over shales are the most important units from the point of view of erosion and the regeneration work completed on this project.

Unit 4a forms the crests and upper slopes or run-off areas of the interfluves and generally consists of convex slopes. Unit 4b forms the lower slopes of the interfluves and generally consists of concave slopes.

The distinction was made because all the major gully erosion is confined to the lower slopes (Unit 4b) and only sheet erosion is present on the upper slopes (Unit 4a). As discussed earlier it was because of this difference that cultural treatments were confined to Unit 4a. A reduction of run-off and an increase of seed supplies resulting from seed washing down from Unit 4a was relied upon to provide the impetus for stabilisation in Unit 4b.

Because of the importance of these units it was proposed to study their vegetation composition and condition in detail. Traverses could, however, only be completed on Unit 4a rather than on both of these units.

Recordings were made every 0.5 km and the dominant vegetation type noted (Introduced, Original or Pioneer) and a condition assessment made.

UNIT	....	....	....	4a. Upper Slopes of Interfluves (157.7 km² 13.2% of area).
Land System	....	....	....	Nelson.
Geology	....	....	....	Nelson, Panton and Negri River Shale all of which are lower Middle Cambrian in age.
Landform	....	....	....	The upper slopes of long moderately sloping interfluves of an inland drainage system.
Soils	....	....	....	Fine textured calcareous soils of the Negri Family derived from Nelson, Panton and Negri River Shales.
Vegetation	....	....	....	The pastures are open grasslands consisting of a mixture of arid short grasses or original species, pioneer species and introduced species. The arid short grasses were found to be dominant over approximately 44% of the area and consisted of <i>Enneapogon polyphyllus</i> (limestone grass), <i>Eragrostis</i> sp (wire grass), <i>Aristida contorta</i> (wind grass) and <i>Sporobolus australasicus</i> (fairy grass). The introduced species were dominant over approximately 47% of the area and consisted of <i>Cenchrus ciliaris</i> (buffel grass), <i>Cenchrus setiger</i> (Birdwood grass) and <i>Aerva javanica</i> (kapok bush). The pioneer species were dominant over approximately 8% of the area and consisted of <i>Salsola kali</i> (roly-poly) <i>Ptilotus exaltatus</i> (mulla-mulla), <i>Boerhavia diffusa</i> (tar-vine) and <i>Pterigeron odoratus</i> (smelly bush).
Erosion	....	....	....	Extensive sheet erosion has removed up to 40cm of topsoil in places. There is no gully erosion. Micro-terracing is prominent throughout.
Stability	....	....	....	The fine texture of this soil makes it extremely susceptible to erosion and it relies on a good vegetative cover for stability. Cover was removed by over grazing and large areas were extensively eroded. Stability has increased in recent years with the removal of stock and cultural regeneration methods.

Condition The overall condition of this unit is fair to good. A breakdown of the condition of the various vegetation types is as follows. The data were derived as previously described.

Dominant Vegetation	% total area	Condition	Score
Introduced	48	Fair-good	2.4
Original	44	Fair-good	2.5
Pioneer	8	Poor	3.9
TOTAL	100	Mean Fair-good	2.5

It can be seen that the introduced species seeded in the regeneration project make a large contribution to the present condition of this unit. This contribution comes from both the area provided with vegetative cover (48%) and the fact that the areas where the vegetation is dominated by introduced species have slightly better condition score than the other two vegetation types. It can only be assumed that without the introduced species both vegetative cover and overall condition would be greatly reduced.

Regeneration work Stock were excluded. As far as possible the whole area was treated by extensive strip cultivation and reseeded with the introduced species *Cenchrus ciliaris*, *Cenchrus setiger* and *Aerva javanica*.

Response Very good overall both to the exclusion of stock (44% of the area dominated by original species) and to the cultural treatment (48% of the area dominated by introduced species) with the poor pioneer dominated areas only 8%.

Capability assessment Now: In its present condition this unit has low to moderate capability. In most cases the vegetative cover has re-established well and is continuing to improve in density and quality.

Under controlled conditions the unit could currently support light stocking of about 4 c.u. km⁻² and pasture condition could be expected to improve. Strict pasture monitoring and control of stock would be essential in any grazing programme.

Potential: Potential capability of this unit is moderate.

It appears likely that the final composition of most of the pastures will be a mixture of arid short grasses and the introduced species on roughly equal proportions. These pastures are attractive to stock and supply better quality grazing than many other areas. Potential carrying capacity would be about six to eight c.u. km⁻².

The unit is sensitive to use and any stocking programme will require close monitoring and supervision to ensure that the stability of the system is maintained.



Plate 8. Crest and upper slopes of interfluves (1976) with small bare area in foreground but generally showing good recovery of vegetation.

UNIT	4b. Lower Slopes of Interfluves (147·78 km², 12·4% of area).
Land system	Nelson.
Geology	Nelson, Panton and Negri River shale which are lower Middle Cambrian in age.
Landform	Lower slopes of long interfluves of inland erosional plain. Interfluves are up to 18 km long. Lower slopes sometimes exceed 2°.
Soils	Fine textured calcareous soils of the Negri Family derived from the Nelson, Panton and Negri River Shale.
Vegetation	Originally this unit was an open grassland of the arid short grasses <i>Enneapogon polyphyllus</i> (limestone grass) <i>Aristida contorta</i> (wind grass) <i>Sporobolus australasicus</i> (fairy grass) and <i>Eragrostis</i> sp (wire grass). However, much of this unit has suffered severe gully erosion along drainage lines and the eroding areas from adjacent areas have merged to form large areas of "badlands" some of which have eroded right back up to the tops of the interfluves. These areas are still almost bare of vegetation or carrying only pioneer species such as <i>Boerhavia diffusa</i> (tar vine) <i>Salsola kali</i> (roly-poly) <i>Ptilotus exaltatus</i> (mulla-mulla) and <i>Trichodesma zeylanicum</i> .
Erosion	Introduced species which have been seeded up slope (Unit 4a) have washed down and colonised in the small pockets of depositional silt in the gullies. These are <i>Cenchrus setiger</i> (Birdwood grass) <i>Cenchrus ciliaris</i> (buffel grass) and <i>Aerva javanica</i> (kapok bush). Severe erosion has occurred over large areas of this unit. Gully erosion is very widespread with some gully systems being up to two km long and hundreds of metres wide. In places where gully systems have merged, large areas of "badlands" have resulted. Gullies up to six to seven metres deep are very common.

Stability ....	....	....	<p>This unit is extremely unstable due to the steep slope, fine soil, and massive run-off which comes from upper slopes. Limited stability has been achieved by the revegetation of the upper slopes which has reduced both the volume and speed of the run-off. Some stability has been achieved towards the lower reaches of the gully systems where the deposition of silt has taken place and revegetation has occurred in the gully floors.</p> <p>Overall the erosional status of this unit is still highly mobile and hence stability is very low. Stability index four to five.</p>
Condition ....	....	....	The majority of this unit is still in poor condition.
Regeneration work ....	....	....	Exclusion of all stock. Cultivation and seeding upslope on Unit 4a which decreased the run-off down on to this unit and supplied seed in the silt that was washed down.
Response ....	....	....	Variable, but generally some stabilisation in most of the gully systems. Small erosional systems still exist within the gullies and will remain until a new equilibrium is reached. Vegetation is still very sparse.
Capability assessment ....	....	....	<p>Now: Capability assessment is very low. These areas should not be stocked. However, apart from fencing these areas out it would be impossible to stock the other land units which border this unit. Whether fencing out is a practical solution is very debatable and a more practical approach may be to exclude them in the stocking rate assessment of any area that is to be stocked. In their present form they are not very attractive to stock.</p> <p>Potential: Future capability is low because of the massive loss of soil. The dissected nature of this country makes it doubtful whether the original potential of this unit will ever be achieved.</p>



Plate 9. Lower slopes of interfluvial showing severe gully erosion.

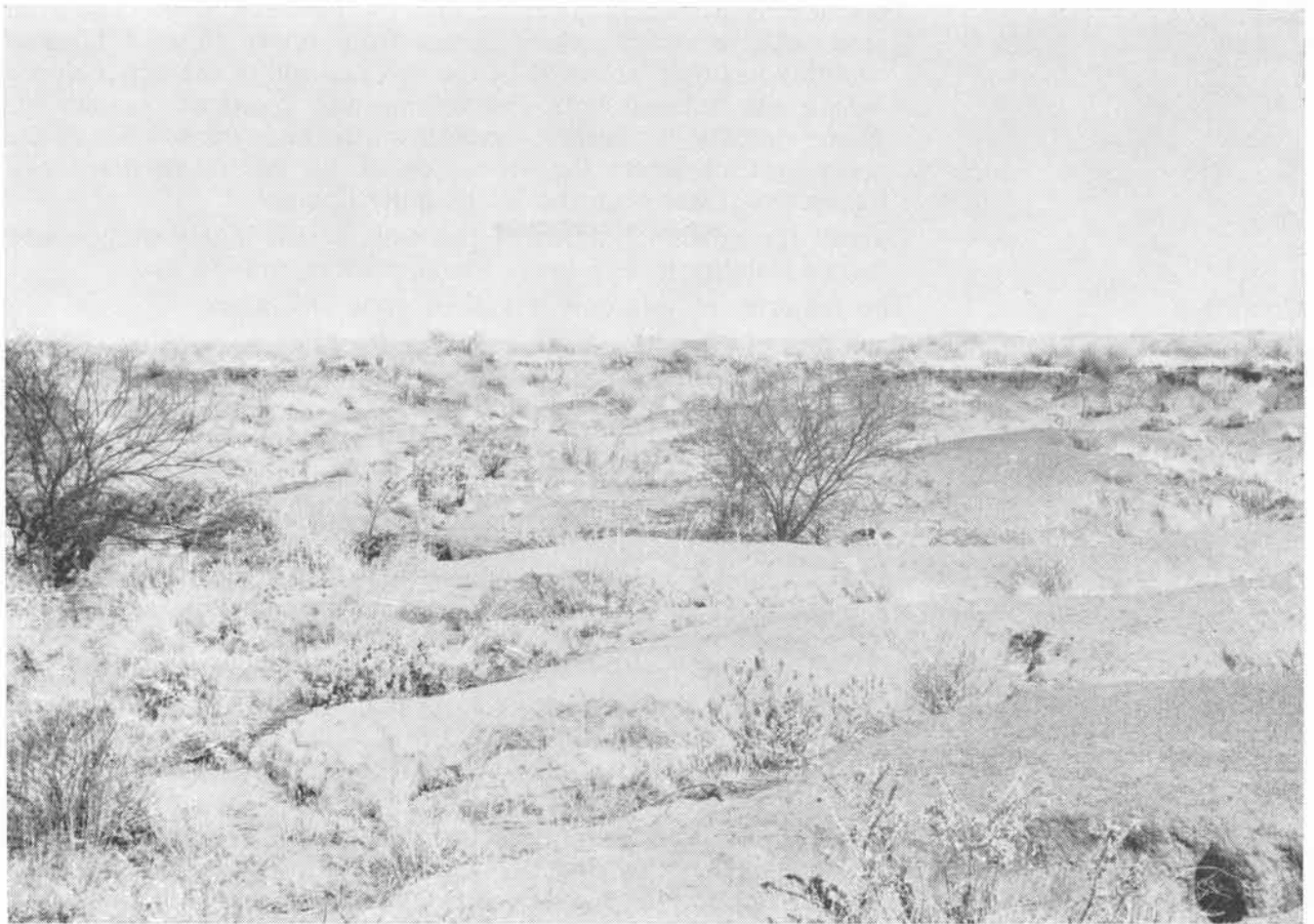


Plate 10. Lower slopes with vegetation establishing in gully bottoms where silt has been deposited.

UNIT	....	....	....	5. Levee Backslopes (101·8 km², 8·5% of area).
Land system	....	....	....	Nelson.
Geology	....	....	....	Quaternary alluvia.
Landform	....	....	....	Depositional alluvial plains along the major rivers.
Soils	....	....	....	Alluvial soils, generally fine textured uniform soils.
Vegetation	....	....	....	Open woodland of <i>Eucalyptus dichromophloia</i> (variable barked bloodwood) and <i>Eucalyptus microtheca</i> (coolibah). The understorey consists of a mixture of <i>Enneapogon polyphyllus</i> (limestone grass), <i>Eragrostis falcata</i> , <i>Aristida browniana</i> (feather top three awn), <i>Chrysopogon fallax</i> (ribbon grass) and <i>Heteropogon contortus</i> (black speargrass). Minor components of the understorey are <i>Sehima nervosum</i> (white grass) and <i>Themeda australis</i> (kangaroo grass). Seeds of the introduced species of <i>Cenchrus ciliaris</i> (buffel grass), <i>Cenchrus setiger</i> (Birdwood grass) and <i>Aerva javanica</i> (kapok bush) have been washed along by run-off and colonised along the levees of the rivers.
Erosion	....	....	....	Some gully erosion occurs along the river frontage and in some cases has eroded back into the levee backslope.

Stability ....	....	....	Generally stable because of the flat nature and good vegetative cover of this unit. Stability Index 1 to 2.
Condition ....	....	....	Good
Regeneration work ....	....	....	Exclusion of stock. No cultural or reseeding work.
Response ....	....	....	Very good. The lack of slope, apart from in the vicinity of fringing gullies, prevented great loss of topsoil and this unit responded very well to treatment.
Capability assessment ....	....	....	<p>Now: Capability assessment is moderate. Caution should be used when stocking this unit because of its proximity to the river. Ideally river frontages should be fenced off, to stop the congregation of large numbers of cattle along the river which greatly increases the stocking pressure. Any stocking would have to be subject to close monitoring and control if the frontage was not fenced.</p> <p>Potential: Future capability is moderate to high providing the river frontage is protected. This can be achieved using various methods. While the majority of the frontage can be fenced "lead in" fences to specific watering points on the river at points where the banks are relatively stable could be constructed. Alternatively water may be pumped from river pools back on to this unit. This unit could be stocked at 6 to 7 c.u. km⁻².</p>



Plate 11. Levee backslopes showing mixed pastures and bloodwood trees.

UNIT	....	....	....	6. Levees, Banks and Streamlines (97·44 km², 8·18% of area).
Land system	....	....	....	Nelson.
Geology	....	....	....	Quaternary alluvia.
Landform	....	....	....	Margins of creeks and rivers, sometimes steeply sloping.
Soils	....	....	....	In most cases soils are alluvial soils, fine textured with a uniform profile.
Vegetation	....	....	....	Woodland fringing communities of <i>Eucalyptus camaldulensis</i> (river gum), <i>Terminalia arostrata</i> (nutwood) and <i>Eucalyptus microtheca</i> (coolibah). The under storey consists of perennial grasses including <i>Chrsopogon fallax</i> (ribbon grass), <i>Heteropogon contortus</i> (black speargrass), <i>Sehima nervosum</i> (white grass), <i>Themeda australis</i> (kangaroo grass) and the introduced species of <i>Cenchrus ciliaris</i> (buffel grass), <i>Cenchrus setiger</i> (Birdwood grass) and <i>Aerva javanica</i> (kapok bush). The stands of the <i>Cenchrus</i> species are particularly vigorous along many of the river banks.
Erosion	....	....	....	Major erosion in the form of fringing gullies exists along the banks of the larger creeks and rivers. These have resulted from cattle pads subjected to massive run-off from the bare areas up slope. Many of these gullies have now stabilised to varying degrees.
Stability	....	....	....	The stability of this unit cannot be considered in isolation as its stability depends very much on the stability of the units immediately upslope. Following the removal of cattle and the revegetation of large areas run-off has been greatly reduced and stability increased. Stability Index—variable.
Condition	....	....	....	Good.
Regeneration work	....	....	....	Exclusion of stock. No cultivation or seeding done, however, the introduced species, <i>Cenchrus</i> and <i>Aerva</i> have washed down and have established over much of the streamlines and associated fringing gullies.
Response	....	....	....	Very good. Areas adjacent to creeks and rivers have a better water regime and this has enabled this area to recover well. Many large fringing gullies have stabilised very well, particularly due to good establishment of <i>Cenchrus setiger</i> and <i>C. ciliaris</i> .
Capability assessment	....	....	....	Now: The potential of this unit is limited because of its small area and the fragile nature of the river bank. Areas along the major rivers should be fenced off where practicable. Stocking rate assessment for present condition is three to four c.u. km ⁻² . Potential: Capability assessment is low to moderate. Maximum potential stocking rate is probably only about four c.u. km ⁻² .



Plate 12. Bank along streamline with vigorous Birdwood grass and native species.

UNIT	....	....	7. Rounded Antrim Hills (6.57 km², 0.5% of area).
Land system	....	....	Antrim.
Geology	....	....	Basaltic Antrim volcanics, middle Lower Cambrian in age.
Landform	....	....	Rounded hills.
Soils	....	....	Very poorly developed, much rock outcrop with basalt boulders.
Vegetation	....	....	Low open woodland of <i>Eucalyptus brevifolia</i> (snappy gum) and <i>Eucalyptus argillacea</i> (southern box) over a lower storey of hard spinifex consisting of <i>Triodia wiseana</i> (limestone spinifex) and <i>Triodia intermedia</i> (lobed spinifex).
Erosion	....	....	Virtually nil.
Stability	....	....	Inherently stable. Stability Index 1.
Condition	....	....	Very good.
Regeneration work	....	....	Nil.
Response	....	....	Not applicable.
Capability assessment	....	....	Now: Very low because of the unattractive pastures. Stocking rate of 1.2 c.u. km ⁻² . Potential: Potential carrying capacity will remain at 1.2 c.u. km ⁻² .

UNIT	8a. Stony Lowlands (134.5 km², 11.3% of area).
Land system	Elder.
Geology	Elder sandstone of Middle Cambrian age.
Landform	Undulating stony lowlands.
Soils	Skeletal soils with sand in between outcrops of sandstone.
Vegetation	Low open woodland of <i>Eucalyptus pruinosa</i> (silver-leafed box), <i>Eucalyptus dichromophloia</i> (variable barked bloodwood) and <i>Lysiphyllum cunninghamii</i> (bauhinia) with a ground storey of strong tussock grasses including <i>Heteropogon contortus</i> (black speargrass), <i>Aristida latifolia</i> (feathertop three awn), <i>Chrysopogon fallax</i> (ribbon grass) and <i>Aristida contorta</i> (wind grass). Small pockets of <i>Enneapogon polyphyllus</i> (limestone grass) and <i>Salsola kali</i> (roly-poly).
Erosion	Very little due to the inherently stable nature of the unit. Water infiltration rates are very high because of the sandy nature of the soil and there is very little run-off.
Stability	Extremely stable. Stability index 1.
Condition	Very good.
Regeneration work	Exclusion of stock. No seeding or cultural treatment.
Response	Fair. Pastures were mostly in good condition prior to treatment, condition has improved slightly.
Capability assessment	Now: Capability assessment is moderate. Pastures are rather unpalatable and stocking rate assessment is about four to five c.u. km ² . Potential: The condition of this pasture is good and not likely to improve. Potential carrying capacity will remain at four to five c.u. km ⁻² .

UNIT	8b. Sandstone Hills (34.99 km², 2.9% of area).
Land system	Elder.
Geology	Elder sandstone of Middle Cambrian age.
Landform	Massive sandstone outcrops.
Soils	Mostly rock outcrops with a few pockets of shallow sands.
Vegetation	<i>Eucalyptus brevifolia</i> (snappy gum) and <i>Eucalyptus pruinosa</i> (silver-leafed box) woodland with an under storey of <i>Plectrachne pungens</i> (curly spinifex), <i>Triodia pungens</i> (Soft spinifex) and <i>Triodia</i> sp. (hard spinifex).
Erosion	Nil.
Stability	Very stable. Stability index 1.
Condition	Very good.
Regeneration work	Nil.
Response	Not applicable.
Capability assessment	Now: Although condition is excellent capability assessment is very low. Pastures are unattractive and stocking rates are only about 1.2 c.u. km ⁻² . Potential: Potential carrying capacity will remain at about 1.2 c.u. km ⁻² .

UNIT	8c. Sandy Lower Slopes (50.66 km², 4.2% of area).
Land system	Elder.
Geology	Elder Sandstone of Middle Cambrian age.
Landform	Small lower slopes up to the sandstone outcrops.
Soils	Deep red sands.
Vegetation	Open woodland of <i>Eucalyptus pruinosa</i> (silver-leaved box) and <i>Lysiphyllum cunninghamii</i> (bauhinia) with a ground storey of <i>Aristida latifolia</i> (feathertop three awn), <i>Aristida contorta</i> (wind grass) and <i>Triodia</i> spp.
Erosion	Nil.
Stability	Its coarse texture and high infiltration rates make this soil very stable. Stability index 1.
Condition	Very good.
Regeneration work	Exclusion of stock, no cultural or seeding treatment.
Response	Fair. Pastures were mostly in good condition prior to treatment, condition has improved slightly.
Capability assessment	Now: Condition is very good and will not improve greatly. Capability assessment is low because pastures are relatively unattractive to livestock. Stocking rate 2.4 c.u. km ⁻² . Potential: As for the present. Stocking rate 2.4 c.u. km ⁻² .

UNIT	9. Sandy Undulating Lowlands (39.28 km², 3.3 of area).
Land system	Buchanan.
Geology	Elder sandstone which is Middle Cambrian age.
Landform	Gentle slopes and crests of gently undulating landscape.
Soils	Deep red sand.
Vegetation	Open woodland of <i>Eucalyptus pruinosa</i> (silver-leaved box) and <i>Lysiphyllum cunninghamii</i> (bauhinia) with a grassy ground storey of <i>Aristida latifolia</i> (feathertop three awn), <i>Aristida browniana</i> (three awn), <i>Chrysopogon fallax</i> (ribbon grass), <i>Enneapogon polyphyllus</i> (limestone grass) and <i>Triodia</i> spp.
Erosion	Very little erosion because of the coarse textured nature of the soil and the high infiltration rates.
Stability	Extremely stable. Stability index 1.
Condition	Very good.
Regeneration work	Exclusion of stock, no cultural or seeding treatment.
Response	Small. Pastures little used by livestock and condition prior to treatment was mostly good.
Capability assessment	Now: The condition of this pasture is very good and could not be expected to improve much. The capability assessment is moderate to low because of the unpalatable nature of the pastures. Stocking rate is estimated at about 4 c.u. km ⁻² . Potential: As for the present situation with stocking rate of about 4 c.u. km ⁻² .

SUSCEPTIBILITY TO EROSION

Different units reacted characteristically to the erosional forces. They are summarised in the following table and described in the following section.

		Erosion	
		No	Yes
Vegetation Degradation	No	1a; 1c; 2a; 7; 8a; 8b; 8c; 9. Total Area; 334.29 km ² .	
	Yes	1b; 2b; 3; 5. Total Area; 454.27 km ² .	4a; 4b; 6. Total Area; 402.96 km ² .

Units 1a; 1b; 1c; 2a; 2b.

These units are derived from limestone and have skeletal soils with a large proportion of rock on the surface. These units carry either *Triodia* pastures or arid short grass pastures. The *Triodia* pastures are unattractive to stock and suffered little degradation, however, the short grass pastures were severely degraded.

Both the rocky nature of the soil and the lack of steep slopes prevented erosion even in areas bared by vegetation degradation.

Unit 3

This unit is the black soil plain areas which carry *Astrelba* and other perennial grasses. These were badly degraded. The soils are extremely heavy clays and have very little slope and suffered no erosion even when bared of vegetation.

Unit 4a and 4b

These units are derived from shale parent material. They carry short grass pastures which were very badly degraded and they have suffered very severe erosion. Several factors contribute to this erosion susceptibility.

- Soils derived from shale material are extremely fine textured calcareous soils which powder very quickly following surface disturbance. With the removal of the vegetation, the surface of the soil was disturbed by stock moving over these areas. The action of either wind or high intensity rainfall from tropical downpours quickly removed the disturbed topsoil. Vast gully systems expanded often from what were initially cattle pads traversing down the slope to water in river pools.

- The slope of Units 4a and 4b is often greater than 1° and up to 2.5° and this accelerates the flow of any water over the surface, greatly increasing its ability to remove loose topsoil.
- Where the cuesta line (Unit 2a) is above Unit 4b the steeper slopes cause a large volume of run-off and this in turn caused very extensive gully erosion and the formation of "badlands". These areas generally exhibited the worst erosion on the catchment and still remain the least stable of the eroded areas. In places up to five and six metres of topsoil was lost and although there has been no grazing pressure for a long period of time plant growth is still very sparse.

Erosion terracing is a feature of the erosion on Unit 4a. This consists of small steps down the slope with vegetation on the lower parts and bare eroding faces behind and up to the foot of the next step above. It appears as though material from the bare eroding faces was transported down by water. However, when passing through the vegetation the water was slowed considerably and much of the material was deposited. This promoted further growth of the vegetation and the step was further built up.

This phenomenon was recorded by Medcalf (1944). It is not known whether it occurred under the natural situation. However, it is suggested that some artificial disturbance would be required to initiate the process and hence it is suggested that it could be a recent phenomenon in the area.

Units 5 and 6

The soils of these two units are of alluvial derivation. The pastures carried on these areas are frontage pastures which consist of mainly *Chrysopogon fallax* (ribbon grass), *Sehima nervosum* (white grass) and *Heteropogon contortus* (black spear grass).

The pastures were very badly degraded, particularly because of the close proximity to the river and the congregation of cattle on these areas.

The soils of these units are very fine textured (very similar to the soils of Units 4a and 4b) and have a high erosion susceptibility. Although the levee backslope (Unit 5) was badly degraded there is very little slope and this helped to prevent severe erosion. The river frontage (Unit 6) has eroded badly in many places. The continual movement of stock up and down the steep river

banks caused deep pads to form. These pads were quickly eroded by the action of water and wind and soon formed massive fringing gullies.

Unit 7

This unit consists of rocky basalt hills which carry *Triodia* spp. (hard spinifex) pastures. These pastures are not very attractive to stock and the grazing pressure exerted on them is negligible. A continuing vegetative cover plus the very resistant nature of the soil has resulted in no erosion of these areas.

Unit 8a, 8b and 8c

These units are derived from Elder Stone. The soil of the three units varies from no soil development with solid rock outcrop (8b), to skeletal soils through to deep red sands. The pastures carried on these units are either spinifex pastures (*Plectrachne pungens* and *Triodia* spp)

or very strong perennial tussock grasses such as *Heteropogon contortus* (black spear grass) and *Sehima nervosum* (white grass).

Both these pasture types are rather unattractive to stock and hence heavy grazing pressure has never been exerted on these units and virtually no degradation of the pastures occurred. The lack of grazing pressure coupled with the stable nature of the soils has resulted in only very minor erosion in small areas.

Unit 9

This unit represents the sand areas of the Buchanan land system and is very similar to Unit 8c.

The soils are deep red sands and the pastures are of the strong perennial tussock grass type, which results in low grazing pressure, very little run-off and virtually no erosion.

DISCUSSION

Improved vegetative cover

There is no doubt that, in terms of re-establishment of vegetation over extensive areas of previously bare and degraded country the project has been successful. In some parts, for instance, pasture density is such that fire control is now one of the major problems within the project area. Severe fires were experienced in some paddocks in 1976, and because of the large quantities of fuel present, proved very difficult to control. Areas burnt out were approximately 35 000 hectares.

The two regeneration techniques adopted, namely protection from grazing and cultivation and seeding operation have each contributed to recovery.

The types of vegetation now present fall into two categories:

- Units where native vegetation has recovered.
- Units where vegetation has been altered by the successful establishment of introduced species.

The majority of the units in the study area fit into the first category. These units are those which have not suffered soil degradation and erosion (Units 1a, 1b and 1c; 2a and 2b; 3; 5; 7; 8a; 8b and 8c; 9) and protection from grazing brought about relatively rapid pasture recovery.

The pastures on these units are probably very similar to the original pastures present before settlement. There are now a few introduced plants (either *Cenchrus* or *Aerva*) established but nowhere do they dominate. In general all these pastures are in good condition.

Two factors which enabled this recovery were the retention of topsoil and the residual seed supply in the soil. These factors should always be considered when looking at degraded areas with a view to regeneration strategies.

On the land units which fall into the second category (Units 4a, 4b and 6) it is extremely unlikely that protection alone would have brought about recovery on the worst areas in the time period 1960 to 1976.

The use of expensive cultivation has been justified in that excellent establishment of *Aerva javanica* (Kapoc bush) and moderate establishment of *Cenchrus setiger* (Birdwood grass) and *C. ciliaris* (buffel grass) has occurred in a very short time and now is the dominant vegetation type over 48 per cent of Unit 4a. Cultivation has also greatly accelerated the recovery of the native species by initiating water penetration and supplying favourable seed bed conditions.

As discussed before, Unit 4a has been subjected to closer study than the other units in order to ascertain the success of the reseeding operation. The percentage of the areas dominated by the various vegetation types are:—

	% Area Dominant	Condition
Original	44	2.5
Introduced	48	2.4
Pioneer	8	3.9

With a 48 per cent dominance of introduced species the seeding operations have obviously been the major factor in the recovery of these eroded units to their present condition of fair to good.

Ryan and Payne (1976) found in line transect studies on Unit 4a that plant density indices as

determined by a method similar to that of Parker (1951) increased from an average of 0.82 to 2.2 over the 12 years of sampling from 1962 to 1974. Over the same period of time plant litter indices increased from 13.1 to 28.9. Plates 13 and 14 illustrate the improvement which has taken place on a transect study site over the period 1963–1974.



Plate 13. Study transect No. 2, September 1963—bare ground and a few pioneer species.



Plate 14. Study transect No. 2, July 1974—dense stands of introduced kapok bush (Aerva javanica) with some grasses beneath the bushes.

Some of the factors which contributed to variability in the present composition of the vegetation on Unit 4a are:

- Position: Areas distant from water have not suffered as much degradation as those areas close to water. These have tended to be the areas where original species predominate.
- Erosion: Those areas which have lost more topsoil than surrounding areas tended to host pioneer plants and be the slowest to recover. This was indicated by the poor condition (3.9) of those areas where pioneer plants are dominant.
- Microclimate: Wetter areas encourage the growth of *Cenchrus* species and this is particularly evident where small hollows and depressions occur and water is trapped.
- Treatments: Although treatment was carried out over all areas of Unit 4a in the study area the results of this treatment have varied according to the time of planting and working and the seasonal conditions following the work. Rainfall variability in the area is considerable and the areas only a few kilometres apart often experience very different rainfalls, particularly in the early part of the season.

Following initial treatment some follow up work was carried out in between the original workings. Where good initial strikes were made then the follow up work started with a greater natural seed supply than follow up work done on areas where initial strikes had failed.

Reduced erosion and siltload in rivers

Evaluation of the effectiveness of treatments at controlling or reducing erosion is difficult. One way of measuring effectiveness is by estimating the silt load of the rivers. It is unfortunate that the gauging station used to make the initial readings when the dam was proposed was only a few kilometres from where the dam wall now stands and is under water. Because of this it is impossible to obtain before and after figures to quantify the success of the regeneration project.

There is however, much observational evidence that treatments have been effective at reducing erosion and soil losses. The following points should be considered.

- *Aerva javanica* (kapoc bush) is an excellent coloniser of large bare areas and has established well on many of these areas.

Although it is not the ideal plant to combat water erosion (c.f. big base perennial grasses) it is an excellent plant for reducing wind erosion.

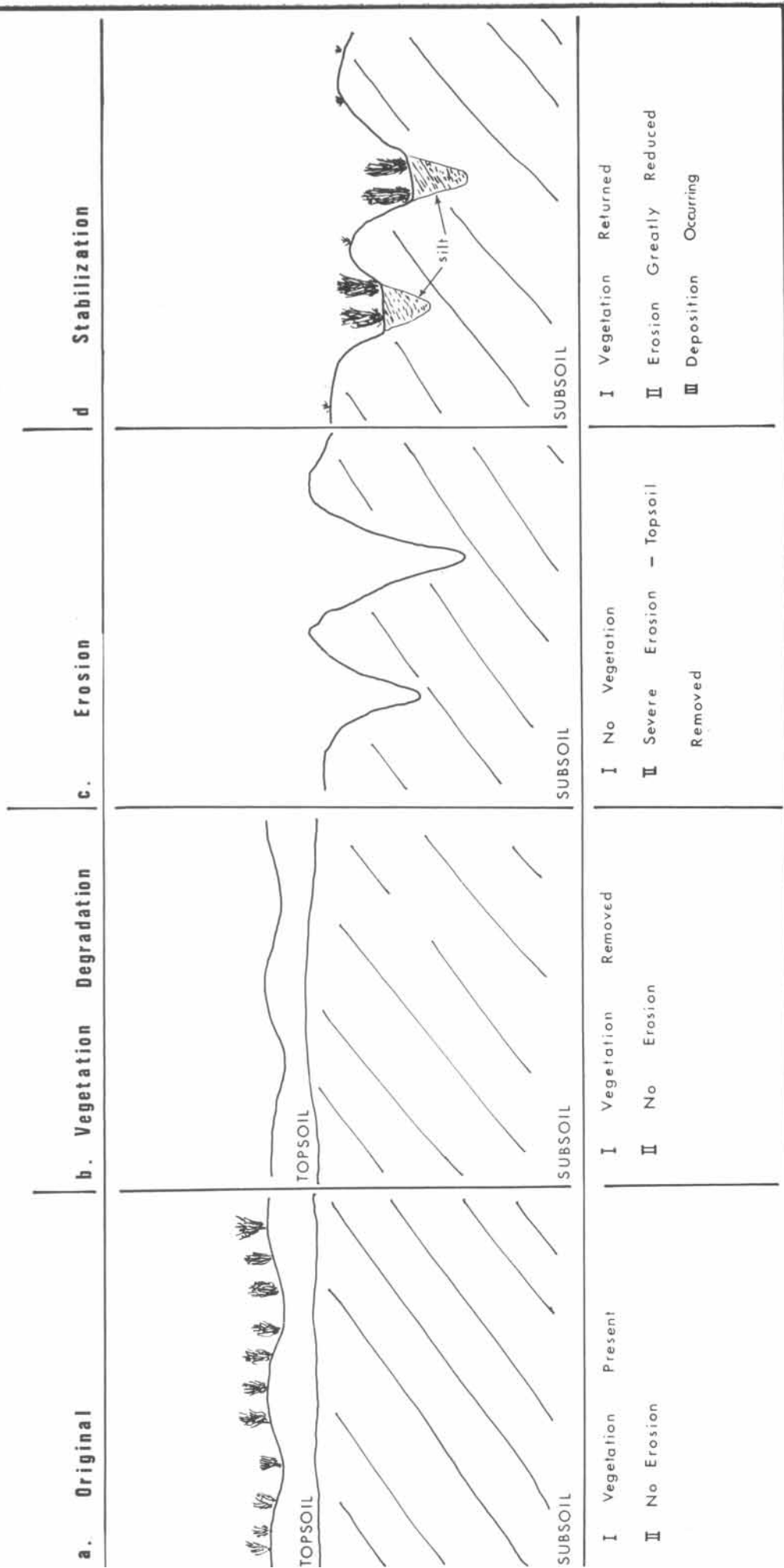
- *Cenchrus ciliaris* (buffel grass) and *C. setiger* (Birdwood grass) thrive wherever moisture conditions are better than average and have established well in these areas. This is particularly evident on the river banks and in the silted areas of the gully systems. Establishment of the introductions has stabilised these areas extremely effectively.
- A lot of the seeded areas have scattered *Cenchrus* plants throughout and as recovery continues the micro-environment should improve assisting the further establishment of *Cenchrus*.
- In those places where *Cenchrus* has been established in a pure stand then the protection offered to that country in the way of permanent vegetative cover is now greater than it was under the weakly perennial *Enneapogon* association.

In general the degradation trend has now been reversed and is now a regeneration trend. The increase in vegetation and surface litter (Ryan and Payne 1976) must increase water penetration by preventing surface sealing and slowing down run-off and those areas which have become revegetated now have wetter micro-environments. This coupled with the greatly increased seed supply can only compound the effect of the initial regeneration.

There is further observational evidence for the reduction of erosion and increasing stability. The large gully systems contained in the lower slopes of the interfluvies (Unit 4b) have all shown some stabilisation. Run-off has been reduced both in intensity and quantity and large amounts of seed have been washed down from above. Most growth has taken place where silt from above has been deposited. Many gullies now are in fact a series of small erosion regimes. Small active erosion sites in a gully may provide silt for a deposition area five to 10 metres farther down the gully.

This levelling effect will continue until overall stabilisation has been achieved. With every deposition of silt the gradient between the active erosional site and the depositional site is reduced and hence the speed of succeeding water flows will be reduced and their ability to transport material will be reduced. This will cause further deposition and hence the cycle will start again with the gradient being further reduced.

Figure 4 : Diagram of the Erosional Cycle



In smaller rills it is not unusual to find dense vegetation right down the rill line or gully path while the surrounding area may have sparse vegetation. Trapped silt in the rill is apparently more fertile and has more favourable moisture relationships than the surrounding subsoil and thus supports more growth (Figure 4).

Initial flows of rivers and creeks do carry a silt load but this must always be expected in this area where rivers rise and fall very quickly. Following these initial flows, however, the creeks and rivers clear very quickly and the silt load becomes negligible for the majority of the time they are flowing.

Although this report deals mainly with the solving of the erosion problem, little has been said concerning the causes of this massive erosion.

Three factors appear to have been necessary:—

- Palatable vegetation: The pastures were palatable and attractive to stock. The effect of heavy continuous stocking was such that the vegetative cover was removed, thus barring the soil to erosive influences.
- An erodible soil: The soils of the area have a very small particle size and a very even profile. This enabled the soil to be broken up by disturbances such as trampling by stock, the fine particles being removed by wind and water.
- Slope: In some areas where the slope was greater than 1° the movement of water was accelerated and greatly increased the rate of removal of unprotected soil.

FUTURE OF THE PROJECT AREA

In the area of study, there is no current regeneration work. Instead a policy of maintenance with regular destocking of the cattle that remain is being pursued.

Future use should be discussed in relation to the newly established vegetation rather than in terms of pasture potential. The correct framework for assessing future use is the present condition of the present pastures.

For all except Units 4a and 4b the condition of the pastures is good. The condition of Unit 4a is only fair to good and the majority of Unit 4b is in poor condition.

The initial aim of the project was to provide catchment protection and prevent the siltation of the dam, and this must be included in future land use systems. The alternative uses that can be considered for the future fall into three categories:

- Classification of the area as a catchment reserve to be managed along similar lines as at present.
- To continue the present policy of catchment protection to some point in the future and then re-introduce grazing to the area.

- To re-introduce controlled grazing in the near future.

The author is of the opinion that some grazing could be undertaken without catchment damage.

Paddock capabilities have been prepared using safe stocking rates for the present condition. These stocking rates, while conservative, should be adhered to in order to guarantee the continued maintenance of the vegetative cover. Where practicable Unit 4b should be fenced out as the condition of this unit is very poor. In paddock assessments, Unit 4b has been taken as zero stocking rate. Any further development should be carried out on units that are suited to intensive development.

Any stocking would necessitate very strict control and close monitoring and this responsibility would have to be borne by government agencies. The type of grazing system would have to be determined in conjunction with people with experience in handling large numbers of cattle over extensive areas.

CONCLUSION

There is little doubt that the majority of the erosion has been halted. This has been achieved by the revegetation of erosion prone areas. The regeneration project has resulted in a new vegetative cover being established over large parts of the area.

The majority of the area is in very good condition and judicious stocking would do little harm.

The management policy for the area up to this stage has been one of total protection. With the regeneration phase over and catchment protection achieved the policy should at least be reviewed and possibly modified to include the stocking of some areas.

ACKNOWLEDGMENTS

The author would like to express his appreciation to the officers of the Rangeland Management Division for their helpful and constructive criticism. Thanks must also go to Mr. Barry Francis for his assistance and to Mr and Mrs Graham Bell for their hospitality at Ord River Station.

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APPENDIX 1.

AREA SUMMARY AND CAPABILITY ASSESSMENT

TOTAL AREA: 119 152 hectares or 1 191.52 km².

Land Unit	Area (km ²)	Area (%)	Carrying capacity for present (1976) condition (c.u. km ⁻²)	Stock nos. (cattle units)
1b	136.04	11.41	5.5	748
1c	30.42	2.55	1.2	37
2a	37.70	3.16	4.0	151
2b	107.78	9.05	5.5	593
3	108.57	9.11	11.0	1194
4a	157.74	13.24	4.0	630
4b	147.78	12.40	Nil	....
5	101.88	8.55	6.5	662
6	97.44	8.18	3.5	341
7	6.74	.57	1.2	8
8a	134.50	11.29	4.5	605
8b	34.99	2.94	1.2	42
8c	50.66	4.25	2.4	122
9	39.28	3.30	4.0	157
Totals	1191.52	100.00		5290

APPENDIX 2.

PADDOCK SUMMARY AND CAPABILITY ASSESSMENT

PADDOCK: Black Gin Paddock.

TOTAL AREA: 8 770 hectares or 87.70 km².

Land Unit	Area (km ²)	Area (%)	Carrying capacity for present (1976) condition (c.u. km ⁻²)	Stock nos. (cattle units)
1b	37.23	42.45	5.5	205
1c	12.32	14.05	1.2	15
2a	2.46	2.80	4.0	10
2b	3.38	3.85	5.5	19
3	1.14	1.30	11.0	13
4a	4.25	4.85	4.0	17
4b	15.70	17.90	Nil	Nil
5	3.81	4.35	6.5	25
6	7.41	8.45	3.5	26
Totals	87.70	100.00		330

COMMENTS

In the use of this paddock the area west of the Forrest River should be fenced out and left destocked.

A continuation of the fence up along the west bank of the Forrest River would exclude large areas of Unit 4b.

Paddock: Charity Experimental Complex.TOTAL AREA: 4 062 hectares or 40.62 km².

Land Unit	Area (km ²)	Area (%)	Carrying capacity for present (1976) condition (c.u. km ⁻²)	Stock nos. (cattle units)
2a	3.30	8.12	4.0	14
2b	12.78	31.40	5.5	71
3	15.80	38.90	11.0	174
5	8.60	21.17	6.5	56
6	0.14	0.35	3.5	1
Totals	40.62	100.00		316

COMMENTS

A total of 135 415 animal grazing days per annum exist in this complex.

Paddock: Dough Boy Paddock: That portion of the paddock east of the Ord River and north of the Nicholson River.TOTAL AREA: 10 630 hectares or 106.30 km².

Land Unit	Area (km ²)	Area (%)	Carrying capacity for present (1976) condition (c.u. km ⁻²)	Stock nos. (cattle units)
2a	4.14	3.89	4.0	17
2b	34.16	32.14	5.5	188
3	20.68	19.45	11.0	228
4a	5.72	5.38	4.0	23
4b	5.81	5.47	Nil	Nil
5	28.12	26.45	6.5	183
6	7.67	7.22	3.5	17
Totals	106.30	100.00		666

Paddock: Duncan Paddock.TOTAL AREA: 1 069 hectares or 10.69 km².

Land Unit	Area (km ²)	Area (%)	Carrying capacity for present (1976) condition (c.u. km ⁻²)	Stock nos. (cattle units)
2a	0.46	4.30	4.0	2
2b	6.74	63.05	5.5	37
4a	1.63	15.25	4.0	7
6	1.86	17.40	3.5	7
Totals	10.69	100.00		53

COMMENTS

A total of 22 995 cattle grazing days per annum are available in this paddock.

Paddock: Eagle Hawk: That portion of the paddock east of the Ord River.

TOTAL AREA: 10 993 hectares or 109.93 km².

Land Unit	Area (km ²)	Area (%)	Carrying capacity for present (1976) condition (c.u. km ⁻²)	Stock nos. (cattle units)
4a	1.95	1.77	4.0	8
5	31.84	28.96	6.5	207
6	2.57	2.34	3.5	9
8a	26.72	24.31	4.5	120
8b	27.56	25.07	1.2	33
8c	19.29	17.55	2.4	46
Totals	109.93	100.00		423

Paddock: Fire Paddock.

TOTAL AREA: 628 hectares or 6.28 km².

Land Unit	Area (km ²)	Area (%)	Carrying capacity for present (1976) condition (c.u. km ⁻²)	Stock nos. (cattle units)
2a	0.46	7.32	4.0	2
2b	1.63	25.96	5.5	9
3	1.63	25.96	11.0	18
4b	0.70	11.15	Nil	Nil
6	1.86	29.61	3.5	7
Totals	6.28	100.00		36

COMMENTS

A total of 14 965 animal grazing days per annum are available in this paddock.

Paddock: Forrest Paddock (large).

TOTAL AREA: 8 936 hectares or 89.36 km².

Land Unit	Area (km ²)	Area (%)	Carrying capacity for present (1976) condition (c.u. km ⁻²)	Stock nos. (cattle units)
1b	44.15	49.41	5.5	243
1c	11.29	12.63	1.2	14
2a	4.65	5.20	4.0	19
2b	11.15	12.48	5.5	61
4b	10.22	11.44	Nil	Nil
6	7.90	8.84	3.5	28
Totals	89.36	100.00		365

PADDOCK: Forrest Paddock (small).TOTAL AREA: 511 hectares or 5.11 km².

Land Unit	Area (km ²)	Area (%)	Carrying capacity for present (1976) condition (c.u. km ⁻²)	Stock nos. (cattle units)
3	1.86	36.4	11.0	21
6	3.25	63.6	3.5	12
Totals	5.11	100.00		33

COMMENTS

A total of 14 235 animal grazing days per annum is available in this paddock.

PADDOCK: Kelly Paddock: That portion of the paddock in Western Australia and excluding the experimental complex.TOTAL AREA: 15 468 hectares or 154.68 km².

Land Unit	Area (km ²)	Area (%)	Carrying capacity for present (1976) condition (c.u. km ⁻²)	Stock nos. (cattle units)
1b	27.89	18.03	5.5	154
2a	8.37	5.41	4.0	34
2b	26.72	17.27	5.5	147
3	1.86	1.20	11.0	21
4a	46.15	29.84	4.0	185
4b	27.98	18.09	Nil	Nil
6	15.17	10.16	3.5	53
Totals	154.68	100.00		594

PADDOCK: Lagoon Paddock: That portion of the paddock which is in Western Australia.TOTAL AREA: 4 866 hectares or 48.66 km².

Land Unit	Area (km ²)	Area (%)	Carrying capacity for present (1976) condition (c.u. km ⁻²)	Stock nos. (cattle units)
2a	3.49	7.17	4.0	14
2b	0.93	1.91	5.5	5
4a	1.95	4.01	4.0	8
4b	2.88	5.92	Nil	Nil
6	5.11	10.50	3.5	18
8a	15.51	32.00	4.5	70
8b	6.97	14.32	1.2	8
8c	10.13	20.82	2.4	24
9	1.63	3.35	4.0	7
Totals	48.66	100.00		154

Paddock: Linnekar Paddock.TOTAL AREA: 25 788 hectares or 257.88 km².

Land Unit	Area (km ²)	Area (%)	Carrying capacity for present (1976) condition (c.u. km ⁻²)	Stock nos. (cattle units)
1b	26.77	10.38	5.5	147
1c	6.81	2.64	1.2	8
2a	4.38	1.70	4.0	17
2b	6.58	2.55	5.5	36
3	48.40	18.77	11.0	532
4a	59.37	23.02	4.0	237
4b	76.87	29.81	Nil	Nil
6	28.70	11.13	3.5	100
Totals	257.88	100.00		1 077

Paddock: Ord River Experimental Complex. This area includes the old Ord horse paddock, East and West Weanner paddocks, Bloodwood paddock, the Homestead, the 32-hectare complex and all airport and all reserve paddocks.

TOTAL AREA: 3 462 hectares or 34.62 km².

Land Unit	Area (km ²)	Area (%)	Carrying capacity for present (1976) condition (c.u. km ⁻²)	Stock nos. (cattle units)
2a	1.39	4.01	4.0	6
2b	3.25	9.39	5.5	18
3	10.92	31.54	11.0	120
4a	15.34	44.31	4.0	62
5	0.93	2.69	6.5	6
6	2.79	8.06	3.5	10
Totals	34.62	100.00		222

COMMENTS

A total of 95 265 cattle grazing days per annum are available in this complex.

Paddock: R. B. Paddock: That portion of the paddock which is in Western Australia.TOTAL AREA: 21 848 hectares or 218.48 km².

Land Unit	Area (km ²)	(%) Area	Carrying capacity for present (1976) condition (c.u. km ⁻²)	Stock nos. (cattle units)
2a	4.60	2.11	4.0	9
3	1.63	0.75	11.0	9
4a	15.80	7.23	4.0	29
4b	7.62	3.49	Nil	Nil
5	17.89	8.19	6.5	53
6	13.01	5.95	3.5	21
7	6.74	3.08	1.2	4
8a	91.84	42.04	4.5	189
8b	0.46	0.21	1.2	1
8c	21.24	9.72	2.4	23
9	37.65	17.23	4.0	69
Totals	218.48	100.00		407

Paddock: Robyn's Paddock.

TOTAL AREA: 1 487 hectares or 14.87 km².

Land Unit	Area (km ²)	(%) Area	Carrying capacity for present (1976) condition (c.u. km ⁻²)	Stock nos. (cattle units)
2b	0.46	3.09	5.5	3
3	3.95	26.56	11.0	44
4a	5.58	37.53	4.0	22
5	4.88	32.82	6.5	32
Totals	14.87	100.00		101

COMMENTS

A total of 43 800 cattle grazing days per annum exist in this paddock.

Paddock: Texas Paddock: That portion of the paddock east of the Ord River and south of the Negri River.

TOTAL AREA: 688 hectares or 6.88 km².

Land Unit	Area (km ²)	(%) Area	Carrying capacity for present (1976) condition (c.u. km ⁻²)	Stock nos. (cattle units)
3	0.7	10.17	11.0	8
4	5.81	84.45	6.5	38
8a	0.37	5.38	4.5	2
Totals	6.88	100.00		48