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# SPECTACULAR RECOVERY IN THE ORD RIVER CATCHMENT

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# SPECTACULAR RECOVERY IN THE ORD RIVER CATCHMENT

**Regeneration work on severely degraded country in what is now known as the Ord River Regeneration Reserve (ORRR) commenced in 1960. The ORRR is in the East Kimberley area of Western Australia with an associated small area in the Northern Territory. The work included strip contour cultivation and seeding (which proceeded at various levels of intensity during the 1960s, 1970s and 1980s), fencing and destocking of cattle by mustering over many years, and the eradication of donkeys.**

**In August 2002 a field inspection of much of the ORRR was undertaken by a group comprising one former and five current officers of the Department of Agriculture. The purpose of the inspection was to record and assess changes in vegetation and soils since the 1960s using repeat photography and ground observations.**

**The inspection was generally confined to the most sensitive land systems (Nelson and Gordon) in the Reserve which were severely degraded by the 1960s. In particular, every attempt was made to relocate and re-photograph sites (now termed 'heritage' sites) that had been initially established in the early 1960s.**

## Background

It is now 44 years since the start of the Ord River Regeneration Project in the East Kimberley area of Western Australia, the largest and most ambitious of its kind in Australian rangelands. The project was initiated because land degradation and erosion in parts of the Ord River catchment posed a sedimentation threat to the downstream reservoir (Lake Argyle) supplying the proposed irrigation area at Kununurra.

The project area (see Figure 1), which is now called the Ord River Regeneration Reserve (ORRR), initially covered about 10,000 $km^2$ of the total area of the catchment of Lake Argyle of 46,000 $km^2$ (Fitzgerald 1968). The area included all of Ord River and Turner cattle stations and parts of Flora Valley and other stations. It included the middle reaches of the Ord River and parts of large tributaries such as the Negri, Forrest, Nicholson, Turner, Elvire and Fox Rivers.

Following settlement in the 1880s, cattle numbers in the East Kimberley expanded rapidly, sustained by an abundance of surface waters and productive pastures. Station infrastructure (i.e. fences and artificial water points) was meagre and cattle control was limited to minimal manipulation of numbers on a broad scale, with virtually no control over where cattle concentrated. By the 1930s the dramatic increase in grazing pressure from cattle and feral donkeys, compounded by the effect of bushfires, was sufficient to exceed the resilience of the country (specifically parts of the Nelson, Gordon, Antrim and Elder land systems).

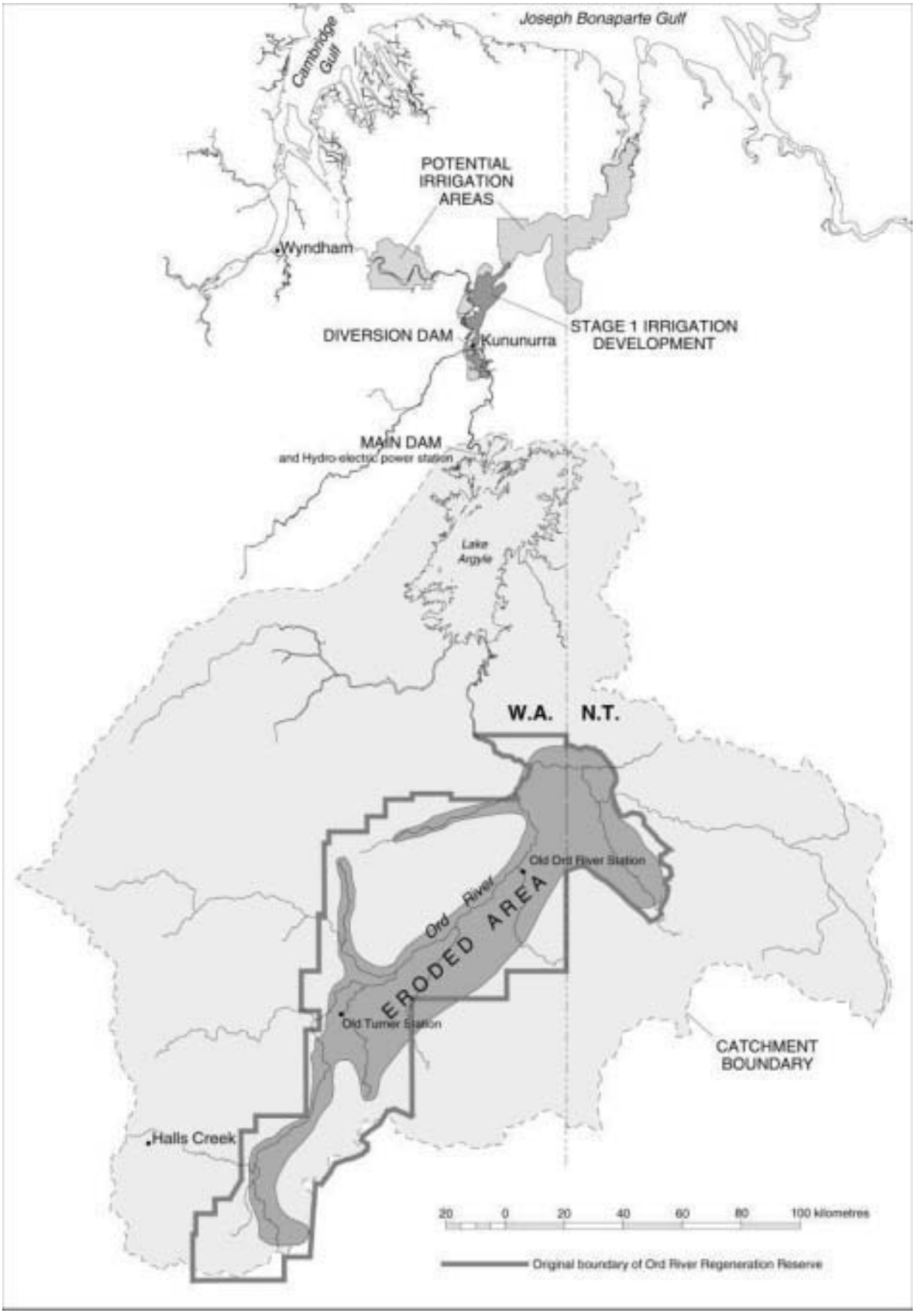


**Figure 1. Location of the Ord River Regeneration Reserve (ORRR).**

Large areas became degraded and eroded. The majority of the eroded country occurred on Ord River, Turner and Flora Valley Stations in Western Australia. However, a significant contiguous area also occurred on Mistake Creek Station in the Northern Territory in the catchment of the Negri River, a major tributary of the Ord. Erosion of the friable, calcareous soils of the area contributed enormous sediment loads to the Ord River, and it was later recognised that this had the potential to silt up the reservoir of the proposed dam for the Ord River Irrigation Scheme.

Although erosion in the Ord River catchment was described in the 1940s (Medcalf 1944, Teakle 1944), it was not recognised as being a problem of sufficient magnitude to warrant remedial action until plans to dam the Ord River were conceived. At the time the sediment load, estimated to average about 29 million tonnes per annum at Coolibah Pocket near the site of the present Ord Dam (Kata 1978), was considered a sufficient threat to the long term storage capacity of the dam to necessitate a stabilisation program on the most severely eroded parts of the catchment.

The regeneration project was commenced in 1960 by the Western Australian Department of Agriculture operating initially from a field camp on Turner Station and later from a base (ORRR depot) established on Ord River Station. In the late 1960s a second depot, Fox River Station (FRS), was established in the south of the project area on land previously included in the Flora Valley Station lease. The project commenced under a cooperative arrangement with station lessees. However, the arrangement did not prove workable and in 1967 Ord River and Turner Stations and parts of the Flora Valley, Ruby Plains and Elvire Stations were resumed by the State government and the area gazetted as a Water Catchment Reserve. In 1987 a large part of the area west of the Ord River (which was not badly degraded) was gazetted as the Purnululu (Bungle Bungle) National Park and Conservation Reserve and is now managed by the Department of Conservation and Land Management.

## Photographs of ORRR country in early 1960s

**Photo 1. Severely sheet eroded plains of the Nelson land system in July 1963. For a short time after the wet season these plains supported sparse miniature annual grasses and herbs but, for most of the year, they were bare and exposed to the action of wind and water.**

**Photo 2. Degraded and sheet eroded plains near Mt Panton (NT) in July 1965. A few residual patches support sparse grasses but most of the surface is bare.**

**Photo 3. Degraded plains of the Nelson land system which previously supported biennial and perennial grasses with a scattered overstorey of small eucalypt trees. June 1962.**

**Photo 4. Active streambank erosion on a minor tributary of the Ord River. March 1964.**

**Photo 5. Bare and eroded slopes and plains of the Nelson land system in August 1963. Note the dead trees in the foreground, suggesting how degraded this land had become.**

**Photo 6. This photograph, taken in August 1963, shows a massive gully system on the lower plains of the Nelson land system. A line of low limestone cuestas in the background stands above the red plains. Vegetation is restricted to bands of sparse grass on micro-terraces arranged more or less on the contour and separated from each other by narrow strips of bare sheet-eroded ground.**

**Photo 7. Gullies on the lower slopes of the Nelson land system were frequently incised many metres through the calcareous red soils and underlying soft shale and siltstone sediments. March 1964.**

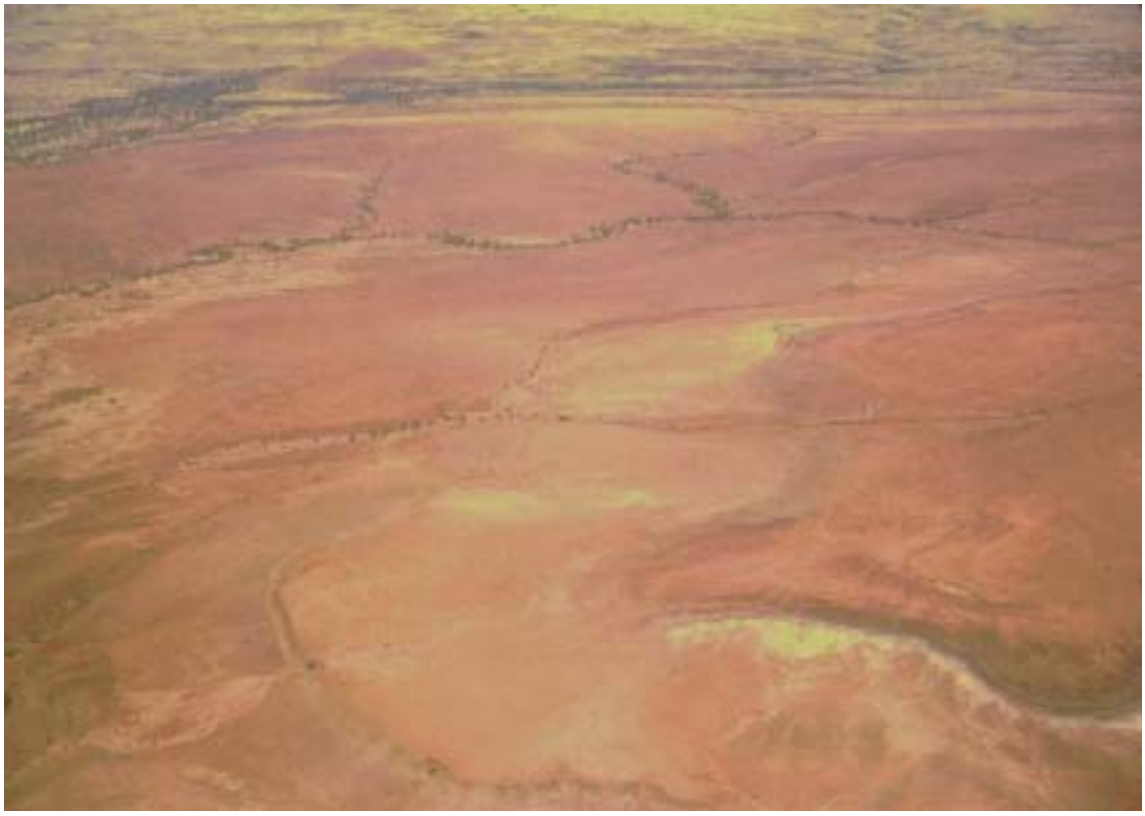

**Photo 8. Bare red ridges and slopes of the Nelson land system. August 1963.**

**Photo 9. Active gully erosion on alluvial frontage plains of the Ord River with White Mountain Range in the background. October 1963.**

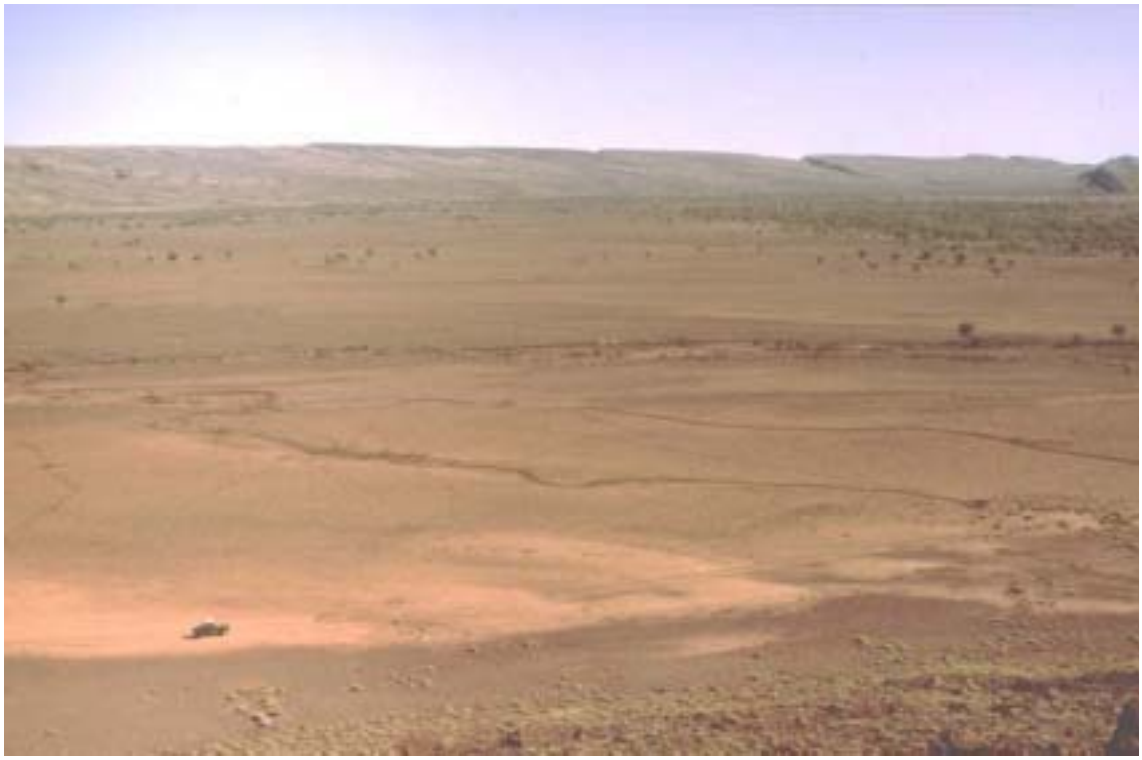

**Photo 10. Bare and eroding plains of the Gordon land system in the Elvire River valley. Originally part of Flora Valley Station, now Fox River Station. July 1964.**

**Photo 11. Ord River Regeneration Reserve base depot from the air. August 1963.**

# Description of the project area

## Climate

The area has a hot, strongly seasonal monsoonal climate characterised by a rainy season of about five months (November-March) and a dry season with very little rainfall for the remainder of the year. The mean annual rainfall (July to June) is 513 mm at the ORRR depot (now abandoned) and 461 mm at Fox River Station (see Table 1)[1]. Mean annual rainfall declines by about 1 mm/km southwards across this part of the Kimberley (Bureau of Meteorology 1996).

Rainfall variability for any one month can be high. Annual rainfall variability is moderately reliable at ORRR, but less reliable at Fox River Station (using the variability index of Bureau of Meteorology 1996, p. 17). Rains generally begin with thunderstorms (the normal start to the wet season) which can generate large volumes of run-off due to intense and sustained rainfall. The maximum daily rainfall recorded at ORRR depot was 194 mm in February 1995, while consecutive days of rainfall have produced over 300 mm in about 8 per cent of years.

Figures 2 and 3 show the annual deviations from the mean rainfall at ORRR depot and Fox River Station since 1959/60. In general, the early years of the project were characterised by below average seasons but runs of very good seasons occurred from the mid-1970s to the early 1980s and also during the 1990s from 1992/93 onwards.

Average daily maximum temperature ranges from 27.1°C in July to 38.4°C in November. Mean monthly relative humidity at 3 p.m. is 22% in July and 20% in November. Mean monthly evaporation rates range from 183 mm in June to 360 mm in October, with an annual rate of 3,248 mm (Halls Creek records, Bureau of Meteorology 1996).

**Table 1. Mean and median rainfall (mm) at Ord River Regeneration Reserve (ORRR) depot and Fox River Station (FRS)**

| | January | February | March | April | May | June | July | August | September | October | November | December | Ann. (J-J) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ORRR mean | 132 | 124 | 73 | 18 | 6 | 3 | 5 | 1 | 3 | 15 | 43 | 90 | 513 |
| ORRR median | 110 | 92 | 48 | 4 | 0 | 0 | 0 | 0 | 0 | 7 | 30 | 84 | 499 |
| FRS mean | 125 | 118 | 63 | 18 | 11 | 5 | 5 | 2 | 4 | 13 | 28 | 69 | 461 |
| FRS median | 98 | 84 | 37 | 4 | 0 | 0 | 0 | 0 | 0 | 5 | 20 | 54 | 447 |

[1] Rainfall records were provided by the SILO website http://www.nrme.qld.gov.au/silo/ These data are interpolated, based on actual rainfall records from Bureau of Meteorology recording stations in the region. The SILO data may therefore differ slightly from actual readings at ORRR depot and Fox River Station. The detailed interpolation methods are described by Jeffrey *et al*. (2001).

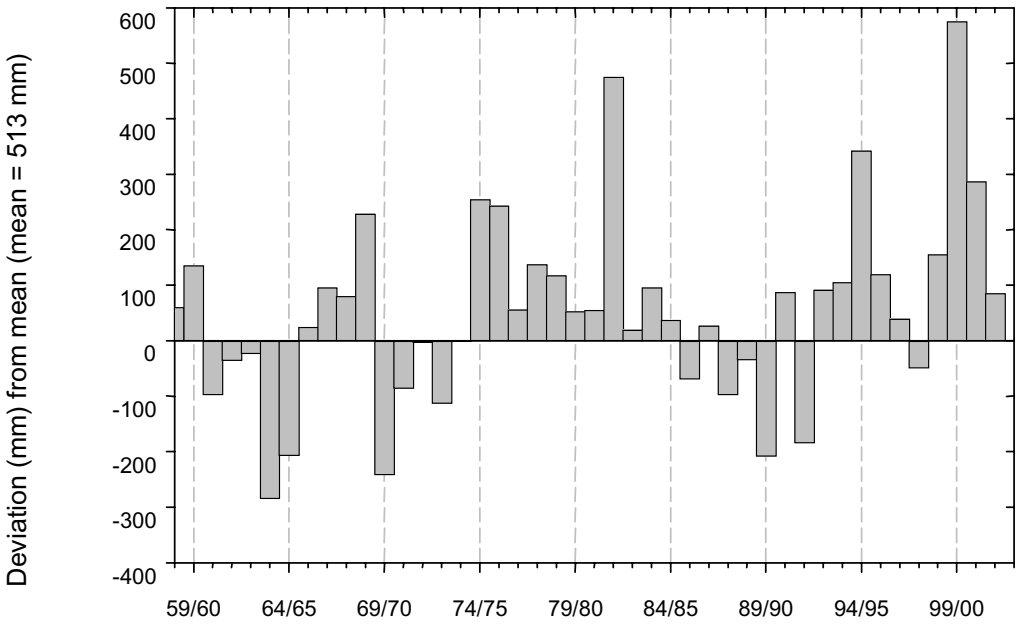


**Figure 2. Annual (July to June) rainfall deviation from long term mean at Ord River Regeneration Reserve depot (1959/60-2001/02).**

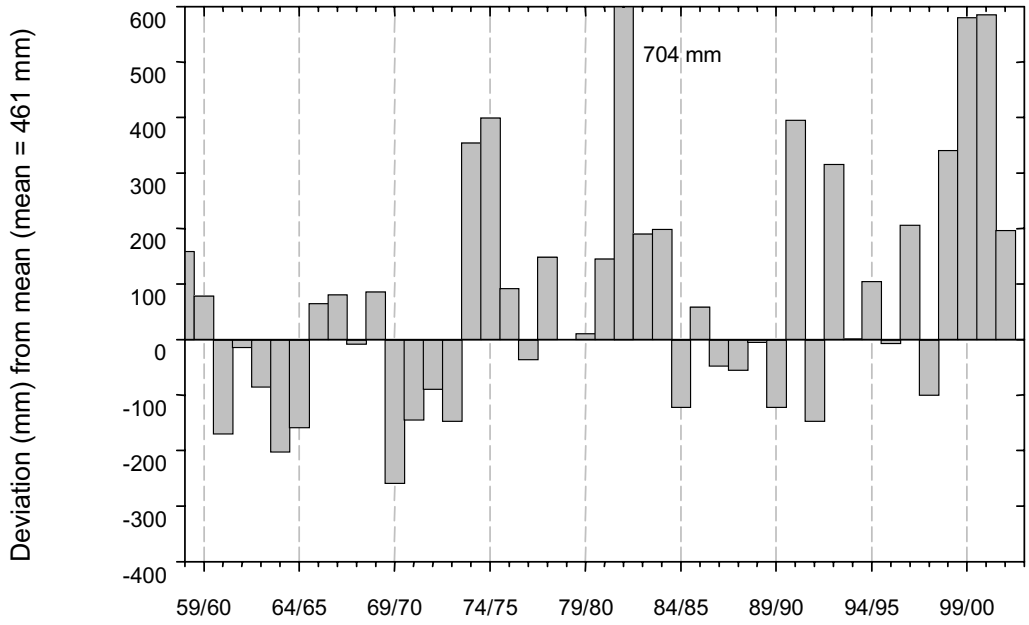


**Figure 3. Annual (July to June) rainfall deviation from long term mean at Fox River Station (1959/60-2001/02).**

## Landforms, soils and vegetation

The regeneration project area consists of extensive, level to gently undulating plains surrounded by more rugged country of low hills of limestone and basalt and prominent sandstone ranges. The plains in the northern parts of the area are characterised by lines of low limestone cuestas with gently inclined backslopes and short, steep breakaway faces standing above more extensive red plains derived from soft shales and siltstones.

Soils of the project area include shallow stony types on hills, footslopes and cuesta tops, cracking clays on lower gilgai ('black soil') plains, and calcareous grey brown loams and light clays over limestone and shale on undulating plains and interfluves. These latter soils are most common on the Nelson and Gordon land systems. They are weakly structured and powdery and, once bared, are particularly susceptible to erosion. Other soils are sandy red earths and alluvial types associated with juvenile alluvial deposits and levees of the major drainage lines.

Vegetation is mainly tussock grassland and grassland/savanna woodland complex dominated by perennial and biennial tussock grasses such as Mitchell grasses (*Astrebla* spp.), ribbon grass (*Chrysopogon fallax*), feathertop (*Aristida latifolia*), white grass (*Sehima nervosum*), buffel grass (*Cenchrus ciliaris*), Birdwood grass (*Cenchrus setigerus*) and limestone grass (*Enneapogon polyphyllus*) and trees such as bloodwoods (*Corymbia* spp.), bauhinia (*Bauhinia cunninghamii*) and *Terminalia* spp. Some large parts of the project area, particularly those with stony soils, support hummock grasses dominated by hard spinifex (*Triodia wiseana*) with scattered trees and shrubs.

Pasture type distribution is strongly influenced by soil type and topography. This results in a mosaic of different pastures, encouraging localised cattle concentrations and overgrazing on the more favoured types. Prolonged uncontrolled grazing in the past had substantially altered some pastures both in species composition (towards annuals or short-lived perennials) and total ground cover. In specific areas, the regeneration process and the introduction of the exotic buffel and Birdwood grasses (*Cenchrus* spp.) have led to dominance by these grasses.

The land systems and their component land units, soils and pastures which comprise the project area have been described by Stewart *et al*. (1970), Ryan (1981) and de Salis (1993). Two major land systems that had been severely degraded and eroded by past overgrazing are the Nelson system in the north of the Reserve and the Gordon system in the south. In Western Australia the Nelson system is unique to the Reserve area but also extends into the Northern Territory. About 90% of the Gordon system is confined to the Reserve. Both systems have particular land units with inherent characteristics (such as pasture type, soil types and slope) which make them highly preferred by cattle and highly susceptible to over-use and erosion.

More detail on these land systems is provided in the boxes on pages 13 and 14.

## NELSON LAND SYSTEM (1661 km$^2$)

A productive but extremely fragile system unique in WA to ORRR.

**Geology:** Middle Cambrian limestones and shales of the Negri Group, Cainozoic alluvium and colluvium including cracking clay soils.

**Geomorphology:** Gently undulating inland erosional plains.

**Vegetation:** Tussock grasslands dominated by the introduced buffel and Birdwood grasses (*Cenchrus* spp.) with scattered shrubs and trees on calcareous loams and Mitchell grasses (*Astrebla* spp.) and ribbon grass (*Chrysopogon fallax*) on cracking clays. Also hummock grasslands of hard spinifex (*Triodia wiseana*) with scattered trees and shrubs on shallow stony soils.

| Land units (code) | Area (km$^2$) | Susceptibility to degradation | Pasture types |
|---|---|---|---|
| **Cuestas (Nc)** | 70 | Very low | Hard spinifex |
| ***Cuesta backslopes (Nb)** | 206 | High | Hard spinifex, *Cenchrus* spp. |
| **Cracking clay plains (Ns)** | 301 | Low to moderate | Black soil plain |
| ***Interfluve upper slopes (Nu)** | 210 | Very high | *Cenchrus* spp. |
| ***Interfluve lower slopes (Nl)** | 320 | Very high | *Cenchrus* spp. |
| ***Frontage plains (Nf)** | 538 | High | Frontage grass *Cenchrus* spp. |
| **Low rises (Nr)** | 16 | Low to moderate | *Cenchrus* spp. |

* These units are highly fragile because they:

- support pastures which are highly preferred by cattle;
- have long gentle to moderate slopes;
- have friable, highly erodible loamy soils.

## GORDON LAND SYSTEM (994 km$^2$)

A moderately productive but fragile system. About 90% of the system in WA falls within ORRR.

**Geology:** Proterozoic dolomites, sandstones, shales and siltstones of the Albert Edward Group, minor Tertiary laterite and calcareous siltstone, Cainozoic alluvium and colluvium including cracking clay soils.

**Geomorphology:** Level to gently undulating inland erosional plains with remnant strike ridges and breakaways.

**Vegetation:** Highly variable. Hummock grasslands of hard spinifex (*Triodia* spp.) on shallow soils, tussock grasslands of limestone grass (*Enneapogon polyphyllus*), buffel and Birdwood grasses (*Cenchrus* spp.) and ribbon grass (*Chrysopogon fallax*) on calcareous loams and alluvial soils, Mitchell grasses (*Astrebla* spp.) and ribbon grass (*Chrysopogon fallax*) on cracking clays, all with scattered shrubs and trees.

| Land units (code) | Area (km$^2$) | Susceptibility to degradation | Pasture types |
|---|---|---|---|
| *Alluvial plains (Ga) | 33 | Variable (low to high) | Black soil plain, Sparse annual grasses |
| Spinifex slopes (Gu) | 79 | Low | Hard spinifex |
| Cracking clay plains (Gs) | 88 | Low to moderate | Black soil plain |
| *Timperley plains (Gy) | 33 | High | Hard spinifex, Short grass, *Cenchrus* spp. |
| *Flat Rock plains (Gr) | 168 | High | Hard spinifex, Black soil plain, Short grass, *Cenchrus* spp. |
| *Frontage plains (Gf) | 251 | High | Frontage grass, *Cenchrus* spp. |
| Strike ridges (Gh) | 45 | Very low | Hard spinifex |
| Breakaways (Gb) | 193 | Very low | Hard spinifex |
| *Erosion plains (Gx) | 104 | High | Hard spinifex, Black soil plain, Short grass, *Cenchrus* spp. |

* Parts of these units are highly fragile because they:

- support pastures which are highly preferred by cattle;
- have soils which are susceptible to erosion.

## The regeneration program and early results

The regeneration program began in 1960 and concentrated on the severely degraded parts of the Nelson land system. Under an agreement with the Northern Territory Administration, the Western Australian Government also carried out rehabilitation work on adjacent country in the Territory.

A fencing program started in 1960 on a large area known as Turner Plains (cover photos) and progressed until about 1968, dividing the project area into a number of large paddocks. Initial mustering to destock paddocks was undertaken by station lessees. However, after resumption of the leases, subsequent mustering and destocking was facilitated by the Ord River Dam Catchment Area (Straying Cattle) Act (gazetted in 1967 and amended in 1969), which vested ownership of all cattle within the Regeneration Reserve to the Crown. Contract musterers and Department of Agriculture staff operated and turned off cattle in most years, until the mid-1990s.

The regeneration program involved destocking, eradication of donkeys and contour cultivation and seeding those degraded areas that were accessible to machinery. Cultivation was carried out using tractor-mounted implements, specifically 5-7 tyne chisel ploughs, opposed disc ploughs with centrally mounted rippers and disc pitters. All cultivations were carried out on the contour, with contours being marked using a mobile hose level. The contour cultivations were in discontinuous parallel strips about 3 m wide and usually separated from each other by 5-10 m of uncultivated ground. Seed boxes were mounted on the tractor or cultivating implements and the introduced species kapok bush (*Aerva javanica*), buffel grass (*Cenchrus ciliaris*) and Birdwood grass (*C. setigerus*) were seeded together.

Cultivation works and seeding continued at various levels of intensity from 1960 until the mid-1980s. Many areas were treated more than once, some three or four times. Repeat or ‘follow-up’ work involved strip cultivation, sometimes without seeding, between the lines of the original cultivations. Additional methods of regeneration such as the construction of large banks for water ponding and water harvesting, spreader sills, check banks and small gully control structures were tested during the course of the project.

By 1974 it was considered that parts of the Regeneration Reserve had recovered sufficiently to be used as a research centre for a series of cattle grazing and management trials. These trials clearly demonstrated the advantages of weaning and Brahman infusion to the pastoral industry (Pratchett and Young 1989, Pratchett *et al*. 1989), but at the same time highlighted the fragility of the vegetation cover and the great difficulties of managing a complex mixture of recovered and still partly degraded country. Grazing management studies in the Regeneration Reserve concluded in 1995.

In its present form the project area is managed from Kununurra by the Department of Agriculture as a water catchment reserve. Management activities include the maintenance of perimeter and internal fencing, grading of access tracks, aerial burning early in the dry season to control wildfire hazards, and the removal of stray cattle, donkeys and camels. A number of paddocks at the Fox River end of the Reserve have been returned to controlled commercial grazing.

Recovery within the project area has been described by Fitzgerald (1968), Ryan (1981) and de Salis (1993). Eight years after the program of works commenced Fitzgerald outlined how the project had been beset by difficulties in the early years, due mainly to a series of adverse seasons and an inability to exclude stock from the areas under treatment. However, following completion of the fencing program and two good seasons (1966/67 and 1967/68) Fitzgerald considered that the whole area showed a marked improvement in vegetation cover.

Ryan considered that there was much observational and some quantitative evidence (Ryan and Payne 1976) that treatments had been effective at improving ground cover and reducing soil losses. Kapok bush had proven to be an excellent coloniser of bare ground; buffel and Birdwood grass had established widely and, in the absence of grazing, native grasses had recovered. Ryan considered that the large gully systems on the lower slopes of the Nelson land system had all shown some stabilisation.

De Salis (1993) reported that by 1981 the regeneration program had re-established vegetation on most of the previously degraded areas. Recovery was enhanced by a run of good seasons from the mid-1970s to the early 1980s. However, condition assessments (1981 data) showed that the rehabilitation process was not complete and that the Regeneration Reserve still had the capacity to contribute large amounts of sediment to Lake Argyle.

Internal reviews by the Department of Agriculture in the mid-1980s and in 1990 highlighted concerns that sediment loads of the Ord River were still unacceptably high. With successful regeneration evident on the upper slopes it was thought that the majority of sediment entering the dam may originate from gully extension, widening and deepening. Gully control measures were tested on a small number of gullies with reasonable success but were not applied as a broad scale treatment because the cost was considered prohibitive.

Since 1990 observational evidence suggests that vegetative cover has continued to improve considerably throughout the project area, but there is no quantitative information concerning gully stabilisation. Good or very good seasonal conditions during most of the 1990s have driven the recovery.

**Photo 12. Contour strip cultivation and seeding with light equipment began in the project area in 1960. This photograph, taken in February 1965, shows a three point linkage mounted chisel plough and chain driven seed box. Seed mixtures were usually buffel and Birdwood grasses and kapok bush.**

**Photo 13. A tractor equipped with a twin opposed disc plough and centrally mounted ripper is following a mobile hose level which is marking the contour line. June 1964.**

**Photo 14. Discontinuous, strip contour cultivations on a degraded plain of the Nelson land system. Additional cultivations between these original workings were frequently undertaken in subsequent years. June 1962.**

**Photo 15. This aerial view, taken in July 1963, shows the patterns of cultivation on the broad, bare interfluves between the gullies and creek lines of the Nelson land system.**

**Photo 16. The introduced kapok bush proved to be an excellent primary coloniser in the early years of the project. This photograph, taken in 1965, shows young stands of kapok bush and grasses established along cultivation lines.**

**Photo 17. Chisel plough workings after light rain, Turner Plains early 1960s.**

**Photo 18. This dense stand of kapok bush was established on banks and in ponded areas on Turner Plains by April 1966. Large quantities of seed were collected by hand from these areas for use elsewhere in the project.**

# Field inspection August 2002

A field inspection of the ORRR was undertaken by five officers of the Department of Agriculture and a former officer from 6-11 August 2002. One officer (Alan Payne) had been closely involved with the very early stages of the project between 1962 and 1965. The main approach taken during inspection was to re-photograph as many old reference sites and monitoring sites as possible to record the changes that had occurred in vegetation and soils since the 1960s.

About 415 km were traversed during the inspection (see Figure 4) and photographs taken at 31 sites which had all been photographed at various times in the past. The locations of all sites were recorded by GPS and are shown in Figure 4.

The type of sites re-photographed during the inspection were:

- **heritage sites** (10) originally photographed in 1962, 1963 or 1964;
- **monitoring sites** (19) originally photographed in 1987 or 1989;
- **fire research sites** (2) originally photographed in 1995.

In addition, a number of photographs were taken at old enclosure sites or as panoramas not taken before but at easily identifiable places within the Reserve.

Site data and records are summarised in Appendix 1 and are stored in the Western Australian Rangeland Monitoring System (WARMS) data base.

The history of photography at sites is detailed below.

**Heritage sites**

| | Photographs | | | | | | |
|---|---|---|---|---|---|---|---|
| | **1962** | **1963** | **1964** | **1965** | **1974** | **1977** | **2002** |
| ORD H1 | | ✓ | | | ✓ | | ✓ |
| ORD H2 | | * | | | ✓ | ✓ | ✓ |
| ORD H4 | | ✓ | | | ✓ | | ✓ |
| ORD H5 | | ✓ | | | ✓ | ✓ | ✓ |
| ORD H7 | | * | | | * | | ✓ |
| ORD H8 | | ✓ | | | ✓ | ✓ | ✓ |
| ORD H12 | ✓ | ✓ | | | | | ✓ |
| NLS H1 | | ✓ | ✓ | ✓ | | | ✓ |
| NLS H1A | | ✓ | ✓ | ✓ | | | ✓ |
| NLS H4 | | | ✓ | ✓ | | | ✓ |

* Photos missing.

Five sites established in 1963 (potentially ORD H3, 6, 9, 10 and 11) were not relocated.

NLS = Nelson Springs (NT) sites treated as part of ORRR in 1960s and 1970s. Two sites (potentially NLS H2 and 3) were not relocated.

**Monitoring sites**

| | Photographs | | | | |
|---|---|---|---|---|---|
| | **1987** | **1988** | **1989** | **1992** | **2002** |
| ORD 45 | ✓ | | ✓ | ✓ | ✓ |
| ORD 46 | ✓ | | ✓ | ✓ | ✓ |
| ORD 51 | ✓ | | ✓ | | ✓ |
| ORD 55 | ✓ | | ✓ | | ✓ |
| ORD 73 | ✓ | | ✓ | | ✓ |
| ORD 82 | ✓ | | ✓ | | ✓ |
| ORD 83 | ✓ | | ✓ | | ✓ |
| ORD 84 | ✓ | ✓ | ✓ | | ✓ |
| ORD 85 | ✓ | | ✓ | | ✓ |
| ORD 87 | ✓ | | ✓ | | ✓ |
| ORD 96 | ✓ | | ✓ | | ✓ |
| FR 1 | | | ✓ | | ✓ |
| FR 3 | | | ✓ | | ✓ |
| FR 11 | | | ✓ | | ✓ |
| FR 12 | | | ✓ | | ✓ |
| FR 20 | | | ✓ | | ✓ |
| FR 24 | | | ✓ | | ✓ |
| FR 39 | | | ✓ | | ✓ |
| FR 41 | | | ✓ | | ✓ |

ORD = Central and northern parts of ORRR.

FR = Fox River Station (southern parts of ORRR).

**Fire research sites**

| | Photographs | | | | |
|---|---|---|---|---|---|
| | **1995** | **1996** | **1998** | **1999** | **2002** |
| ORD F2 | ✓ | ✓ | | ✓ | ✓ |
| ORD F4 | ✓ | ✓ | ✓ | ✓ | ✓ |

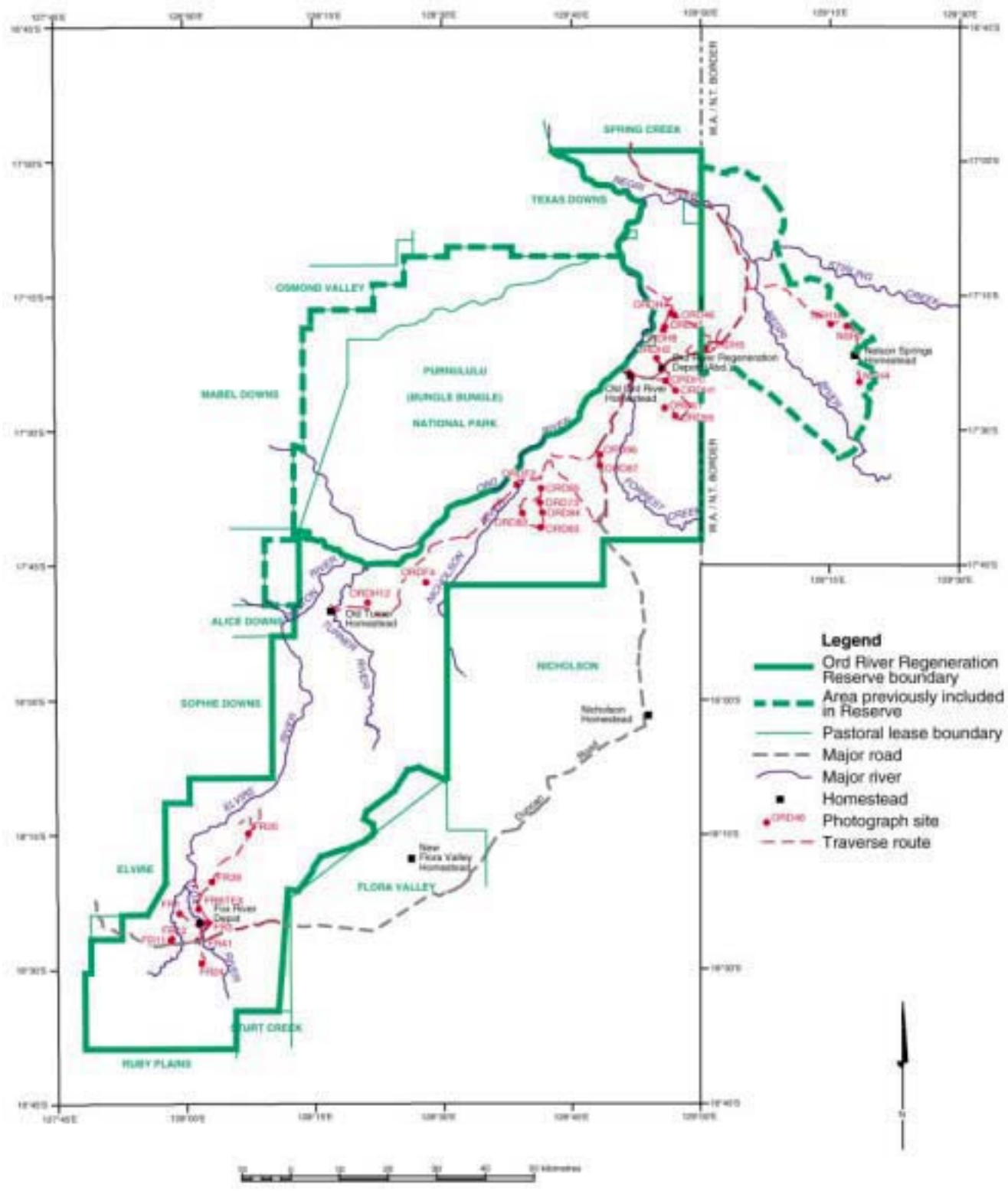


**Figure 4. Ord River Regeneration Reserve - traverse routes and photo sites August 2002.**

## Findings and conclusions

Changes on the Nelson and Gordon land systems since 1960 have generally been remarkable and are further discussed below and summarised in Tables 2 and 3.

The repeat photographs taken in 2002 clearly show that there have been profound vegetation changes in terms of botanical composition, species richness, plant density, biomass and, to a lesser extent, vegetation structure since the early 1960s when the project was in its infancy (Payne 2002).

Although the photographs do not readily depict it, recent observations and prior knowledge suggest that there have also been marked improvements in soil surface conditions over much of the project area. High perennial grass densities, high levels of standing biomass and abundant litter provide protection to soil surfaces. Cryptogamic soil crusts are well developed and widespread.

Gently sloping interfluves of the Nelson land system (land units Nu and Nl), which were previously widely micro-terraced and sheet-eroded, are now mostly stabilised by ground cover. Most large gully systems on interfluve lower slopes of Nelson (Nl) are stabilised or partly stabilised by dense grass and shrub cover extending right to the edge of gullies and established in gully floors.

One of the largest and most spectacular areas of recovery of the Nelson land system is on Turner Plains (about 170 $km^2$) in the centre of the Reserve area (see photos 17, 18, 27, 28, 37, 38 and cover).

Many parts of the Gordon land system that were actively eroding in the 1960s and 1980s (part of units Ga, Gf, Gr, Gy and Gx) are now stabilised by ground cover. Recovery on the frontage plains unit (Gf) is particularly dramatic, with stands of the introduced *Cenchrus* spp. grasses and native perennial grasses such as ribbon grass (*Chrysopogon fallax*) and shrubs providing dense ground cover and abundant biomass. The alluvial plains unit (Ga) of Gordon still includes some bare scalded tracts up to a few hundred metres in extent. These areas have hardsetting sodic clay soils which are very difficult habitats for plant establishment and are not responsive to conventional treatments such as contour ripping or furrowing. However, water ponding undertaken in the 1970s and 80s has been successful in ameliorating soil conditions and establishing fair to good stands of perennial grass in most affected areas.

### 1960/1965

- Large areas of the Nelson and Gordon land systems (and smaller areas of other systems) were seriously degraded with depleted pastures and active soil erosion. The Short grass pasture type (annual grasses and the short-lived perennial limestone grass *Enneapogon polyphyllus*, with minor components of other perennial grasses) was dominant on units Nb, Nu and Nl of the Nelson system and a minor component on some units of the Gordon system. This pasture type was highly preferred by cattle, particularly during the wet season, and was frequently degraded to sparse or very sparse stands of limestone grass and miniature annuals or bare ground.

- Sheet erosion, scalding, micro-terracing, rill and gully erosion were widespread and active on units Nb, Nu, Nl and Nf of the Nelson system and units Ga, Gy, Gr, Gf and Gx of the Gordon system.

- The introduced buffel and Birdwood grasses (*Cenchrus* spp.) were only occasionally present.

- Kapok bush (*Aerva javanica*), an exotic shrub to be introduced later, was not present in 1960.

- Rubber bush (*Calotropis procera*), an exotic already established in the NT was not present.

## 1981

- Many of the units of the Nelson land system were dominated by a kapok bush disclimax (a mixture of kapok bush, limestone grass and *Cenchrus* spp.) rather than degraded Short grass pastures as in 1960.

- The regeneration program had re-established vegetation on most of the previously degraded areas and presumably reduced the extent of active erosion.

- About 27% of the Reserve was still classified as in poor condition and about 400 $km^2$ was still severely degraded and eroded.

- Rubber bush was well established in the Reserve.

## 2002

- Dense ground cover of introduced and native perennial grasses occurred over much of the Reserve and biomass production far exceeded that seen in the early 1960s. Areas up to a few hundred metres in extent on parts of the Gordon land system (land unit Ga) were still scalded and only supported annuals in season. Most other parts of the Gordon system were well vegetated by perennial grasses.

- The majority of the most sensitive and previously severely degraded parts of the Reserve were dominated by dense stands of introduced *Cenchrus* spp. grasses.

- Active soil erosion was rarely seen during the August 2002 inspection but occasionally occurred on areas up to a few hundred metres in extent. Of 32 sites that were photographed and described 27 (84%) had stable soil surfaces with well developed cryptogamic crusts. Five sites (16%) were assessed as having slight or minor erosion.

- Range condition from a pastoral perspective on the 32 sites was assessed as follows: very good 5, good 12, fair 12, poor 2, very poor 1.

- Large gully systems on the lower slopes (Nl) of the Nelson land system were stabilised or partly stabilised by perennial grasses and shrubs which were densely established to the edges of the gullies and on the gully floors. Some gullies continued to cut back upslope but the rate of extension was expected to be reduced with the restoration of ground cover.

- Although kapok bush was still found in the Reserve it was no longer dominant or co-dominant in any pastures as was the case in 1981. It has been replaced by *Cenchrus* spp. and native grasses.

- Rubber bush was common and widespread throughout the Reserve.

- Mimosa bush (*Acacia farnesiana*) was much more widespread than in 1960.
- Considerable re-establishment of bloodwoods (*Corymbia* sp.) and other tree species had occurred over many parts of the Reserve.

**Table 2. Nelson land system and pasture types 1960, 1981 and 2002**

| Unit | Pasture type(s) D = dominant, C = co-dominant, m = minor | | | Range condition (2002) and changes since 1960 or 1981 |
|---|---|---|---|---|
| | 1960 | 1981* | 2002 | |
| Cuestas (Nc) | D Hard spinifex<br>m Short grass | D Hard spinifex<br>m Short grass<br>m Kapok bush disclimax | D Hard spinifex<br>m Short grass<br>m *Cenchrus* spp. | Good. Scattered re-establishment of bloodwoods and other trees. |
| Cuesta backslopes (Nb) | C Hard spinifex<br>C Short grass<br>m Black soil plain | C Hard spinifex<br>C Short grass<br>m Kapok bush<br>m Black soil plain | C Hard spinifex<br>C *Cenchrus* spp.<br>m Black soil plain | Good. Marked reduction of kapok bush since 1981, change to *Cenchrus* co-dominance. Considerable re-establishment of bloodwoods and other trees. Scattered rubber bush (none in 1960). |
| Cracking clay plains (Ns) | D Black soil plain | D Black soil plain | D Black soil plain | Good. Marked improvement in grass density since 1960 but little change in botanical composition. |
| Interfluve upper slopes (Nu) | D Short grass | D Kapok bush disclimax in all seral stages<br>m Short grass | D *Cenchrus* spp. | Mostly good. Dramatic change to *Cenchrus* dominance. Much more biomass than in 1960. Negligible active erosion. Much reduced kapok bush since 1981. Scattered rubber bush (none in 1960). Increased mimosa bush since 1960. Re-establishment of bloodwoods and other trees. |
| Interfluve lower slopes (Nl) | D Short grass | D Kapok bush disclimax in all seral stages.<br>m Short grass | D *Cenchrus* spp. | Fair to good. Change to *Cenchrus* dominance. Reduced kapok bush. Rubber bush common (none in 1960). Increased mimosa bush since 1960. Re-establishment of bloodwoods and other trees. Vegetation well established in many gullies. |
| Frontage plains (Nf) | D Frontage grass | D Frontage grass<br>m Hard spinifex | C Frontage grass<br>C *Cenchrus* spp. | Good. Increased biomass and *Cenchrus* since 1960 and 1981. Negligible active erosion. Scattered rubber bush (none in 1960). Increase in trees and shrubs since 1960. |
| Low rises (Nr) | ? | D Kapok bush disclimax<br>m Short grass<br>m Hard spinifex | (?) D *Cenchrus* spp.<br>(?) m Short grass<br>(?) m Hard spinifex | (?) Good. |

* From de Salis 1993, who describes kapok bush disclimax as a mixture of variable proportions of kapok bush, limestone grass and *Cenchrus* spp.

**Table 3. Gordon land system and pasture types 1965, 1981 and 2002**

| Unit | Pasture type(s) D = dominant, C = co-dominant, m = minor | | | Range condition (2002) and changes since 1965 or 1981 |
|---|---|---|---|---|
| | 1965 | 1981* | 2002 | |
| Alluvial plains (Ga) | (a) D Black soil plain<br>(b) Scalded tracts - bare of perennials | (a) D Black soil plain<br>(b) Scalded tracts - bare of perennials | (a) D Black soil plain<br>(b) Scalded tracts<br>C bare<br>C Black soil plain | (a) Good.<br>(b) Poor to good, some areas still bare, others covered with perennial grasses. |
| Spinifex slopes (Gu) | D Mostly Hard spinifex | C Hard spinifex<br>C Black soil plain | D Hard spinifex<br>m Black soil plain | Good. |
| Cracking clay plains (Gs) | D Degraded Black soil plain | D Black soil plain | D Black soil plain | Mostly good. Considerable improvement in grass density since 1965 but little change in botanical composition. |
| Timperley plains (Gy) | D Hard spinifex<br>m Degraded Short grass | D Hard spinifex<br>m Short grass<br>m Kapok bush disclimax | D Hard spinifex<br>m Short grass<br>m *Cenchrus* spp. | Good. Improvement in condition since 1965. Spread of *Cenchrus* spp. since 1965. |
| Flat Rock plains (Gr) | D Hard spinifex<br>m Degraded Short grass and other grasslands | D Hard spinifex<br>m Black soil plain<br>m Frontage grass | D Hard spinifex<br>m Black soil plain<br>m Short grass<br>m *Cenchrus* spp. | Good. Marked improvement in condition of grasslands since 1965. Spread of *Cenchrus* spp. since 1965. |
| Frontage plains (Gf) | D Severely degraded Frontage grass | C Frontage grass<br>C Black soil plain | C Frontage grass<br>C Black soil plain<br>C *Cenchrus* spp. | Good. Dramatic improvement since 1965. *Cenchrus* spp. dominant along drainage lines. Heavy biomass. |
| Strike ridges (Gh) | D Hard spinifex | D Hard spinifex | D Hard spinifex | Good. |
| Breakaways (Gb) | D Hard spinifex | D Hard spinifex | D Hard spinifex | Good. |
| Erosion plain (Gx) | D Hard spinifex<br>m Degraded Short grass and other grasslands | C Hard spinifex<br>C Frontage grass<br>C Black soil plain | Not inspected but expect:<br>C Hard spinifex<br>C Black soil plain<br>m Short grass<br>m *Cenchrus* spp. | Not inspected but expect good condition with marked improvement since 1965. |

* From de Salis 1993, who describes kapok bush disclimax as a mixture of variable proportions of kapok bush, limestone grass and *Cenchrus* spp.

## Reasons for the changes since 1960/1965

There are several factors which are believed to be responsible for the dramatic increase in biomass, species richness and abundance of plants and the improved soil surface conditions observed within the Reserve since recording sites were first established in 1963. Clearly the management practices applied within the Reserve were significant drivers of the change and while it is not possible to rank the contributions due to individual practices, their integrated effect, allied with favourable seasons, achieved a result which would probably surprise the people responsible for the project when it was initiated.

Management for rehabilitation on the Reserve comprised four elements:

- Fencing as an aid to mustering and controlling the location of cattle and controlling cattle grazing pressure.
- Progressive reduction of grazing pressure by cattle to near zero. An estimated 143,000 cattle were turned off between 1961 and 1990 (de Salis 1993); present cattle numbers are negligible.
- Removal of feral animals, particularly donkeys. The total number of donkeys destroyed since the project commenced is unknown but from 1979 to 1981 the Agricultural Protection Board claimed 15,138 donkeys shot from helicopters (de Salis 1993); present donkey numbers are negligible.
- Treatment of degraded country over many years by the cultivation of niches for plant establishment and the introduction of perennial plant seed. Buffel and Birdwood grass and kapok bush emerged as key components of the revegetation work.

For most years of the last decade rainfall on the Reserve has been well above the average (see Figures 2 and 3), a situation which was a major driver of the observed changes. As the plant communities on the Reserve are now dominated by long-lived perennial species, a return to a more normal rainfall pattern is unlikely to reverse the recent trends in the condition of the soils and vegetation in the Reserve.

## Repeat photographs

Many of the repeat photographs in this section are taken about 40 years apart and clearly show marked changes in vegetation. For most sites the original steel marker pickets were relocated in August 2002 but for some sites the original markers could not be relocated. The position of these latter sites was approximated from the original photographs and prior knowledge. The use of repeat photography for assessing vegetation change over time has been described, and the relatively few Australian examples summarised by Pickard (2002).

***Site ORD H1, Nelson land system***

**Photo 19. September 1963.**

**Photo 20. August 2002.**

***Site ORD H4, Nelson land system***

**Photo 21. September 1963.**

**Photo 22. August 2002.**

***Site ORD H5, Nelson land system***

**Photo 23. September 1963.**

**Photo 24. August 2002.**

***Site ORD H8, Nelson land system***


**Photo 25. September 1963.**

**Photo 26. August 2002.**

**Photo 27. Alan Payne at site ORD H12, Nelson land system, Turner Plains and the Hardman Range, 1962.**

**Photo 28. Alan Payne at site ORD H12, Nelson land system, Turner Plains and the Hardman Range, August 2002.**

**Photo 29. Site NLS H4, Nelson land system (NT), July 1964.**

**Photo 30. Near site NLS H4, Nelson land system (NT), August 2002.**

**Photo 31. Site NLS H1, Nelson land system (NT). February 1965.**

**Photo 32. Near site NLS H1, Nelson land system (NT). August 2002.**

**Photo 33. Duncan Road crossing on the Negri River showing large amounts of sediment deposited on the crossing by the river. May 1963.**

**Photo 34. Duncan Road crossing on the Negri River, August 2002. The vigour of the eucalypt trees on the far bank of the river has improved considerably since 1963.**

## Additional photographs

**Photo 35. Gully control test area on the lower slopes of the Nelson land system. August 2002.**

**Photo 36. Revegetation on a ponded scald on the Gordon land system, Fox River Station. August 2002.**

**Photo 37.** **Contouring with a dumpy level for strip cultivation works on the Turner Plains. June 1960.**

**Photo 38.** **Dense cover of grass on Turner Plains. August 2002.**

**Photo 39. The Elvire River valley (Fox River Station) has regenerated remarkably in the last 20 years. This view, from near Stallion Yard, was taken in August 2002. In the 1970s light aircraft were able to land on scalded flats then in the left of the photo.**

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# Appendix 1. Site types within ORRR inspected and photographed in August 2002

Summary of all sites visited during the August 2002 inspection. ORD = Ord River Station. FOX = Fox River Station. NLS = Nelson Springs Station. RMS = Rangeland Monitoring Site. FIRE = Fire research site of the Kununurra District Office. HERITAGE = Photo sites installed during the early period of the Ord Regeneration Reserve. 'NEAR' HERITAGE = Heritage sites that could not be precisely relocated in August 2002. PANORAMA = Landscape scale photos 'stitched together' to compare with similar photos or known areas from an earlier period. EXCL = Exclosure site. Y = Yes. N = No.

| | Front picket | Installation date | Reassessment dates | Perennial grass cover change | Perennial grass richness change | Overstorey cover change | Comments (e.g. soil surface, species richness, woody cover, eucalypt regeneration, current range condition) |
|---|---|---|---|---|---|---|---|
| **ORD RMS** | | | | | | | |
| ORD 45 | Y | 01/07/87 | 21/06/89<br>01/05/92<br>11/08/02 | Increase | ? | Static | Soil surface well crusted. Good cover of buffel and ribbon grass with some moribund tillers. Some bare patches in 1992. |
| ORD 46 | Y | 01/07/87 | 21/06/89<br>01/05/92<br>06/08/02 | Increase | Increase | Increase | The site has changed from being dominated by annuals and biennials to being dominated by perennials. Even since 1992 many of the bare patches have covered over. Buffel grass throughout the site. Eucalypt overstorey beginning to form. Soil crust now well developed. |
| ORD 51 | Y | 01/07/87 | 21/06/89<br>07/08/02 | Increase | ? | Increase | Site has good cover, with little inter-tussock space. Mostly buffel grass and some feathertop on photosite but a range of native species in surrounding areas. Some moribund tillers on buffel grass. |
| ORD 55 | Y | 01/07/87 | 21/06/89<br>07/08/02 | Static | Increase | Increase | The site and surrounding area have improved considerably. Limestone grass dominance now replaced by native perennial grasses. |
| ORD 73 | Y | 01/07/87 | 21/06/89<br>08/08/02 | Increase | Static | Static | Good grass density (Birdwood and buffel) although numerous dead grass butts. |
| ORD 82 | Y | 01/07/87 | 21/06/89<br>08/08/02 | Increase | Static | Static | Bare areas seen in earlier photos now have some perennial grass (buffel) cover. Destocking in the late 1980s appears to have been very effective. |
| ORD 83 | Y | 01/07/87 | 21/06/89<br>08/08/02 | Static | Static | Increase | This site has good cover of Birdwood grass, with plenty of litter and some soil crust. This area of Wire Creek Paddock suffered much less from grazing because it is about 8 km from water. |
| ORD 84 | Y | 01/07/87 | 01/09/88<br>21/06/89<br>08/08/02 | Increase | Static | Static | Site is recovering, but still has a way to go. |

| | Front picket | Installation date | Reassessment dates | Perennial grass cover change | Perennial grass richness change | Overstorey cover change | Comments (e.g. soil surface, species richness, woody cover, eucalypt regeneration, current range condition) |
|---|---|---|---|---|---|---|---|
| **ORD RMS continued …** | | | | | | | |
| ORD 85 | Y | 01/07/87 | 21/06/89<br>08/08/02 | Increase | Static | Static | Generally good cover, bare areas are filling in. Site is dominated by Birdwood grass. |
| ORD 87 | Y | 01/07/87 | 21/06/89<br>07/08/02 | Increase | Increase | Increase | The improvement was not as great on this site as on some others. Soil redistribution (sheeting and terracing) is still occurring and pioneer species such as kapok bush still dominate. |
| ORD 96 | Y | 01/07/87 | 21/06/89<br>07/08/02 | Static | Static | Static | The site is recovering from a decline in the 1980s but still has some way to go. |
| **ORD FIRE** | | | | | | | |
| ORD F2 | Y | 01/11/95 | 04/09/96<br>15/10/99<br>08/08/02 | Static | Static | Static | This area of black soil plain is in excellent condition, with dense native perennial grasses. Feathertop, although present, is not a significant component. |
| ORD F4 | Y | 01/11/95 | 05/09/96<br>24/06/98<br>15/10/99<br>08/08/02 | Increase | Static | Increase | The site, dominated by *Cenchrus* spp. is very dense, with some moribund tillers. Good cryptogamic crust with sparse mantle of limestone. Recent increase in rubber bush. |
| **ORD HERITAGE** | | | | | | | |
| ORD H2 | Y | Sept. 1963 (no photo available) | July 1974<br>July 1977<br>07/08/02 | Increase | Increase | Increase | The site retains considerable bare ground and is still dominated by pioneer species – but it is improving. |
| ORD H4 | Y | Sept. 1963 | July 1974<br>July 1977<br>06/08/02 | Increase | Increase | Increase | The site showed some improvement from 1963 to 1977 and then more improvement to 2002. Some eucalypt regeneration throughout the area. |
| ORD H5 | Y | Sept. 1963 | July 1974<br>July 1977<br>07/08/02 | Increase | Increase | Increase | The site has shown marked improvement although some bare ground and micro-terracing remains. In 1963 the site was in poor condition, dominated by limestone grass with extensive micro-terracing. There were no trees or shrubs. By 1974 and 1977 the site had improved but trees and shrubs remained absent. By 2002, perennial grass cover (*Cenchrus* spp. and native) had increased markedly with eucalypt regeneration and some rubber bush. |

| | Front picket | Installation date | Reassessment dates | Perennial grass cover change | Perennial grass richness change | Overstorey cover change | Comments (e.g. soil surface, species richness, woody cover, eucalypt regeneration, current range condition) |
|---|---|---|---|---|---|---|---|
| **ORD HERITAGE continued …** | | | | | | | |
| ORD H7 | Y | Sept.1963 (no photo available) | 1974 (no photo available)<br>07/08/02 | ? | ? | ? | Not possible to assess change although site currently assessed as good condition, suggesting that improvement has occurred. Buffel grass is dominant, recent (April 2002) cool burn over site. |
| ORD H8 | Y | Sept. 1963 | July 1974<br>July 1977<br>11/08/02 | Increase | Increase | Increase | Good soil surface cover and mix of perennial grasses but dominated by buffel. Much improvement since 1963. |
| **ORD 'NEAR' HERITAGE** | | | | | | | |
| ORD H1 | N | Sept. 1963 | July 1974<br>July 1977<br>07/08/02 | Increase | Increase | Increase | In 1963 this was an almost bare red soil flat with a few annual species. By 2002 there was a dense cover of buffel grass and a good mix of other species. |
| ORD H12 | N | Sept. 1963 | 08/08/02 | Increase | Increase | Increase | In 1963, this area on the Turner Plain was bare, stripped and sheet eroded. There were dead eucalypts with exposed roots. Improvement to 2002 has been substantial, with a dense cover of *Cenchrus* spp., native perennial grasses and overstorey changes including recovery of eucalypts. |
| **ORD PANORAMA** | | | | | | | |
| | | | 09/08/02 | Increase | Increase | Increase | The Turner Plain has shown spectacular improvement since the 1960s with dense cover of *Cenchrus* spp., native perennial grasses and overstorey changes including recovery of eucalypts. |
| **FOX RMS** | | | | | | | |
| FR 1 | Y | 24/09/89 | 09/08/02 | Increase | Increase | Static | The site is still in poor condition but is improving somewhat, with a range of perennial grasses in the vicinity. |
| FR 3 | Y | 24/08/89 | 09/08/02 | Static | Static | Increase | The site has changed from being dominated by mixed hummock (spinifex) and tussock grass to hummock grass and woody shrubs (e.g. bardie bush, *Acacia victoriae*). |
| FR 11 | Y | 24/08/89 | 09/08/02 | Static | Static | Decrease | This site is in good condition, well covered in native perennial bunch grasses. |
| FR 12 | Y | 24/08/89 | 09/08/02 | Increase | Increase | Static | The site remains in poor condition and is predominantly bare ground. There are a range of perennial grasses in the vicinity. |

| | Front picket | Installation date | Reassessment dates | Perennial grass cover change | Perennial grass richness change | Overstorey cover change | Comments (e.g. soil surface, species richness, woody cover, eucalypt regeneration, current range condition) |
|---|---|---|---|---|---|---|---|
| **FOX RMS continued …** | | | | | | | |
| FR 20 | Y | 24/08/89 | 10/08/02 | Static | Static | Static | The site is in very good condition although there is some feathertop present. The soil surface condition is good with no erosion. |
| FR 24 | Y | 24/08/89 | 09/08/02 | Increase | Increase | Static | The area has improved significantly since 1989, although there is still considerable bare ground. A small amount of rilling persists. |
| FR 39 | Y | 24/08/89 | 10/08/02 | Increase | ? | Static | The site is in good condition with only small amounts of feathertop. No erosion. There has been slight improvement since 1989. |
| FR 41 | Y | 24/08/89 | 09/08/02 | Increase | Increase | Static | Although the site remains in fair condition, there is a reasonable mix of perennial species in the vicinity and there is no erosion. |
| **FOX EXCL** | | | | | | | |
| FR BTEX | Y | ? | 10/08/02 | ? | ? | ? | The site remains in good condition. |
| FR SDEX | Y | ? | 10/08/02 | Static | Static | Static | The site remains in good range condition, although buffel grass and feathertop are dominant. There is no erosion. |
| **FOX PANORAMA** | | | | | | | |
| STALLION YARD (flightline) | N | n/a | 10/08/02 | Increases | ? | Increase | The Stallion Yard area has shown substantial improvement since the 1960s, going from bare ground (flat enough to land a light aircraft) to well covered with ribbon grass. |
| **NLS 'NEAR' HERITAGE** | | | | | | | |
| NLS H1 | N | Sept. 1964 | Feb. 1965<br>June 1965<br>06/08/02 | Increase | Increase | Increase | In 1964 this site was bare ground, recently chisel ploughed. By 1965 there was some establishment in furrows but bare ground between. By 2002 the site had improved markedly with good cover of perennial grasses (*Cenchrus* spp. and native) and an increasing overstorey of eucalypts. |
| NLS H4 | N | July 1964 | Sept.-Oct. 1964<br>July 1965<br>11/08/02 | Increase | Increase | Increase | In 1964 this site was bare ground, sheet eroded throughout with no vegetation except one relict eucalypt. While still only in fair condition with slight sheeting, there has been dramatic improvement in ground cover (dominated by *Cenchrus* spp.) as well as an increasing overstorey of eucalypts. |