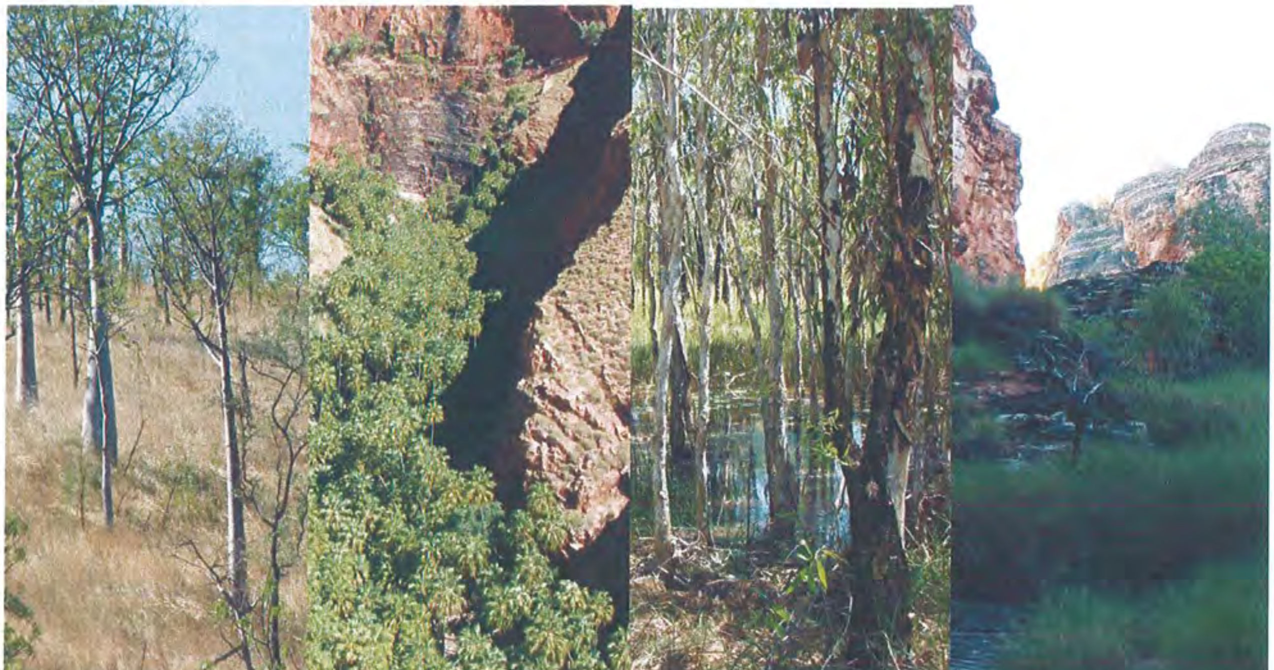
Benchmarking Biodiversity

LAND RESOURCE MAPPING IN THE ORD RIVER CATCHMENT

LANDFORM
VEGETATION
SOILS

"to understand, manage and protect our natural assets we need to know what and where they are".

T. Handasyde, P. Tille, A. Payne, N. Schoknecht, K. Carnes



Department of Agriculture and Food

Rangelands NRM
Western Australia

Department of Environment and Conservation
Our environment, our future

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This work was built on and utilised much historic land resource mapping and site information. Particularly (but not restricted to) DAFWA rangeland and soils work, ORD Bonaparte Program (CSIRO) mapping project, vegetation mapping of Lower Ord Ramsar Site (CALM 1998) and WA Herbarium records (DEC).

EXECUTIVE SUMMARY

The Ord River catchment lies in the east Kimberley in the extreme north-east of Western Australia and extends across the border into the Northern Territory. It was recognised as a priority catchment by the National Action Plan for Salinity and Water Quality (NAP). This project, biodiversity benchmarking by land resource mapping, was funded by NAP through Rangelands NRM Western Australia (Rangelands NRM), in partnership with the Ord Catchment Reference Group (OCRG).[1]

The project:

- brought together and standardised existing Ord River catchment land resource mapping held by the Department of Agriculture and Food (DAFWA) and Department of Environment and Conservation (DEC). The classification system used to standardise this mapping was adapted from the Northern Territory land unit mapping system (Napier *et al* in prep.). Ord River catchment and Northern Territory mapping will therefore be compatible.
- mapped to land unit level an additional 4400 sq km of the Ord River catchment.
- redigitised 2200 sq km of vegetation mapping previously not able to be accurately displayed in a Geographical Information System with other land resource data.
- utilised and built on existing DAFWA database systems to ensure post project security of data and mapping and that this information would remain accessible to land managers, government agencies, and other interested parties to inform further work.

It was possible to achieve a significant amount of work in a short period of time by utilising knowledge, experience and resources contributed by DAFWA, DEC, NAP, OCRG and the Land and Vegetation Unit, Northern Territory Department of Natural Resources, Environment, the Arts and Sport (NRETAS).

Land resource mapping, particularly vegetation and associated habitat mapping, provides an important tool to aid land managers in addressing threats to the environment. The impacts of changed fire regimes, feral animals and weeds are considered to be contributing to a dramatic decline in mammal species across northern Australia (Rothwell 2009). By enabling the development of an understanding of change that is occurring in the landscape, land resource mapping assists in management planning addressing associated issues. Land unit mapping also provides a valuable 'common language' tool that can encourage communication and cooperation between neighbouring land managers when seeking to jointly deal with land management issues.

A significant portion of the Ord River catchment still requires mapping at land unit scale. In this often rugged landscape with limited access, the continuation of this work will assist land managers in the difficult task of managing threats to the environment and so help protect the biodiversity, cultural and pastoral values of this unique region.

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[1] the Ord Catchment Reference Group is now known as the East Kimberley Reference Group.

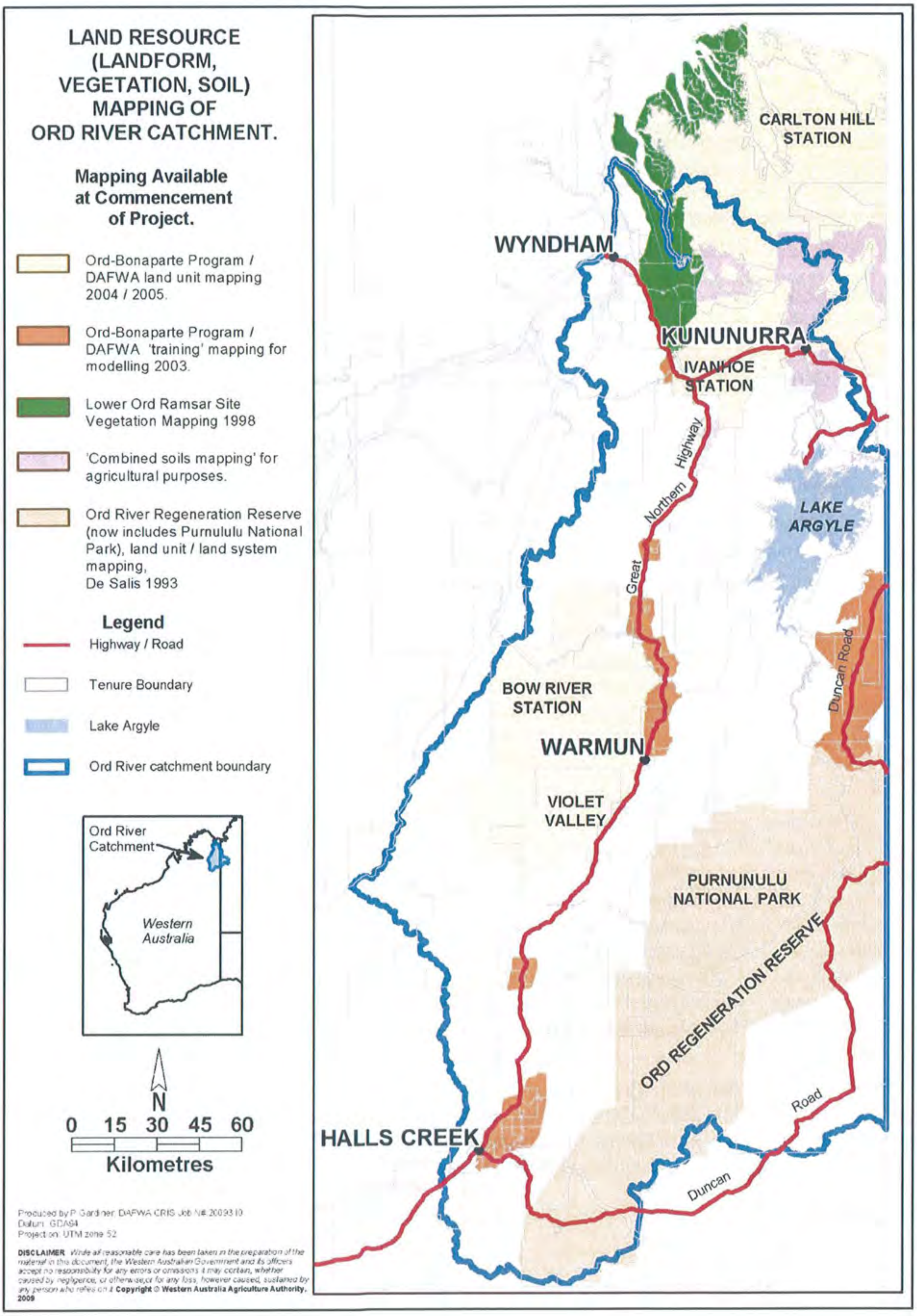

Figure 1. Land resource mapping in the Ord River catchment available at the commencement of this project.

INTRODUCTION

The Ord River catchment lies in the east Kimberley in the extreme north-east of Western Australia and extends across the border into the Northern Territory. Tenures within the Kimberley and the Ord River catchment are primarily pastoral land, Aboriginal land and conservation reserves.[1] These tenures are generally extensive and coupled with a rugged landscape, difficult and expensive to manage.

'Land unit' mapping which classifies country based on position in the landscape, vegetation and soils can be a useful tool and is an appropriate starting point when considering management issues. These include the impacts of fire, feral animals and weeds on fauna and flora and associated habitats, erodible soils and pastures for grazing.

Land unit mapping can also be an important tool in encouraging cooperative land management planning between neighbouring tenures. Maps provide a readily understandable format that can assist in discussion of sometimes complex issues. They can encourage identification of common goals or reasonable compromise.

Vegetation, being often the most obvious indicator of change in the landscape, is an important component of land unit mapping and was a particular focus of this project. Vegetation may be affected by seasonal conditions, climatic events, climatic change, inappropriate fire regimes, feral animals, weeds and management practices. Change in vegetation composition or abundance correspondingly modifies resources for fauna, pastoral enterprises and cultural aspirations or practises.

Additionally, within the diverse Kimberley landscape there are small pockets of country which despite their limited size are of great importance to biodiversity. Often dependant on water (e.g. rainforest patches or melaleuca thickets) the structure of and plant species associated with these small areas can differ markedly to that in the surrounding country. These areas are therefore likely to support fauna absent in the surrounding country.

The protection of vulnerable vegetation communities and associated habitats can only be included in management planning if their vulnerability and location are known. The continued decline in mammal species across northern Australia (Rothwell 2009) highlights the urgency of managing country to overcome threats to the environment such as changed fire regimes, feral animals and weeds.

This project brings together and builds on land unit and vegetation mapping already undertaken in the Ord River catchment. The utilisation of existing DAFWA database systems ensures that this work will remain available and be stored and maintained in a system that can be added to post this project. Collaboration between DEC and DAFWA resulted in experienced staff being available to undertake the work.

It is likely that in some areas an even more detailed level of classification of natural assets will be necessary to understand the impacts of changed fire regimes, feral animals, weeds, etc. The 'nested' or hierarchical system in which the mapping has been attributed enables more detailed data to be incorporated with existing data. In such a system, information or mapping can also be 'grouped up' for the purpose of broader scale reporting.

Land unit mapping that extends across tenure boundaries is an important tool in enabling:

- a better understanding of the distribution and make-up of vegetation communities.
- communication and co-operation between neighbouring land managers resulting in management planning that is better able to protect the natural assets and vegetation communities found in the Ord River catchment.

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[1] the Ord River Irrigation Area (ORIA) a discrete agricultural area in the north of the catchment, was not the focus of this project. However detailed soils mapping already available for the ORIA was attributed to conform with other project data.

BACKGROUND

There are several broad scale mapping classifications of land resources relevant to the Kimberley. These include:

- Interim Biogeographic Regions of Australia (IBRA)
- Vegetation of the Australian Tropical Savannas
- Pre European Vegetation (Western Australia)
- State geological mapping
- Land system mapping of Western Australia

(see Appendix 1 for details of this mapping).

However, although useful when reporting at a regional scale the detail of this mapping is insufficient to assist with on-ground management.

Land systems as mapped for the Western Australian rangelands, are defined as "a recurring pattern of landform, vegetation and soil". Land system maps have been available for the east Kimberley since 1970 (Stewart *et al* 1970). Although these original descriptions included a break down into sub-units, known as land units, based on landform, vegetation and soil, the boundaries of these land units were not delineated.

In 2004/2005, a joint Ord Bonaparte Program/DAFWA project delineated land units for Carlton Hill, Ivanhoe, Bow River and Violet Valley stations in the Ord River catchment (Schoknecht *et al.* 2004, 2005). In the interests of developing a standardised mapping system, conventions used were adapted from those in use in the adjoining Northern Territory (Napier *et al.*). This system differed somewhat from that used earlier by Stewart *et al.* (1970) but was better able to take advantage of computer technology.

As well as this 2004/2005 work, a number of other more detailed mapping projects (scale <1:100,000) had been undertaken in the Ord River catchment. These included soil surveys, mainly in or related to the Ord River Irrigation Area (Appendix 2), land unit mapping of the Ord River Regeneration Reserve (De Salis 1993) and vegetation mapping of the Lower Ord Ramsar Site (CALM 1998). Additionally, small areas had been mapped in detail as part of the pilot modelling component of the Ord Bonaparte Program/DAFWA project (Appendix 5).[1]

These more detailed surveys were however all done as separate projects and due to a lack of standardisation and inconsistencies in data collection, the data and information associated with the different surveys has not been queryable across project or tenure boundaries. Additionally several of these datasets have until now been unpublished and therefore have not been accessible to inform or function as a basis for further work (outside of DAFWA).

DAFWA had established in the 2004/2005 work, a land unit mapping system suitable for recording land resource information at a scale relevant to on-ground management.

Project funding was therefore used to contract DAFWA to:

- standardise existing land resource data available for the Ord River catchment and make this publicly available.
- redigitise the Lower Ord Ramsar Site vegetation mapping so as to rectify georeferencing problems associated with this data.
- assess whether the Lower Ord Ramsar Site data could be attributed to conform with the DAFWA soil-landscape hierarchy (Figure 2).
- undertake additional land unit mapping within the Ord River catchment.

[1] Vegetation and weed mapping of the Lake Kununurra Foreshore Reserve is also currently being finalised for the Shire of Wyndham-East Kimberley.

METHODS

1. Land unit classification and description – conventions

This project continued with conventions established by Schoknecht *et al.* (2004, 2005). These conventions, adapted from those in use in the Northern Territory (Napier *et al.* in prep)[1], subdivided the land systems of Stewart *et al.* (1970) into land units:

a) Land units are first classified according to one of 10 defined landform patterns:

1. Plateau surface
2. Escarpment and/or steep sideslopes to plateau
3. Rolling to steep hills (> 90m relative relief)
4. Undulating to rolling low hills (30 – 90m relative relief)
5. Gently undulating to rolling rises (9- 30m relative relief)
6. Level to undulating plains (<9m relative relief)
7. Level to undulating alluvial plains and backplains (<9 m relative relief)
8. River systems, creeklines, drainage areas, their levees, terraces, flood out areas, anastomotic plains, backplains & swamps
9. Steep low hills (30 – 90 m relative relief)
10. Steep low rises (9 – 30 m relative relief)
11. Low linear sandy banks and low dunes.

b) The landform pattern is then described according to geological origins so the description for **6** (above) could read:
- **Level to undulating plains (<9m relative relief) on granite or colluvium.**

c) This is then described according to soil and vegetation, the previous example becoming:
- **Level to undulating plains (<9m relative relief) on granite or colluvium with red or brown sandy or loamy earths. *Eucalyptus brevifolia* and *Corymbia opaca* trees over *Carissa lanceolata* shrubs. Grasses such as *Chrysopogon fallax*, *Heteropogon contortus* & *Enneapogon* spp.**[2]

d) This project and Schoknecht *et al.* (2004, 2005) included, where it was considered to be of value and there was sufficient information, a further subdivision of land units based on soils, vegetation, or other features relevant to use of the mapping - this subdivision is known as a phase. The phase subdivision still requires standardisation.

Within a land unit, soils and vegetation can incorporate some to considerable variation. A land unit description is therefore 'descriptive' rather than 'prescriptive'.

2. Selection of areas to be mapped

Lower Ord Ramsar Site (Parry Lagoons and Lower Ord River Nature Reserves): remapping

The vegetation of the Lower Ord Ramsar Site had been mapped in detail (CALM 1998) utilising a stereoscope and 1:50,000 aerial photography, consulting hard copies of J.S.Beard's vegetation mapping[3] and a considerable amount of fieldwork (Vernes 2009, pers.comm.). Not originally georeferenced, subsequent attempts to georeference this data for use in a Geographical Information System (GIS) had yielded inaccurate results.

The most cost effective method of making this mapping available for use in a GIS was to remap the vegetation associations based on the original mapping.

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[1] Napier *et al.* (in prep) conventions are derived from the Australian Soil and Land Survey Field Handbook (NCST 2009).

[2] Vegetation conventions in NCST (2009) used for this project, replace the terms woodland, shrubland and grassland with trees, shrubs, grasses. Land unit descriptions for this project have not as yet been updated to this terminology.

[3] Beard's vegetation mapping is the basis of Pre European Vegetation (Appendix 1).

Mabel Downs, Texas Downs and Osmond Valley stations: new mapping

The decision to map this area was driven primarily by the availability of digital data - high resolution orthorectified photo mosaics (aerial photography), 1:100,000 to 1:250,000 scale geological mapping and some survey site data (details in Table 1).

Additionally, mapping this area would link existing land unit mapping for Bow River station (Schoknecht *et al.* 2005) and Ord River Regeneration Reserve (De Salis 1993).[1] It was expected that availability of this existing adjoining mapping and associated relevant site data, would speed up the mapping process (important given the limited time frame for completion of the work).

It was also hoped that there might be sufficient time, to extend the mapping in this area to include the Osmond Range (proposed conservation reserve, part of the Purnululu Conservation Reserve and Unallocated Crown Land). This was achieved.

3. Work undertaken pre field work

Lower Ord Ramsar Site (Parry Lagoons and Lower Ord River Nature Reserves: remapping

The inaccurately georeferenced linework was reviewed on a computer screen against orthorectified photo mosaic aerial photography and redrawn[2] by identifying the intent of the original mapping (Figures 4 & 5).

There was some reinterpretation of the original mapping - some boundaries were more tightly defined and some boundaries were modified where the original linework did not match the patterns on the current orthorectified photo mosaics (Figures 4 & 5).[3]

A preliminary grouping of vegetation associations into land units was undertaken based on landform, vegetation, contour and geological data. Details of data used and data status are recorded in Table 1.

Mabel Downs, Texas Downs and Osmond Valley stations and the Osmond Ranges: new mapping

Preliminary delineation of land units were recorded directly on-screen[2]
These were based on interpretation of georeferenced:

- colour orthorectified photo mosaics generated from aerial photographs
- contour data - to assess relief and slope
- 1:100,000 and 1:250,000 scale geological mapping.

Additionally the following georeferenced datasets were referred to:

- DAFWA land system and land unit (Bow River) mapping
- survey site data (Figure 4)
- radiometric data
- Landsat 7 Thematic Mapper imagery
- Satellite imagery on Google Earth (not incorporated on screen as a georeferenced layer; this may be a useful layer for some areas in future work).

Detail of data used is recorded in Table 1.

[1] The original Ord River Regeneration Reserve mapping will require remapping in the future. This mapping was undertaken to help address soil erosion in the Reserve. Mapping was based on an earlier classification system (De Salis 1993) and was not mapped consistently as land units (some areas remained mapped only to land system level). However, future remapping to conform with Schoknecht *et al.* (2004, 2005), will be made easier by the existence of the mapping undertaken for this project in the central Ord River catchment. Purnululu National Park and Conservation Reserve were excised from the original Ord River Regeneration Reserve in 1986.

[2] Linework was captured into an Intergraph Geomedia warehouse.

[3] Note: 1990 & 1994 aerial photography was used for the original mapping. A 2004 orthorectified photo mosaic was used for the remapping. Differences in some of the linework may be attributable to a change in vegetation: it appears that some change has occurred since the original mapping due to erosion, deposition and spread or contraction of mangroves.

4. Fieldwork

Data collection – standards and conventions

- Soils data was described according to the Australian Soil and Land Survey Field Handbook, (NCST 2009) and recorded on Sheet A (Appendix 3).
- Vegetation data was recorded to conform or be compatible with NCST (2009). These classifications are compatible with the National Vegetation Information System (NVIS)[1]. Vegetation and biodiversity related data was recorded on Sheet B (Appendix 3).
- Sheet C (Appendix 3) incorporates landform and basic rock and soils attributes. In the absence of a soils scientist, this sheet would be used in lieu of Sheet A.

General reconnaissance trip

An initial reconnaissance field trip was undertaken to familiarise project personnel with the project area.

As the intention of this project was that land units would be compatible with those mapped in the Northern Territory, mapping personnel from (NRETAS)[2] participated in this trip, to discuss methodology in use in the Northern Territory, particularly in relation to soils data.

Lower Ord Ramsar Site (Parry Lagoons and Lower Ord River Nature Reserves: field work

Four days were allocated to reconnaissance and data collection in Parry Lagoons (one soil and one vegetation person). This was to help inform the re-mapping process and review the original vegetation descriptions.

- Landform, vegetation and soils data was recorded at 22 sites. Brief descriptions were made at an additional 40 sites.
- All data was recorded on data sheets A and B (Appendix 3).
- The field work utilised a 'real-time tracking' computer setup - ArcView software and a Garmin GPS plug-in. This enabled current and (previous) positions to be reviewed on-screen against vector and raster data (orthorectified photo mosaics, geology and land systems) as required.

Additionally, the initial field work identified an anomaly in some of the vegetation associations classified in the original report as rainforest and spring vegetation. Data was therefore collected from 14 sites to review this classification (sites, otherwise inaccessible, were accessed by helicopter). This work, undertaken at the end of the project is still being incorporated with and reviewed against existing data.

Mabel Downs, Texas Downs and Osmond Valley stations and the Osmond Range: field work

- Two field trips totalling 17 days were spent reviewing preliminary mapping and collecting landform, vegetation and soils data.
- The 4 personnel on each trip worked as 2 teams, (one soils and one vegetation person per team). Site locations (Figure 3) were restricted by vehicle access except for 2 days use of a helicopter to survey sites in the Osmond Range (not accessible by vehicle).
- Vegetation/soils data was recorded at 98 sites and brief descriptions at 80 additional sites
- The field work utilised a 'real-time tracking' computer setup - ArcView software and a Garmin GPS plug-in. This enabled current and (previous) positions to be reviewed on-screen against vector and raster data (orthorectified photo mosaics, geology and land systems) as required.
- All site data was recorded on data sheets A and B (Appendix 3).

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[1] NVIS classifications will progressively be changed to match NCST (NCST 2009, p 74).

[2] Land and Vegetation Unit, Northern Territory Department of Natural Resources, Environment, the Arts and Sport.

5. Post fieldwork modification to linework and descriptions

- Post field work the preliminary mapping was modified based on fieldwork ground-truthing with reference to site data.
- Existing land unit descriptions were reviewed and modified if necessary.
- Where necessary, new land units were described based on site data.
- Linework was 'edge matched' with existing adjoining data and associated attributes updated as necessary.[1]

A useful data set that became available only toward the end of the mapping process was the vegetation records from DAFWA rangeland condition assessments. As there was insufficient time to utilise this data fully it was only referred to where existing data for a particular land unit was limited.

6. Database – data attribution and storage

Site and map unit (land unit) data is attributed in the DAFWA database system according to the DAFWA soil-landscape hierarchy (Figure 2).

DAFWA has four database systems relevant to this project:

- **Map unit polygons** - collectively these polygons are stored as **digital linework** (land unit linework is stored here).
- **Map Unit Database** – map unit (land unit) descriptions and associated data.
- **SoilCalc Database** - interpretive soil and landform information used for land capability analysis.
- **Soil Profile Database** - includes site specific information such as soil profile descriptions, the results of laboratory analyses and photographs. Vegetation data will be stored in this database. The online ORACLE version of this database requires modification to adequately incorporate vegetation and other biodiversity data recorded for this project. Currently soils and landscape data has been entered directly into ORACLE while vegetation data is being entered into an offline database for later uploading to ORACLE.

[1] Edge-matching of Carlton Hill station and Ord River Nature Reserve linework has not as yet been done. The Ord River Regeneration Reserve mapping (which now encompasses Purnululu National Park) requires further work to conform with and therefore to be edge-matched with 2008-2009 mapping - see Table 2 for details.

1. Region

Broad subdivisions of the Australian continent

e.g. **Kimberley Region**
(3)

2. Province

Provides a broad overview of the whole state - suitable for maps at scales of about 1:5,000,000

e.g. **Southern Kimberley Ranges Province**
(31)

3. Zone

Area defined on geomorphological or geological criteria - suitable for regional perspectives

e.g. **Halls Creek Ridges Zone**
(314)

4. Land system

Areas with recurring patterns of landforms, soils and vegetation - suitable for regional mapping at scales of about 1:250,000

e.g. **Wickham land system**
(314Wk)

5. Land unit

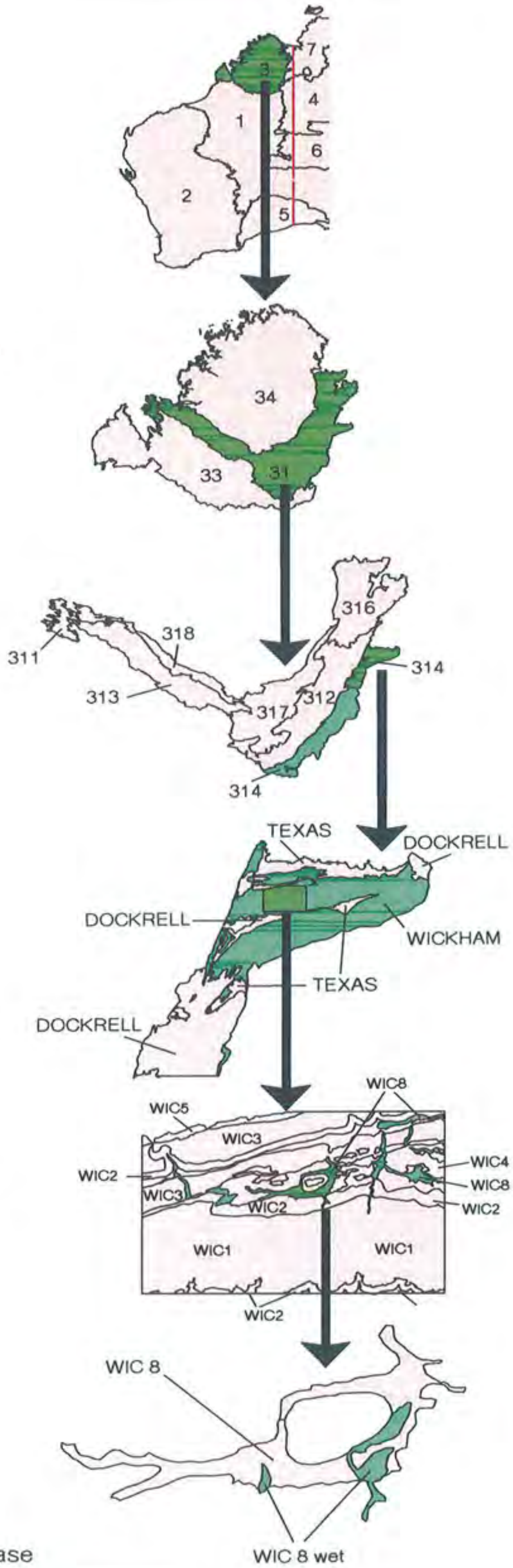
Classified according to position in landscape*
Further described by vegetation and soils - suitable for mapping at scales of 1:50,000 - 1:100,000

e.g. **Wickham 'river system' land unit**
(314Wk_8)

6. Land unit phase

Further division of land unit based on vegetation association, soil type or other specific interest

e.g. **Wickham 'river system' wet phase**
(314Wk_8l50) - In this instance "l" signifies alluvium*
and "50" has been assigned to represent the "wet" phase



Note: Codes in brackets are as entered into DAFWA's Map Unit Database
* Napier et al in prep.

Figure 2. DAFWA soil-landscape hierarchy - data is attributed in the database to comply with this hierarchy (in the Kimberley land systems are commonly known by three letter codes, however in the database land systems are attributed with 2 letter codes).

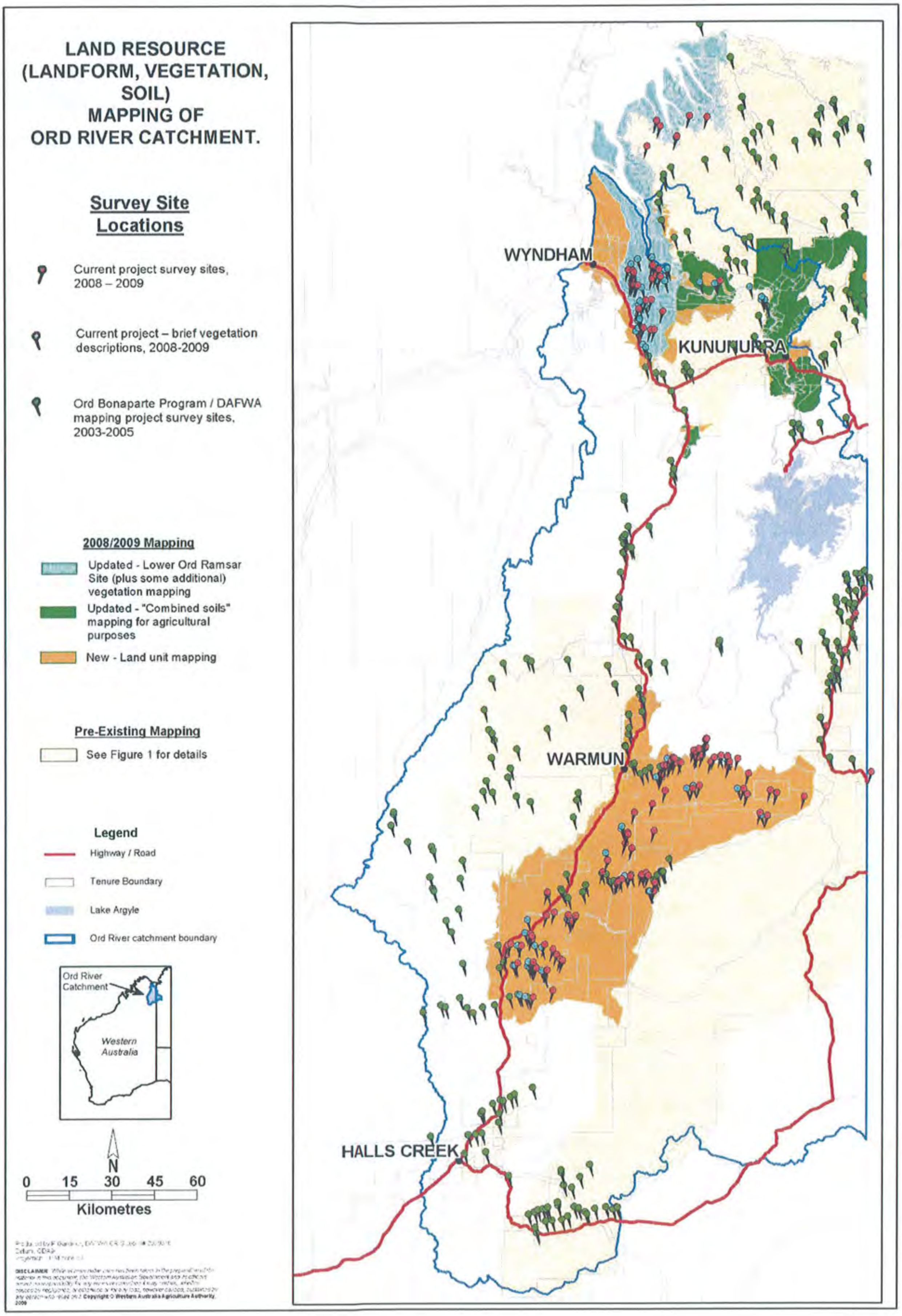


Figure 3. Location of sites where land unit and / or vegetation data was collected in 2003-2005 and in 2008-2009.

Table 1. Details of new mapping, and remapping in the Ord River catchment, 2008 – 2009
(Transverse Mercator Projection, Geocentric Datum of Australia (GDA94), Map Grid of Australia 1994 Zone 52).

<table>
<tr><th>New mapping and re-mapping</th><th>Data used to inform mapping</th><th>Nominal scale of mapping</th><th>Topographic maps (1:100,000)</th><th>Comments</th></tr>
<tr><td>New land unit mapping:
Mabel Downs, Texas Downs, Purnululu Conservation Reserve and Unallocated Crown Land that will be managed as part of the DEC estate post 2015.</td><td>• Geology: - scale 1:100,000 and 1:250,000 (Appendix 1)
• Contour data: 10 m contours - from 1:50,000 Army Survey topographic maps, 1992 (Microstation design files) were available for all of the area except Osmond 1:100,000 map sheet where only contours generated from 1 second digital elevation model (Space Shuttle data) were available; this data is less reliable than the Army Survey topographic maps.
• Aerial photography: orthorectified photo mosaics generated from 1:25,000 scale colour aerial photographs, flown July 2004.
• Other datasets referred to:
- WA rangeland land system mapping
- Violet Valley and Bow River land unit mapping
- Radiometric data
- Landsat 7 Thematic Mapper imagery
- Satellite imagery on Google Earth (not incorporated on screen as a georeferenced layer; this may be a useful layer for some areas in future work).
• Field data (2008-2009): 98 survey & 80 brief description sites (Figure 2).
• Field data (2003-2005): 41 survey sites (Figure 2).</td><td>1:50,000</td><td>4462 – McIntosh
4463 – Mount Remarkable
4564 – Bow
4563 – Turkey Creek
4562 – Dixon
4663 – Osmond</td><td>• Preliminary mapping - delineated directly on-screen using Geomedia.
• Two field trips (17 days) – reviewing preliminary mapping and collecting landform, vegetation and soils data:
- utilised a 'real-time tracking' computer setup - ArcView software & Garmin GPS plug-in. This enabled position(s) to be reviewed against preliminary mapping and other digital data.
• Post field work - preliminary mapping modified based on fieldwork ground-truthing with reference to site data.
• Linework -'edge matched' with Bow River station mapping and adjoining 'training' mapping and associated attributes updated as necessary (adjoining De Salis mapping is land systems only).
• Existing land unit descriptions updated based on site data if necessary.</td></tr>
<tr><td>Re-mapping of vegetation associations:
Lower Ord Ramsar Site - Parry Lagoons Nature Reserve section (CALM 1998).</td><td>• Original linework: this had been georeferenced but results were inaccurate.
• Orthorectified photo mosaics: - derived from 1:25,000 colour aerial photographs, July 2004.
• 10 m contours: - 1:50,000 scale Army Survey topographic maps, 1992 (Microstation design file)
• Geology: - Cambridge Gulf 1:250,000 map sheet (GSWA 1970); ESRI shapefile format.
• Field data (1998): could not be located.
• Field data (2008): 22 survey sites & 40 brief description sites (Figure 2).</td><td>1:50,000</td><td>4566 – Erskine
4567 – Wyndham</td><td>• Inaccurately georeferenced linework reviewed on-screen against orthorectified photo mosaic & redrawn (in Geomedia) by identifying intent of original mapping.
• Vegetation associations attributed to enable merging with adjacent Carlton Hill and Ivanhoe land unit mapping. Vegetation descriptions currently being reviewed against Carlton Hill - Ivanhoe station land units; this may result in modification of either vegetation or land unit descriptions.
• 'Rainforest / spring classification' (original mapping) is still being reviewed.
• Additional field work will enable further refinement of vegetation descriptions and mapping.</td></tr>
</table>

Re-mapping of vegetation associations: Lower Ord Ramsar Site - Ord River Nature Reserve section (CALM 1998).	• **Original linework:** this had been georeferenced but results were inaccurate. • **Orthorectified photo mosaics**: - generated from 1:25,000 colour aerial photographs, July 2004. • **Field data (1998):** could not be located. • **Field data (2009):** data recorded from 14 sites (Figure 2) to help clarify 'rainforest /spring vegetation' classification anomalies.	1:50,000	4567 – Wyndham 4568 – Medusa 4667 – Carlton 4668 – Knob Hill	• Inaccurately georeferenced linework reviewed on-screen against orthorectified photo mosaic & redrawn (in Geomedia) by identifying intent of original mapping. • Vegetation associations attributed to enable merging with adjacent Carlton Hill land unit mapping. Vegetation descriptions currently being reviewed against Carlton Hill land units - may result in modification of either vegetation or land unit descriptions. • 'Rainforest / spring vegetation' classification (original mapping) is still being reviewed. • Additional field work will enable further refinement of vegetation descriptions and mapping.
New mapping: Mirima National Park.	• **Orthorectified photo mosaics:** derived from 1:25,000 colour aerial photographs, June 2005.	1:50,000	4666 – Kununurra	• Preliminary desk-top mapping only. • No ground truthing undertaken.

Table 2. Land resource mapping for the Ord River catchment available at commencement of this project (Figure 1).

Land unit, vegetation & soils mapping existing at commencement of project	Data type	Nominal scale of mapping	Project and project personnel	Publication	Data modifications	Comments
Carlton Hill and Ivanhoe stations land unit mapping	Land unit	<1:100,000	Ord Bonaparte Program / DAFWA, land unit mapping. A. Payne, N. Schoknecht, S. Williams, 2004.	See Appendix 5 for history of this mapping. Additional details of this work are recorded by Tille (in prep).	• Edge matched with adjacent / overlapping Parry Lagoons and 'Combined Ord Valley soil' mapping. • Data attributed to conform with DAFWA soil-landscape mapping hierarchy (Figure 2). • Minor modification to land unit descriptions to conform with standardisation.	• Still to be edge-matched with Lower Ord Nature Reserve mapping. • Standardisation of some land unit classes still required. • Some inconsistencies in linework still to be reviewed.
Violet Valley and Bow River stations land unit mapping.	Land unit	<1:50,000	Ord Bonaparte Program / DAFWA, land unit mapping. A. Payne, N. Schoknecht, 2005.	See Appendix 5 for history of this mapping. Additional details of this work are recorded by Tille (in prep).	• Edge matched with adjacent / overlapping Mabel Downs and OBP 'training' mapping. • Data attributed to conform with DAFWA soil-landscape mapping hierarchy (Figure 2).	• Standardisation of some land unit classes still required. • Some inconsistencies in linework still to be reviewed.

					• Minor modification to land unit descriptions to conform with standardistion and new site data.	
Ord River Regeneration Reserve land unit mapping.	Land unit and land system (land unit mapping still requires standardisati on with Schoknecht *e t al.* (2004, 2005).	<1:100,000	Ord River Regeneration Reserve, resource inventory and condition survey (De Salis, 1993).	De Salis J (1993). Resource inventory and condition survey of the Ord River Regeneration Reserve. Western Australian Department of Agriculture Miscellaneous Publication 14/93.		• Land units mapping still to be updated, to conform with Schoknecht *et al* (2004, 2005) & attributed, to conform with DAFWA soil-landscape hierarchy. • Still to be edge-matched with 'training mapping' (Appendix 5). • Further comments on mapping - Tille (in prep).
Lower Ord Ramsar Site (Parry Lagoons and Ord River Nature Reserves) vegetation mapping (see Appendix 4 for details of original mapping).	Vegetation mapping.	<1:100,000	Vegetation mapping for Lower Ord Ramsar Site. G.Graham, T.Vernes, C.Done, M.Pittavino.	Lower Ord Ramsar Site Draft Management Report (Department of Conservation and Land Management, Kununurra, WA. 1998.	Re-mapped - see Table 1.	• originally mapped using 1:50,000 aerial photography, J.S.Beard's vegetation mapping[1] and a considerable amount of fieldwork. Not originally geo-referenced; attempts to subsequently geo-reference inaccurate. • Included in original report as 4 x A3 and 1 x A4 maps (Appendix 4).
Ord Bonaparte Program 'training' land unit mapping (see Appendix 5 for details).	Land unit	unspecified	Ord Bonaparte Program / DAFWA, pilot land unit modelling project. N. Schoknecht, A.Payne, P.Baird, DAFWA. E.Bui & D.Simon, CSIRO Land and Water (2003)	Mapping not published.		• Inconsistencies in linework still to be addressed. • Additional comments on mapping – Appendix 5 & Tillie (in prep).
Ord Valley soils mapping – Various surveys amalgamated into 'Combined Ord Valley soils'.	Soils mapping undertaken primarily for agricultural purposes.	<1:50,000	• List of surveys and associated reports (Appendix 2 & 6). • History of mapping by Tille (in prep.).	• List of surveys and associated reports (Appendix 2 & 6). • History of mapping by Tille (in prep.).	• Mapping attributed to conform with DAFWA soil-landscape mapping hierarchy (Figure 2). • Linework edge-matched with adjacent / overlapping mapping.	• Attributed according to DAFWA soil-landscape hierarchy, data can now be displayed at land unit level with other Ord catchment land unit mapping. • There is also vegetation data for these surveys in the hard copy reports.

[1] Pre European Vegetation mapping (Appendix 1) is based on vegetation mapping by J.S. Beard.

RESULTS / PROJECT OUTCOMES

Vegetation associations had been mapped for the Lower Ord Ramsar Site (Parry Lagoons and the Ord River Nature Reserves) prior to the commencement of this project (CALM 1998). However this mapping could not be accurately viewed in a GIS due to problems with georeferencing (Table 2). These vegetation associations have now been remapped (Figures 7 & 8) [1] and can be reviewed against other digital data such as fire scars, weed and feral animal distribution, etc. The mapping can now more easily be used to assist in management planning and as a framework for more detailed mapping if required. The data has been attributed according to the DAFWA soil-landscape hierarchy so it can be reviewed at land unit level with adjoining mapping. Table 1 details work undertaken and status of data.

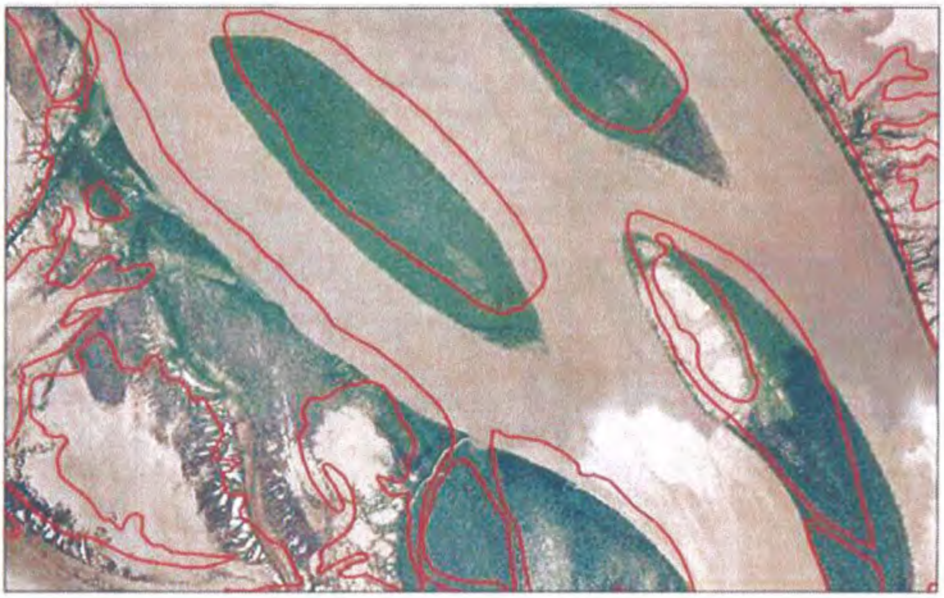


Figure 4. Original vegetation mapping for the Lower Ord Ramsar Site and 2004 orthorectified photo mosaic (georeferencing of original linework yielded inaccurate results).

Figure 5. Lower Ord Ramsar Site vegetation mapping - remapped directly onto a computer screen, based on interpretation of intent of original linework and 2004 orthorectified photo mosaic (aerial photography).

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[1] There has been some modification of the original linework where this did not match patterns on the current orthophoto mosaic and some boundaries have been more tightly defined – these changes are still being reviewed.

A further 4400 sq km of land unit mapping was undertaken for this project in the central section of the Ord River catchment (Figures 6 and 9). Mapping encompassed Mabel Downs, Texas Downs and Osmond Valley stations, Purnululu Conservation Reserve and Unallocated Crown Land (some of which will become part of conservation estate post 2015). This mapping has been attributed according to the DAFWA soil-landscape hierarchy and edge-matched with existing land unit mapping for Bow River station (Schoknecht *et al* 2004).

Figure 9 shows this new land unit mapping and adjacent existing mapping for Bow River station and Violet Valley, 'coloured up' according to landform pattern. This enables the extent of these different landforms to be reviewed across a much greater area than previously available. Alternatively the land units could be interrogated on geology, vegetation or soils although further standardisation of the mapping data is required to improve the usefulness of these classifications.

Other land resource mapping that existed prior to the commencement of this project (Figure 1) has now also been edge matched with adjoining mapping so that it can be reviewed across the extent of the data at land unit level.[1] This previously existing mapping which has been attributed according to the DAFWA soil-landscape hierarchy (Figure 2) includes[2]:

- land unit mapping for Carlton Hill, Ivanhoe, Bow River and Violet Valley stations (Schoknecht *et al.* 2004, 2005).
- 'combined soils' mapping - primarily soils mapping for the Ord River Irrigation Area (Appendix 2).

The DAFWA soil-landscape 'nested' hierarchy (Figure 2) with which the data for this project has been attributed enables data from different projects (and with varying levels of detail) to be recorded and available in the one system. For example 'phase' level mapping such as vegetation mapping for the Lower Ord Ramsar Site or soils mapping as delineated for the Ord River Irrigation Area are recorded in the same system as land unit mapping and can be 'grouped up' to land unit level if required. This enables a more extensive coverage of mapping at land unit level than would otherwise be available.

Land unit conventions have been adapted from the land unit mapping system in use in the Northern Territory (Napier *et al* in prep.). These conventions are derived from the Australian Soil and Land Survey Field Handbook (NCST, 2009). Soils and vegetation site data has also been recorded based on NCST (2009). Mapping and data will therefore be compatible with Northern Territory land unit mapping.[3]

Figure 6 shows the extent of new and updated land resource mapping available for the Ord River catchment at the completion of this project in context of mapping available at the commencement of the project.

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[1] Edge-matching of Carlton Hill station and Ord River Nature Reserve linework has not as yet been done.

[2] The Ord River Regeneration Reserve mapping (which now encompasses Purnululu National Park) requires further work to conform with Schoknecht *et al* (2004, 2005) and 2008-2009 mapping - see Table 2 for details. Ord Bonaparte Program / DAFWA 'training mapping' (Figure 1) has still to be attributed and edge-mapped with other mapping.

[3] Vegetation data is also compatible with the NVIS classifications used by Australian Wildlife Conservancy at Mornington station for vegetation mapping. NVIS will progressively be changed to match NCST (NCST 2009, p 74).

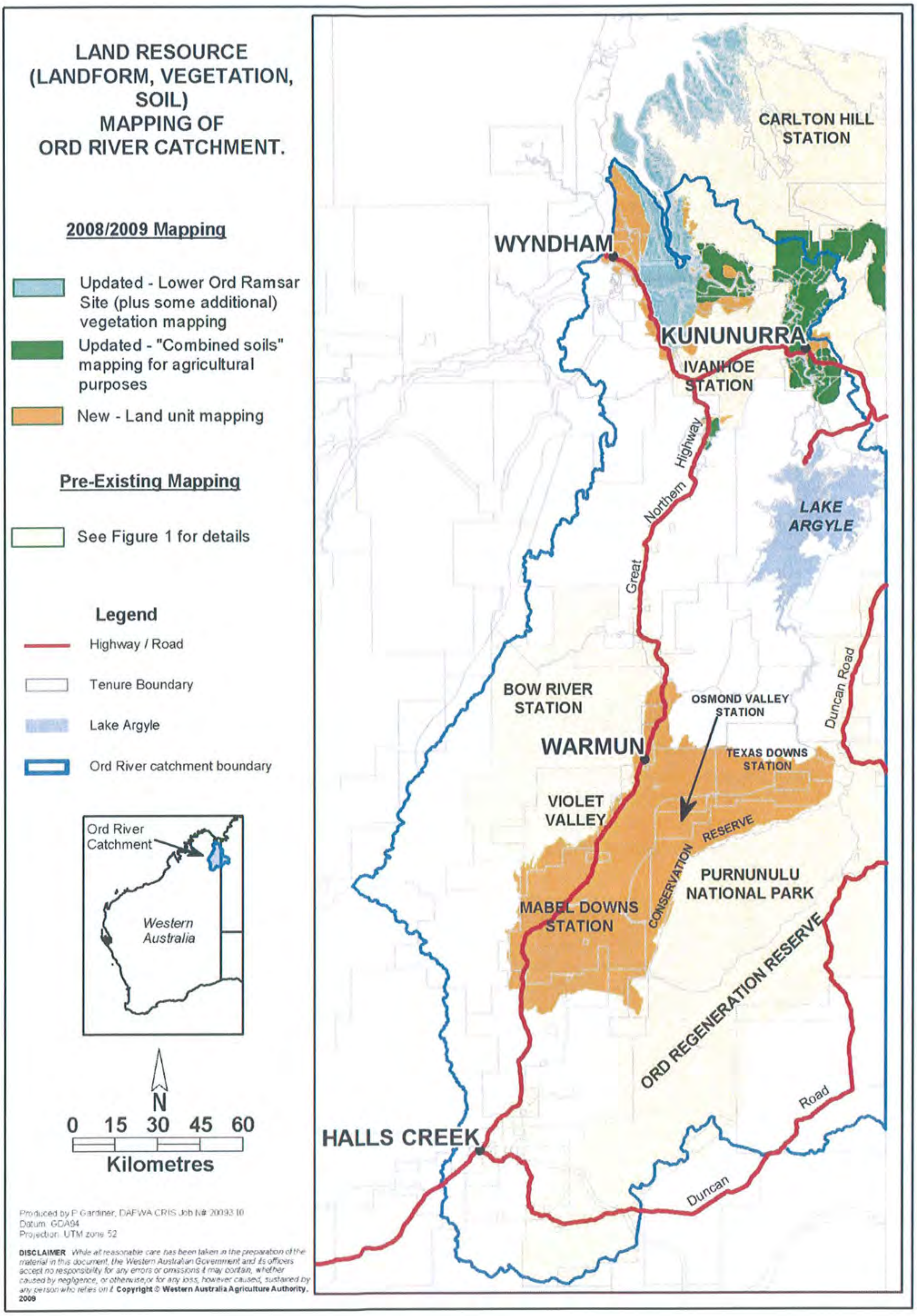

Figure 6. Land resource mapping available for the Ord River catchment at completion of this project.

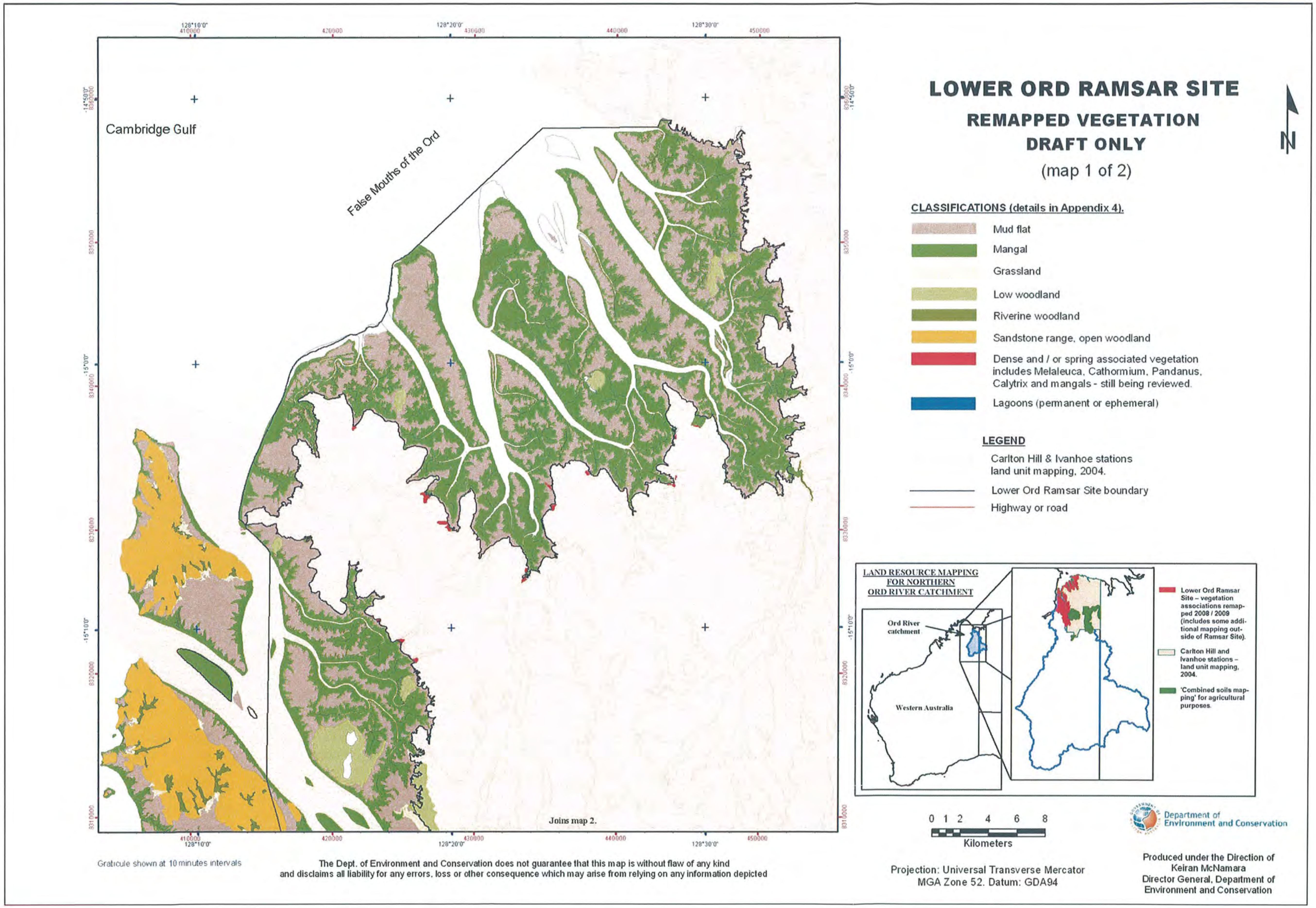

Figure 7. Map 1 of 2 - vegetation mapping for the Lower Ord Ramsar Site (includes Parry Lagoons and Ord River Nature Reserves). Originally mapped in 1998, linework was redigitised for this project to overcome georeferencing problems (see RESULTS / PROJECT OUTCOMES for further details).

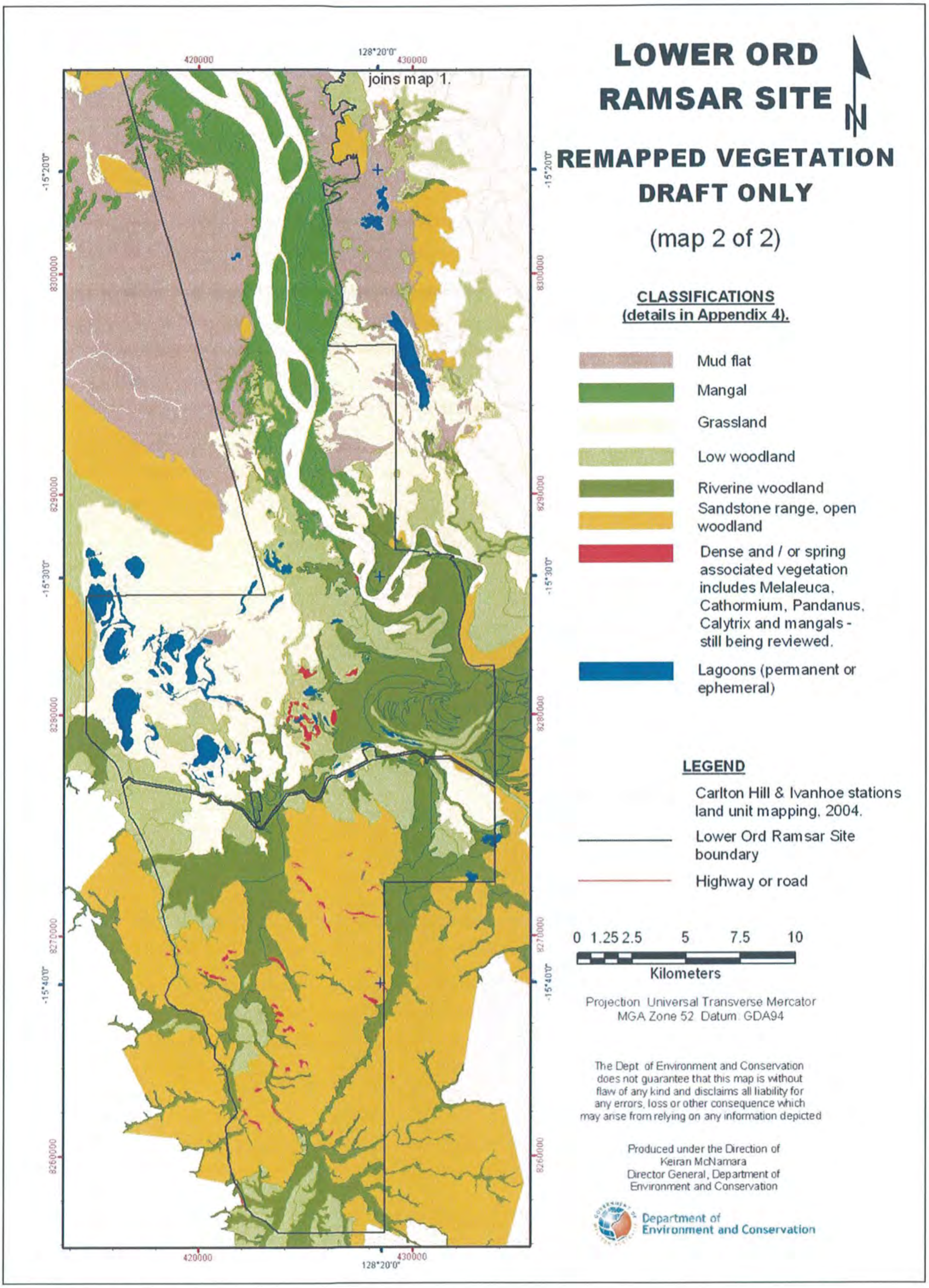

Figure 8. Map 2 of 2 - vegetation mapping for the Lower Ord Ramsar Site (includes Parry Lagoons and Ord River Nature Reserves). Originally mapped in 1998, linework was redigitised for this project to overcome georeferencing problems (see RESULTS / PROJECT OUTCOMES for further details).

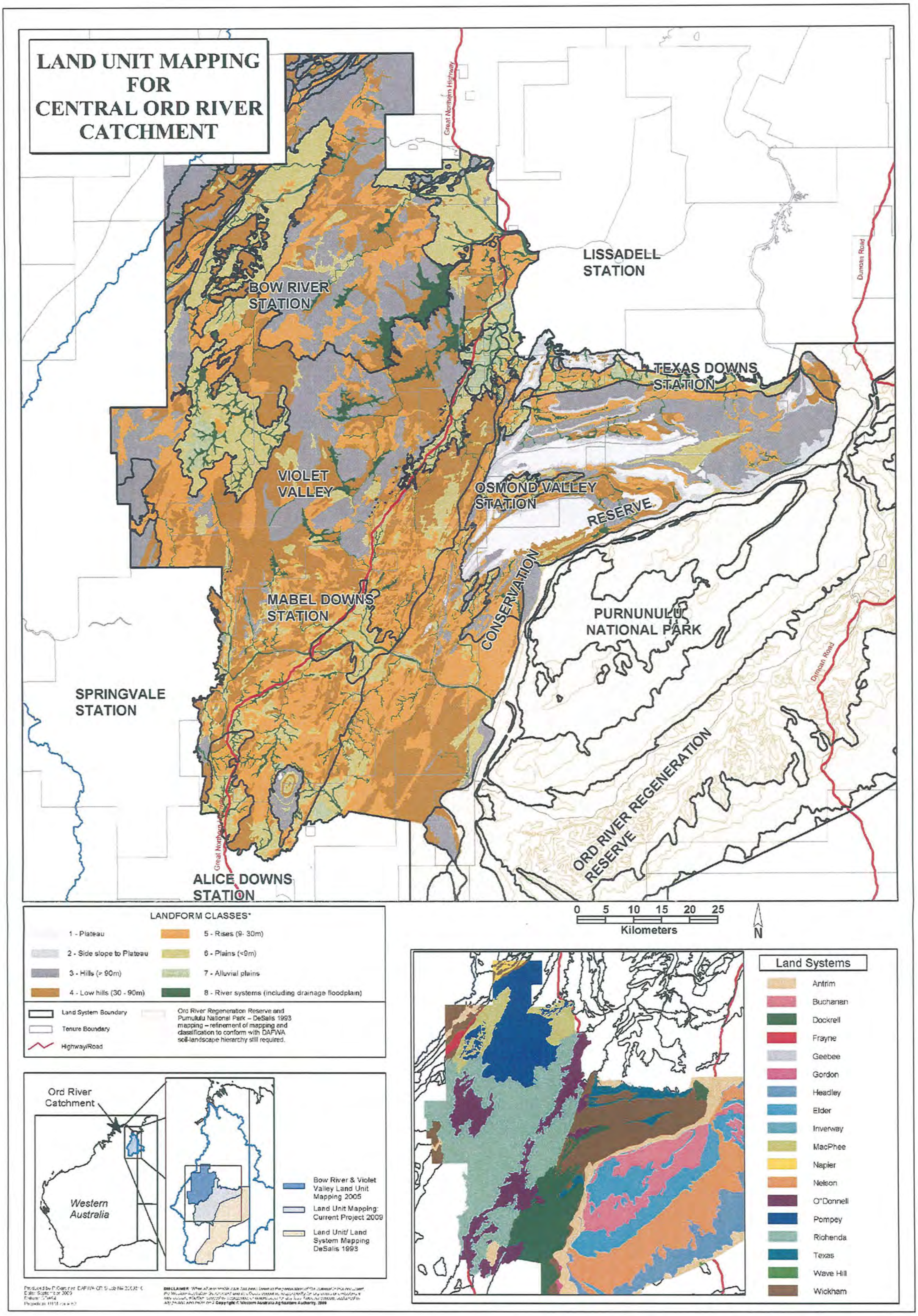

Figure 9. Land unit mapping for the central section of the Ord River catchment available at completion of this project. As an example of how the mapping might be used it is displayed here according to landform.* Landform can be further subdivided based on geology, vegetation and soils.

* See METHODS for expanded landform descriptions.

DISCUSSION

Importance - understanding and communication

Land resource mapping, particularly vegetation mapping is an important tool in:

- developing an understanding of the different vegetation communities and habitats that exist and where these are located.
- helping to understand and manage the impacts of inappropriate fire regimes, weeds, feral animals, over-grazing by domestic stock and other threats to the environment.

Land resource mapping also provides a 'common language' communication tool. It can help land managers in more clearly identifying to others areas they have concerns about or that are of importance to them. This is particularly of value when neighbouring land managers manage country for different purposes, such as conservation and pastoralism. A better understanding of the concerns of neighbours encourages cooperation and can help therefore in protecting vulnerable areas or species.

Managing country

Fire - extensive hot fires are a primary threat to biodiversity, pastoralism and cultural values. Allowing sufficient time for areas burnt in such fires to recover or be recolonised is a major challenge for land managers. Reviewing fire scars and fire scar history against land unit mapping can help build a picture of fire sources and patterns. By identifying where vulnerable species or communities, or high value grazing lands are located in relation to past or anticipated fire, land unit mapping can assist in more effective use of resources to protect such areas.

Feral animals and weeds - reviewing the distribution of feral animals and weeds against land unit mapping can enable a clearer understanding of associated issues such as source of invasion, reason for invasion, other potentially vulnerable areas, etc.

Infrastructure placement - land unit mapping provides a tool to help decide appropriate placement of infrastructure, particularly road and fence alignment – important in protecting vulnerable areas, minimising erosion and for the effective use of resources.

More detailed mapping - of particular importance for vulnerable species or communities.

Land unit mapping provides a framework within which more detailed mapping can be incorporated. Within the landscape there are pockets of country that may be quite small in size but are important for maintaining biodiversity or have particular cultural or pastoral value. These include:

- pockets of more diverse vegetation that survive in rock protected areas or where soil moisture remains available; such areas can provide food or shelter otherwise absent.
- vegetation associations that include trees with nesting hollows suitable for species such as the gouldian finch and arboreal mammals.
- small areas of productive black soil plain pasture.
- species of value as cultural resources.

As an example of this more detailed mapping, a 'wet' phase of vegetation (generally water dependent) was mapped for this project in the Osmond Range area. This 'phase' can be clearly identified on aerial photography. The distinctly denser vegetation is primarily associated with creek, river or gorge systems or seepage areas. In the Wickham land system they were generally mapped as a 'phase' of the 'river systems' land unit (Figure 2).

Although not undertaken for this current work, this 'wet' phase could be further classified according to the different vegetation associations (Figures 10 - 13).

Note: As this was only an example of 'phase' mapping, the process of identifying 'wet' phases was not exhaustive. Further examination of aerial photography is required to complete this classification. 'Wet' phases have often already been identified (by aerial photographic interpretation) as springs on 1: 50,000 scale topographic maps. Topographic maps will therefore be a useful guide in further mapping such areas.

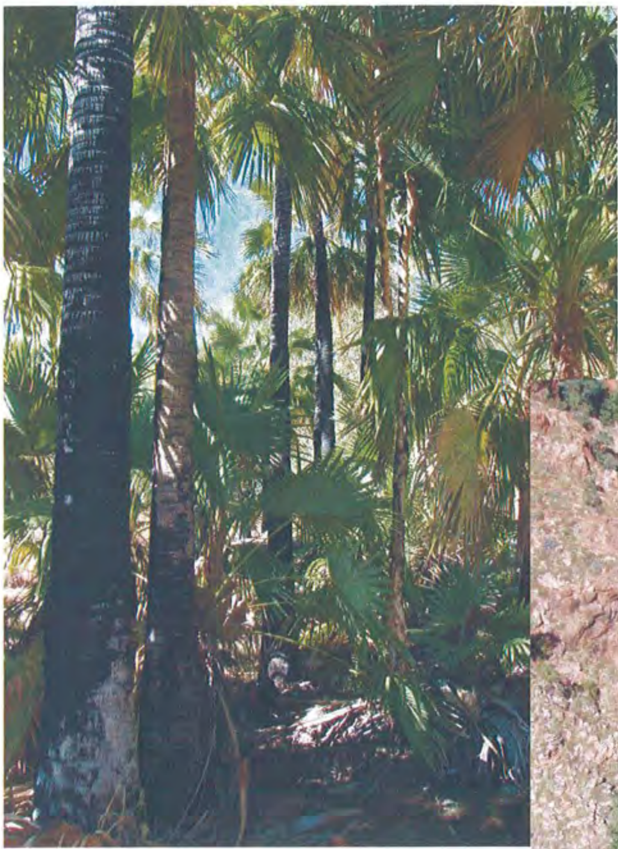

Figure 10 (left) & Figure 11 (below): discrete area of vegetation dominated by palms (*Livistona victoriae).*

Figure 12 (above) & Figure 13 (right): dense creekline vegetation dominated by paperbarks (*Melaleuca leucadendra).*

Surveys and stratification of monitoring sites

Two of the more obvious applications for land unit mapping are to assist in:

- planning representative surveys.
- selecting suitable locations for monitoring sites that seek to monitor the occurrence or abundance of flora and fauna and potential change in these.

Land unit mapping enables consideration of diversity in country and therefore the representativeness of survey or monitoring sites. As illustrated in the previous example (Figures 10 – 13), if monitoring is to adequately identify and record change, refinement of land unit mapping into 'phases' is likely to be extremely important for some land units at least.

Figure 3 shows how road access strongly limited the representativeness of sites able to be visited for this current project. Access issues can lead to serious bias in monitoring and special resources may be required to ensure monitoring is sufficiently representative.

DAFWA periodically assesses rangeland condition on pastoral leases based on a large number of pasture and erosion assessments made at 1 km intervals along station tracks. The results are extrapolated to provide an assessment of rangeland condition within the constituent land systems and across the lease as a whole. The availability of land unit mapping should improve DAFWA's ability to assess the representativeness of the data collected and potentially enable an improved method of extrapolation that would reduce the effects of sampling bias.

Note: tree and grass species recorded during these rangeland condition assessments can provide useful additional site based information for land unit mapping.

Carbon accounting.

Mapping of vegetation associations is the basis of carbon accounting and sequestration research. In northern Australia, changed fire regimes are considered to be impacting on vegetation structure and function. As different vegetation communities have different capacities to sequester and/or release carbon, this in turn may lead to changes in greenhouse gas emissions. Detailed vegetation mapping is therefore a primary resource in the carbon assessment and accounting process.

Ord River Irrigation Area and history of land resource mapping projects

Although the Ord River Irrigation Area (ORIA) was not a focus of this project, soils mapping for this area was edge-matched with adjoining land unit mapping and attributed according to the DAFWA soils-landscape hierarchy. It is worth noting, particularly as there have been recent vegetation surveys undertaken in the ORIA, that many of the existing soil surveys also included some vegetation data (still only in the hard copy reports - Appendix 6). The availability of the soils data also provides an opportunity to assess how well discrete communities identified through soils mapping are represented and protected within the conservation estate.

In exploring the relationships between the various land resource surveys undertaken in the Ord River catchment, it was decided that the detail of the often complex history of this mapping, particularly soil surveys in the ORIA, would more suitably form the basis of a companion report. This report is currently in progress (Tille in prep).

Availability of mapping and data compiled for this project

DAFWA is already the custodian of the majority of land resource mapping undertaken in the Ord River catchment and has databases able to incorporate additional land resource data. DAFWA is prepared to continue this land resource data custodian role and ensure that this data remains available to other agencies via existing data sharing arrangements. The mapping will also be publicly available so that the work undertaken, can be used to underpin and direct further or more detailed land resource mapping and classification by land managers or others outside of agencies.[1]

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[1] Contact details to obtain data and mapping are: Department of Agriculture and Food Western Australia, Geographical Information Services, Locked Bag 4, Bentley Delivery Centre WA 6983. Email: gis@agric.wa.gov.au Phone: (08) 9368 3925

CONCLUSIONS

Vegetation is a readily visible means of classifying country. In association with position in the landscape and soil it enables recognition of different habitats, pastures and fuel types. It is also therefore an indicator of fauna that might be utilising an area and the number of stock an area should be able to support. Vegetation type is also indicative of available fuel and can therefore aid in fire management planning.

Mapping vegetation associations and habitats establishes an environmental baseline. It enables this information to be passed on to inform future management. This helps in avoiding 'incremental creep', whereby a new base line is created with each change of management

It is vital that there is a better awareness and understanding of how changed fire regimes, feral animals and weeds are impacting on biodiversity. Management planning can only take into account vulnerable plant and animal species and associated habitats if vulnerability is known and the location of associated habitats communicated to management.

Land unit mapping:

- provides a framework within which a more detailed understanding of threats to the environment can be developed.
- enables the extent and potential impacts of fire, weeds and feral or domestic animals on different vegetation communities to be reviewed and taken into account in management planning.
- provides a 'common language' tool that can encourage communication and cooperation between neighbouring land managers when seeking to jointly deal with land management issues.

This project commenced in the second half of 2008 and was therefore only able to make limited use of both the 2008 and 2009 dry seasons. The substantial outcomes achieved by the project in this quite short time frame would not have been possible but for inter-agency cooperation and sharing of expertise and resources. The opportunity to utilise and build on existing DAFWA land unit mapping experience, data and database systems was critical. This was an efficient and effective arrangement.

This project has:

- enabled a significant amount of land resource mapping data previously collected by DAFWA to be attributed in a standardised hierarchical system. The system used enables compatibility with land unit mapping being undertaken in the adjacent Northern Territory.
- made available for use in a GIS, vegetation mapping previously undertaken by DEC at the Lower Ord Ramsar Site. This mapping has been attributed in accordance with the DAFWA soil-landscape hierarchy.
- mapped to land unit level an additional 4400 sq km on Mabel Downs, Texas Downs, Osmond Valley stations, Purnululu Conservation Reserve and UCL land that will become part of the conservation estate.
- entered data and mapping attributes from this project into DAFWA database systems ensuring that the data will remain available after completion of this project.

RECOMMENDATIONS AND FURTHER WORK

Collaboration between DEC and DAFWA on this project made apparent a significant duplication of expertise and resource use. The Interim Biogeographic Regions of Australia (Appendix 1) and the DAFWA soil-landscape hierarchy (Figure 2) both seek to provide a natural resource classification system.

- As both of these systems are still in an interim stage of development, it would seem timely that inter-agency collaboration and sharing of expertise is extended to explore the possibilities of aligning these two systems.
- One natural resource classification system will aid communication and encourage cooperation between both agencies and land managers, whether they seek to protect biodiversity, pastoral or cultural values.

Mapping undertaken for this project has identified some anomalies with existing mapping that could not be addressed in the available time. These anomalies are identified in Tables 1 and 2 and in Tille (in prep).

There are still significant portions of the Ord River catchment that have only broad scale land system or vegetation mapping. Completing land unit mapping of the catchment will provide a valuable tool to help inform and prioritise land management practices.

Trialling and exploration of uses for the land unit mapping as undertaken during this project will enable its further refinement and development. Development that enables the mapping to more specifically inform management planning decisions can only assist in the goal of looking after and protecting this challenging environment.

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Personal Communications

Vernes, T. (2009) Consultant to Department of Conservation and Land Management on *Lower Ord Ramsar Site Draft Management Report* and associated mapping.

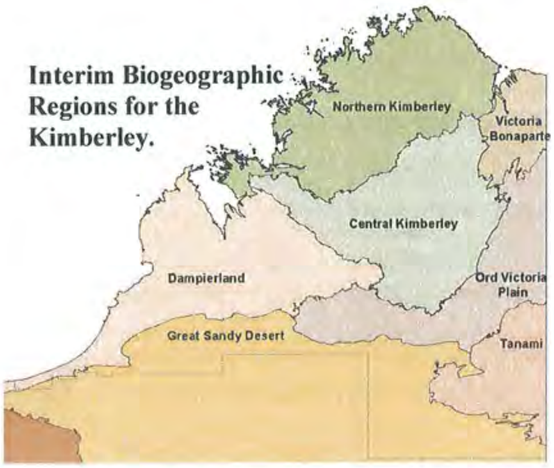
APPENDIX 1: Regional scale mapping classification available for the Kimberley.

Appendix 1a: Interim Biogeographic Regions of Australia (IBRA) Version 6.1

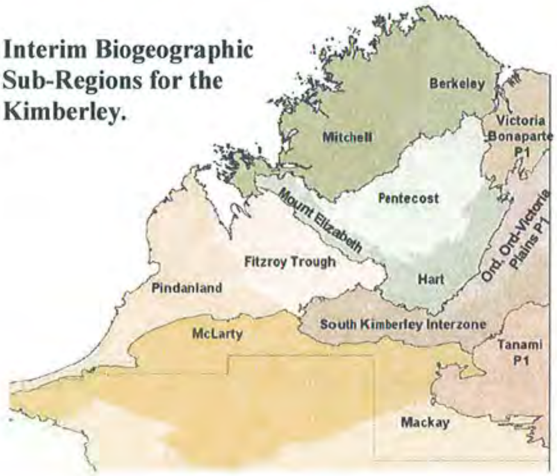
http://www.deh.gov.au/parks/nrs/ibra/

"**Abstract:** Interim Biogeographic Regionalisation for Australia (IBRA) version 6.1 represents a landscape based approach to classifying the land surface of Australia. 85 biogeographic regions and 405 sub regions have been delineated, each reflecting a unifying set of major environmental influences which shape the occurrence of flora and fauna and their interaction with the physical environment across Australia.

The IBRA Version 6.1 data consists of two datasets. IBRA bioregions, which is a larger scale regional classification of homogenous ecosystems, and sub regions, which are more localised. "



Interim Biogeographic Regions for the Kimberley.



Interim Biogeographic Sub-Regions for the Kimberley.


Interim Biogeographic Regions for Australia.

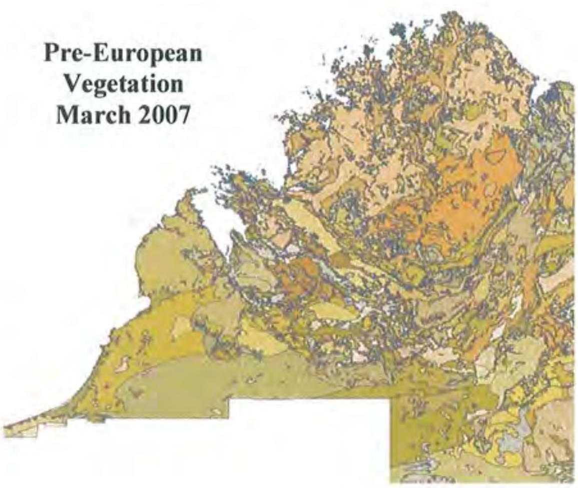
Appendix 1b: Vegetation mapping of the Kimberley.

There are two data sets that have broad scale (similar scale) vegetation mapping of the Kimberley. These are:

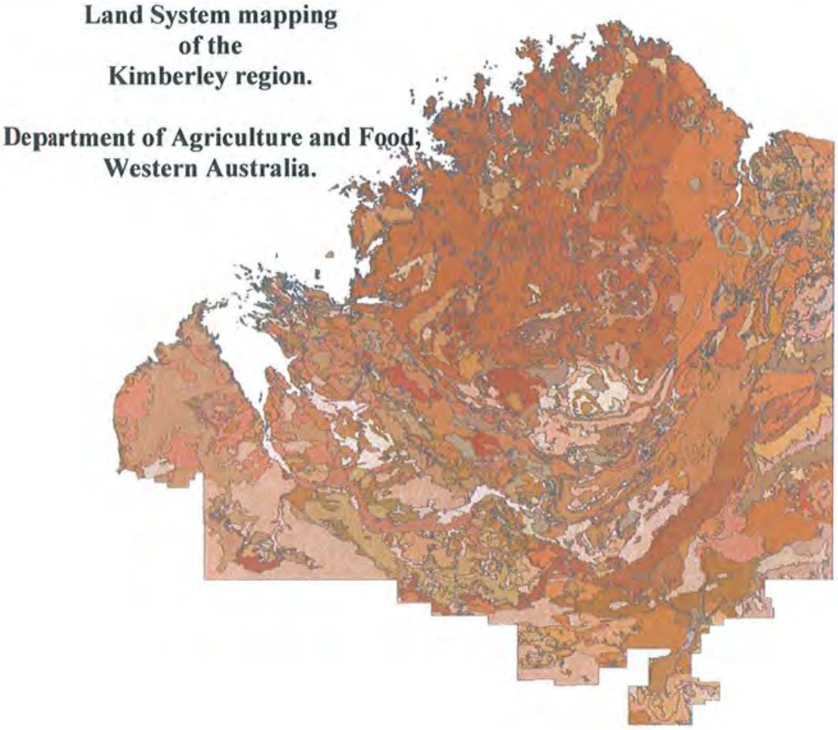
Pre-European Vegetation - DAFWA & DEC, March 2007. "This is a State-wide coverage at a scale of 1:250 000 based on the work of J S Beard, supplemented where necessary to give a uniform standard of mapping detail."

and

Vegetation of the Australian Tropical Savannas - Queensland Environmental Protection Agency and the Tropical Savannas Cooperative Research Centre, 2001. This data set covers the north of Australia and therefore enables Kimberley data to be compared or analysed against vegetation associations in the Northern Territory and Queensland which are subject to similar management issues and climate.

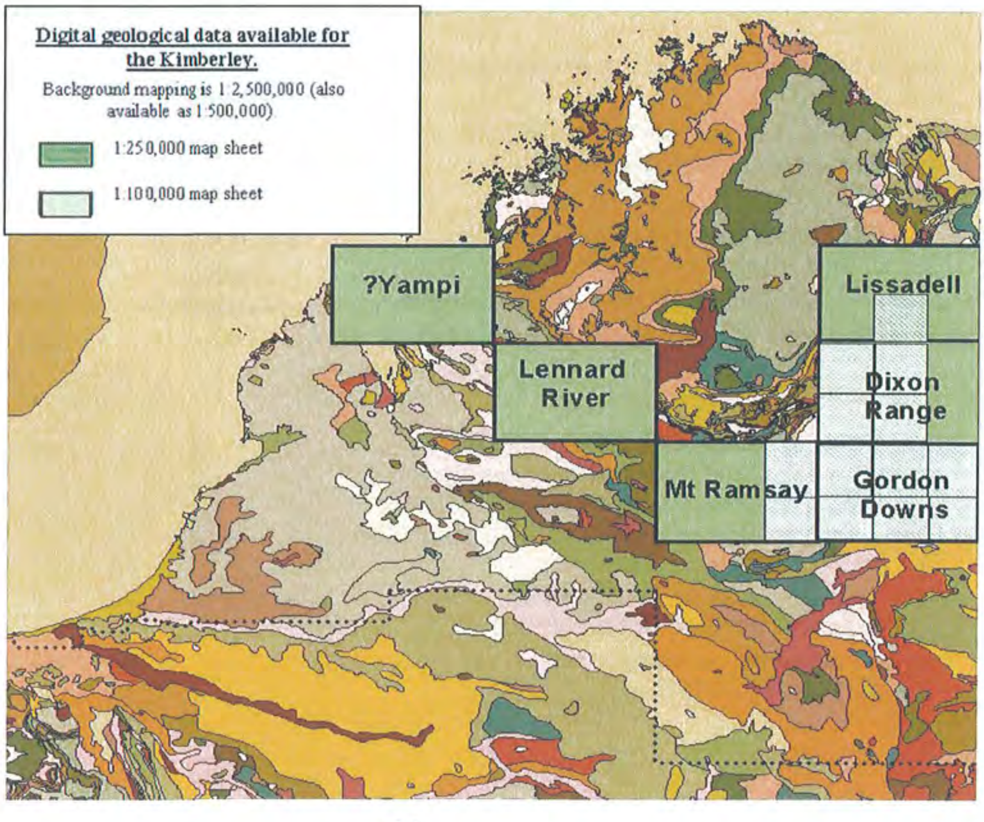

Pre-European Vegetation March 2007

Appendix 1c: Land system mapping of the Kimberley Region, Department of Agriculture and Food, Western Australia, 2008.



Appendix 1d: Department of Mines and Petroleum, Western Australia - State geological mapping.

http://mapserver.doir.wa.gov.au/datacentre2/digitalgeology_enh2.asp (DMP has some additional geological data for 1:250,000 map sheets not shown on their website – enquire directly).



APPENDIX 2: Soil surveys amalgamated to form 'Combined Ord Valley soils mapping' (Schoknecht & Goulding unpubl).

See Appendix 6 for availability of associated reports. Detail and the history of these projects is recorded in Tille (in prep)

Additional Packsaddle Plains (Clarke unpub)
Carlton Plains (Stoneman 1988)
Ivanhoe North-west (Dixon and Holman unpub)
Ivanhoe Plain (Aldrick *et al.* 1990)
Knox Creek Plain (Schoknecht and Grose 1996b)
Kununurra Groundnut (Dixon and Petheram 1979)
Ivanhoe West Bank (Schoknecht and Grose 1996a)
Ivanhoe West Bank South (Schoknecht and Sherrard unpub)
Kingston Rest (Schoknecht unpub)
Mantinea Flats/Goose Hill (Burvill 1991)
Mantinea Loop (Schoknecht and Grose 1996c)
Maxwell-Biyoogoong Plains (Schoknecht unpub)
North-west Packsaddle (Schoknecht 1996a)
Packsaddle Infill (Schoknecht 1996b)
Packsaddle Plains (Stoneman 1981)
Weaber Plain (Dixon 1996)

DESCRIBED BY: SCHN ~~HICP~~ / DATE 1 / 7 / 2009	104 EASTING / 105 NORTHING: GDA94 ZONE 52 428029 / 8109835	SOIL CLASS '33 P A E C	202 PRE MAP UNIT SYSTEM UNIT: 314Wk_Scl6	LOCATION	DEPTH TO REGOLITH: 70	SURVEY: OBP	SITE NO: 434

GEOLOGY 206: CRC (OVER SHALE)	MAP ID / FIELD ID	207-212 LAND USE CATA / TYPE: Rangeland	DRAINAGE: 5; FREE WATER — CM	219-132 LAND DEGRADATION: NIL	VEGETATION TYPE: SPECIES

304 PATTERN TYPE: UR	LAND FORM ELEMENT 306: FOOTSLOPE	SLOPE 5 %	MICRORELIEF TYPE 319: SMOOTH	SURFACE FRAG / LITH: 40 % 200 MM SANDSTONE; % MM; % MM	328 SURFACE COND: HARDSETTING	ROCK OUTCROP: — %

502 SAMP	503 HOR	504-6 DEPTH AND BOUNDRY	507 COLOUR	511 MOIST STAT	512 MOTTLES	517 TEXTURE	SAND FRAC	'19 - '22 STRUCTURE / FABRIC	STONES/ INCLUSIONS	CAL NONWET	537 PH	PROFILE CM
	A1	0 - 15 CM; SH AB CL GR DIF	10YR4/4	D	ABUN / %; CONT; COL	SL; WITH O.M.C		GR W; SIZ 10 MM; PED SB; FAB	ABU % 30; SHA A S; LIT SA; SIZ MM 20	CALC; NON WET	6	0–20
	B1	15 - 30 CM; SH AB CL GR DIF	7.5YR4/4	D	ABUN / %; CONT; COL	LC; WITH O.M.C		GR M; SIZ 5 MM; PED AB; FAB	ABU % 2; SHA; LIT SA; SIZ MM 5	CALC; NON WET	6.5	20–40
	B2	30 - 70 CM; SH AB CL GR DIF	7.5YR4/4	M	ABUN / %; CONT; COL	MC; WITH O.M.C		GR M; SIZ 5 MM; PED AB; FAB	ABU % 0; SHA; LIT; SIZ MM	CALC; NON WET	7.5	40–60
	BC	70 - 75+ CM; SH AB CL GR DIF	~~10YR~~ 10YR4/4	D	ABUN / %; CONT; COL	LC; WITH O.M.C		GR; SIZ MM; PED; FAB	ABU % 20; SHA A S; LIT SHALE; SIZ MM 5	CALC; NON WET	8	60–80
		- CM; SH AB CL GR DIF			ABUN %; CONT; COL	WITH O.M.C		GR; SIZ MM; PED; FAB	ABU % SHA LIT SIZ	CALC; NON WET		80–100

NOTES: SANDSTONE COBBLES ON SURFACE, WEATHERED SHALE @ 70 CM
FINE SHALE EXPOSED IN SIDE OF A ERODING GULLY TO NORTH

WASG: YELLOW/BROWN SHALLOW LOAMY DUPLEX
ASC: BROWN CHROMOSOL

Appendix 3b: Data Sheet B – Vegetation (and Habitat) data

***SHEET B - VEGETATION** (and HABITAT)* — **TENURE NAME:**

SITE:	**Site type**:Survey/Brief Description/Comment.	LandSystem_LandUnit:	**Recorder:**
			Date:
Site Coordinates:	**Accuracy:** **Elev:** **Slope:**		**Time:**

Tallest Stratum ( )		**Mid-Stratum ( )**		**Mid-Stratum 2** (if applic.)		**Lower Stratum ( )**	
Growth form		**Growth form**		**Growth form**		**Growth form**	
Tree/Palm	Sedge	Tree/Palm	Sedge	Tree/Palm	Sedge	Tree/Palm	Sedge
Tree malle (>8m)	Rush	Tree malle (>8m)	Rush	Tree malle (>8m)	Rush	Tree malle (>8m)	Rush
Shrub Mallee (<8m)	Forb	Shrub Mallee (<8m)	Forb	Shrub Mallee (<8m)	Forb	Shrub Mallee (<8m)	Forb
Tree / Shrub	Fern	Tree / Shrub	Fern	Tree / Shrub	Fern	Tree / Shrub	Fern
Shrub	Moss	Shrub	Moss	Shrub	Moss	Shrub	Moss
Heath shrub	Lichen	Heath shrub	Lichen	Heath shrub	Lichen	Heath shrub	Lichen
Chenopod shrub	Vine	Chenopod shrub	Vine	Chenopod shrub	Vine	Chenopod shrub	Vine
Hummock grass	Palm	Hummock grass	Palm	Hummock grass	Palm	Hummock grass	Palm
Tussock grass	Cycad	Tussock grass	Cycad	Tussock grass	Cycad	Tussock grass	Cycad
Height	**Crown Cover %**	**Height**	**Crown Cover %**	**Height**	**Crown Cover %**	**Height**	**Fol.Cover %**
20-35m	**D** >80	20-35m	**D** >80	20-35m	**D** >80	20-35m	**D** 70-100%
10 - 20m	**M** 80-50	10 - 20m	**M** 80-50	10 - 20m	**M** 80-50	10 - 20m	**M** 30-70%
5 - 10m	**S** 50-20	5 - 10m	**S** 50-20	5 - 10m	**S** 50-20	5 - 10m	**S** 10-30%
2 - 5m	**V** 20-0.25	2 - 5m	**V** 20-0.25	2 - 5m	**V** 20-0.25	2 - 5m	**V** 0.2 -10%
1 - 2m	**I** <0.25	1 - 2m	**I** <0.25	1 - 2m	**I** <0.25	1 - 2m	**I** <0.2%
0.5 - 1m	**L** < 0.25	0.5 - 1m	**L** < 0.25	0.5 - 1m	**L** < 0.25	0.5 - 1m	**L** <0.2%
0.26-0.5m	**E**	0.26-0.5m	**E**	0.26-0.5m	**E**	0.26-0.5m	**E** <3% (of tot.fol.cover
0.05-0.25m		0.05-0.25m		0.05-0.25m		0.05-0.25m	
Est.Crown Cover % :		**Est.Crown Cover %** :		**Est.Crown Cover %** :		**Est.FoliageCover %:**	
Crown separation[2]		Crown separation[3]					

Dominant taxa (include Sp. No.)	D Hgt.	**Dominant taxa** (include Sp. No.)	D Hgt.	**Dominant taxa**(Ann or Per?) (include Sp. No.)	D Hgt.	**Dominant taxa**(Ann or Per?) (include Sp. No.)	D Hgt A/P
Other taxa		**Other taxa**		**Other taxa**		**Other taxa**	A/P

Habitat trees	**Termite mounds**	**Grazing**	**Fire history / evidence:**
Tree hollows: Nil/Occ/Common	Nil	Nil / light / mod. / heavy	Year of fire if known.
Trees with hollows:	Occassional	Grazer:	No evidence of fire.
dead/alive/mostdead/most alive	Numerous	Cattle, horse, native herb., pig, other	Patchy burn/ minor damage.
			Some trees/shrubs killed

Hydrology: permanent / ephemeral / seasonally inundated / tidally inundated / other.

Pasture Group:

Most trees shrubs killed
1-2yrs/ 2-5yrs/ >5yrs
Scorch Height?

SUMMARY SITE DESCRIPTION / OTHER NOTES (surrounding area, habitat, erosion, weeds, grazing impacts, etc

Ground Cover:
Bare ground
Litter & annual veg.
Bedrock&surface fragms.>2cm
Gravel < 2cm.
Cryptogramic crust.
100%

Photos:

Appendix 3c: Data Sheet C – Landform data (to be printed on the reverse side of 'Sheet B – Vegetation and Habitat' and completed in lieu of 'Sheet A - Soils' if detailed soils data not collected).

Slope:

LANDFORM ELEMENT (40m across)

Morphological type 13

C	*Crest*	F	*Flat*
U	*Upper slope*	V	*Open depression (vale)*
M	*Mid slope*	D	*Closed depression*
L	*Lower slope*	H	*Hillock*
S	*Simple slope*	R	*Ridge*

Location within landform element 20

T	*Top third of the height of the landform element*
M	*Middle third of the height of the landform element*
B	*Bottom third of the height of the landform element*

Landform element type 24

Crest

HCR	*Hill crest*	DUC	*Dunecrest*
SUS	*Summit surface*		

Hillock

TOR	*Tor*	TUM	*Tumulus*
DUN	*Dune**	MOU	*Mound*
CON	*Cone*		

Ridge

LEV	*Levee*	LUN	*Lunette*
SCR	*Scroll*	FOR	*Foredune*
BAR	*Bar*	BRI	*Beach ridge*
PST	*Prior stream*	EMB	*Embankment**
DUN	*Dune**	DAM	*Dam*

Slope

HSL	*Hillslope*	LDS	*Landslide*
BEN	*Bench*	TAL	*Talus*
BER	*Berm*	DUS	*Duneslope*
SCA	*Scarp*	PED	*Pediment**
SFS	*Scarp-foot slope*	FOO	*Footslope*
BAN	*Bank*	CUT	*Cut face*
CLI	*Cliff*	EMB	*Embankment**
CFS	*Cliff-foot slope*	BRK	*Breakaway*
BEA	*Beach*		

Flat

PED	*Pediment**	RPL	*Rock- platform*
FAN	*Fan*	TDF	*Tidal flat*
PLA	*Plain*	STF	*Supratidal flat*
VLF	*Valley flat*	ITF	*Intertidal flat*
BKP	*Backplain*	REF	*Reef flat*
FLD	*Flood-out*	COS	*Cut-over surface*
CBE	*Channel bench*	FIL	*Fill-top*
RFL	*Rock flat*	SCD	*Scald*
TEF	*Terrace flat*	SRP	*Scroll plain*
TEP	*Terrace plain*	BER	*Berm**

Open depression

ALC	*Alcove*	SWL	*Swale*
DDE	*Drainage depression*	EST	*Estuary*
GUL	*Gully*	TDC	*Tidal Creek*
STC	*Stream channel*	TRE	*Trench*
STB	*Stream bed*	CIR	*Cirque*
SWP	*Swamp**		

Closed depression

DOL	*Doline*	CIR	*Cirque**
OXB	*Ox-bow*	CRA	*Crater*
LAK	*Lake*	MAA	*Maar*
SWP	*Swamp**	LAG	*Lagoon*
PLY	*Playa*	PIT	*Pit*
BOU	*Blow-out*		

[* Occurs in more than one morphological type.]

LAND SURFACE 87

Disturbance of site 88

0	*No effective disturbance*
1	*No effective disturbance except grazing by hoofed animals*
2	*Limited clearing*
8	*Highly disturbed, e.g. mining, urban*

COARSE FRAGMENTS ON THE SURFACE

TYPE

Abundance

0	*No coarse fragments*	0
1	*Very slightly; very few*	<2%
2	*Slightly; few*	2%-10%
3	*No qualifier; common*	10%-20%
4	*Moderately; many*	20%-50%
5	*Very; abundant*	50%-90%
6	*Extremely; very abundant*	>90%

Size

1	*Fine gravelly, small pebbles*	2-6 mm
2	*Medium gravelly; medium pebbles*	6-20 mm
3	*Coarse gravelly; large pebbles*	20-60 mn
4	*Cobbly; or cobbles*	60-200 m
5	*Stony; stones*	200-600 r
6	*Bouldery; or boulders*	600 mm-:
7	*Large boulders*	>2m

Shape

A	*Angular*	S	*Subangular*
U	*Subrounded*	R	*Rounded*
AT	*Angular tabular*	ST	*Subangular*
UT	*Subrounded tabular*	RT	*Rounded ta*
AP	*Angular platy*	SP	*Subangular*
UP	*Subrounded platy*	RP	*Rounded pl*

ROCK OUTCROP

TYPE

Abundance

0	*No bedrock exposed*	
1	*Very slightly rocky*	<2%
2	*Slightly rocky*	*2-10%*
3	*Rocky*	*10-20%*
4	*Very rocky*	*20-50%*
5	*Rockland*	*>50%*

Runoff

0	*No runoff*	3	*Moderately rapi*
1	*Very slow*	4	*Rapid*
2	*Slow*	5	*Very rapid*

SOIL

COLOUR

Profile		Soil Depth	
U	Uniform	1	skele
G	Gradational	2	shall
D	Duplex	3	deep

Field Texture (118)		Soil Surfac	
S	Sand	G	Crackir
LS	Loamy sand	M	Self-mu
CS	Clayey sand	L	Loose
SL	Sandy loam	S	Soft
L	Loam	F	Firm
ZL	Silty loam	H	Hard se
SCL	Sandy clay loam	C	Surface
CL	Clay loam	X	Surface
CLS	Clay loam sandy		
ZCL	Silty clay loam		
LC	Light clay		
LMC	Light medium clay		
MC	Medium clay		
MHC	Medium heavy clay		
HC	Heavy clay		

% Cover Leaf Litter Litter

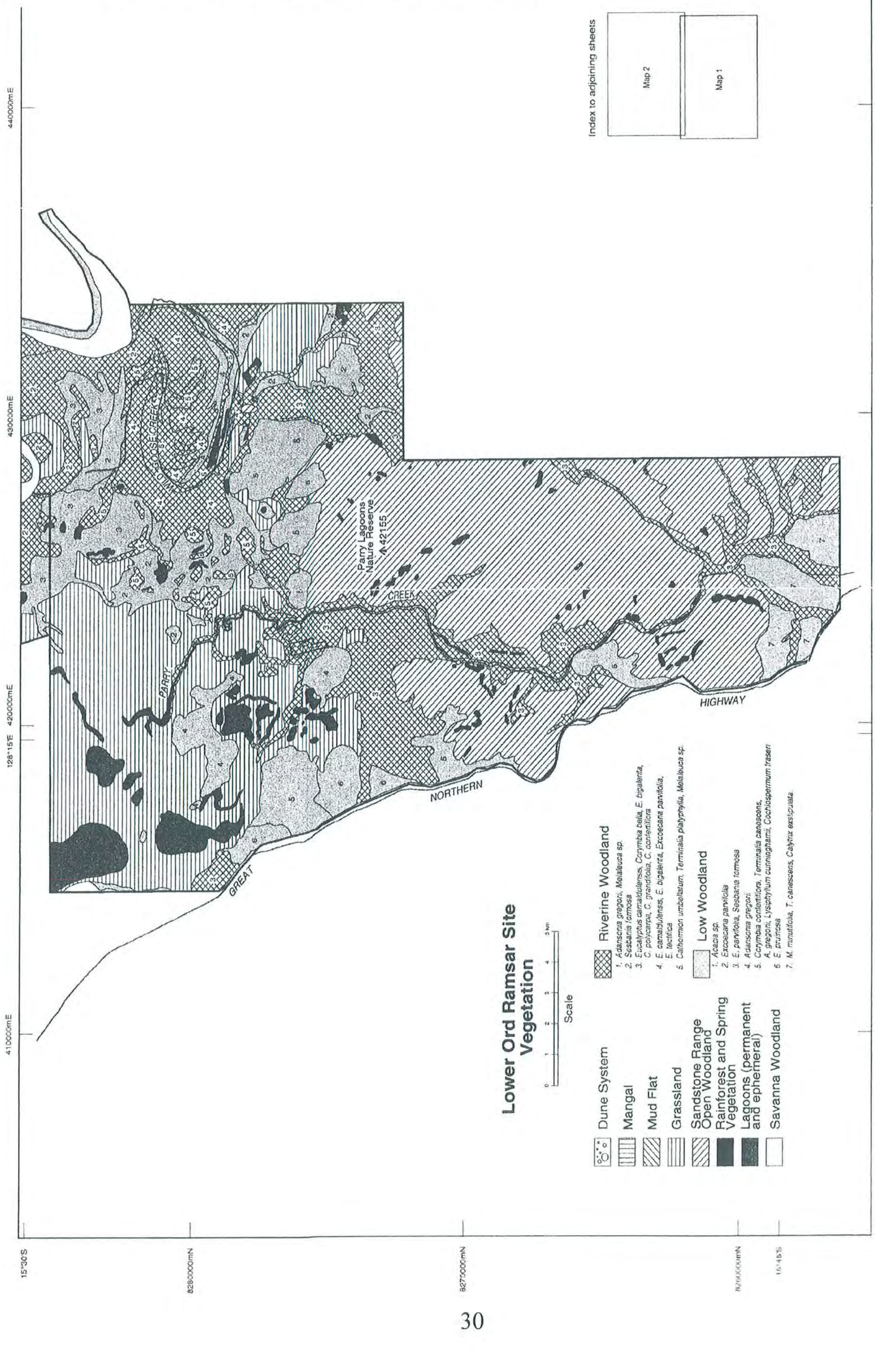
% Cover bare soil

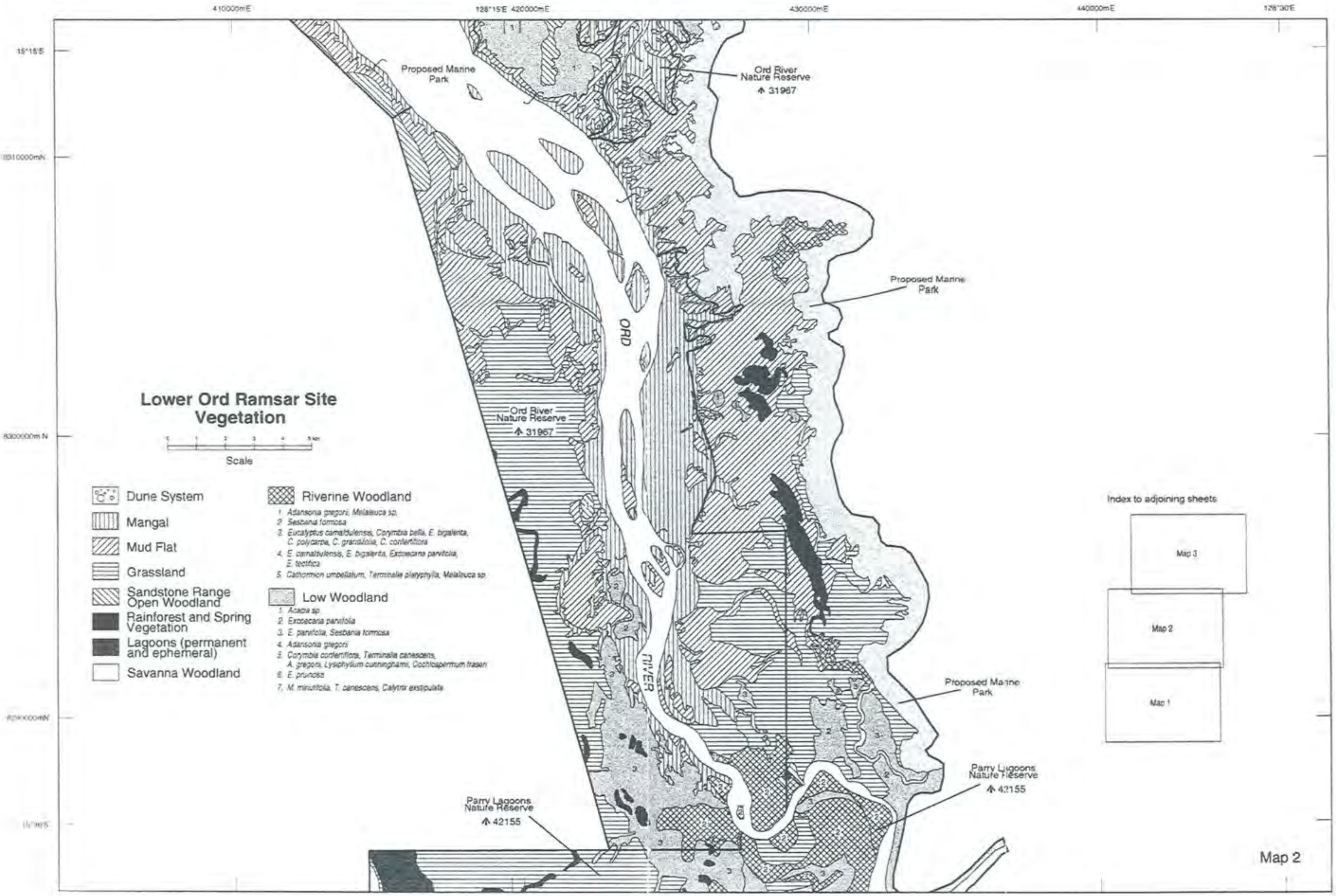
% Cover rock

Note: Classifications are according to the Australian Soil and Land Survey Field Handbook, (NCST 2009). Layout of Sheet C is based on Kimberley Islands data sheet (Dept. of Environment and Conservation, WA. 2007).

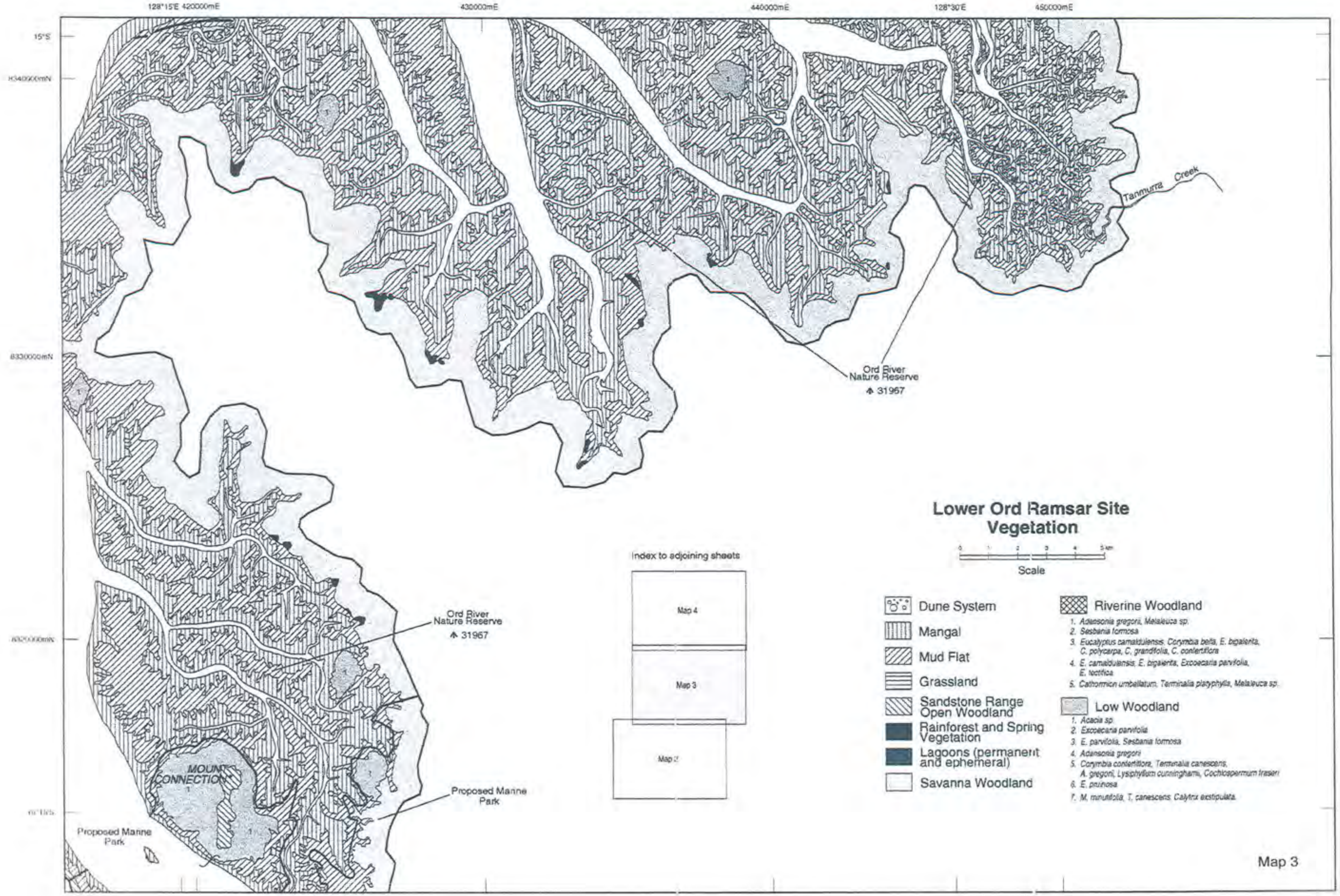
APPENDIX 4: Vegetation maps and vegetation descriptions from Lower Ord Ramsar Site Draft Management Report, Department of Conservation and Land Management, Kununurra, WA. 1998 (Maps 1-4 printed in original report as A3 and Map 5 as A4).

Appendix 4a: Vegetation Map 1 (A3 map in original report).

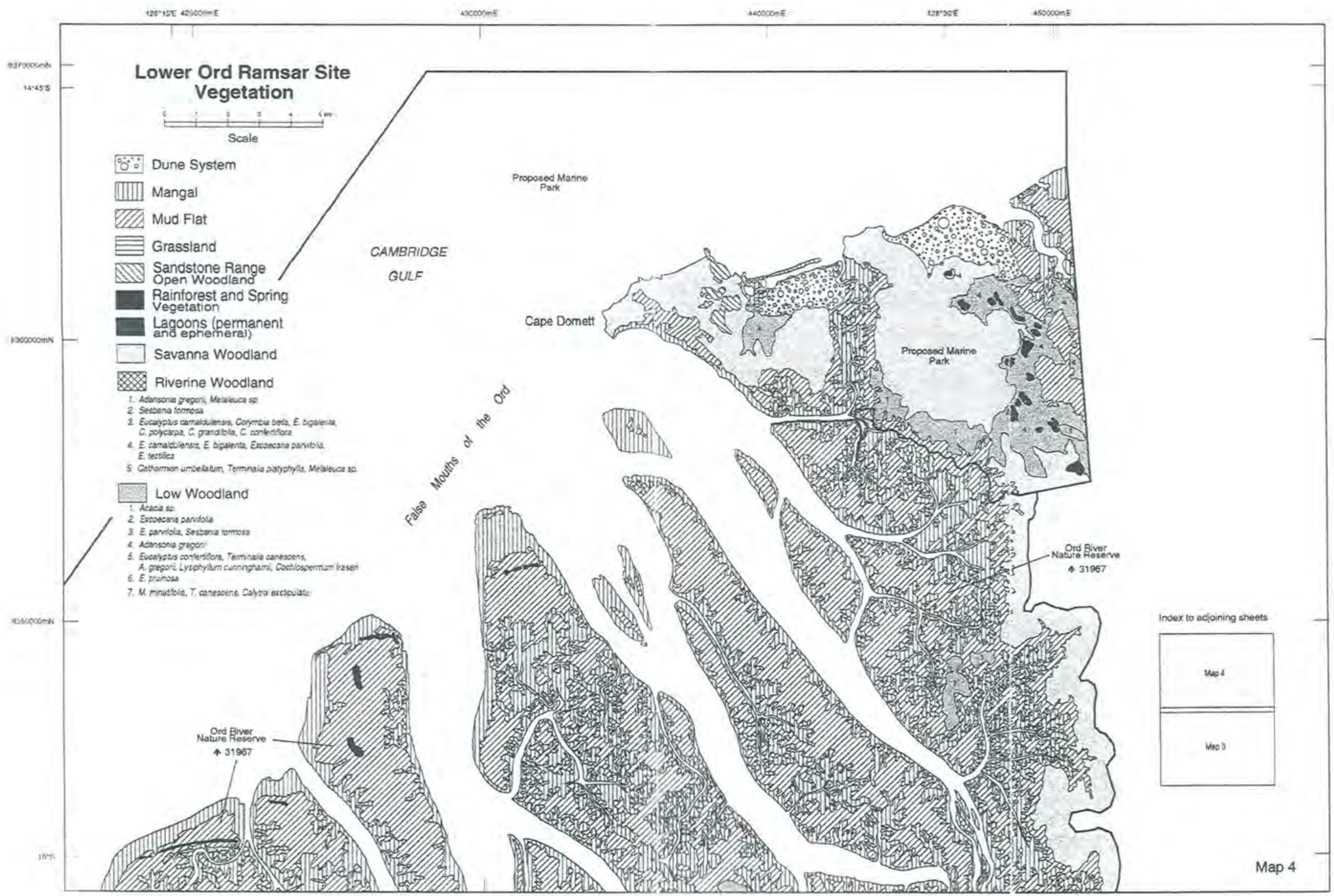




Appendix 4a: Vegetation Map 2 (A3 map in original report).

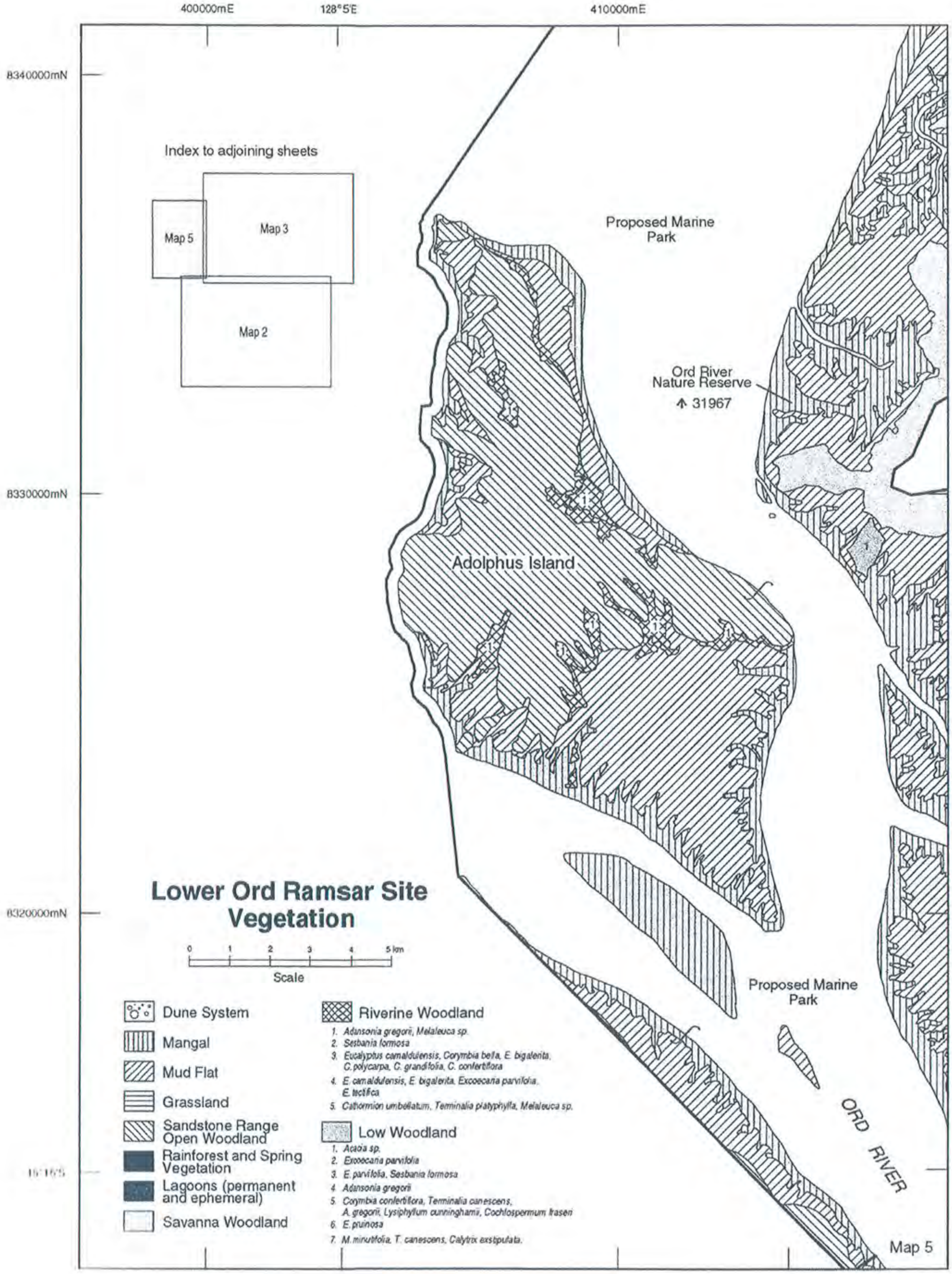


Appendix 4a: Vegetation Map 3 (A3 map in original report).



Appendix 4a: Vegetation Map 4 (A3 map in original report).

Appendix 4a: Vegetation Map 5 (A4 map in original report).



Appendix 4b : Vegetation descriptions from Lower Ord Ramsar Site Draft Management Report, Department of Conservation and Land Management, Kununurra, WA. 1998.

Very small patch of rainforest at the edge of mudflats north of the Ord River (Photo: Tanya Vernes)

The mapping has given a more detailed description of the vegetation of the Site. The following descriptions of the associations defined relate directly to the maps.

1. **Dune System.**
Coastal dunes with *Spinifex longifolius* and *Ipomoea pes-caprae* form a low cover with a heavy infestation of the introduced species *Calotropis procera* along the top of the dunes.

Vine thicket vegetation occurs in the sheltered swales. At present the vine thicket is degraded by cattle grazing. The understorey consists of low trees, shrubs and vines. There is virtually no ground flora apart from a few young seedlings. Common species in the vine thicket include *Gyrocarpus americanus*, *Brachychiton viscidulus*, *Exocarpos latifolius*, *Crotalaria cunninghamii*, *Laportea interrupta*, *Flueggea virosa*, *Jasminum didymum*, *Operculina aequisepala*, *Protasparagus retusifolia*, *Grewia retusifolia* and *Canarium australianum*.

Pockets of *Melaleuca dealbata* with a sedge understorey form in the most sheltered drainage areas. *M. acacioides*, *Adansonia gregorii* and *Xerochloa imberbis* occur in patches on the sandy flats between the sea and the woodland or mangal areas.

2. **Mud Flat.**
Bare mud with very high salinity. This hypersalinity is a result of frequent flooding followed by intense evaporation. Vegetation is largely absent, however there are occasional individuals or clumps of *Adansonia gregorii* and short grasses occurring where there is freshwater seepage. Less frequently inundated areas of the mudflat support low shrublands of samphire and low grasslands of *Sporobolus virginicus* and *Xerochloa imberbis*. Associated plants include *Brachyachne convergens*, *Dactyloctenium radulans*, *Salsola kali*, *Neptunia spp.* and *Fimbristylis spp.*

3. **Mangal.**
Extensive areas of mangroves occur within the False Mouths of the Ord. They line most of the shores of this area and the channels and the drainage creeks that incise the mudflats. Where salinity and flooding conditions are suitable they cover the mudflats. Of the sixteen species of mangrove recorded for Western Australia fourteen are found at the Site.

Species include; *Avicennia marina*, *Lumnitzera racemosa*, *Ceriops tagal*, *Bruguiera parviflora*, *B. exaristata*, *Excoecaria agallocha*, *Osbornia octodonta*, *Rhizophora stylosa*, *Camptostemon schultzii*, *Sonneratia alba*, *Xylocarpus moluccensis*, *Aegialitis annulata* and *Aegiceras corniculatum*.

As salinity and flooding conditions change mangal is gradually replaced along the banks of the Ord River by fringing *Sesbania formosa* or *Excoecaria parvifolia* low woodland.

Mangals are often zoned (occurring in distinct bands) according to a variety of physical, chemical and biological factors. The map scale used in this report precluded showing those zones.

Mangroves also occur as pure stands, paired associations and mixed stands. The most common paired association is between *Avicennia marina* and *Ceriops tagal*.

4. **Grassland.**
The herbland/grassland communities that occur on the Parry Lagoon's floodplain are the most extensive in WA. *Oryza australiense* and *Diplachne parviflora* dominate the wetland grassland. The semi-woody herb *Sesbania cannabina* forms an extensive closed herbland at wetland margins and across the floodplain in the wet season, dying off and collapsing during the dry. The other annual shrub present is *Aeschynomene indica*. *Sorghum spp.* grows on the drier margins. *Sporobolus spp.* occurs in near tidal areas. Samphires include *Halosarcia indica* and *Tecticornia verrucosa*. The dominant sedge in the marshes is *Eleocharis brassii*.

5. **Low Woodland.**
On the accompanying maps 'low woodland' is divided into seven categories. The numbers of these categories are shown on the maps and the descriptions are given here.

1. Acacia spp.
Acacia dominated woodland occurs within, but separate to, mangal communities and mudflats. This is most likely as a result of differing soils and moisture conditions. The fringing vegetation of these stands is predominantly *Melaleuca acacioides* and less commonly *M. acacioides* and *Ceriops tagal*. Grasses can also form a zone between the mangal and/or mudflat such as at the Red Hill woodland, where *Acacia lysiphloia* also forms an outer zone. Surrounding Mt Connection there is an *Acacia* dominated woodland with fringing vegetation of *M. acacioides*. The dominant species is *Acacia lysiphloia* on the western and southern sides. This woodland has scattered *Adansonia gregorii*, *Eucalyptus miniata*, *E. microtheca* and *E. pruinosa*. The dominant tall grass is *Heteropogon contortus*.

2. Excoecaria parvifolia.
Almost pure *Excoecaria parvifolia* stands occur on the flood plains near Wild Goose Creek, graduating into grassland south and west, and mudflat to the north. *E. parvifolia* is also the dominant vegetation around some soaks and lagoons such as Marlgu.

***3. Excoecaria parvifolia* and *Sesbania formosa*.**
Excoecaria parvifolia and *Sesbania formosa* forms in association with *S. cannabina*, *Parkinsonia aculeata*, *Passiflora foetida* and occasional *Eucalyptus tectifica* around Wild Goose Creek.

Telegraph Hill is a basalt outcrop that supports *A. gregorii* as the dominant species with *Gyrocarpus americanus, Cochlospermum fraseri, Terminalia canescens, Grevillea striata* and *Lysiphyllum cunninghamii*.

The sand/alluvium deposits in the very northern section of the Site support an *Adansonia gregorii* dominated woodland over grasses. Some soakage areas of *Sesbania formosa, Typha domingensis* and sedges also occur.

5. Corymbia confertiflora, Terminalia canescens, Adansonia gregorii, Lysiphyllum cunninghamii* and *Cochlospermum fraseri.
The sandstone-dolomite outcrops occurring in Parry Lagoons Nature Reserve forms rocky mounds with little soil supporting the above species over spinifex hummock grasses.

At the southern end of the reserve where the Old Hall's Creek Road joins the Great Northern Highway this association also includes *Eucalyptus tectifica, Corymbia grandifolia, Melaleuca minutifolia, Atalaya spp.* over *Sorghum* grasses.

6. Eucalyptus pruinosa.
A woodland of *Eucalyptus pruinosa* with scattered *Corymbia grandifolia, C. confertiflora, Lysiphyllum cunninghamii, Terminalia canescens, Adansonia gregorii, Grevillea striata* and *Gyrocarpus americanus.*

7. Melaleuca minutifolia.
A low shrubland of *Melaleuca minutifolia, Terminalia canescens and Calytrix exstipulata,* on dry, rocky, sandstone hills. Other common species include *Corymbia confertiflora, E. pruinosa, E. tectifica* and *Adansonia gregorii* Found in drainage areas are *Grevillea pyramidalis, Cochlospermum fraseri, Hakea spp.* There is some *Owenia vernicosa* and *Eucalyptus miniata* in localised areas.

6. Sandstone Range Open Woodland.
The rocky hills of Pentecost Sandstone support open woodlands that include *Corymbia drysdalensis* and *Terminalia canescens* with scattered *Xanthostemon paradoxus, Owenia vernicosa* and *Adansonia gregorii* over spinifex and tussock grasslands. There is some *Eucalyptus tectifica, Corymbia grandifolia* on lower slopes.

Terminalia canescens is common, often occurring as the dominant species.

On Adolphus Island there are steep slopes of sparse woodland cover including *Gyrocarpus americanus, Acacia spp., Calytrix spp., Melaleuca minutifolia* (?), *Corymbia drysdalensis, Adansonia gregorii, Brachychiton incanus* and *Terminalia spp.*

The Mt Connection outcrop has a sparse tree cover. The summit has scattered *Adansonia gregorii* over spinifex hummock grasses and the lower slopes include *Lysiphyllum cunninghamii, Ficus leucotricha, Gyrocarpus americanus, Cochlospermum fraseri, Brachychiton paradoxus, Terminalia canescens* and *Grevillea refracta.* The peak of the silty quartz at the southern end has a few individuals of *Corymbia drysdalensis* but is otherwise treeless.

7. Riverine Woodland.
This is divided into five further associations.

1. Adansonia gregorii* and *Melaleuca spp.
The drainage areas at the interface of the sandstone ranges and mudflat on Adolphus Island support *Adansonia gregorii* and *Melaleuca spp.* with some scattered *Cathormion umbellatum.*

2. Sesbania formosa
Sesbania formosa forms stands adjacent to the Ord River south of mangal vegetation. Other species include: *Passiflora foetida, Excoecaria parvifolia, Melaleuca leucadendra* (?), *Acacia spp., Adansonia gregorii, Eucalyptus camaldulensis* and *Pandanus aquatica. Parkinsonia aculeata* is also present.

3. Eucalyptus camaldulensis, E. bella, E. bigalerita, Corymbia polycarpa, C. confertiflora.* and *C. grandifolia
Also included with these eucalypts are *E. tectifica, E. microtheca, Acacia plectocarpa, Melaleuca spp, Adansonia gregorii, Buchanania obovata, Trichodesma zeylanicum* and *Crotalaria cunninghamii.* Less abundant species include *Pandanus spiralis, Calytrix exstipulata, Verticordia spp., Gardenia spp., Exocarpos latifolia, Gyrocarpus americanus, Ficus opposita, Acacia colei, A. translucens, Jacksonia spp., Lysiphyllum cunninghamii, Grevillea pyramidalis* and *Calotropis procera.* The ground layer consists mainly of *Sorghum. Themeda triandra* is common in patches.

4. Eucalyptus camaldulensis, E. bigalerita, E. tectifica* and *Excoecaria parvifolia.
At Wild Goose Creek there is an open forest consisting of *Eucalyptus camaldulensis* and *E. bigalerita* dominant with *E. tectifica, Excoecaria parvifolia, Cathormion umbellatum, Melaleuca leucadendra, Parkinsonia aculeata, Xanthium occidentale, Passiflora foetida* and scattered occurrences of *Acacia farnesiana* on the outer edges.

***5. Cathormion umbellatum, Terminalia platyphylla* and *Melaleuca* sp.**
Patches of *Cathormion umbellatum, Terminalia platyphylla* and *Melaleuca spp.* occurs predominantly on the floodplains in the north of Parry Lagoons Nature Reserve.

8. Rainforest (aquifer forest) and Spring Vegetation
There is *Pandanus spiralis* dominated vegetation around freshwater springs such as at Palm Springs. Rainforest species are also present.

Scree slope rainforests occur occasionally on the steep sides of the sandstone ranges. These are usually very small patches.

Species that have been recorded for these areas include *Abrus precatorius, Brachychiton diversifolius, Exocarpos latifolius, Crotalaria cunninghamii, Passiflora foetida, Flueggea virosa, Jasminum didymum, Operculina aequisepala, Protasparagus retusifolia, Grewia retusifolia, Canarium australianum, Laportea interrupta, Gymnanthera oblonga,* and *Brocea javanica.*

Freshwater springs occur between the mudflat/mangal interface and savanna woodland. Other species associated with spring areas include *Cyperus spp., Terminalia platyphylla, T. ferdinandiana, Pandanus spiralis, Ficus opposita* and *Lophostemon grandiflorus.*

A freshwater spring located on the west side of the Ord River near the mangal and Sesbania interface is dominated by *Sesbania formosa* with *Pandanus spiralis, Melaleuca leucadendra, Parkinsonia aculeata* and *Ficus sp.*

As for vine thicket vegetation, these patches of scree slope, aquifer and spring vegetation have some protection from fire due to moist conditions and topographic characteristics.

9. Major Rivers and Lagoons (permanent and ephemeral).
Only the major semi-permanent creeks and lagoons have been included in the mapping. The Ord River is the only permanent waterway included in the mapping and is described according to the relevant classes occurring along its banks.

Principal aquatic plants in the semi-permanent lagoons and seasonal wetlands include *Ipomoea diamantinensis, Nymphaea gigantea, Nymphoides indica, N. crenata, Utricularia spp.* and *Ceratophyllum spp.*.

The most common species found along the main rivers and their tributaries are: *Terminalia platyphylla, T. bursarina, Barringtonia acutangula, Melaleuca argentea, M. leucadendra, Eucalyptus bella, E. camaldulensis, E. bigalerita, Lophostemon grandiflorus, Acacia colei, Ficus coronulata* and *Nauclea orientalis.* The tall reed *Phragmites karka* is patchily distributed.

APPENDIX 5: Internal DAFWA review of Ord Bonaparte Program / DAFWA pilot land unit mapping project, 2003.

Project 2.1 Biophysical characterisation

Land unit mapping for the Ord and Keep River catchments
Progress report and future directions.
Noel Schoknecht
11 September 2003

The objective of the original land unit mapping project was to use available geophysical land resource datasets, with targeted ground-truthing, to improve the quality of the land resource mapping for the Ord (and more recently the Keep River) catchments in WA.

The agreed outputs were:
1. Land unit map in the Western Australian part of the Ord catchment.
2. Land unit descriptions, including soil and landform types and vegetation associations.

Situation prior to commencement of project

The main biophysical datasets presently available for the Western Australian part of the Ord and Keep River catchments in the Kimberley region of Australia are land systems mapping (nominal scale 1:250,000) conducted by CSIRO fifty years ago and regional vegetation mapping by John Beard (1979). By contrast, the Northern Territory part of the Ord River catchment has recent detailed land unit mapping (nominal scale 1:50,000 to 1:100,000) as the result of a lengthy mapping program. The driver for the new mapping program is the assumption that land management in the Ord and Keep River catchments would benefit from land unit mapping similar to that available in the Northern Territory.

Methodology

Background

Traditional techniques for mapping at the land unit scale are expensive, and require extensive fieldwork. Funds to conduct land unit mapping using these techniques are not available in WA, and a project was initiated as part of the Ord-Bonaparte Program to trial new techniques for land unit mapping.

Experience has shown that the main predictors for land units in the Kimberley are geology, landform and climate, and as these are becoming available at a relevant scale it was considered that a modelling approach to map land units could work. In addition there is training data (land unit mapping in NT, scattered soil/land unit surveys in Ord) that can assist a modelling approach. In recent years important new digital datasets have become available, including the 1:50,000 based Army digital elevation model, digital geology (1:250,00 and 1:100,000) and remote sensed satellite information (e.g. Landsat TM).

Land unit mapping trial - method 1

The first strategy was to use the new datasets to map out the unmapped land units described in the land systems report. This method was abandoned when analysis showed that the land system boundaries were not accurately placed, and in some places were just incorrect. In many cases the variability within a land system was as great as that between land systems. A recent mapping exercise (2003) to improve the quality of the land systems by digitising from original acetate sheets has been unsuccessful, and the mapping is in fact less accurately placed than the original digitised effort. This problem will need to be addressed to make the new mapping more usable.

Land unit mapping trial – method 2

The second strategy was to adopt a modelling approach developed by CSIRO Land and Water. This had successfully used to model land units across the Murray-Darling Basin. This process relies on a representative set of training data (sites and map units in representative terrain including the NT mapping) and a modelling approach using a range of digital datasets (numerous attributes of the digital elevation model, geology, climate, and satellite imagery) to model land units across the remainder of the catchment.

The land unit naming convention used by the Northern Territory was adopted, where map units names are composed of three symbols, one for landform, one for geology and one for soil/vegetation. The soil/vegetation symbol was later split, so that a land unit symbol ended up with a four component name.

All available soil and land mapping in the Ord was labelled with the new land unit naming convention, and two fieldtrips were conducted to collect data in areas where it was considered that there was inadequate representative training data.

CSIRO land and water has three attempts at modelling using their system, but unfortunately the model has difficulty predicting far beyond the training data. This was confirmed during a validation field trip in August 2003.

Some reasons are for poor prediction are:
- The training data is either inaccurate, includes a high level of heterogeneity, or is not representative of all areas in the catchment
- The digital datasets do not include good enough predictor variables
- The digital data are not at a high enough resolution

The key problem however is that the process is a "black box" – all the data is sent to the modellers, and then the mapper awaits an output without any further intervention. This issue was confounded by the remote location of the modelling team (Canberra) whilst the field experts were in Perth/Kununurra.

So, although some of the outputs were interesting, and at a detailed scale, the general high variability of the result meant that it is hard to use, and is not ready for field application or publication.

The majority of the funds to date have been spent on acquiring field data and mapping of training areas. These data are useful regardless of the current modelling output, and can be an important input in the continuation of the mapping effort.

Lessons learnt by method 2

- If a modelling approach is used, the modellers and mappers must be in regular contact and work in the same geographical location.
- That expert intervention must occur during the modelling process to help the model make decisions.
- That modelling will only work if we clearly understand the processes driving the landscape *and* we have digital datasets (at an appropriate scale) of the environmental variables (or surrogates) which describe these processes.
- Not enough of the Ord catchment has the required datasets and a necessary scale to enable a modelling approach *alone* to work.

Other outputs of the project

The August 2003 fieldwork trialled the use of real-time tracking of location in conjunction with the display of several vector and raster datasets. This was achieved using ArcView with a plug-in that enabled a Garmin GPS to input real-time co-ordinates. Similar products are available in other software packages. Thus field mapping and development of rules can be developed whilst travelling through the landscape.

The way forward

Ord-Bonaparte mapping

Future mapping will be conducted in the office using a combination of expert understanding of landscape processes combined with the display of all datasets overlaid in the same geographic space on the computer screen.

In the past mapping has been done on unrectified aerial photos using other map products (e.g geology) to assist the mapping process. This is slow, and the data has to be transferred from the aerial photos to the computer which is a labourious process. The new mapping will be done directly on screen switching on and off digital datasets (including a 3D model of the DEM for terrain) as required. The modelled output from the land unit mapping will also be a useful input in this process.

This technique is estimated to at least double the rate of mapping coverage compared to traditional techniques. This technique is currently being used successful by the Natural resources Assessment Group of the Department Agriculture to upscale mapping in the agricultural south-west.

Maintaining the land systems information in the land unit mapping is valuable so that a better land system map can be derived from the detailed mapping. This linkage has been lost in the Northern Territory land unit mapping, and the future land unit map for the Ord will have land systems embedded into the mapping.

Proposed actions for 2003

Alan Payne and Noel Schoknecht will do a land unit map of Carlton Hills Station in October 2003 to demonstrate this process. Depending on the time that this takes, an accurate estimate of the time required to do the remainder of the catchment is difficult, although current estimates are, given the high level of data already available for the Ord, that two experts dedicated for three months, would be sufficient to complete the map and basic legend. This final product would not be able to be achieved in 2003, but could be completed in 2004.

Mapping for remainder of Kimberley

The same process could be applied to the remainder of the Kimberley, pulling in digital datasets (such as digital elevation models) where available, and displaying all the best available data (including scans of non-digital maps) geo-referenced into the computer screen for the mapping exercise.

The mapping exercise would again need targetted fieldwork to inform the expert-directed on-screen mapping. I would imagine it would take at least two years with the equivalent two full-time officers and in the order of $500,000 to complete the remainder of the Kimberley pastoral areas.

N. Schoknecht, 2003.

APPENDIX 6: Summary of Ord River catchment land resource mapping and availability of associated survey reports.

Survey name and reference	Accompanying report?	Report published?	Report still in print?	Report available on-line?	Library copy	Report reference
Additional Packsaddle Plains (Clarke unpub)	Y	N	-	N	-	Unpublished.
Carlton Hill & Ivanhoe Stations - land unit mapping (Schoknecht *et al.* unpub)	N	-	-	-	-	Unpublished.
Carlton Plains (Stoneman 1988)	Y	Y	??	Y	DAFWA	Stoneman TC (1981). Packsaddle Plains soil survey. Western Australian Department of Agriculture. Technical Bulletin No. 55.
Carlton Reach Plain (Burvill 1991)	Y	Y	??	N	DAFWA	Burvill GH (1991). Soil surveys and related investigations in the Ord River area, East Kimberley, 1944. Technical Bulletin No. 80. Western Australian Department of Agriculture.
Combined Kimberley (DAFWA unpub)	N	-	-	-	-	Unpublished.
Combined Ord Valley (DAFWA unpub)	N	-	-	-	-	Unpublished.
Ivanhoe North West (Dixon and Holman unpub)	Y	N	-	N	DAFWA	Unpublished.
Ivanhoe Plain (Aldrick *et al.* 1988)	Y	Y	??	N	DAFWA	Aldrick JM and Moody PW (1977). Report on the soils of the Lower Weaber Plain and Keep Plains, NT. Technical Bulletin 19. Animal Industry and Agriculture Branch, Department of the Northern Territory.
Ivanhoe West Bank (Schoknecht and Grose 1996)	Y	Y	??	Y	DAFWA	Schoknecht N and Grose C (1996a). Soils of the Ivanhoe West Bank, East Kimberley, Western Australia. Agriculture Western Australia, Resource Management Technical Report 155.
Ivanhoe West Bank South (Schoknecht and Sherrard unpub)	N	-	-	-	-	Unpublished.
Kimberley Research Station (Gunn 1969)	Y	Y	N	N	DAFWA	Gunn RH (1969). Soils of the Kimberley Research Station, Kununurra, WA. CSIRO Division of Land Research Technical Memo 69/21.
Kingston Rest (Schoknecht unpub)	N	-	-	-	-	Unpublished.
Knox Creek Plain (Schoknecht and Grose 1996)	Y	Y	??	Y	DAFWA	Schoknecht N and Grose C (1996b). Soils of the Knox Creek Plain, East Kimberley Western Australia and Northern Territory. Agriculture Western Australia. Resource Management Technical Report 153.
Kununurra groundnut (Dixon and Petheram 1979)	Y	Y	??	N	DAFWA	Dixon JC and Petheram RJ (1979). Soil potential for groundnut production at Kununurra, Western Australia: Report of a survy conducted in January 1979. Western Australian Department of AgricultureTechnichal Bulletin No. 50.
Lower Weaber and Keep River Plains (Aldrick and Moody 1977)	Y	Y	??	-	DAFWA	Aldrick JM and Moody PW (1977). Report on the soils of the Lower Weaber Plain and Keep Plains, NT. Technical Bulletin 19. Animal Industry and Agriculture Branch, Department of the Northern Territory.
Mantinea Flats-Goose Hill (Burvill 1991)	Y	Y	??	N	DAFWA	Burvill GH (1991). Soil surveys and related investigations in the Ord River area, East Kimberley, 1944. Technical Bulletin No. 80. Western Australian Department of Agriculture.

Survey name and reference	Accompanying report?	Report published?	Report still in print?	Report available on-line?	Library copy	Report reference
Mantinea Loop (Schoknecht and Grose 1996)	Y	Y	??	Y	DAFWA	Schoknecht N and Grose C (1996c). Soils of the Mantinea Loop, Ord River Valley, East Kimberley Western Australia. Agriculture Western Australia. Resource Management Technical Report 154.
Maxwell-Biyoogoong Plain (Schoknecht unpub)	N	-	-	-	-	Unpublished.
Northern Territory Ord River Catchment (Aldrick *et al.* 1978)	Y	Y	??	N	DAFWA	Aldrick JM, Howe DF and Dunlop CR (1978). Report on the lands of the Ord River catchment, Northern Territory. Technical Bulletin 24, Animal Industry and Agriculture Branch, Department of the Northern Territory.
North-west Packsaddle (Schoknecht 1996)	Y	Y	??	Y	DAFWA	Schoknecht N (1996a). Assessment of the suitability for Agriculture of the North-west Packsaddle area Kununurra. Agriculture Western Australia. Resource Management Technical Report 156.
Ord River Regeneration Reserve (De Salis 1993)	Y	Y	N	N	DAFWA	De Salis J (1993). Resource inventory and condition survey of the Ord River Regeneration Reserve. Western Australian Department of Agriculture Miscellaneous Publication 14/93.
Ord-Bonaparte modelled (Schoknecht. unpub)	Y	N	-	N	-	Unpublished.
Ord-Bonaparte 'training' mapping (Payne unpub)	N	-	-	-	-	Unpublished.
Ord-Victoria (Stewart *et al.* 1970)	Y	Y	N	N	DAFWA	Stewart GA, Perry RA, Paterson SJ, Traves DM, Slatyer RO, Dunn PR, Jones PJ and Sleeman JR (1970). Lands of the Ord-Victoria area, Western Australia and Northern Territory. CSIRO Land Research Series No. 28.
Packsaddle Infill (Schoknecht 1996)	Y	Y	??	Y	DAFWA	Schoknecht N (1996b). Assessment of the suitability for agriculture of the Packsaddle infill area, Kununurra. Resource Management Technical Report 157. Agriculture Western Australia.
Packsaddle Plains (Stoneman 1981)	Y	Y	??	N	DAFWA	Stoneman TC (1981). Packsaddle Plains soil survey. Western Australian Department of Agriculture. Technical Bulletin No. 55.
Lower Ord Ramsar Site (CALM 1998)	Y	Y	??	N	DEC	CALM (1998). Lower Ord Ramsar Site Draft Management Report June 1998. Western Australian Department of Conservation & Land Management, Kununurra.
Victoria River District (Napier *et al.* in prep.)	Y	in prep	-	-	-	In preparation.
Bow River -Violet Valley Stations land unit mapping (Schoknecht *et al.* unpub)	N	-	-	-	-	Unpublished.
Weaber Plain (Dixon 1996)	Y	Y	??	Y	DAFWA	Dixon JC (1996). Soils of the Weaber Plain, East Kimberley, Western Australia. Resource Management Technical Report 152. Agriculture Western Australia.
West Kimberley (Speck *et al.* 1964)	Y	Y	N	-	DAFWA	Speck NH, Wright RL, Rutherford GK, Fitzgerald K, Thomas F, Arnold JM, Basinski JJ, Fitzpatrick EA, Lazarides M and Perry RA (1964). General report on the lands of the west Kimberley area, W.A. CSIRO Land Research Series No. 9.

LAND RESOURCE MAPPING IN THE ORD RIVER CATCHMENT.

LANDFORM
VEGETATION
SOILS

Land Resource Mapping Surveys

- New land unit mapping, 2008-2009.
- Remapped, 2008 / 2009 - Lower Ord Ramsar Site vegetation associations (based on Department of Conservation and Land Management mapping, 1998).
- New preliminary desktop mapping, 2008 / 2009 – no associated ground truthing.
- Updated mapping, 2008 / 2009 - 'Combined soils mapping', for agricultural purposes (primarily in the Ord River Irrigation Area). Updated to align with Department of Agriculture and Food Western Australia (DAFWA) soils-landscape hierarchy.
- Land unit mapping, 2003 / 2005 - Ord Bonaparte Program / DAFWA project.
- 'Training mapping' for land unit modeling, 2003 - Ord Bonaparte Program / DAFWA.
- Still to be updated – Ord River Regeneration Reserve land unit / land system mapping (De Salis 1993). Includes Purnululu National Park and Conservation Reserve which were excised from the Ord River Regeneration Reserve post the original mapping.
- Incorporated with 2008 / 2009 mapping - Ord Bonaparte Program / DAFWA land unit 'training mapping'.
- Incorporated with 2008 / 2009 mapping - Ord River Regeneration Reserve land system mapping (Desalis 1993).

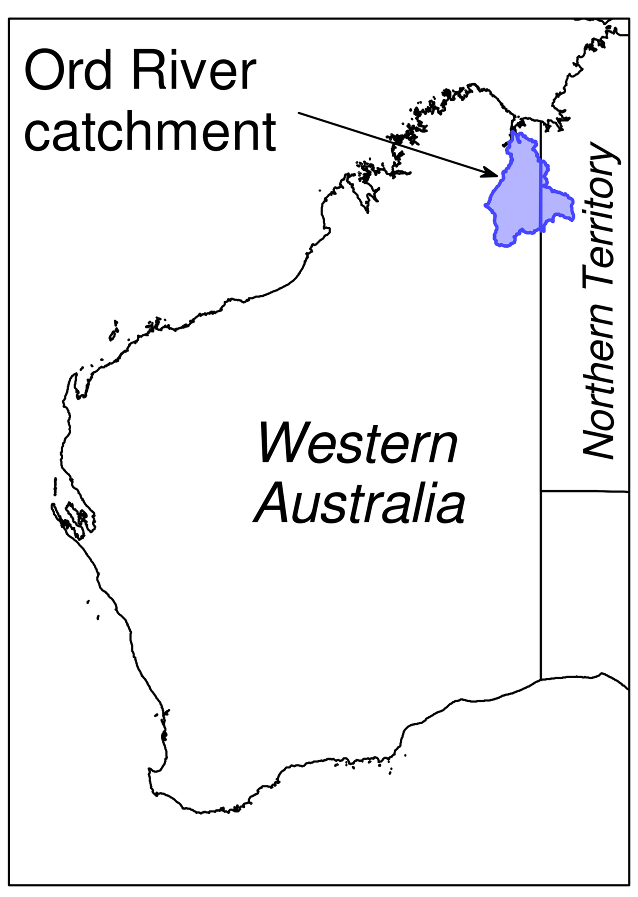
Legend

- Land unit boundaries – mapped based on landform. Land units are then further described according to geology, vegetation and soils.
- Highway / Road
- Tenure Boundary
- Lake Argyle
- Ord River catchment boundary

N

0 25 50 75

Kilometres



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