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Lower Gascoyne land resources survey

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LOWER GASCOYNE

LAND RESOURCES SURVEY

By Peter Tille and Henry Smolinski

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Summary

This report was commissioned by the Lower Gascoyne Management Strategy to identify land with potential for horticultural development outside the existing irrigation area.

A soil survey of the lower Gascoyne River was conducted between 4 September and 3 October 2001 by Peter Tille and Henry Smolinski of the Department of Agriculture. This covered 22,740 hectares, mainly on Brickhouse Station. Investigations extended along the river east of the existing irrigation area, and onto Doorawarrah Station 14 km upstream of Rocky Pool.

This survey followed a Scoping Report in 2000 by Land Assessment Pty. Ltd. which identified eight focus areas, six of which have formed the basis for the current survey. These are Focus Areas 1, 2, 3, 4, 6 and 8 that cover a total of 10,701 ha. Focus Areas 5 and 7 were not surveyed following advice from the Lower Gascoyne Management Strategy's Local Implementation Committee.

The maps produced from this survey are presented on the accompanying compact disc. Within the focus areas, the survey identified 500 ha of well-drained, non-saline alluvial sands and loams of the Gascoyne association ('good Gascoyne soils') that are highly suitable for horticulture. This includes 307 ha within Focus Area 2, mostly adjacent to existing plantations on the south side of the Gascoyne River. Of this, 140 ha are within the boundaries of the Carnarvon Water Reserve. A further 76 ha of these soils are found in Focus Areas 1 and 6, north of the river. These areas of 'good Gascoyne soils' are bisected by a number of drainage channels that are prone to flooding and erosion.

Type, location and areas (in hectares) of land mapped in survey

Survey area (ha)	Gascoyne soils				Sand dunes	Highly unsuitable	Total
	Good	Marginal	Erosion-prone	Undifferentiated			
Focus Area 1	68	118	19			184	389
Focus Area 2	307	289	192	14	13	1,052	1,867
Focus Area 3	73	136	33	15	22	999	1,278
Focus Area 4	44	236	103		290	2,539	3,212
Focus Area 6	8	38	10			247	303
Focus Area 8		58	361		437	2,796	3,652
Focus Areas	**500**	**875**	**718**	**29**	**762**	**7,817**	**10,701**
Other areas[1]	104	92	261	187	1,345	6,755	8,744
Focus + other	**604**	**967**	**979**	**216**	**2,107**	**14,572**	**19,445**
Water Reserve[2]	257	163	502	1,224	8	1,141	3,295
TOTAL	**861**	**1,130**	**1,481**	**1,440**	**2,115**	**15,713**	**22,740**

1 Only includes land outside the focus areas and outside the Carnarvon Water Reserve.
2 Excludes areas of the Water Reserve located within Focus Areas 2 and 4.

A further 875 ha within the focus areas were classed as 'marginal Gascoyne soils' due to salinity or coarse texture. These mostly lie adjacent to 'good Gascoyne soils'. While topsoil salinity levels are not usually excessive, values above 20 mS/m are common and some yield decline could be expected in many horticultural crops. Salinity values up to 500 mS/m were recorded in the deeper subsoil of many of these profiles. Their suitability for horticulture will depend on how they respond to irrigation. In deep sandy soils it may be possible to leach the salt out of the root zone resulting in higher productivity. In heavier soils or where a drainage impediment occurs at depth, salinity could build up under irrigation decreasing productivity.

Away from the river, 762 ha of sand dunes with potential for horticultural development were identified in the focus areas. However, the individual dunes mostly occur as narrow linear features that are too small for large-scale horticultural developments.

More than three-quarters of the focus areas (8,535 ha) contained soils which are not suitable for development. This includes land with high risk of flooding and soil erosion (718 ha) and soils with salinity, sodicity and poor structure (7,817 ha).

While the on-ground survey was concentrated within the focus areas identified in the Scoping Report, mapping of an additional 12,039 ha of surrounding land was undertaken where aerial photograph coverage was available. Because few sites were examined in these surrounding areas, the mapping is of lesser quality. Although this mapping identified 361 ha of 'good Gascoyne soils', only 104 ha were situated outside the Water Reserve. There are also 255 ha of 'marginal Gascoyne soils' (only 92 ha outside the Water Reserve) and 1,411 ha of 'undifferentiated Gascoyne soils', comprising a combination of the 'good' and 'marginal Gascoyne soils'. Only 187 ha of these were located outside the Water Reserve.

To aid land use planning in the Carnarvon district, the maps from this survey have been matched with the existing mapping of the Carnarvon Land Conservation District (Wells *et al.* 1992) and the surrounds of the irrigation district (Wells and Bessell-Browne 1990). Using the map unit hierarchy developed by the Department of Agriculture, it has been possible to produce a seamless soil-landscape map across these areas (see Appendix D for details).

Recommendations

1. This survey was undertaken to identify land with potential for horticultural development. The scale of the mapping (1:50,000) is not suitable for planning the details of land release or property layout. More detailed mapping, at a scale of 1:15,000, within any areas that have been earmarked for development, is recommended. This would present more accurate patterns of existing soil salinity, as well as the nature of the subsoil that will indicate areas prone to waterlogging and potential future salinity.

2. The risk of soil erosion during Gascoyne flood events is inherently very high for most arable areas under consideration. As demonstrated following the floods in March 2000, the risk is greatest where the land is regularly cultivated and water flows are concentrated. Any future horticultural development that was to rely on the importation of topsoil to replace that lost during floods could not be considered as a sustainable land use. For this reason it is essential that protected buffer strips are retained along the river banks and that development not occur on the lower river terraces, drainage depressions and flow zones on the upper terraces. Details of flooding patterns need to be considered prior to land selection. The likely effects on flood flows of any new levee banks or control structures also need to be considered.

3. There is limited information concerning the effects of soil salinity on crops in the Carnarvon district. The predicted yield reductions are based largely on overseas data. Investigations of crop performance at varying levels of soil salinity within the existing irrigation area would benefit the industry and provide better indication of land suitability within the survey area.

The coarse sandy phase of the River Sandy Terrace Subsystem (Ri1s) upstream from Rocky Pool supports a very open acacia shrubland with buffel grass dominating the understorey. These coarse sands have lower capability for horticultural development than other sands of the Gascoyne association due to poorer moisture and nutrient retention.

Contents

Introduction

This report was commissioned to provide information on land resources suitable for intensive agriculture in the Lower Gascoyne, east of the existing irrigation area and extending to 14 km upstream of Rocky Pool.

The existing irrigation industry near Carnarvon is based on 2,186 hectares bordering the Gascoyne River (see Figure 1). It is estimated that just over 1,000 hectares is currently cropped using an average of 7.5 gigalitres (gL) of irrigation water per annum. Studies on the Carnarvon horticulture industry indicate that inadequate property size, low unit returns and inefficiencies of production are major impediments to future development.

The Lower Gascoyne Management Strategy identifies three main goals. One of these is to explore opportunities for new developments.

Previous hydrological studies of the Rocky Pool aquifer provide a conservative estimate of sustainable supplies of 8 gL per annum, with 4 gL nominated for irrigation purposes. However, the quality and quantity of the potential supplies need to be proven through an extensive drilling program.

It is anticipated that any new horticultural precinct development would be based on properties of a larger scale with a focus on production for export markets. The study also investigated areas adjacent to the existing irrigation area that may be developed with existing or additional water supplies. In addition to providing an assessment of suitable soils for horticultural development, this report also identifies soils that would be suitable for topsoil replacement in the event of flood erosion.

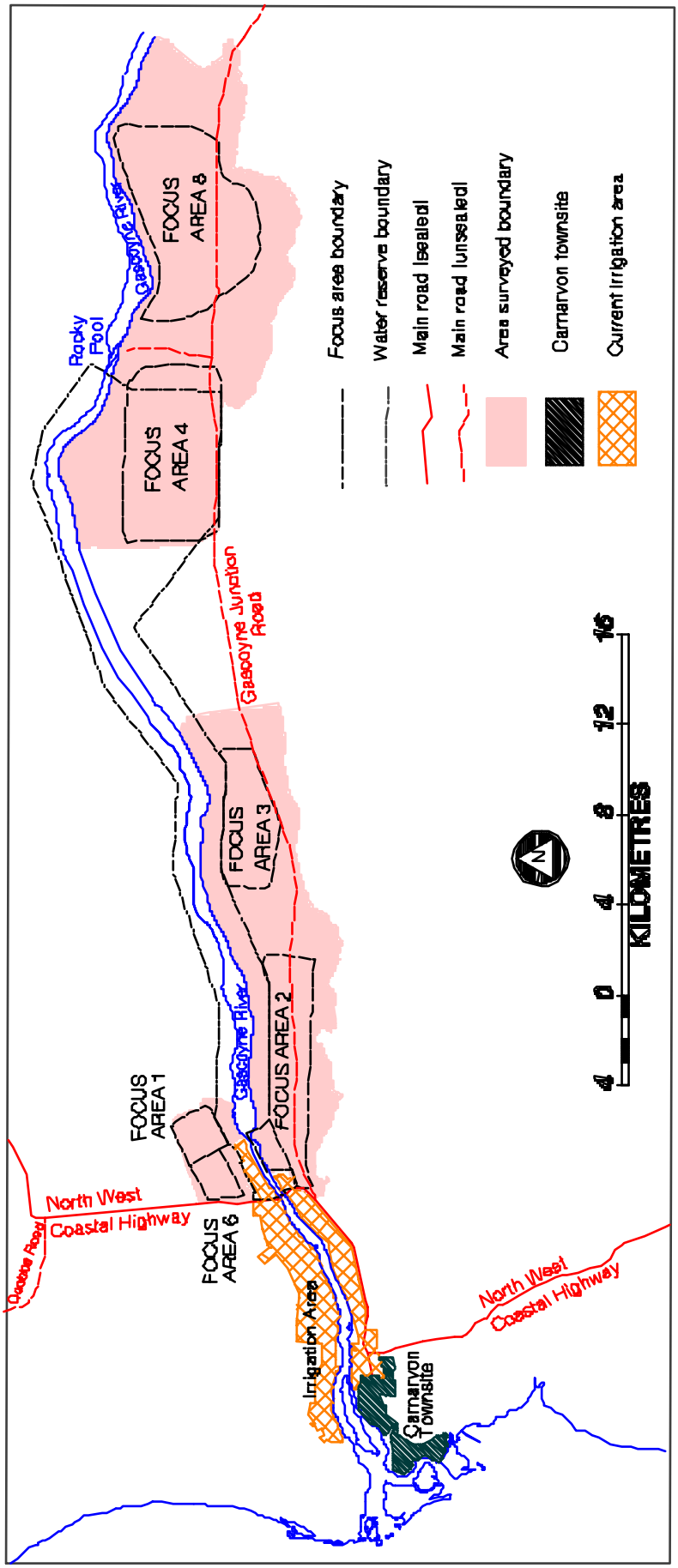

Figure 1: Location of the survey area and focus areas

Previous surveys

Previous land resource surveys of the Lower Gascoyne fall into two categories: mapping and characterisation of soil associations; and mapping of land systems.

Soil associations

Soil research within the Carnarvon area was carried out by the CSIRO (Bettenay 1964, Chapman and Keay 1965a, Bettenay 1966, Bettenay *et al.* 1971). Their work identified four major soil associations within the existing irrigation area and its surrounds. A broad reconnaissance survey mapped these associations along the Gascoyne River upstream to Rocky Pool. These four associations represent the most common soil types, related landforms and parent materials.

- **Gascoyne association:** Close to the Gascoyne River and occupying levees slightly elevated above the adjacent floodplain. Soils are brown deep sands and loams.
- **Coburn association:** On gently sloping backplains of low relief, situated further from the river. Vegetation is sparse and eroded claypans occupy a large proportion of the area. Soils include loamy earths, duplex soils and clays.
- **Doorawarrah association:** On floodplains, levees and channels of prior streams, with some dunes. Vegetation cover is sufficiently widespread to prevent extensive wind erosion. Soils are red-brown and mostly duplex.
- **Moyamber association:** On floodplains on which vegetation has been largely denuded and eroded claypans occupy a large proportion of the area. Red-brown duplex soils under vegetated areas with clays in the eroded areas.

Bettenay *et al.* (1971) identified the Gascoyne association as being the most suitable for irrigated crops, while recognising that the variations within this association can influence their capability. They identified the Doorawarrah as having some potential for irrigation, though careful management would be required because of poor subsoil drainage and the presence of saline layers. They considered the Coburn and Moyamber associations unsuited to irrigation due to subsoil salinity and sodicity.

Wells and Bessell-Browne (1990) provided more detailed mapping around the edges of the existing irrigation area. They identified: 18 soil/landform units which were subdivisions of the Gascoyne association; seven subdivisions of the Coburn association; two intergrades of these associations; and two belonging to the Brown association (reddish-brown siliceous sands and earthy sands on dunes and sandplain). They also presented capability ratings for various horticultural crops on each of the units.

Land systems

Mapping of land systems covering the entire survey at a scale of 1:250,000 was completed by Payne *et al.* (1980) as part of the Carnarvon Basin survey. Land system mapping is based on principles outlined by Christian and Stewart (1953), with land systems representing distinct recurring patterns of topography, soils and vegetation. Systems occurring within the survey area are:

Delta land system: Floodplains supporting low shrublands of bluebush and saltbush, widely degraded and eroded. This system contains mostly the Coburn and Moyamber associations, with minor areas of Gascoyne and Doorawarrah associations on the edges.

River land system: Seasonally active alluvial plains supporting tall shrublands of acacias on deep sandy and loamy soils. This system is equivalent to the Gascoyne association mapped by Bettenay *et al.* (1971), but overlaps the edge of the Coburn association in places.

Sable land system: Nearly flat alluvial plain with occasional sandy rises. Soils are predominantly sandy red duplex soils. This system contains mostly the Doorawarrah association, with some Moyamber association.

Sandal land system: Numerous low sandy rises and banks. Soils include deep red sands and sandy or Loamy duplex soils. This system contains mostly the Doorawarrah and Moyamber associations, but overlies a large area of Gascoyne to the north of Rocky Pool.

Target land system: Gently sloping plains with sandy banks, narrow interbanks and numerous circular lakes carrying tall acacia shrubland. Red sands and red duplex soils are common. This system occurs outside the mapping of Bettenay *et al.* (1971).

Wells *et al.* (1992) provided more detailed mapping of these land systems in the Carnarvon Land Conservation District (lying to the west of the area surveyed for this report), dividing them into component sub-systems.

The survey area

The soil-landscape survey was conducted along the lower Gascoyne River, with the focus areas outlined in the Scoping Report produced by Land Assessment Pty. Ltd. (2000) forming the basis for determining the area surveyed (see Figure 1). The Lower Gascoyne Committee requested that the survey cover Focus Areas 1, 2, 3, 4, 6 and 8 - a total of 10,701 ha. While the field survey was conducted primarily within these areas, some of the surrounding land was also mapped (mainly through the interpretation of aerial photographs). This covered an additional 12,039 ha, raising the total mapped to 22,740 ha.

Focus Areas 1 and 6 are north of the river on Brickhouse Station adjacent to the existing irrigation area and extending east of the North West Coastal Highway. Focus Areas 2, 3, 4, and 8 are on the south side of the river on Brickhouse Station, extending along the Gascoyne Junction Road east of the existing irrigation area. Part of Focus Area 8 extends onto the western edge of Doorawarrah Station, 14 km upstream of Rocky Pool. Focus Areas 5 and 7 were not surveyed following advice from the Committee that being situated away from the river or roads, they were unlikely to be developed.

The Carnarvon Water Reserve is situated along the Gascoyne River throughout most of the survey area. It extends from the North West Coastal Highway some 36 km upstream, and is approximately 2 km wide for most of this distance. Under current policy, this reserve is a Priority 1 Water Source Protection Area within which irrigated agriculture will not be permitted. A small portion of Focus Area 2 (around Brickhouse homestead) and most of Focus Area 4 lie within the Water Reserve.

Survey methods

Prior to the field survey, preliminary soil-landscape unit boundaries were drawn onto aerial photographs with the aid of existing surveys and stereoscopic interpretation. The most recent photos available were used, but the age and scale varied as shown below:

Focus Area	Photos	Job No.	Film No.	Scale	Date	Runs
1 & 6	Carnarvon DEM (black and white)	990258	WA4293	1:10,000	19/06/99	4 & 5
2 & 3	Gascoyne Junction Road (colour)	960700	WA3767	1:25,000	4/08/96	1
4 & 8	Carnarvon Shire (black and white)	920656	WA3131	1:40,000	17/10/92	38 & 39

The mapping was undertaken for production at a scale of 1:50,000 and the map units were designed to fit the Department of Agriculture mapping hierarchy which allows for correlation between different surveys. The units shown on the attached maps are sub-divisions of the land systems identified by Payne *et al.* (1977) and are mostly presented at subsystem level (with some mapped to phase level). Where possible, the map unit names of Wells *et al.* (1990) were adopted for the subsystems. For example, map unit Ri represents the entire River System, map unit Ri2 represents the Loamy Terrace Subsystem within the River System, and map unit Ri2s represents the saline phase of the loamy terraces.

Field survey was conducted between 4 September and 3 October 2001 by Peter Tille and Henry Smolinski, and concentrated on the focus areas identified by Land Assessment Pty. Ltd. The area was mapped using the free survey technique and over 250 sites were described (Figure 2). Site locations were recorded with a hand-held global positioning system (GPS). At most sites the soil profile was examined using a hand auger to 150-200 cm where conditions were suitable. At 10 sites in Focus Area 2 the profiles were described in backhoe pits. Soil samples were collected from a number of profiles and samples from 15 were sent to the CSBP laboratories for chemical analysis (see Appendix B).

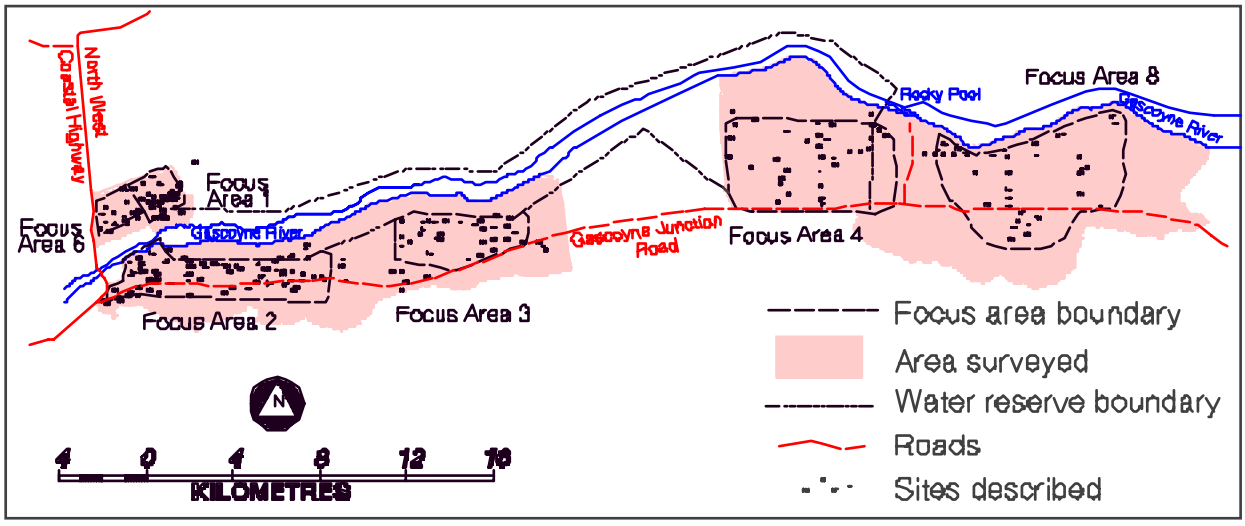

Figure 2: Location of sites described during survey

In describing the sites, the terminology of McDonald *et al.* (1990) was adopted. Data routinely recorded included:

- vegetation structure and dominant species
- landform features
- soil colour - using the Munsell Color Chart (Munsell Colour Company 1975)
- soil texture - described by hand texturing
- soil structure
- the presence of gravel and segregations
- soil pH using a pocket pH meter or with field pH kit (Raupach and Tucker 1959)
- soil salinity using a pocket electrical conductivity (EC) meter.

To describe soil salinity, the following definitions based on van Gool *et al.* (in prep) are used:

	$EC_{1:5}$ (mS/m)	**Estimated ECe (mS/m)**
Very low	<20	<200
Low	20-35	200-400
Moderately high	35-70	400-800
Very high	75-150	800-1600
Extreme	>150	>1600

In the initial stages of the survey it was apparent that vegetation was a very useful indicator of soil characteristics, especially salinity and drainage (John Stretch pers. comm.). Well drained non-saline alluvial soils generally carried denser, taller shrubland communities with no chenopods or very few. Saline and poorly structured soils carried stunted, scattered vegetation dominated by chenopod species, most notably silver saltbush (*Atriplex bunburyana*) and Gascoyne bluebush (*Maireana polypterygia*). Gascoyne mulla mulla (*Ptilotus polakii*) is another species indicating saline conditions.

The field survey was biased towards examining areas of the River System because the associated Gascoyne association had previously been shown most suitable for irrigation. The Gascoyne soils are usually associated with dense shrubland that can be delineated on aerial photographs. Determination of soil-landscape boundaries within the River System was achieved by a mixture of interpreting vegetation and landform patterns on the aerial photograph, site description and recording changes in the presence of indicator species. Mapping of boundaries within the Delta, Sable, Sandal and Target Systems was based primarily on the interpretation of vegetation patterns on the aerial photographs, with a lower intensity of site inspections.

The average site density within the focus areas was in the order of one site to every 50 ha. While this is the minimum recommended for a 1:50,000 scale survey by Gunn *et al.* (1988), the survey was more intensive in and around the River System, and less intensive in areas with little irrigation potential. The site density in Focus Areas 1, 2 and 6 that had the highest proportion of Gascoyne soils was about one site per 10-20 ha. This is within the guidelines for a mapping scale of 1:25,000.

Outside the focus areas, the mapping was mostly based on aerial photograph interpretation only. A few sites around the edges were inspected, as well as sites within sand dunes. Elsewhere, boundaries outside the focus areas were drawn by extrapolation of aerial

photograph patterns identified from within the focus areas. For this reason it was not possible to differentiate the terrace subsystems and phases of the River System within the Water Reserve.

The map unit boundaries and labels were captured from the photographs using a computer-aided mapping system operated on MicroStation software. Site locations were added from the GPS readings. The linework, labels and site locations were captured using the AGD84 Datum and then transferred into the GDA94 Datum.

Mapping units

Forty-one map units (systems, subsystems and phases) are shown on the accompanying maps. A summary of these units with their dominant soils is provided below. The units are described in more detail in Appendix C.

The systems correlate to the land systems identified by Payne *et al.* (1980). In naming the subsystems, the conventions of Wells *et al.* (1992) were adopted where relevant, with the exception of the Sable System where the same subsystem codes used for the Delta, Sandal and Target Systems were adopted. The correlation between the subsystems as mapped in this survey and by Wells *et al.* may not always be exact. As indicated, the vegetation composition and density are major factors in defining subsystems. It was common to identify equivalent subsystems (soil-vegetation associations) in several systems e.g. areas of bluebush flat occurred in three different systems (see Sd2, Tg2 and Sb2 below).

Cn - Channel System: Incised rocky streams and creek lines with truncated marginal slopes and stony narrow fringing plains supporting scattered to very scattered shrublands.

De - Delta System: Floodplains of the Gascoyne River supporting open to very open acacia shrublands with bluebush and saltbush understorey, widely degraded and eroded.

De1 - Delta Sand Dune Subsystem: Brown association soils
De2 - Delta Bluebush Flat Subsystem: Coburn and Moyamber associations
De3 - Delta Bluebush-Acacia Scrub Subsystem: Coburn and Moyamber associations
De4 - Delta Acacia Scrub Subsystem: Coburn and Moyamber associations
De5 - Delta Scald Subsystem: Coburn and Moyamber associations
De6 - Delta Claypan Subsystem: Coburn and Moyamber associations
De7 - Delta Drainage Depression Subsystem: Coburn and Moyamber associations
De10 - Delta Swamp Subsystem.

Ri - River System: Seasonally active floodplains of the Gascoyne River supporting moderately close tall acacia shrublands with an understorey including buffel grass

Ri1 - River Sandy Terrace Subsystem: Gascoyne 'light-textured' soils
Ri1c - River Sandy Terrace Subsystem (coarse sand phase): Gascoyne 'light-textured' soils
Ri1s - River Sandy Terrace Subsystem (saline phase): Gascoyne 'light-textured' soils
Ri2 - River Loamy Terrace Subsystem: Gascoyne 'medium-textured' soils
Ri2s - River Loamy Terrace Subsystem (saline phase): Gascoyne 'medium-textured' soils
Ri3 - River Clayey Terrace Subsystem: Gascoyne 'heavy-textured' soils
Ri3s - River Clayey Terrace Subsystem (saline phase): Gascoyne 'heavy-textured' soils
Ri4 - River Drainage Depression Subsystem: Gascoyne association
Ri4fz - River Drainage Depression Subsystem (flow zone phase): Gascoyne association
Ri5 - River Sand Ridge Levee Subsystem: River sands
Ri6 - River Lower Terrace Subsystem: Gascoyne association
Ri7 - River Low Lying Sandy Terrace Subsystem: River sands
Ri8 - River Saline Duplex Terrace Subsystem: Coburn red-brown duplexes
Ri9 - River Rocky Margin Subsystem:
Ri10 - River Relict Channel Subsystem: Gascoyne association and Coburn red-brown duplexes
Ri11 - River Relict Terrace Subsystem: Gascoyne association and Coburn red-brown duplexes
RiU - River Undifferentiated Terraces Subsystem: Gascoyne association.

Sb – Sable System: Nearly flat alluvial plain with occasional sandy rises supporting low shrublands of saltbush and bluebush and some tall acacia shrublands.

Sb1 - Sable Sand Dune Subsystem: Brown association soils
Sb2 - Sable Bluebush Flat Subsystem: Doorawarrah and Moyamber associations
Sb5 - Sable Scald Subsystem: Moyamber association.

Sd – Sandal System: Alluvial plain with numerous low sandy rises and banks open to very open low acacia shrublands with bluebush and saltbush understorey.

Sd1 - Sandal Sand Dune Subsystem: Brown association soils
Sd2 - Sandal Bluebush Flat Subsystem: Doorawarrah and Moyamber associations
Sd3 - Sandal Bluebush-Acacia Scrub Subsystem: Doorawarrah and Moyamber associations
Sd4 - Sandal Acacia Scrub Subsystem: Doorawarrah and Moyamber associations
Sd5 - Sandal Scald Subsystem: Moyamber association
Sd6 - Sandal Claypan Subsystem: Moyamber association
Sd10 - Sandal Swamp Subsystem.

Tg – Target System: Gently sloping plains, carrying tall acacia shrubland, with sandy banks, narrow interbanks and numerous circular lakes.

Tg1 - Target Sand Dune Subsystem: Brown association soils
Tg4 - Target Acacia Scrub Subsystem: Doorawarrah and Moyamber associations
Tg4c - Target Acacia Scrub Subsystem (claypan phase): Doorawarrah and Moyamber
Tg5 - Target Scald Subsystem: Doorawarrah and Moyamber associations
Tg6 - Target Claypan Subsystem: Moyamber association.

Of the 41 map units identified from field survey, only six have a high to fair capability for irrigated horticulture - those which contain the '*good Gascoyne soils*' (Ri1 and Ri2) and the sand dunes (De1, Sb1. Sd1 and Tg1).

Within the River System six units contain '*marginal Gascoyne soils*' with a fair to low capability for irrigated horticulture. In most cases restricted subsoil drainage and the risk of salinity are the limiting factors (Ri1s, Ri2s, Ri3, Ri11), but coarser textured sands are a limitation on others (Ri1c and Ri5).

Other units within the River System may contain suitable soils, but the risk of flooding and associated soil erosion make them unsuited to horticultural development (Ri4, Ri4fz, Ri6, Ri7, Ri9, Ri10). The remaining units in the River System (Ri3s and Ri8) and most of the Delta, Sable, Sandal and Target Systems are unsuitable for horticulture due to restricted subsoil drainage and high salinity levels.

The Scoping Report prepared by Land Resource Assessment (2000) suggested that 40% of the Sandal System might be suitable for irrigated horticulture, with a further 40% being possibly suitable. For the Target System these proportions were 30% and 10% respectively. This assessment was based on the component land units presented by Payne *et al.* (1987), with the sandy banks and plains being considered suitable, and the interbanks being considered possibly suitable. These sandy banks and sandplain were found to comprise about 20% of the Sandal System (Sd1), and about 12% of the Target System (Tg1), within the survey area. The soils of the interbanks were found to be unsuitable for horticulture, containing mostly shallow duplex soils of the Moyamber and Doorawarrah associations.

Soil associations

The soils encountered during field survey generally conformed to the descriptions and properties described by Bettenay *et al.* (1971) and Wells and Bessell-Browne (1990). Although five soil associations have been defined, it is common to find various intergrades between them. This is to be expected as the soil parent material was developed from reworked stratified alluvium that is spatially complex.

Bettenay *et al.* (1971) caused a certain degree of confusion by applying the names Gascoyne and Doorawarrah to layers of alluvial deposits as well as their soil associations. The Gascoyne association is derived mostly from the Gascoyne alluvial layer and the Doorawarrah association is derived mostly from the Doorawarrah alluvial layer, as is the Moyamber association. The Coburn association has formed where the Gascoyne alluvial layer overlies the Doorawarrah alluvial layer.

Gascoyne association soils

Gascoyne soils are developed from relatively recent alluvial deposits that border the Gascoyne River and consist of sand, silt and clay. These are reddish-brown sands to clay loams. Soils are generally friable and well-drained, and most commonly have very low to low salinity levels. Vegetation is dominated by acacia shrubland.

The general soil distribution pattern finds the coarser textured sands closest to the river, while the finer sediments (loams and clay loams) occur in back plains further from the faster flowing channels. Gascoyne soils generally have a high fine sand content, low coarse sand and moderate silt and clay. Flecks of mica are often present throughout the profile. Although generally considered to be deep uniform or gradational soils, they often consist of several stratified soil horizons within the top 200 cm.

Gascoyne soils are typically reddish-brown to yellowish red (5YR4/4-4/6). The occurrence of clay loam or clay layers within the soil profile is usually associated with increased accumulation of carbonates (high alkalinity), salts and boron. Soil sodicity and reduced permeability are also characteristics of finer textured layers. Three main types of Gascoyne association soils have been identified:

Gascoyne 'light-textured' soils

These are the soils in which a sand or sandy loam texture predominates. They fall mainly into the Red sandy earth and Red loamy earth groups, with occasional Red deep sands (Schoknecht 2002). Topsoil textures range from loamy fine sands to fine sandy loams. Topsoils are loose to firm and generally structureless with a sandy fabric. In the profiles with a loamy or clayey fine sand surface horizon, the texture typically increases to a fine sandy loam (or occasionally silty loam) by 50 cm. Sandy clay loam horizons may be encountered by 100 cm, and the texture may increase below this depth. Lime segregations are absent or rare.

Reference Soil Profiles: A18, B27, C45

Gascoyne 'medium-textured' soils

These are the soils in which fine sandy clay loam or silt loam textures predominate. They fall into the Red loamy earths group (Schoknecht 2002). Topsoil textures range from fine sandy loams to fine sandy clay loams. In profiles with a sandy loam surface horizon, there is typically a gradual increase to a silty loam or light sandy clay loam texture by 50 cm, and often to a silty clay loam or clay loam (fine sandy) by 100 cm. Profiles with a silt loam surface may be uniform throughout the top metre, or gradually increase to a silty clay loam or clay loam (fine sandy). Weak to moderate development of sub-angular blocky structure is usually evident. Lime segregations are absent or rare within the profile. Clays or light-textured horizons may also be encountered within the subsoil below 100 cm.
Reference Soil Profiles: B26, B31, C46, C47, C81, C83, C84

Gascoyne 'heavy-textured' soils

These are the soils in which clay loam or clay textures predominate. They fall mainly into the Red loamy earth and Red/brown non-cracking clay groups, with some Calcareous loamy earths and Red shallow loamy duplexes (Schoknecht 2002). Topsoil textures are typically silty clay loams, but may range from fine sandy clay loams to silty clays. Sometimes a thin (<10 cm) surface layer of sandy or silty loam is present, overlying a silty clay loam or silty clay. These soils exhibit moderate to strong sub-angular blocky structure. Few to common lime segregations may be encountered within lower topsoil and subsoil. Few gypsum segregations may also occur below 100 cm. The soil reaction trend is alkaline. Topsoils are slightly acid to alkaline (pH 6.5-8.0) while subsoils are neutral to strongly alkaline (pH 7.5-9.0).
Reference Soil Profiles: A14, C44, C82, C85

Coburn association soils

These soils occur on back plains and floodplains inland from the Gascoyne association. They are similar to the medium and heavy-textured Gascoyne soils but generally have a finer sand fraction and more silt and clay. Coburn soils support sparser vegetation than Gascoyne and chenopod shrubs are common. Many of these soils have been subject to erosion, part or all of the topsoil stripped. Red shallow sandy duplex soils (largely absent from the Gascoyne association) are common. Alkaline red shallow loamy duplexes, Red shallow loamy duplexes, Red deep sandy duplexes, Red loamy earths and Red/brown non-cracking clays (Schoknecht 2002) also occur. Clay loam or clay layers typically encountered within 100 cm and these subsoils tend to be massive and dense, resulting in restricted drainage. Moderately high to extreme levels of salt are often encountered within the subsoils.

The Coburn soils are usually developed from recent layer of Gascoyne alluvial layer which at variable depth overlies much older layer of truncated Doorawarrah alluvial layer. The upper Gascoyne alluvial layer is typically a reddish-brown to yellowish red (5YR4/4-4/6) colour and often consists of shallow clayey sand to sandy loam topsoil overlying clay loam or light clay. Boundaries between these materials are clear to gradual and usually associated with slight darkening and illuviation of clay within the upper 5 cm of the clayey horizon. These clayey subsoils usually display weak to moderately developed sub-angular blocky structure.

The Doorawarrah alluvial layer is often encountered within 200 cm. It is a red (2.5YR4/6) sand to medium clay with a fine to coarse grain size. Several stratified layers may occur. Alluvial gravel derived from mixed igneous and sedimentary origin may be contained within the Doorawarrah alluvial layer. The medium to fine-textured horizons of the Doorawarrah alluvial layer are commonly massive and dense. Such poor physical properties are commonly associated with high sodicity.

Salinity levels can be highly variable within the Doorawarrah alluvial layer, but are often very high to extreme. Areas that are scalded or dominated by silver saltbush (*Atriplex bunburyana*) are not always highly saline within the upper 150 cm although, in the limited deep profiles that were sampled, very highly to extremely saline layers were usually encountered by 250 cm. It is expected the frequency of flooding, drainage and micro-relief would influence the accumulation of salts in the profile.
Reference Soil Profiles: B7, C63, F32

The Coburn soil most common within the River System is:

Coburn red-brown duplex

These soils have a reddish-brown to yellowish red (5YR4/4-4/6) sandy or loamy topsoil (similar to the Gascoyne soils) which sits on top of a heavy-textured subsoil. They fall mainly into the Red shallow and Deep sandy duplex soil groups, with some Red shallow loamy duplexes (Schoknecht 2002). Topsoil textures range from fine loamy sands to fine sandy loams, occasionally silty loams. The subsoil commences abruptly at 10-50 cm and is typically a silty clay loam to silty clay (sometimes a fine sandy clay loam). The subsoil is usually highly to extremely saline and often sodic.
Reference Soil Profile: F32

Doorawarrah and Moyamber association soils

Doorawarrah soils are predominantly duplex soils developed entirely from the Doorawarrah alluvial layer. Vegetation is a scattered acacia shrubland with a Gascoyne bluebush (*Maireana polypterygia*) understorey. Red shallow sandy duplex soils (Schoknecht 2002) were most commonly encountered in this survey, though Red deep sandy and loamy duplexes, and Red loamy and sandy earths were also present. Topsoil is usually a loose, red (2.5YR4/4-4/6) sand (occasionally a sandy loam). The bottom of the sandy topsoil is often bleached. Clayey subsoils are also red-coloured, and usually massive. They often contain lime and may contain gypsum. Sodicity, poor soil structure and restricted drainage are common in the subsoil. Salinity levels can be highly variable, but are usually very high to extreme below 100 cm.

The Moyamber soils are differentiated from the Doorawarrah association mainly in that the sandy topsoils are badly eroded by water and wind. They are predominantly Red shallow sandy or Loamy duplex soils and Red/brown non-cracking clays (Schoknecht 2002).

Moyamber soils are associated with poorly drained back plains situated between the river and prior river levees. The vegetation communities are dominated by degraded low Gascoyne bluebush (*Maireana polypterygia*) shrublands. The have also developed entirely from the Doorawarrah alluvial layer. As a result of erosion, they tend to have shallower topsoil and higher clay content than the Doorawarrah association. The clayey subsoils that occur close to the surface are commonly highly to extremely saline and sodic.
Reference Soil Profile: C48

Brown association soils

Soils have developed on sand dunes or alluvial benches. They are commonly Red deep sands and Red sandy earths with some Red loamy earths and Red deep sandy duplex soils (Schoknecht 2002) along the periphery of the dunes. Sandy topsoils are structureless and loose or massive with earthy fabric. Colour suggests that they are derived predominantly from the Doorawarrah alluvial layer, particularly further from the river. Soil texture often increases to sandy loam at 50-150 cm, and lime may be present in this subsoil. Salinity levels are generally very low and soil profiles are well drained to rapidly drained.
Reference Soil Profiles: D19, D53, F28

Soil analysis and soil capability

Soil samples were collected from 15 profiles. Most belonged to the Gascoyne association that is used for horticulture within the current irrigation area. Analytical results are presented in Appendix B.

Soil analysis results conform to data published by Bettenay *et al.* in 1971. The soil reaction trend is alkaline to strongly alkaline. Topsoil horizons are generally neutral to alkaline (pH 7.0-8.0), while subsoils are alkaline to strongly alkaline (pH 8.0-9.4). Soil alkalinity is associated with fine segregations of lime and carbonate salts (sodium carbonate and bicarbonate). Lime is rarely visible within coarse-textured sands or sandy loams. The clay loams may exhibit sporadic fine segregations below 60 cm.

Analysis indicates that zinc levels are low in all profiles.

Gascoyne association

The Gascoyne association soils are seen as having the greatest potential for irrigated horticulture, with virtually all existing plantations and irrigated crops on these soils. This is because Gascoyne association soils are deep, typically well-drained (with good subsoil structure or fabric) and have good moisture and nutrient-holding capacities. The soils possess high levels of potassium in particularly the medium to fine textured soils. As indicated by Bettenay *et al.* (1971), potassium is associated with illitic clays that are derived from mica that is clearly evident throughout the Gascoyne alluvial layer. Levels of bicarbonate-extractable phosphorus are moderate to high within all topsoil horizons and low to moderate within the subsoil layers.

The accumulation of salts (particularly sodium chloride) is generally not considered to be a problem. However, there appears to be a trend for salinity levels to increase in proportion to the distance from the coast. Silver saltbush (*Atriplex bunburyana*), an indicator of soil salinity, was found growing over a significant proportion of Gascoyne soils in the survey area. Moderately high to extreme levels of salt (to 500 mS/m at 100-200 cm) were found in the subsoils of a number of profiles. Even at depths of 50-100 cm soil salinity levels to 200 mS/m were encountered.

Table 2 gives some indication of the yield reductions which can be expected in some of the crops grown in the Carnarvon district at different levels of soil salinity. As can be seen, even low levels of salinity (20-35 mS/m) can lead to significant yield reductions in many horticultural crops. Soils with very high and very low salinity levels can be found close to each other, and salinity levels within a profile can change dramatically following heavy rain or a flood. The distribution of salts stored in the soil can vary greatly, both spatially and over time. It is therefore difficult in a survey such as this to map the extent of the saline soils precisely, even if many samples are analysed. Vegetation is probably the best indicator.

How salinity levels in these soils will change when they are irrigated is also difficult to predict. The quality of the water supplies and irrigation management will be very important. On light-textured soils where the subsoil is highly permeable, there is potential to leach salts from the profile under irrigation. In such cases crop yields should not be adversely affected.

In the heavy-textured profiles, or where there are restrictions to subsoil drainage, salinity levels are likely to build up over time as salt is added through irrigation water, and yield declines can be expected.

Table 2: Predicted yield reductions at varying levels of soil salinity ($EC_{1:5}$) adapted from George and Wren (1985)

% yield reduction	0		10		25		50		100	
	Loam	Clay	Loam	Clay	Loam	Clay	Loam	Clay	Loam	Clay
Crop	Soil salinity (mS/m)									
Avocado	11	16	16	22	22	31	33	46	53	74
Banana	9	12	-	-	-	-	-	-	-	-
Bean	9	12	13	19	20	28	32	45	57	80
Corn	16	22	28	40	46	64	76	106	-	-
Cucumber	22	31	29	41	39	54	55	78	88	124
Date	35	49	60	84	96	135	157	221	281	396
Grape	13	19	22	31	36	51	59	83	105	148
Grapefruit	16	22	21	30	30	42	43	61	70	99
Lucerne	18	25	30	42	47	67	78	110	-	-
Olive	24	33	33	47	48	68	74	104	123	173
Onion	11	15	16	22	24	33	38	53	-	-
Orange	15	21	20	28	28	40	42	59	70	99
Peach	15	21	19	27	25	36	36	51	57	80
Pepper	13	19	19	27	29	41	45	63	75	105
Rock melon	19	27	32	45	50	70	80	113	141	198
Squash	22	31	33	47	42	59	55	78	-	-
Tomato	22	31	31	43	44	62	72	101	119	167
Zucchini	41	58	51	72	65	91	88	124	-	-

Gascoyne soils exhibiting moderate to extreme subsoil salinity typically have high exchangeable sodium in the heavier subsoil layers. In the profiles sampled, exchangeable sodium percentages (ESP) of 6 to 25 were often encountered below 100 cm. Surface sodicity levels were generally low. When the ESP exceeds 6, a soil is considered to be sodic. Sodicity is related to poor physical properties and sodic soils generally exhibit massive and dense horizons that are prone to dispersion with reduced permeability and poor aeration.

Boron toxicity has been encountered within the established irrigation area and impacts on sensitive crops such as citrus and grape vines (Chapman and Keay 1965b). Boron is not readily mobile and tends to accumulate within alkaline, fine-textured horizons. Boron levels in excess of 1 ppm may result in plant toxicity and most Gascoyne association soils sampled contained at least one horizon above this level. Subsoil levels of 2-5 ppm boron were common. Boron may also be present in significant concentrations in the local groundwater.

Wells and Bessell-Browne (1990) presented capability ratings for the Gascoyne soils for a variety of crops using the Department of Agriculture's five class rating system:

- Gascoyne 'light-textured' soils were assessed as having a high rating (class 2) for all crops assessed (i.e. tomatoes, beans, capsicums, cucumbers, bananas and mangoes).
- Gascoyne 'medium-textured' soils had a high rating (class 2) for bananas and mangoes and a high rating for the vegetable crops, except where there was a clayey subsoil at 30-100 cm. Here the rating was fair (class 3) with waterlogging risk being the main limitation.
- Gascoyne 'heavy-textured' soils had a fair rating (class 3) for all crops except cucumbers, for which the rating was low (class 4) due to waterlogging risk. Soil workability and waterlogging risk were the limitations for other crops, while rooting conditions were the limitation for bananas and mangoes. Where these soils occurred in closed depressions the waterlogging risk resulted in a low rating for all vegetable crops.
- Ratings for the saline Gascoyne association soils (Gascoyne-Coburn intergrades) ranged from fair to low (classes 3-4) depending on the crop and soil texture, with the lower rating on heavier textures.

The non-saline Gascoyne 'light and medium-textured' soils can be considered '*good Gascoyne soils*'. The non-saline Gascoyne 'heavy-textured' soils and the saline Gascoyne 'light and medium-textured' soils can be considered '*marginal Gascoyne soils*'.

Coburn, Moyamber and Doorawarrah association

Only small areas of Coburn soils fall within the current irrigation area. Most no longer support crops or plantations, or have never been developed. Wells and Bessell-Browne (1990) rated the Coburn soils as having low to very low capability (classes 4-5) for all the crops assessed, with salinity and waterlogging risk being the main limitations.

Bettenay *et al.* (1971) stated that the adverse physical properties associated with high levels of exchangeable sodium and high content of soluble salt render the Coburn and Moyamber association soils unsuitable for irrigation. These sodic soils generally exhibit massive and dense horizons that are prone to dispersion with reduced permeability and poor aeration. Reduced infiltration, poor aeration and cloddy, hardsetting topsoils are characteristics that commonly develop when they are cultivated. Data presented by Bettenay (1966) show sodium chloride comprising between 40 and 90% of the total soluble salts in the subsoils of the Coburn and Moyamber associations.

While salinity and sodicity levels in the only Moyamber profile sampled for laboratory analysis (Profile C48) were low, it was only possible to sample this profile to a depth of 100 cm as the clay below this was too hard for the backhoe to excavate.

Bettenay *et al.* (1971) likened the Doorawarrah soils to the red-brown earths that are extensively irrigated in eastern Australia. They suggested that these soils had some potential for horticultural development, but that careful irrigation management would be required because of low permeability and salinity in the clayey subsoils. In this survey it was found that the free draining sandy topsoils were usually shallow (typically less than 30 cm), and that moderately high to extreme salinity levels (up to 400 mS/m) were often encountered within the top 100 cm of the profile. As with the Coburn and Moyamber associations, these soils appear highly unsuitable for irrigated horticulture.

High levels of boron have been encountered on all alluvial soils within the irrigation area. Bettenay *et al.* (1971) showed the duplex soils of the Coburn and Moyamber associations as having higher boron levels than the Doorawarrah association.

Brown association

With the exception of a couple of small plantations, these soils are not currently used for horticulture. However they have a fair to high capability (classes 2-3). They are deep, well-drained and easy to work. Being elevated above the surrounding plains, they have the added advantage of not usually being subject to flooding.

Many local growers would consider the Brown association soils as too sandy and rapidly drained for irrigation. However, the coarser grained Spearwood sands of the Swan Coastal Plain north and south of Perth have high capability for horticulture with careful irrigation scheduling. In comparison, the Brown association sands would be expected to have better moisture and nutrient retention characteristics than the Spearwood sands. Because they have lower clay content than most Gascoyne soils, more intense management of irrigation scheduling than currently practised in the plantation areas would be required. Smaller, more frequent applications are likely to be necessary and soil moisture levels would need to be carefully monitored.

Salinity levels are low. As most profiles are deep and highly permeable, there is good potential for leaching salt that accumulates in the root zone under irrigation. There is a moderate to high risk of wind erosion on these dunes and windbreaks would need to be established if they were developed for horticulture. Some land reshaping may also be required on the higher dunes.

Potential horticultural areas

Table 3 summarises the survey findings for the focus areas identified in the Scoping Report (Land Resource Assessment 2000). Results from the additional land mapped outside focus areas are presented in Table 4, while Table 5 presents combined data from Tables 2 and 3. The findings are summarised graphically in Figures 3 and 4.

Focus areas

Land suitable for horticultural development is found mostly within the River System and on sand dunes in the Sable, Sandal and Target Systems. Along with the Delta System, most of the Sable, Sandal and Target Systems is unsuitable. This finding differs from the suggested suitability of the Sandal and Target Systems in the Scoping Report (see comments in Mapping units above).

Table 3: Land categories within focus areas

Focus Area (ha)	Gascoyne soils				Sand dunes	Highly unsuitable soils	Area surveyed
	Good	Marginal	Erosion-prone	Undifferentiated			
1	68	118	19	-	-	184	389
2	307 (140*)	289 (20*)	192 (44*)	14	13	1,052	1,867 (204*)
3	73	136	33	15	22	999	1,278
4	44 (17*)	236 (213*)	103 (88*)	- -	290 (275*)	2,539 (2,286*)	3,212 (2,879*)
6	8	38	10	-	-	247	303
8	-	58	361	-	437	2,796	3,652
Total	**500** **(157*)**	**875** **(233*)**	**718** **(132*)**	**29** **-**	**762** **(275*)**	**7,817** **(2,286*)**	**10,701** **(3,083*)**

* Portion within the Water Reserve.

'Good Gascoyne soils': Non-saline sands and loams on upper terraces of the River System are most suited to horticulture. These cover 500 ha and are most extensive in Focus Area 2.

'Marginal Gascoyne soils': A significant portion of the River System contains Gascoyne soils that carried silver saltbush (*Atriplex bunburyana*) and in which low to very high salinity levels (typically 20-500 mS/m $EC_{1:5}$) were recorded. Existing salinity is likely to result in reduced crop yields and where subsoil drainage is restricted, is likely to build up under irrigation. It is very difficult to map the extent of these saline soils precisely. Also included as '*marginal Gascoyne soils*' are terraces with coarse sandy soils with poorer moisture and nutrient retention capacities than other Gascoyne soils.

Erosion-prone Gascoyne soils: Include 718 ha of low lying river terraces and drainage channels that are most susceptible to flooding. Despite often containing good quality soils the very high risk of crop damage and soil loss during flooding renders these areas unsuitable for development.

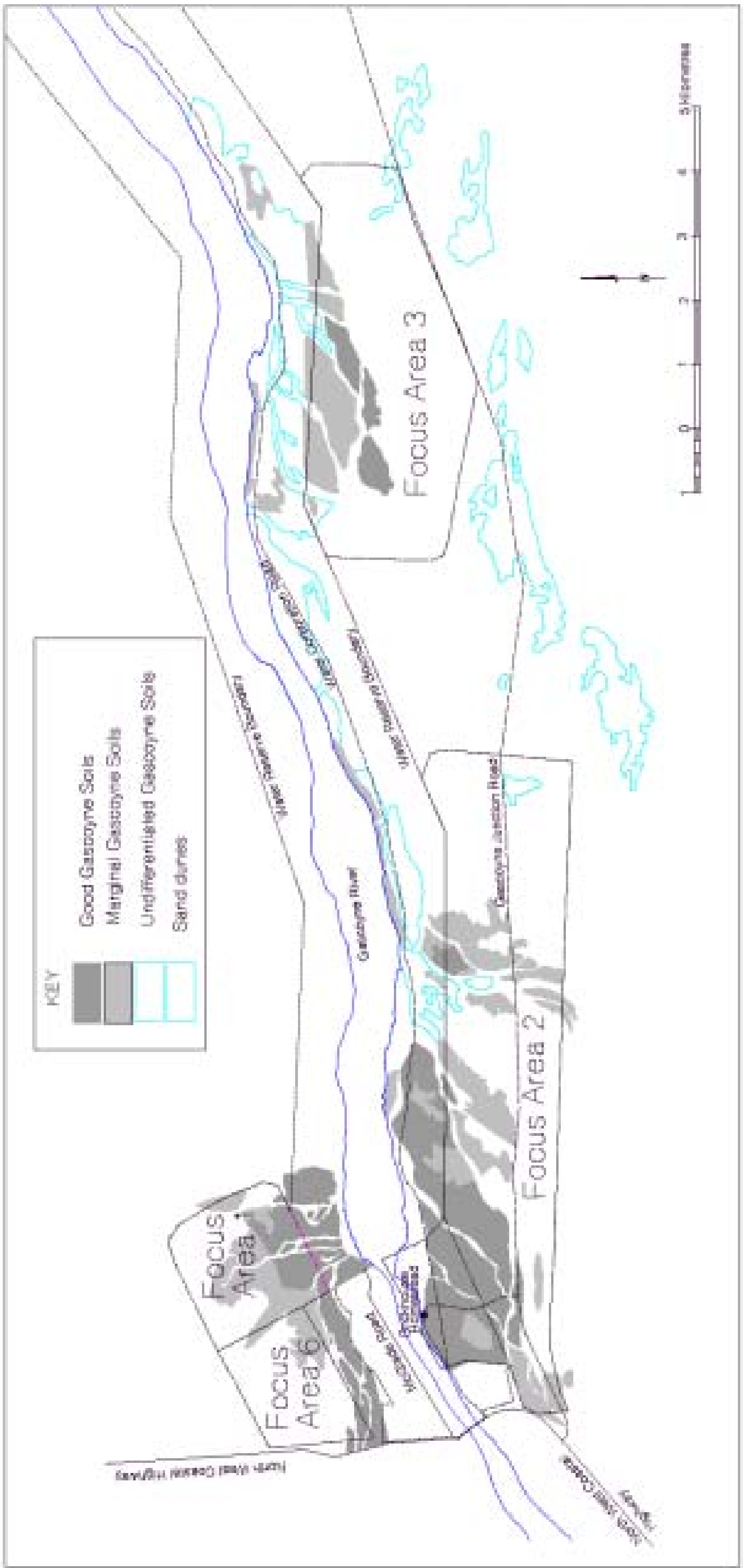

Figure 3: Soils with potential for horticulture in and around Focus Areas 1, 2, 3 and 6.

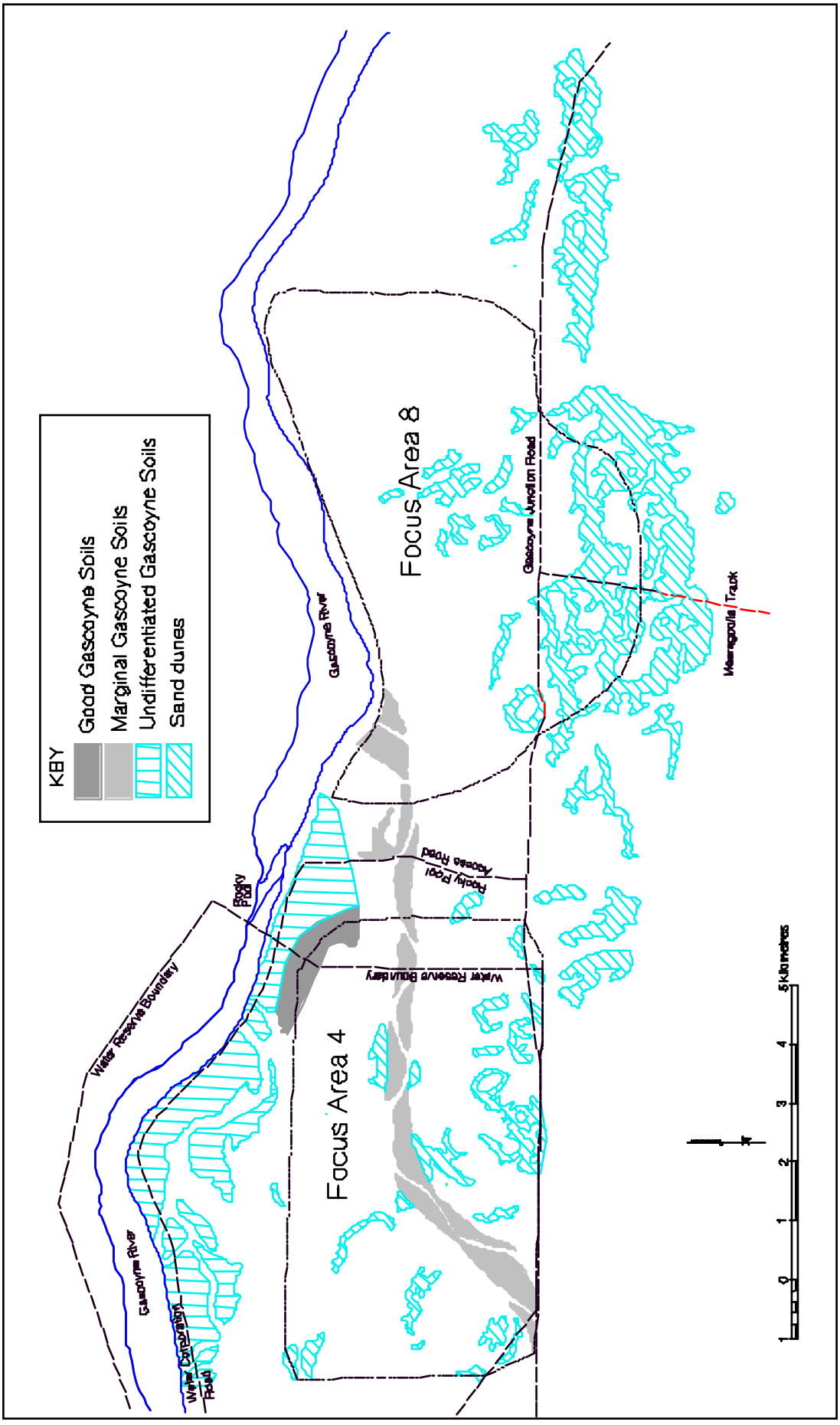

Figure 4: Soils with potential for horticulture in and around Focus Areas 4 and 8.

Undifferentiated Gascoyne soils: Terraces of the River System were not examined in the field as most lie outside the focus areas (only 29 ha were mapped within focus areas). These areas contain a mixture of '*good*' and '*marginal Gascoyne soils*'. Given the proportions of these soils in the focus areas, somewhere between a third and a half is likely to be suitable for horticulture.

Sand dunes: Contain deep, well-drained fine-grained sands with a high to fair capability for horticulture. Although the dunes cover 762 ha within the focus areas, they mostly occur as narrow, linear features, too small for large scale horticultural development.

Additional survey area

Assessment of additional land mapped outside focus areas identified in the Scoping Report is presented in Table 4. A summary of the total area mapped is presented in Table 5.

Table 4: Additional land mapped outside focus areas identified in Scoping Report

Area (ha)	Gascoyne soils				Sand dunes	Highly unsuitable	Area surveyed
	Good	Marginal	Erosion-prone	Undifferentiated			
Outside Water Reserve	104	92	261	8,744	187	1,345	6,755
Inside Water Reserve	257	163	502	3,295	1,224	8	1,141
TOTAL	**361**	**255**	**763**	**12,039**	**1,411**	**1,353**	**7,896**

Table 5: Summary of all land mapped

Area	Gascoyne soils				Sand dunes	Highly unsuitable	Area surveyed
	Good	Marginal	Erosion-prone	Undifferentiated			
Focus Area 1	68	118	19	-	-	184	389
Focus Area 2	307	289	192	14	13	1,052	1,867
Focus Area 3	73	136	33	15	22	999	1,278
Focus Area 4	44	236	103	-	290	2,539	3,212
Focus Area 6	8	38	10	-	-	247	303
Focus Area 8	-	58	361	-	437	2,796	3,652
Other areas*	104	92	261	187	1,345	6,755	8,744
TOTAL	**604**	**967**	**979**	**216**	**2,107**	**14,572**	**19,445**
Water Reserve**	257	163	502	1,224	8	1,141	3,295
GRAND TOTAL	**861**	**1,130**	**1,481**	**1,440**	**2,115**	**15,713**	**22,740**

* Excludes areas within the Water Reserve.

** Excludes areas of the Water Reserve located within Focus Areas 2 and 4.

Water Reserve. The 3,083 ha of Water Reserve within Focus Areas 2 and 4 are discussed above. A further 3,295 ha were mapped by air photo interpretation with limited field inspection. This identified about 2,160 ha of the River System, including 257 ha of 'good Gascoyne soils' and 163 ha of 'marginal Gascoyne soils'. Most of the remaining River System (1,224 ha) was mapped as Undifferentiated Terraces Subsystem, of which a third to a half is likely to be suitable for irrigation. These terraces are approximately 500 m wide and lie directly adjacent to the river bank between Focus Areas 2 and 3, and 3 and 4. Once a buffer strip was excised to protect the river bank from erosion, only a narrow strip of land

would remain available for development. There were also 502 ha of drainage channels and low level river terraces identified that are prone to flooding and erosion.

The remainder of the mapping comprises 8,744 ha outside the Water Reserve and focus areas. While it consists largely of unsuitable highly saline duplex soils (6,755 ha), two sizeable areas of sand dunes that have potential for development were identified. These were between Focus Areas 2 and 3, with 167 ha on the Gascoyne Junction Road and 106 ha to its south. Some limited field investigations were undertaken in these dunes, but further investigation would be required to ensure the consistency of the soil types within them. Other large areas of dunes are located south and south-east of Focus Area 8. For most, the distance from water supplies, and other infrastructure such as power and communications may make them of lower value for development than other locations where the provision of services could be less expensive.

A brief reconnaissance of the Ella Land System, approximately 40 km upstream from Rocky Pool, was also undertaken on Doorawarrah Station. It was considered that this system might have potential for horticulture because it was described by Payne *et al.* (1987) as containing 55% dunes and sandy banks. This system appeared to contain large areas of unsuitable shallow duplex soils, and the dunes were often narrow and steep.

Focus Area descriptions

Focus Areas 1 and 6 form a continuous area covering 692 ha to the north and east of the McGlade Road plantations on the north side of the river. It excludes areas adjacent to McGlade Road previously surveyed by Wells (1990).

Focus Areas 1 and 6 contain the second largest area for potential horticultural development. About 274 ha of River System were identified, mostly within Focus Area 1. The soils were predominantly 'light' and 'medium-textured' Gascoyne soils, with 'heavy-textured' Gascoyne soils towards the northern margins. In general, salinity levels were higher in the medium to heavier Gascoyne soils and increased with distance from the river. Non-saline Gascoyne soils cover 76 ha of this system, while existing salinity could be expected to lead to reduced crop yields over 156 ha. About 29 ha of drainage channels in this system have been identified as unsuited to development due to the flooding and erosion risk. A further 120 ha of River System lies between Focus Area 6 and the existing McGlade Road plantations. Some is channel, prone to flooding and erosion.

The rest of Focus Areas 1 and 6 consists of the Delta System (431 ha) which is not suited to horticultural development. It is dominated by Coburn soils, saline shallow sandy duplexes, typically with 5-20 cm of sandy topsoil overlying highly saline and sodic clayey subsoil.

Focus Area 2 covers 1,867 ha on the south of the river and extending about 10 km east of existing plantations along the Gascoyne Junction Road. It includes 204 ha around Brickhouse Homestead within the Water Reserve. About 854 ha of the River System was identified in Focus Area 2. The soil types ranged from light to heavy-textured Gascoyne soils, with the texture trending heavier with increasing distance from the river. Salinity levels in these soils also tend to increase away from the river.

The western portion of Focus Area 2 contains 307 ha of non-saline 'light and medium-textured' Gascoyne soils. This is the largest area identified as having high capability for

horticultural development, though it is bisected by several drainage channels that reduce the potential block sizes. About 289 ha of saline or clayey 'marginal Gascoyne soils' are also present, some lying within areas of non-saline soils. A further 192 ha of drainage channels and low lying river terraces are classified as unsuitable for development due to the high risk of flooding and water erosion.

The remaining 1,052 ha of Focus Area 2 are dominated by saline, shallow duplex soils unsuited to horticulture. The sandy topsoil is typically 5-20 cm deep and salinity and sodicity levels in the clayey subsoil are typically very high to extreme. Most of the unsuitable areas occur on the Delta System (Coburn and Moyamber association soils), with an area of Sandal System in the south-east corner (Doorawarrah soils).

Focus Area 3 covers 1,278 ha located between the river and the Gascoyne Junction Road about 15 km east of the North West Coastal Highway. It has limited areas of soil with potential for horticultural development.

The area contains about 258 ha of the River System, with 'light and medium-textured' Gascoyne soils situated along its northern boundary. More than half of these soils (about 136 ha) have subsoils with low to extreme salinity ($EC_{1:5}$ 20-400 mS/m). A further 33 ha of the River System consists of drainage channels prone to flooding and erosion.

The remainder occurs on the Delta and Sandal Systems, which are dominated by saline, shallow sandy duplex soils of the Coburn, Doorawarrah and Moyamber associations. The sandy topsoil is typically 5-20 cm deep and salinity levels in the clayey subsoil are very high to extreme. Areas with potential for horticultural development are restricted to the 22 ha of low sand dunes which rise above the duplex soil flats of the Sandal System. These dunes have fine to medium-grained red sands which are more than 100 cm deep but are narrow (100-250 m wide) and linear, making them unsuited to large scale developments.

Focus Area 4 covers 3,212 ha, of which almost 90% (2,879 ha) is situated within the Water Reserve. It is between the river and the Gascoyne Junction Road to the west of the Rocky Pool Access Road. Focus Area 4 contains only minor areas with potential for horticultural development.

Focus Area 4 contains 444 ha of River System containing Gascoyne association soils and Coburn red-brown duplex soils. In the north-east corner about 44 ha of 'light-textured' Gascoyne soils are suitable for horticulture and 61 ha of highly saline Coburn red-brown duplex soils. The remaining 339 ha of the River System consist of relict alluvial deposits which cut across Focus Area 4. These deposits are 300-600 m wide and bisected by a drainage channel. The soils are highly variable (coarse sands, loamy earths and saline duplex soils with massive subsoil horizons) and this relict channel has marginal value for horticulture. There is also risk of erosive flood water moving down this channel.

The remainder occurs on the Sandal and Sable Systems, which are dominated by saline shallow sandy duplex soils of the Doorawarrah and Moyamber associations (2,539 ha). On these systems, areas of horticultural potential are restricted to sand dunes (290 ha). Though these dunes are unsuited to large scale development due to their narrow, linear nature, they are not prone to flooding and could be used for smaller developments. They would be susceptible to wind erosion if not managed carefully.

Focus Area 8 covers 3,652 ha east of the Rocky Pool Access Road, extending south from the river across the Gascoyne Junction Road. It contains only small isolated patches of soil with potential for horticultural development.

Although Focus Area 8 contains about 654 ha of the River System, more than half (361 ha) consists of low level river terraces that are prone to flooding and erosion. Most less flood-prone areas of the River System (236 ha) consist of Coburn red-brown duplex soils (sand over clay), that are unsuitable for horticultural development due to salinity. Only about 58 ha of well-drained sandy Gascoyne Soils are on the upper river terraces. These soils are coarse grained and have only fair capability for horticulture.

The remainder of Focus Area 8 occurs on the Sandal and Target Systems that are dominated by highly saline shallow sandy duplex soils. The sandy topsoil is typically 5-20 cm deep and salinity levels in the clayey subsoil are very high to extreme. Areas with potential for horticultural development within the Sandal and Target Systems are restricted to the low sand dunes that rise above the duplex soil flats. Dune soils consist of fine-grained red sands more than 100 cm deep. These dunes are not prone to flooding, but would be susceptible to wind erosion. Although Focus Area 8 contains 437 ha of sand dunes, the individual dunes are mostly isolated, occurring as long, narrow (100-250 m wide) areas that would be unsuited to large developments.

Acknowledgements

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Appendix A - Representative soil types

Soil association: Gascoyne 'light-textured'
Site no: A18, MGA94 780067 mE; 7253037 mN; zone 49
Map unit: Ri1
WA Soil Group: Red sandy earth
Australian Soil Classification: Haplic Hypocalcic Kandosol
Soil Taxonomy: Typic Torriorthent

Profile description

Horizon	Depth (cm)	Description
A11	0-15	Reddish-brown (5YR4/4) **loamy very fine sand**; weak coarse sub-angular blocky structure (dry); pH 7.6, $EC_{1:5}$ 9 mS/m; ESP 7%, 0.9 ppm boron. Clear boundary to;
A12	15-50	Yellowish-red (5YR 4/6) **loamy very fine sand (+)**; massive, earthy fabric (dry); pH 8.9. $EC_{1:5}$ 5 mS/m. Diffuse boundary to;
2A11	50-100	Yellowish-red (5YR4/6) **very fine sandy loam (-)**; massive, earthy fabric (dry); pH 8.7, $EC_{1:5}$ 10 mS/m; ESP 5%, 0.7 ppm boron. Diffuse boundary to;
2A12k	100-180	Yellowish-red (5YR4/6) **very fine sandy loam (+)**; massive, earthy fabric (dry), slightly calcareous; pH 8.9, $EC_{1:5}$ 11 mS/m. Diffuse boundary to;
2A13	180-200	Yellowish-red (5YR4/6) **very fine sandy loam**; massive, earthy fabric (dry); pH 9.1, $EC_{1:5}$ 8 mS/m; ESP 6%, 1.0 ppm boron.

Soil association: Gascoyne 'light-textured'
Site no: B27, MGA94, 782608 mE; 7254619 mN, zone 49
Map unit: Ri1s
WA Soil Group: Red sandy earth
Australian Soil Classification: Sodic Hypocalcic Red Kandosol
Soil Taxonomy: Typic Torriorthent

Profile description

Horizon	Depth (cm)	Description
A11	0-60	Reddish brown (5YR 4/4) moist **clayey fine sand**; massive structure; earthy fabric; pH 7.6; $EC_{1:5}$ 4 mS/m; ESP 3%, 0.3 ppm boron. Diffuse boundary to;
B21k	60-110	Reddish brown (5YR 4/4) moist **fine sandy loam**; weak, subangular blocky structure; rough-ped fabric; slightly calcareous; pH 9.1; $EC_{1:5}$ 8 mS/m; ESP 4%, 0.6 ppm boron. Gradual boundary to;
B22k	110-190+	Reddish brown (5YR 4/4) moist **silty clay loam**; weak, subangular blocky structure; rough-ped fabric; slightly calcareous; pH 9.4; $EC_{1:5}$ 22 mS/m; ESP 23%, 4.2 ppm boron.

Soil association: Gascoyne 'light-textured'
Site no: C45, MGA94, 782738 mE; 7251629 mN; zone 49
Map unit: Ri1
WA Soil Group: Red loamy earth
Australian Soil Classification: Regolithic Orthic Tenosol
Soil Taxonomy: Typic Torriorthent

Profile description

Horizon	Depth (cm)	Description
A11	0-20	Reddish-brown (5YR4/4) **very fine sandy loam**; moderate, platy structure, rough ped fabric; pH 8.0; $EC_{1:5}$ 11 mS/m; ESP 4%, 0.9 ppm boron. Abrupt boundary to;
B1	20-60	Reddish-brown (5YR 4/4) **very fine sandy loam**; weak, medium sub-angular blocky structure, rough ped fabric; pH 7.7, $EC_{1:5}$ 4 mS/m. Gradual boundary to;
B2k	60-80	Yellowish-red (5YR4/6) **fine sandy loam**; weak sub-angular blocky structure; rough ped fabric; pH 8.7; $EC_{1:5}$ 6 mS/m; ESP 3%, 0.4 ppm boron.
2A11	80-150	Yellowish-red (5YR4/6) **loamy fine sand**; massive, sandy fabric; pH 8.2; $EC_{1:5}$ 4 mS/m. Clear boundary to;
2A12	150-200	Yellowish-red (5YR4/6) **loamy fine sand**; massive, loamy fine sand, massive, sandy fabric; pH 8.7; $EC_{1:5}$ 4 mS/m; ESP 8%, 0.8 ppm boron.

Soil association: Gascoyne 'medium-textured'
Site no: B26, 782990 mE; 7254675 mN; zone49
Map unit: Ri2s
WA Soil Group: Red loamy earth
Australian Soil Classification: Sodic Eutrophic Red Dermosol
Soil Taxonomy: Typic Haplargid

Profile description

Horizon	Depth (cm)	Description
A1	0-10	Reddish brown (5YR 4/4) moist **fine sandy loam**; weak, platy structure; rough-ped fabric; pH 7.7, $EC_{1:5}$ 7 mS/m; ESP 7%, 0.4 ppm boron. Clear boundary to;
B1	10-90	Reddish brown (5YR 4/4) moist **silty loam**; moderate, subangular blocky structure; rough-ped fabric; pH 9.3, $EC_{1:5}$ 14 mS/m; ESP 10%, 1.6 ppm boron. Gradual boundary to;
B21	90-140	Yellowish red (5YR 4/6) moist **sandy clay loam**; pH 8.3, $EC_{1:5}$ 69 mS/m; ESP 17%, 1.9 ppm boron;
B22	140-200+	Red (2.5YR 4/6) moist **sandy clay loam**; pH 8.3, $EC_{1:5}$ 39 mS/m; ESP 18%, 2.1 ppm boron.

Soil association: Gascoyne 'medium-textured'
Site no: B31, 783354 mE; 7255197 mN; zone 49
Map unit: Ri2s
WA Soil Group: Red loamy earth
Australian Soil Classification: Sodic Hypocalcic Red Kandosol
Soil Taxonomy: Typic Torriorthent

Profile description

Horizon	Depth (cm)	Description
A11	0-7	Reddish-brown (5YR4/4) **clayey fine sand**; massive, earthy fabric; pH 7.3; $EC_{1:5}$ 4 mS/m; ESP 4%, 0.5 ppm boron. Clear boundary to;
B1	7-40	Reddish-brown (5YR 4/4) **light sandy clay loam**; weak, medium sub-angular blocky structure, rough ped fabric; pH 8.7; $EC_{1:5}$ 4 mS/m; ESP 5%, 0.8 ppm boron. Gradual boundary to;
B21k	40-100	Reddish-brown (5YR4/4) **fine sandy clay loam**; slight acid effervescence; pH 8.0; $EC_{1:5}$ 9 mS/m.
B22y	100-180	Reddish-brown (5YR4/4) **silty clay**; very few gypsum segregations; pH 7.8; $EC_{1:5}$ 9 mS/m; ESP 23%, 4.0 ppm boron.

Soil association: Gascoyne 'medium-textured'
Site no: C46, 784925 mE; 7251487 mN; zone 49
Map unit: Ri4
WA Soil Group: Red loamy earth
Australian Soil Classification: Sodic Hypocalcic Red Kandosol
Soil Taxonomy: Typic Paleargid

Profile description

Horizon	Depth (cm)	Description
A1	0-20	Dark reddish brown (5YR 3/4) moist **fine sandy loam**; weak consistence; moderate, subangular blocky structure; rough-ped fabric; pH 7.1; $EC_{1:5}$ 5 mS/m; ESP 2%, 0.4 ppm boron. Clear boundary to;
B2	20-60	Reddish brown (5YR 4/4) moist **fine sandy clay loam**; firm consistence; weak, 10-20 mm, subangular blocky structure; rough-ped fabric; pH 7.9; $EC_{1:5}$ 3 mS/m; ESP 3%, 0.4 ppm boron. Clear boundary to;
2A1k	60-90	Yellowish red (5YR 4/6) moist **fine sandy loam**; very weak consistence; massive, subangular blocky structure; earthy fabric; fine calcareous soft segregations; pH 8.7; $EC_{1:5}$ 7.5 mS/m. Clear boundary to;
2B2k	90-130	Yellowish red (5YR 4/6) moist **clay loam, fine sandy**; very firm consistence; weak, 10-20 mm, subangular blocky structure; earthy fabric; fine calcareous soft segregations; moderately calcareous; pH 9.3; $EC_{1:5}$ 12 mS/m; ESP 13%, 1.1 ppm boron. Gradual boundary to;
3A1k	130-200+	Yellowish red (5YR 4/6) moist **fine sandy loam**; very weak consistence; massive structure; earthy fabric; fine calcareous soft segregations; slightly calcareous; pH 8.5; $EC_{1:5}$ 32 mS/m; ESP 22%, 2.1 ppm boron.

Soil association: Gascoyne 'medium-textured'
Site no: C47, 787268 mE; 7251232mN; zone 49
Map unit: Ri2s
WA Soil Group: Alkaline red shallow loamy duplex
Australian Soil Classification: Hypocalcic Subnatric Red Sodosol
Soil Taxonomy: Typic Paleargid

Profile description

Horizon	Depth (cm)	Description
A1	0-20	Reddish brown (5YR 4/4) moist **fine sandy loam**; dry soil; moderate, platy structure; rough-ped fabric; pH 7.7; EC_{15} 17 mS/m; ESP 4%, 0.6 ppm boron. Clear boundary to;
B2k	20-70	Reddish brown (5YR 4/4) moist **clay loam, fine sandy (+)**; dry soil; moderate, subangular blocky structure; rough-ped fabric; 3% carbonate segregations; slightly calcareous; pH 9.2; EC_{15} 17 mS/m; ESP 12%, 2.4 ppm boron.
2A1	70-160	Dark red (2.5YR 3/6) moist **sandy loam**; dry soil; massive structure; earthy fabric; rare manganiferous segregations; pH 8.5.
2B2	160-200	Red (2.5YR 4/6) moist **clay loam, sandy**; dry soil; massive structure; earthy fabric; rare manganiferous segregations; pH 9.1; EC_{15} 13 mS/m; ESP 15%, 2.8 ppm boron.
3B2	200-230	Red (2.5YR 4/6) moist **sandy clay loam**; moderately moist soil; pH 8.8; EC_{15} 82 mS/m.

Soil association: Gascoyne 'medium-textured'
Site no: C81, 781704 mE; 7251148 mN; zone 49
Map unit: Ri2
WA Soil Group: Red loamy earth
Australian Soil Classification: Sodic Hypocalcic Red Dermosol
Soil Taxonomy: Typic Haplargid

Profile description

Horizon	Depth (cm)	Description
A11	0-15	Dark reddish-brown (5YR4/5) **fine sandy loam**; massive (dry), earthy fabric; pH 7.5. Abrupt boundary to;
B1	15-35	Reddish-brown (5YR 4/5) **silt loam**; weak, medium sub-angular blocky structure; pH 7.5. Gradual boundary to;
B2k	35-120	Reddish-brown (5YR4/5) **fine sandy clay loam (weak)**; strong, medium sub-angular blocky structure; pH 8.5; few fine lime segregations. Clear boundary to;
2A1	120-200	Reddish-brown (5YR4/5) **clayey fine sand**; massive, earthy fabric; pH 8.0.

Soil association: Gascoyne 'medium-textured'
Site no: C83, 783710 mE; 7251679 mN; zone 49
Map unit: Ri2s
WA Soil Group: Calcareous loamy earth
Australian Soil Classification: Sodic Hypocalcic Red Dermosol
Soil Taxonomy: Typic Haplargid

Profile description

Horizon	Depth (cm)	Description
A1	0-20	Reddish brown (5YR 4/4) moist **silty loam**; very weak consistence; weak, subangular blocky structure; earthy fabric; pH 7.7; $EC_{1:5}$ 20 mS/m; ESP 8%, 0.8 ppm boron. Clear boundary to;
B2k	20-75	Reddish brown (5YR 4/4) moist **clay loam**, **fine sandy**; firm consistence; strong, subangular blocky structure; earthy fabric; very few calcareous segregations; moderately calcareous; pH 9.0; $EC_{1:5}$ 37 mS/m; ESP 19%, 2.4 ppm boron. Gradual boundary to;
2B2k	75-115	Reddish brown (5YR 4/4) moist **fine sandy clay loam**; firm consistence; massive structure; earthy fabric; very few calcareous; moderately calcareous; pH 9.6; $EC_{1:5}$ 22 mS/m; ESP 18%, 2.4 ppm boron. Clear boundary to;
3B2k	115-200	Yellowish red (5YR 4/6) moist **silty clay**; strong, subangular blocky structure; rough-ped fabric; few calcareous; moderately calcareous; pH 9.3; $EC_{1:5}$ 44 mS/m; ESP 27%, 4.8 ppm boron.
4B2	200-290	Reddish brown (5YR 4/4) moist **silty clay**; pH 7.6; $EC_{1:5}$ 209 mS/m; ESP 53%, 4.3 ppm boron.

Soil association: Gascoyne 'medium-textured'
Site no: C84, 784358 mE; 7251481 mN; zone 49
Map unit: Ri2s
WA Soil Group: Red loamy earth
Australian Soil Classification: Sodic Eutrophic Red Dermosol
Soil Taxonomy: Typic Paleargid

Profile description

Horizon	Depth (cm)	Description
A11	0-30	Reddish brown (5YR 4/4) moist **fine sandy loam**; massive structure; earthy fabric; pH 7.4; $EC_{1:5}$ 5 mS/m; ESP 1%, 0.6 ppm boron. Clear boundary to;
B1	30-40	Reddish brown (5YR 4/4) moist **light sandy clay loam**; massive structure; earthy fabric; pH 8.7; $EC_{1:5}$ 9 mS/m; ESP 2%, 1.3 ppm boron. Abrupt boundary to;
B2	40-80	Reddish brown (5YR 4/4) moist **silty clay loam**; moderate, subangular blocky structure; rough-ped fabric; pH 8.0. Gradual boundary to;
2B1	80-120	Yellowish red (5YR 4/6) moist **fine sandy clay loam**; massive structure; earthy fabric; pH 8.6; $EC_{1:5}$ 14 mS/m; ESP 6%, 2.4 ppm boron. Clear boundary to;
2B2	120-190+	Reddish brown (5YR 4/4) moist **silty clay**; strong, subangular blocky structure; rough-ped fabric; pH 8.6; $EC_{1:5}$ 13 mS/m.

Soil association: Gascoyne 'heavy-textured'
Site no: A14, 780727 mE; 7254972 mN; zone 49
Map unit: Ri3s
WA Soil Group: Calcareous loamy earth
Australian Soil Classification: Sodic Hypocalcic Red Dermosol
Soil Taxonomy: Typic Torriorthent

Profile description

Horizon	Depth (cm)	Description
A1	0-30	Reddish brown (5YR 4/4) moist **silty clay loam**; moderate, angular blocky structure; rough-ped fabric; non-calcareous; pH 8.0; $EC_{1:5}$ 13 mS/m; ESP 4%, 1.5 ppm boron. Gradual boundary to;
B2k	30-90	Reddish brown (5YR 4/4) moist **silty clay loam**; moderately calcareous; pH 9.4; $EC_{1:5}$ 18 mS/m; ESP 10%, 3.1 ppm boron. Gradual boundary to;
2B21k	90-130	Yellowish red (5YR 4/6) moist **silty light clay**; moderately calcareous; pH 9.2; $EC_{1:5}$ 22 mS/m. Gradual boundary to;
2B22k	130-150+	Yellowish red (5YR 4/6) moist **silty light clay**; medium calcareous nodules; highly calcareous; pH 9.4; $EC_{1:5}$ 41 mS/m; ESP 12%, 6.6 ppm boron.

Soil association: Gascoyne 'heavy-textured'
Site no: C44, 781913 mE; 7250819 mN; zone 49
Map unit: Ri2
Soil Group: Red loamy earth
Australian Soil Classification: Haplic Eutrophic Red Kandosol
Soil Taxonomy: Typic Torriorthent

Profile description

Horizon	Depth (cm)	Description
A11	0-20	Reddish-brown (5YR4/4) **silty clay loam (light)**; strong, coarse platy structure; rough ped fabric; pH 7.6; $EC_{1:5}$ 16 mS/m; ESP 2%, 1.1 ppm boron. Clear boundary to;
A12	20-40	Reddish-brown (5YR 4/4) **silty clay loam**; weak, medium to coarse sub-angular blocky structure, rough ped fabric; pH 7.4; $EC_{1:5}$ 5 mS/m; ESP 1%, 0.6 ppm boron. Gradual boundary to;
B21	40-80	Yellowish-red (5YR4/6) **silty clay loam**; weak, medium to coarse sub-angular blocky structure, rough ped fabric; pH 9.0. Gradual boundary to;
B22	80-120	Yellowish-red (5YR4/6) **silty clay loam**; weak, medium to coarse sub-angular blocky structure, rough ped fabric; pH 9.0. Gradual boundary to;
B23	120-160	Yellowish-red (5YR4/6) **silty clay loam**; weak, medium sub-angular blocky structure, rough ped fabric; pH 8.2; $EC_{1:5}$ 7 mS/m; ESP 6%, 1.1 ppm boron.

Soil association: Gascoyne 'heavy-textured'
Site no: C82, 782171 mE; 7251185 mN; zone 49
Map unit: Ri2
WA Soil Group: Red loamy earth
Australian Soil Classification: Sodic Hypocalcic Red Dermosol
Soil Taxonomy: Typic Torriorthent

Profile description

Horizon	Depth (cm)	Description
A11	0-15	Reddish brown (5YR 4/4) moist **silty clay loam**; weak, subangular blocky structure; rough-ped fabric; pH 7.8; $EC_{1:5}$ 9 mS/m; ESP 3%, 0.8 ppm boron. Gradual boundary to;
A12	15-50	Reddish brown (5YR 4/4) moist **silty clay loam**; weak, subangular blocky structure; rough-ped fabric; pH 8.5; $EC_{1:5}$ 6 mS/m; ESP 5%, 1.1 ppm boron. Gradual boundary to;
2B2k	50-110	Yellowish red (5YR 4/5) moist **silty clay**; strong, subangular blocky structure; rough-ped fabric; very few calcareous segregations and moderate effervescence; pH 9.1; $EC_{1:5}$ 13 mS/m; ESP 10%, 2.0 ppm boron. Abrupt boundary to;
3A1	110-200	Yellowish red (5YR 4/6) moist **loamy fine sand**; single grain structure; sandy fabric; pH 8.8; $EC_{1:5}$ 7 mS/m; ESP 14%, 1.0 ppm boron.

Soil association: Gascoyne 'heavy-textured'
Site no: C85, 785521 mE; 7251431 mN; zone 49
Map unit: Ri2s
WA Soil Group: Red loamy earth
Australian Soil Classification: Sodic Hypocalcic Red Dermosol
Soil Taxonomy: Typic Haplargid

Profile description

Horizon	Depth (cm)	Description
A11	0-10	Dark reddish-brown (5YR3/3) **silt loam**; massive (dry), earthy fabric; pH 7.6; $EC_{1:5}$ 11 mS/m; ESP 5%, 0.9 ppm boron. Clear boundary to;
B1	10-40	Reddish-brown (5YR 4/4) **clay loam fine sandy**; moderate, medium sub-angular blocky structure; pH 8.3; $EC_{1:5}$ 7 mS/m; ESP 6%, 0.9 ppm boron. Gradual boundary to;
B2k	40-120	Reddish-brown (5YR4/4) **clay loam, fine sandy**; strong, medium sub-angular blocky structure; few fine lime segregations and acid effervescence; pH 9.5; $EC_{1:5}$ 24 mS/m; ESP 23%, 2.6 ppm boron. Diffuse boundary to;
2A1y	120-155	Reddish-brown (5YR4/4) **light sandy clay loam**; massive, earthy fabric; pH 8.5. Few gypsum segregations.
2B2y	155-260	Reddish-brown (5YR4/4) **fine sandy clay loam**; massive, earthy fabric; pH 8.6; $EC_{1:5}$ 49 mS/m; ESP 38%, 5.0 ppm boron. Few gypsum segregations.
2B3y	260-280	Reddish-brown (5YR4/4) **light clay**; pH 7.9; $EC_{1:5}$ 460 mS/m. Few gypsum segregations.

Soil association: Coburn red-brown duplex
Site no: F32, 211623 mE; 7257414 mN; zone 50
Map unit: Ri8
WA Soil Group: Red shallow sandy duplex
Australian Soil Classification: Hypocalcic Hypernatric Red Sodosol
Soil Taxonomy: Typic Paleargid

Profile description

Horizon	Depth (cm)	Description
A11	0-25	Reddish-brown (5YR4/4) **loamy fine sand**; massive structure (dry), sandy fabric; Clear boundary to;
B1	25-50	Yellowish-red (5YR 4/6) **fine sandy clay loam**; massive, earthy fabric (dry) ; pH 8.7; $EC_{1:5}$ 47 mS/m; ESP 25%, 1.6 ppm boron. Diffuse boundary to;
B2	50-100	Yellowish-red (5YR4/6) **very fine sandy clay loam**; massive, earthy fabric (dry); pH 8.0. $EC_{1:5}$ 129 mS/m. Diffuse boundary to;
2B2ky	100-150	Yellowish-red (5YR4/6) **very fine sandy clay loam**; pH 8.1. $EC_{1:5}$ 140 mS/m. Few gypsum and fine lime segregations and slight acid effervescence.
2B2y	150-200	Yellowish-red (5YR4/6) **fine sandy clay loam**; pH 8.7; $EC_{1:5}$ 78 mS/m; ESP 28%, 5.8 ppm boron.

Soil association: Coburn
Site no: B7, 781952 mE; 7254721 mN; zone 49
Map unit: De3
WA Soil Group: Red shallow sandy duplex
Australian Soil Classification: Calcic Mesonatric Red Sodosol
Soil Taxonomy: Typic Paleargid

Profile description

Horizon	Depth (cm)	Description
A11	0-20	Dark reddish-brown (5YR4/4) **clayey fine sand**; structureless, loose, sandy fabric; pH 7.0. Clear boundary to;
B2k	20-80	Reddish-brown (5YR4/4) **silty loam (+)**; strong, medium to coarse blocky structure; pH 8.5. Few fine lime segregations and very strong acid efferves cence. Clear boundary to;
D	80-90	Yellowish-red to red (2.5-5YR4/6) **silty clay loam**; few lime segregations; pH 8.8; $EC_{1:5}$ 306 mS/m.

Soil association: Coburn
Site no: C63, 782372 mE; 7250117 mN; zone 49
Map unit: De4
WA Soil Group: Red shallow sandy duplex
Australian Soil Classification: Hypocalcic Mesonatric Red Sodosol
Soil Taxonomy: Typic Paleargid

Profile description

Horizon	Depth (cm)	Description
A11	0-20	Red (2.5YR4/6) **clayey very fine sand**; massive, sandy fabric; pH 7.1; EC_{15} 25 mS/m. Clear boundary to;
B1	20-80	Red (2.5YR 4/6) **clay loam, fine sandy**; massive, earthy fabric; pH 7.2; EC_{15} 106 mS/m. Gradual boundary to;
B2ky	80-130	Red (2.5YR4/6) **very fine sandy clay**; very few gypsum segregations and slight acid effervescence; pH 7.2; EC_{15} 540 mS/m. Gradual boundary to;
2B2	130-180	Red (2.5YR4/8) **medium to heavy clay**; pH 7.2; EC_{15} 560 mS/m.

Soil association: Moyamber
Site no: C48, 788084 mE; 7250117 mN; zone 49
Map unit: De2
WA Soil Group: Red shallow sandy duplex
Australian Soil Classification: Haplic Eutrophic Red Chromosol
Soil Taxonomy: Typic Paleargid

Profile description

Horizon	Depth (cm)	Description
A11	0-10	Reddish-brown (5YR4/4) **loamy coarse sand** with few coarse quartz gravel; weak coarse platy structure, sandy fabric; pH 7.3; EC_{15} 3 mS/m; ESP 4%, 0.4 ppm boron. Abrupt boundary to;
B1	10-30	Yellowish-red (5YR 4/6) **sandy light clay**; weak, medium sub-angular blocky structure, smooth ped fabric; pH 7.1; EC_{15} 6 mS/m; ESP 3%, 0.4 ppm boron. Gradual boundary to;
B21	30-90	Red (2.5YR4/6) **sandy clay**; weak, coarse sub-angular blocky structure, rough ped fabric; pH 7.9. EC_{15} 4 mS/m. Clear boundary to;
B22	90-100	Red (5YR4/5) **sandy light clay**; weak medium sub-angular blocky structure, rough ped fabric; pH 8.5; EC_{15} 5 mS/m; ESP 5%, 1.4 ppm boron.

Soil association: Brown sand
Site no: F28, 216023 mE; 7254163 nN; zone 50
Map unit: Sd1
WA Soil Group: Red deep sand
Australian Soil Classification: Arenic Orthic Tenosol
Soil Taxonomy: Typic Torripsamment

Profile description

Horizon	Depth (cm)	Description
A1	0-50	Red (2.5YR 4/6) **loamy sand**; single grain structure; sandy fabric; pH 7.6; EC_{15} 4 mS/m. Diffuse boundary to;
B	50-140	Red (2.5YR 4/6) **loamy sand**; pH 7.7; EC_{15} 3.5 mS/m.
C	140-155	Red (2.5YR 4/6) **sandy loam**; pH 7.7; EC_{15} 10 mS/m.
D	155+	Becomes very hard to dig.

Soil association: Brown sand
Site no: D53, 799902 mE; 7252522 mN; zone 49
Map unit: Sd1
WA Soil Group: Red sandy earth
Australian Soil Classification: Arenic Orthic Tenosol
Soil Taxonomy: Typic Torriorthent

Profile description

Horizon	Depth (cm)	Description
A1	0-15	Red (2.5YR 4/6) **loamy sand**; massive structure; smooth-ped fabric; pH 7.9. EC_{15} 2.5 mS/m. Gradual boundary to;
B1	15-80	Red (2.5YR 4/6) **loamy fine sand**; massive structure; smooth-ped fabric; pH 8.0; EC_{15} 2.5 mS/m. Diffuse boundary to;
B21	80-140	Red (2.5YR 4/6) **fine sandy loam (-)**; pH 8.4. EC_{15} 5 mS/m. Clear boundary to;
B22k	140-180+	Yellowish red (5YR 4/6) **fine sandy loam**; few medium calcareous nodules; pH 9.0; EC_{15} 11 mS/m.

Soil association: Brown loam
Site no: D19, 794803 mE; 7250889 mN; zone 49
Map unit: Sd1
WA Soil Group: Red loamy earth
Australian Soil Classification: Sodic Hypocalcic Red Kandosol
Soil Taxonomy: Typic Torriorthent or Typic Camborthid

Profile description

Horizon	Depth (cm)	Description
A11	0-20	Reddish-brown (5YR4/4) **sandy loam**; massive, earthy fabric; pH 8.0. Clear boundary to;
B2	20-80	Yellowish-red (5YR4/6) **light sandy clay loam**; moderate, medium sub-angular blocky structure; pH 8. Gradual boundary to;
B2k	80-180	Yellowish-red (5YR4/6) **fine sandy loam**; massive, earthy fabric, common lime segregations; pH 8.5; EC_{15} 203 mS/m. Gradual boundary to;
D	180-250	Red (2.5YR4/8) **loamy fine sand**; structureless, loose sandy fabric; pH 7.8; EC_{15} 98 mS/m.

Appendix B - Laboratory methods and analysis

The laboratory results presented in Table B1 were received from CSBP. All the profiles are described in Appendix A. Unless specified, analytical methods follow procedures outlined in: Rayment, G.E. and Higginson, F.R. (1992) 'Australian Laboratory Handbook of Soil and Water Chemical Methods' (Inkata Press, Melbourne).

Available phosphorus and potassium were measured using the Colwell method. Soils were tumbled with 0.5 M sodium bicarbonate solution adjusted to pH 8.5 for 16 hours at 25^{o}C employing a soil to solution ratio of 1:100. The acidified extract was treated with ammonium molybdate/antimony trichloride reagent and the concentration of phosphate was measured calorimetrically at 880 nm. The concentration of potassium is determined using a flame atomic absorption spectrophotometer at 766.5 nm.

Ammonium and nitrate nitrogen were measured simultaneously using a Lachat Flow Injection Analyser. Soils were tumbled with 1M potassium chloride for 1 hour at 25^{o}C employing a soil to solution ratio of 1:5. The concentration of ammonium nitrogen was measured colorimetrically at 420 nm using the indo-phenol blue reaction. The nitrate was reduced to nitrite through a copperised –cadmium column and the nitrite measured calorimetrically at 520 nm.
Reference: Searle, P.L. (1984). The Bertholt or indophenol reaction and its use in the analytical chemistry of nitrogen. *Analyst* **109**, 549-568.

Conductivity and pH: Soils were stirred in deionised water for 1 hour at 25^{o}C employing a soil:solution ratio of 1:5. The pH_w of the extract was measured using a combination pH electrode, and the electrical conductivity measured using a conductivity electrode calibrated against 0.01KCl. After pH_w and EC had been measured, calcium chloride solution was added to produce a concentration of 0.01M $CaCl_2$ and pH_{CaCl} determined using a combination pH electrode.

Reactive Iron: Soils were tumbled in Tamm's reagent (oxalic acid/ammonium oxalate) for 1 hour employing a soil to solution ratio of 1:33. The concentration of iron was determined using a flame atomic absorption spectrophotometer at 248.3 nm.

Extractable Sulphur: Soils were extracted at 40^{o}C for 3 hours with 0.25 M potassium chloride and the sulphate sulphur measured by ICP.
Reference: Blair G.J., Chinoim, N., Lefroy, R.D.B., Anderson, G.C. and Crocker, G.J. (1991). *Australian Journal of Soil Research* **29**, 619-626.

Most of the profiles were sampled in areas of 'good' or 'marginal Gascoyne soils'. In the tables below, the soil type is shown in brackets underneath the site number. The following codes are used:

C – Coburn red-brown duplex soil
Gl – Gascoyne 'light-textured' soil
Gm – Gascoyne 'medium-textured' soil
Gh – Gascoyne 'heavy-textured' soil
M – Moyamber duplex soil

Table B1: Laboratory analysis results

Site No. (soil)	Depth (cm)	NO_3^-	NH_4^+	P	K	S	Org. Carb.	React. Fe	$EC_{1:5}$ (mS/m)	pH $CaCl_2$	pH H_2O
A14	0-30	16	2	25	1230	16.8	0.59	555	13.0	7.3	8.0
(Gh)	50-70	3	2	15	951	7.0	0.33	502	17.6	8.5	9.4
	130-150	3	2	10	658	40.7	0.12	619	21.5	8.4	9.4
A18	0-15	11	4	37	756	6.6	0.82	899	8.6	6.7	7.6
(Gl)	60-90	2	1	8	337	3.4	0.23	576	5.2	7.7	8.7
	160-190	2	2	5	160	4.4	0.11	375	7.8	8.2	9.1
B26	0-10	3	2	20	567	3.3	0.26	517	6.6	6.7	7.7
(Gm)	30-40	2	1	14	545	6.5	0.22	583	14.4	8.3	9.3
	90-100	2	1	7	207	114.0	0.15	362	68.5	8.1	8.3
	150-200	1	2	5	148	45.5	0.09	390	39.1	8.1	8.3
B27	0-10	4	2	24	657	3.6	0.35	438	3.8	6.6	7.6
(Gl)	60-80	2	1	7	303	3.2	0.24	355	8.4	8.3	9.1
	150-180	2	2	12	425	9.3	0.29	715	21.5	8.4	9.4
B31	0-10	4	3	25	536	3.1	0.46	419	4.2	6.5	7.3
(Gm)	30-40	3	3	10	420	6.2	0.23	559	9.0	8.0	8.7
	150-180	2	4	8	191	494.0	0.16	444	99.0	7.6	7.8
C44	0-20	27	3	63	1290	23.0	1.88	1160	16.0	7.2	7.6
(Gh)	20-40	5	2	18	734	4.4	0.47	559	4.6	6.7	7.4
	140-160	2	2	16	427	4.3	0.26	971	7.2	7.8	8.2
C45	0-20	5	1	29	751	6.4	0.46	449	10.8	7.3	8.0
(Gl)	60-80	2	2	4	215	2.4	0.16	374	6.7	8.0	8.7
	180-200	2	2	7	194	4.3	0.11	301	4.0	7.7	8.7
C46	0-20	6	2	33	660	3.6	0.39	593	4.5	6.7	7.1
(Gm)	20-40	3	2	15	482	2.3	0.27	481	3.3	7.0	7.9
	100-120	2	2	6	239	6.6	0.17	399	11.8	8.5	9.3
	170-190	2	2	6	151	12.6	0.10	452	32.0	8.0	8.5
C47	0-20	24	2	24	835	11.9	0.53	508	17.4	7.4	7.7
(Gm)	30-50	2	1	8	475	9.3	0.25	406	16.5	8.4	9.2
	170-190	2	1	2	217	17.3	0.07	394	12.7	8.5	9.1
C48	0-10	5	2	11	185	2.9	0.15	353	3.4	6.7	7.3
(M)	10-30	9	2	12	400	5.3	0.26	828	6.3	6.6	7.1
	80-100	3	2	4	318	2.9	0.08	344	4.9	7.7	8.5
C82	0-10	10	2	41	1356	7.9	0.72	689	8.6	6.8	7.8
(Gh)	20-40	4	1	24	922	3.8	0.39	582	6.4	7.4	8.5
	60-80	2	1	20	533	14.8	0.20	437	13.2	8.2	9.1
	150-180	1	2	5	230	25.8	0.08	244	6.9	7.8	8.8
C83	0-15	9	2	24	1004	13.9	0.78	708	20.2	7.6	7.7
(Gm)	30-50	2	1	22	787	35.5	0.31	974	37.2	8.3	9.0
	80-100	2	2	10	480	13.1	0.13	314	22.2	8.8	9.6
	150-180	1	2	8	442	156.0	0.17	418	44.0	8.6	9.3
	220-250	2	2	12	284	382.0	0.13	354	209.3	7.5	7.6
C84	0-20	3	2	28	621	5.3	0.58	498	4.6	7.1	7.4
(Gm)	50-70	2	1	9	561	5.5	0.33	497	9.4	8.1	8.7
	150-180	4	2	16	506	10.3	0.28	744	14.2	8.2	8.6
C85	0-10	15	1	46	959	9.0	0.83	877	10.8	7.1	7.6
(Gh)	20-40	3	2	11	659	5.2	0.32	640	6.6	7.4	8.3
	60-80	2	2	9	303	17.0	0.24	433	23.9	8.6	9.5
	160-180	4	3	16	258	198.0	0.32	647	48.8	7.9	8.6
F32	30-50	1	2	4	246	18.3	0.09	773	47.4	8.1	8.7
(C)	170-200	1	1	3	145	94.2	0.05	642	77.7	8.3	8.7

Site No. (soil)	Depth (cm)	DTPA (ppm)				B	Exchangeable cations (ppm)				ESP
		Cu	Zn	Mn	Fe		Ca	Mg	Na	K	
A14	0-30	0.79	0.42	5.86	2.74	1.5	7.71	2.97	0.58	2.97	4.1%
(Gh)	50-70	0.76	0.16	3.00	2.51	3.1	9.87	2.75	1.68	2.33	10.1%
	130-150	0.63	0.10	2.67	2.57	6.6	8.51	2.74	1.75	1.55	12.0%
A18	0-15	1.06	0.63	8.76	5.63	0.9	6.65	2.68	0.84	1.63	7.1%
(Gl)	60-90	0.53	0.09	3.32	4.40	0.7	7.61	1.98	0.53	0.71	4.9%
	160-190	0.35	0.08	1.56	2.72	1.0	7.50	1.64	0.61	0.34	6.0%
B26	0-10	0.58	0.20	5.09	4.03	0.4	3.80	1.86	0.53	1.21	7.2%
(Gm)	30-40	0.83	0.21	3.33	4.94	1.6	12.15	2.78	1.72	1.27	9.6%
	90-100	0.42	0.11	1.77	2.89	1.9	5.27	1.36	1.44	0.47	16.9%
	150-200	0.31	0.07	1.64	1.88	2.1	4.45	1.34	1.37	0.35	18.2%
B27	0-10	0.45	0.34	5.21	4.84	0.3	3.03	1.80	0.20	1.35	3.1%
(Gl)	60-80	0.33	0.11	2.27	3.06	0.6	7.39	1.26	0.37	0.66	3.8%
	150-180	1.00	0.17	2.83	5.23	4.2	11.75	2.51	4.42	0.97	22.5%
B31	0-10	0.42	0.43	6.77	5.55	0.5	2.59	1.22	0.22	1.25	4.2%
(Gm)	30-40	0.51	0.22	3.80	2.89	0.8	6.82	2.09	0.48	0.97	4.6%
	150-180	0.76	0.26	2.13	5.25	4.0	7.35	3.17	3.19	0.46	22.5%
C44	0-20	1.09	0.71	9.23	10.01	1.1	9.70	3.70	0.29	2.66	1.8%
(Gh)	20-40	0.66	0.25	4.48	4.93	0.6	8.93	3.10	0.11	1.51	0.8%
	140-160	0.99	0.17	2.95	5.58	1.1	12.82	3.36	1.00	0.96	5.5%
C45	0-20	0.38	0.45	5.32	4.02	0.9	3.38	1.88	0.27	1.79	3.7%
(Gl)	60-80	0.37	0.05	1.99	3.39	0.4	6.47	1.51	0.29	0.48	3.3%
	180-200	0.29	0.12	1.61	3.69	0.8	4.37	1.62	0.59	0.43	8.4%
C46	0-20	0.53	0.43	4.94	7.31	0.4	4.02	2.25	0.15	1.29	1.9%
(Gm)	20-40	0.55	0.11	3.77	4.38	0.4	5.58	2.07	0.23	1.06	2.6%
	100-120	0.53	0.07	2.35	3.51	1.1	8.42	1.93	1.66	0.60	13.2%
	170-190	0.33	0.08	1.42	2.45	2.1	4.63	1.31	1.75	0.37	21.7%
C47	0-20	0.89	0.31	6.25	4.11	0.6	6.57	2.12	0.44	1.79	4.0%
(Gm)	30-50	0.73	0.13	2.11	4.23	2.4	10.52	2.54	1.92	1.06	12.0%
	170-190	0.34	0.08	1.26	3.09	2.8	5.13	1.27	1.25	0.53	15.3%
C48	0-10	0.26	0.26	5.56	3.66	0.4	0.88	0.39	0.07	0.49	3.8%
(M)	10-30	0.73	0.21	7.22	3.63	0.4	4.33	1.40	0.18	0.93	2.6%
	80-100	0.58	0.13	2.44	5.27	1.4	7.41	1.93	0.48	0.79	4.5%
C82	0-10	1.24	0.63	6.70	7.86	0.8	7.27	3.14	0.36	3.04	2.6%
(Gh)	20-40	0.76	0.15	2.91	4.45	1.1	10.87	2.50	0.82	1.77	5.1%
	60-80	0.71	0.12	1.80	4.36	2.0	9.75	2.19	1.50	1.17	10.3%
	150-180	0.21	0.04	1.22	1.22	1.0	3.31	0.77	0.72	0.54	13.5%
C83	0-15	0.85	0.46	6.97	5.60	0.8	8.38	2.47	1.11	2.09	7.9%
(Gm)	30-50	0.80	0.23	2.78	5.10	2.4	9.94	2.76	3.25	1.43	18.7%
	80-100	0.51	0.21	1.68	4.27	2.4	7.72	1.85	2.39	1.05	18.4%
	150-180	0.84	0.14	2.05	6.04	4.8	9.37	2.75	4.81	1.00	26.8%
	220-250	1.11	0.21	3.63	6.80	4.3	4.87	3.25	9.94	0.65	53.1%
C84	0-20	0.31	0.28	4.31	4.58	0.6	5.24	1.46	0.11	1.36	1.3%
(Gm)	50-70	0.60	0.09	1.82	3.75	1.3	11.00	2.10	0.29	1.26	2.0%
	150-180	0.92	0.13	3.21	6.37	2.4	11.97	2.75	1.03	1.01	6.1%
C85	0-10	0.72	0.59	11.28	8.92	0.9	5.39	2.10	0.55	1.98	5.5%
(Gh)	20-40	0.84	0.05	2.79	6.14	0.9	9.07	3.58	0.98	1.39	6.5%
	60-80	0.76	0.15	2.14	7.92	2.6	8.07	2.73	3.47	0.75	23.1%
	160-180	0.89	0.36	2.42	20.04	5.0	6.03	2.05	5.28	0.56	37.9%
F32	30-50	0.58	0.10	3.48	4.33	1.6	5.56	2.16	2.82	0.55	25.4%
(C)	170-200	0.34	0.18	1.54	2.69	5.8	6.00	2.02	3.29	0.36	28.2%

Appendix C – Detailed map unit descriptions

This describes the systems, subsystems and phases shown on the accompanying maps (with systems listed alphabetically). Table C1 summarises the areas of each system mapped.

Table C1: Areas of mapping systems

System	Total area mapped		Mapped within focus areas	
	(ha)	(%)	(ha)	(%)
Channel	129	0.6	-	0
Delta	4,598	20.2	1,996	18.7
River	5,483	24.1	2,484	23.2
Sable	2,070	9.1	1,162	10.9
Sandal	7,150	31.4	3,576	33.4
Target	3,310	14.6	1,483	13.9
Total	**22,740**		**10,701**	

Map units with greater potential for horticultural development are described in more detail. The full map unit code from soil-landscape mapping hierarchy developed by the Department of Agriculture is shown in brackets following the map unit name.

Cn - Channel System (235Cn)

Total area mapped: 129 ha (0.6%)

Incised rocky streams and creeklines with truncated marginal slopes and stony narrow fringing plains supporting scattered to very scattered shrublands of variable composition.

This system is on the banks of the Gascoyne River upstream of Cardawarra Pool (and Focus Area 8). It occurs totally outside of the focus areas and no field inspections were undertaken. Payne *et al.* (1980) described the soils as loams, clays and duplex profiles that are often shallow or contain hardpans. This system is likely to be similar to Ri9 subsystem.

This system is likely to have a low to very low capability for horticulture due to the uneven, dissected land surface, shallow soils and the high risk of flooding and water erosion.

De - Delta System (235De)

Total area mapped: 4,598 ha (20.2%) Within focus areas: 1,996 ha (18.7%)

Floodplains of the Gascoyne River supporting open to very open acacia shrublands with bluebush and saltbush understorey, widely degraded and eroded.

Topography: Delta System comprises a level alluvial plain that forms a backplain of the Gascoyne River. It lies adjacent to the River System, downstream from Rocky Pool on Focus Areas 1, 2, 3, 4 and 6. This backplain has few to common flow lines and a smooth to very gently undulating or hummocky microrelief. Erosional and depositional surfaces resulting from overland flow are often evident while bare and scalded surfaces are present.

Geology: Reworked Quaternary alluvial clay, silt sand and gravel.

Vegetation: Acacia open shrubland to very scattered bluebush low shrubland.
Canopy cover: 1-10%; Height: 0.8-4 m.
Emergent species: Prickly acacia (*Acacia victoriae*), curara (*Acacia tetragonophylla*), silver barked wattle (*Acacia sclerosperma*) and needle bush (*Hakea preissii*). Scattered coolibah (*Eucalyptus coolabah*) may also be present.
Mid-storey species: Climbing saltbush (*Rhagodia eremaea*) and minga (*Heterodendrum oleaefolium*) are most common, with occasional cotton bush (*Ptilotus obovatus*) and currant bush (*Scaevola spinescens*).
Understorey species: Gascoyne bluebush (*Maireana polypterygia*) is common with silver saltbush (*Atriplex bunburyana*) often present. Spiny bluebush (*Maireana aphylla*) and *Sclerolaena* spp. may also be present. Although buffel grass (*Cenchrus ciliaris*) is widespread, it is usually a minor component.

Soils: Delta System contains a mixture of Coburn and Moyamber association soils. These are mostly Red shallow sandy and Loamy duplex soils (often alkaline) and Red loamy earths. Red, non-cracking clays are also present. Subsoils are typically heavy-textured with restricted drainage, and salinity levels are often extreme ($EC_{1:5}$ 200-2000 mS/m). Salinity is spatially highly variable, and low to extreme values can occur over short distances.

Soil limitations and land management:
- Clay loam subsoils contain moderately high to extreme levels of salt
- Inherently poor structure with massive and dense subsoils being common
- High risk of soil structure decline
- Moderate to high risk of inundation or prolonged waterlogging
- Reduced trafficability
- Calcareous subsoils
- Moderate to high risk of boron toxicity on clay loams
- Risk of flooding and water erosion.

Land capability: Largely unsuited to horticultural development (low to very low capability, classes 4-5), due to poor profile drainage, moderately high to extreme salinity levels and the risk of increasing salinity under irrigation. The main exception is the well-drained soils belonging to the Brown association in the Delta Sand Dune Subsystem (De1). Only 11 ha of this subsystem were mapped.

Delta System does seem to have a greater area of flats containing pockets of soil with low salinity levels than the Sandal, Sable and Target Systems. These pockets are most likely to occur on the Delta Acacia Scrub Subsystem (De4) but would be difficult to identify accurately without the aid of intensive soil sampling. These areas would still be prone to developing salinity under irrigation due to poor profile drainage.

Delta System was divided into subsystems, mainly through the interpretation of landscape features and vegetation patterns seen on the aerial photographs:

De1 - Delta Sand Dune Subsystem (235De_1)

Total area mapped: 11 ha (<0.1%) Within focus areas: 11 ha (0.1%)

Small, scattered low (1.5-2.5 m) sandy rises, banks and sand dunes occurring on the alluvial plain. Vegetation consists of scattered acacia shrubland with *Rhagodia* and *Eremophila* spp. in the second stratum. Major soils are Brown association sands: deep (typically >200 cm), fine to medium-grained, reddish sands (less commonly sandy loams). Red deep sandy duplex soils are found on the periphery of this subsystem.

The soils have fair to high capability for horticulture. They are deep and well-drained, easy to work and the fine-grained sands have reasonable moisture and nutrient retention. However, the small area of the individual dunes (1-4 ha) severely limits their potential for development. There is a moderate to high risk of wind erosion, especially under vegetable cropping.

This subsystem is very similar to the smaller dunes mapped as Sb1, Sd2 and Tg1. The equivalent unit mapped by Wells and Bessell-Browne (1990) is Cr.

De2 - Delta Bluebush Flat Subsystem (235De_2)

Total area mapped: 654 ha (2.9%) Within focus areas: 378 ha (3.5%)

Plains carrying scattered to very scattered low (0.8-1.2 m high) shrubland dominated by Gascoyne bluebush (*Maireana polypterygia*). Taller acacia shrubs are uncommon. Dominant soils belong to the Coburn and Moyamber associations, with Red shallow sandy or Loamy duplex soils (often alkaline) being most common. Duplex soils have loose to hardsetting sandy topsoils while polygonal cracking is characteristic of medium to fine textured topsoils. Most clayey subsoil horizons are poorly structured, being massive and extremely dense. Soil salinity is spatially highly variable, low to extreme salinity values can occur over short distances.

This subsystem is very similar to both Sb2 and Sd2, but has more loamy earths and lower salinity levels. De2 can be differentiated from De3 by the dominance of bluebush and reduced vegetation height. Soil salinity levels are generally higher. It has more bare or scalded areas than De3, but considerably less than found in De5. The equivalent unit mapped by Wells and Bessell-Browne (1990) is C, though GC2 and GC2 partially correspond.

De3 - Delta Bluebush-Acacia Scrub Subsystem (235De_3)

Total area mapped: 344 ha (1.5%) Within focus areas: 184 ha (1.7%)

Plains carrying very open acacia shrubland (2-4 m high) with an understorey dominated by Gascoyne bluebush (*Maireana polypterygia*). Dominant soils belong to the Coburn and Moyamber associations, with Red shallow sandy or Loamy duplex soils (often alkaline) being most common.

This subsystem is very similar to Sd3, but has slightly more loamy earths and salinity levels are generally a bit lower.

This is an intergrade between De2 and De4. It can be differentiated from De4 by the more open structure of the shrubland and predominance of bluebush in the understorey. Soil salinity levels are generally a little higher and it tends to have more bare or scalded areas. De3 has more acacia shrubs than De2, and tends to be less saline and scalded. This unit partially corresponds to GC3 mapped by Wells and Bessell-Browne (1990).

De4 - Delta Acacia Scrub Subsystem (235De_4)

Total area mapped: 1,518 ha (6.7%) Within focus areas: 680 ha (6.4%)

Plains carrying open acacia shrubland (2-4 m high) with an understorey containing Gascoyne bluebush (*Maireana polypterygia*) and silver saltbush (*Atriplex bunburyana*). Dominant soils belong to the Coburn and Moyamber associations, with Red shallow sandy or Loamy duplex soils (often alkaline) being most common.

This subsystem is very similar to Sd4 and Tg4, but has a slightly higher proportion of loamy earths, and salinity levels are generally a bit lower.

De4 can be differentiated from De3 by the less open structure of the shrubland and fewer bluebush in the understorey. Soil salinity levels are generally a little lower and it also tends to have fewer bare or scalded areas.

Ri3 and Ri3s are similar but carry denser acacia scrub with Gascoyne bluebush generally absent. Gascoyne, rather than Coburn soils, dominate Ri3 and Ri3s. Salinity levels and the occurrence of scalds are also lower, especially in Ri3. The equivalent unit mapped by Wells and Bessell-Browne (1990) is Ce1.

De5 - Delta Scald Subsystem (235De_5)

Total area mapped: 1,119 ha (5.3%) Within focus areas: 439 ha (4.1%)

Plains with prominent scalding. Bare scalds cover more than 50% of this subsystem. Vegetation on non-scalded area is an open to very sparse acacia shrubland (2-4 m high) with an understorey dominated by Gascoyne bluebush (*Maireana polypterygia*).

Dominant soils belong to the Coburn and Moyamber associations, and include Red shallow sandy and Loamy duplex soils, Red loamy earths (clay loam texture) and Red/brown non-cracking clays. The soils are characterised by surface crusting and polygonal cracking. Most subsoil horizons are highly to extremely saline, while topsoil salinity varies. Salt

inflorescence can be evident on the soil surface. Although soil structure is occasionally well developed angular blocky, most soils are massive and dense.

This subsystem is similar to Sb5, Sd5 and Tg5, but has a higher proportion of scalds. It can be differentiated from De2 by the predominance of scalding. Soil salinity levels are generally a little higher. It may be similar to De7, but does not occur as distinct linear depressions that carry water flows. The equivalent unit mapped by Wells and Bessell-Browne (1990) is Ce2.

De6 - Delta Claypan Subsystem (235De_6)

Total area mapped: 24 ha (0.1%) Within focus areas: 0 ha

Slight depressions on the floodplain consisting of circular salt lakes and drainage foci that are predominantly bare of vegetation. Some claypans may carry a few annual grasses, annual saltbush or Gascoyne bluebush (*Maireana polypterygia*). These claypans are prone to inundation following heavy rainfall.

Soils have developed from stratified silty and clayey sediments derived from the Doorawarrah alluvial layer. The claypan surface usually exhibits a polygonal or reticulated pattern which may be shiny and laminated by the precipitation of silicates and salts. Surfaces may also have a thin cover of siliceous sand or silt brought on by aeolian reworking. Subsoils are reddish-brown clay loam to clay which may exhibit black manganese-iron segregations and fine gypsum crystals. Topsoils are slightly acid to neutral while subsoils are alkaline.

Claypans are generally saline; salinity of the upper 60 cm may be low to high while subsoils are highly to extremely saline.

This subsystem is very similar to Sb6, Sd6 and Tg6, though it is not usually surrounded by sand dunes. De6 can be differentiated from De5 in that it occurs as discrete claypans rather than a mosaic of scalds and vegetated areas. Unlike De7 it occurs as circular closed depressions.

De7 - Delta Drainage Depression Subsystem (235De_7)

Total area mapped: 828 ha (3.6%) Within focus areas: 297 ha (2.8%)

Shallow, open drainage depressions that are broad and poorly vegetated. These depressions generally contain a narrow sinuous drainage channel that shows evidence of erosional and depositional surfaces. Associated drainage banks are often broad and inconspicuous containing very low levees consisting of alluvial sand and silt. Bare and scalded areas are common, associated with minor oxbows and depressions.

Vegetation is highly variable consisting of open acacia shrubland (canopy cover <5-20% and <1.0-4.0 m high) with Gascoyne bluebush (*Maireana polypterygia*) and spiny bluebush (*Maireana aphylla*) being conspicuous. Silver saltbush (*Atriplex bunburyana*) and coolibah (*Eucalyptus coolabah*) are often present.

Sediments in the depressions are reworked recent alluvium consisting of sand, silt and clay overlying older red Quaternary alluvium, which may contain alluvial gravel. Dominant soils belong to the Coburn and Moyamber associations, and include Red shallow sandy and Red shallow loamy duplex soils, Red loamy earths (clay loam texture) and Red/brown non-cracking clays. Loamy Gascoyne topsoils overlying red horizons of the Doorawarrah layer

may be present. Soils are generally poorly structured with massive and extremely dense subsoils developed from the Doorawarrah layer. Subsoil salinity is extremely variable with non-saline and extremely saline soils being encountered.

This is similar to Ri4, but has less vegetation cover and more scalds. Gascoyne bluebush is also common, unlike in Ri4. De7 is dominated by Coburn and Moyamber association rather than Gascoyne soils, and is more likely to be saline than Ri4.

It may be similar De5, but occurs as distinct linear depressions that carry water flows. he equivalent units mapped by Wells and Bessell-Browne (1990) are Csc and Cdp.

De10 - Delta Swamp Subsystem (235De10)

Total area mapped: 20 ha (0.1%) Within focus areas: 6 ha (0.1%)

Slight depressions on the floodplain forming circular swamps. Although the centre of the swamp is often bare the margins carry native tussock grasses, including swamp grass (*Eragrostis australasica*), reeds and thickets of coolibah (*Eucalyptus coolabah*), sometimes with silver-barked wattle (*Acacia sclerosperma*) and curara (*Acacia tetragonophylla*). These swamps are usually dry but fill with water following heavy rain or flooding. Depending on the internal drainage and frequency of inundation, the centre of the swamp may also carry *Eucalyptus coolabah* or tussock grasses.

The soils have developed from stratified, reddish-brown, silty and clayey alluvial sediments and include Red cracking clays, Red/brown non-cracking clays or Red shallow loamy duplex soils. The surface usually exhibits a polygonal or reticulated pattern when dry and the upper horizons may have a strong sub-angular blocky structure. Topsoils are dark reddish-brown due to increased accumulation of organic matter under moist soil conditions. Salinity levels are usually very low to low.

This subsystem is very similar to Sd10. It is differentiated from De6 in being more vegetated and less saline.

Ri - River System (235Ri)

Total area mapped: 5,483 ha (24.1%) Within focus areas: 2,484 ha (23.2%)

Seasonally active floodplains of the Gascoyne River supporting moderately close tall acacia shrublands with an understorey including buffel grass (*Cenchrus ciliaris*) and fringing communities of river red gum (*Eucalyptus camaldulensis*) and coolibah (*Eucalyptus coolabah*). This system consists of depositional surface formed of Quaternary alluvium. Upper and lower terraces are usually present. Dominant soils are deep sands and loams of the Gascoyne association.

River System contains most land suitable for horticultural development. For this reason it was the main focus of field investigations. It was divided into 11 subsystems with 5 additional phases described in detail below:

Ri1 - River Sandy Terrace Subsystem (235Ri_1)

Total area mapped: 518 ha (2.3%) Within focus areas: 244 ha (2.3%)

Level alluvial plain developed on the upper terraces of the Gascoyne River and carrying acacia shrubland with an understorey including buffel grass (*Cenchrus ciliaris*). Saltbush species are usually absent. Gascoyne 'light-textured' soils are dominant with smaller areas of the Gascoyne 'medium-textured' soils. Profiles are well-drained and generally non-saline.

Topography: Level alluvial plain, dissected by a few flow lines, on the broad upper terraces of the Gascoyne River. Level to very gently undulating microrelief of <30 cm. This unit usually occupies the portion of the upper terrace closest to the Gascoyne River channel, and generally encountered within 1 km of the Gascoyne River.

Geology: Quaternary alluvium, consisting of uniform or stratified sand to clay loam containing mica.

Vegetation: Acacia shrubland or open shrubland. Canopy cover: 5-20%; Height: 2-4 m.
Emergent species: Silver barked wattle (*Acacia sclerosperma*) and prickly acacia (*Acacia victoriae*) with curara (*Acacia tetragonophylla*) less common. Scattered coolibah (*Eucalyptus coolabah*) is often present, and needle bush (*Hakea preissii*).
Mid-storey species: Climbing saltbush (*Rhagodia eremaea*) and minga (*Heterodendrum oleaefolium*) are reasonably common.
Understorey species: Buffel grass (*Cenchrus ciliaris*) is the dominant understorey. *Sclerolaena* spp. are often present.

Soils: Predominantly Gascoyne 'light-textured' and some 'medium-textured' soils with deep and well-drained profiles. Small areas of Gascoyne 'heavy-textured' soils may be present. These profiles are well-drained and predominantly non-saline, with very low levels of salt within the subsoil ($EC_{1:5}$ is typically less than 15 mS/m). Occasional highly saline profiles.

Related map units: Similar to Ri2, but contains more Gascoyne 'light-textured' soils. It differs from Ri6 in being situated on the upper terraces of the Gascoyne River (Ri6 is on the lower terraces and more susceptible to flooding). In the coarse phase (Ri1c), medium to coarse-grained sands dominate. The saline phase (Ri1s) is prone to salinity and typically

identified by the presence of silver saltbush. The equivalent units mapped by Wells and Bessell-Browne (1990) are Gl, Glc and Gl+.

Soil limitations and land management:
- Gascoyne 'light-textured' soils can be prone to wind erosion
- Low to moderate risk of boron toxicity in all soil types
- Risk of soil loss during major flooding events, especially if surface is left disturbed or unprotected.

Land capability: High capability (class 2) for annual and perennial horticultural crops provided soil structure is maintained.

Ri1c - River Sandy Terrace Subsystem, coarse sand phase (235Ri_1c)

Total area mapped: 56 ha (0.2%) Within focus areas: 54 ha (0.5%)

Level alluvial plain developed on the upper terraces of the Gascoyne River and carrying very open acacia shrubland with a buffel grass (*Cenchrus ciliaris*) understorey. Medium to coarse-grained Gascoyne 'light-textured' soils are dominant. Soils are well-drained and relatively non-saline.

Topography: Level alluvial plain, dissected by a few flow lines, on the broad upper terraces of the Gascoyne River. Level to very gently undulating micro-relief of <30 cm. This unit was only identified upstream from Rocky Pool.

Geology: Quaternary alluvium, consisting of uniform or stratified sand to clay loam containing mica.

Vegetation: Very open acacia shrubland and tussock grassland.
Canopy cover: 1-5%; Height: 2-4 m.
Emergent species: Silver barked wattle (*Acacia sclerosperma*) is dominant; also wanyu (*Acacia ramulosa*), needle bush (*Hakea preissii*) and curara (*Acacia tetragonophylla*).
Mid-storey species: Emu bush (*Eremophila* spp.), minga (*Heterodendrum oleaefolium*).
Understorey species: Buffel grass (*Cenchrus ciliaris*) is dominant.

Soils: Mostly Gascoyne 'light-textured' soils dominated by loamy sands to weak sandy loams which are medium to coarse-grained. Profiles are well-drained and predominantly non-saline, with very low levels of salt occurring within the subsoil ($EC_{1:5}$ is typically less than 10 mS/m). Some areas with higher salinity levels may occur.

Related map units: Similar to Ri1, but has fewer Gascoyne 'medium-textured' soils. The Gascoyne 'light-textured' soils are medium to coarse-grained with low clay content. Vegetation cover is generally more open on the coarse-textured soils.

Soil limitations and land management:
- Gascoyne 'light-textured' soils can be prone to wind erosion
- Low to moderate risk of boron toxicity in all soil types
- Risk of soil loss during major flooding events, especially if surface is left disturbed or unprotected
- Low moisture retention in coarse sandy soils.

Land capability: Fair to low (classes 3-4) for annual and perennial horticulture. Irrigation would need to be more frequent due to low clay content and coarser sand grain size.

Ri1s - River Sandy Terrace Subsystem, saline phase (235Ri_1s)

Total area mapped: 240 ha (1.1%) Within focus areas: 163 ha (1.5%)

Level alluvial plain developed on the upper terraces of the Gascoyne River and carrying acacia shrubland or very open acacia shrubland (sometimes degraded) with an understorey including silver saltbush (*Atriplex bunburyana*). Dominant soils are Gascoyne 'light-textured' soils with smaller areas of the Gascoyne 'medium-textured' soils. Soil profiles are well-drained and often saline.

Topography: Level alluvial plain, dissected by a few flow lines, on the broad upper terraces of the Gascoyne River. Level to very gently undulating micro-relief of <30 cm. Small scattered scalds are sometimes present. Usually occupies part of the upper terrace closest to the Gascoyne River channel, and generally encountered within 1 km of the river.

Geology: Quaternary alluvium, consisting of uniform or stratified sand to clay loam containing mica.

Vegetation: Acacia shrubland or open shrubland. Canopy cover: 1-20%; Height: 2-4 m.
Emergent species: Silver barked wattle (*Acacia sclerosperma*) and prickly acacia (*Acacia victoriae*) are dominant while needle bush (*Hakea preissii*) is often present. Scattered coolibah (*Eucalyptus coolabah*) may be found.
Mid-storey species: Climbing saltbush (*Rhagodia eremaea*) is common while minga (*Heterodendrum oleaefolium*) may be present.
Understorey species: Silver saltbush (*Atriplex bunburyana*) and buffel grass (*Cenchrus ciliaris*) are common with some *Sclerolaena* spp.

Soils: Predominantly Gascoyne 'light-textured' soils with some 'medium-textured' soils. The profile is deep and well-drained. Small areas of Gascoyne 'heavy-textured' soils or Coburn red-brown duplexes may also be present. Moderately high to extreme levels of salt commonly occur within the subsoil ($EC_{1:5}$ at 50-100 cm is often in the 15-200 mS/m range, $EC_{1:5}$ at 100-200 cm is often in the 50-400 mS/m range).

Related map units: Very similar to Ri1, but subsoil salinity is typically higher. Silver saltbush is usually present, and vegetation cover is often less dense. Scalds are sometimes present. Unit differs from Ri2s which has a higher proportion of Gascoyne 'medium-textured' soils. It partially corresponds to GC1 (and possibly GC2) mapped by Wells and Bessell-Browne (1990).

Soil limitations and land management:
- Subsoil salinity levels likely to reduce crop yields
- Gascoyne 'light-textured' soils can be prone to wind erosion
- Low to moderate risk of boron toxicity in all soil types
- Risk of soil loss during major flooding events, especially if soil surface is left disturbed or unprotected.

Land capability: This unit has a low to fair capability (classes 3-4) for annual and perennial horticulture. It is more suited to shallow-rooted crops such as vegetables and bananas. Subsoil salinity may limit mango and citrus production. Because many of the soils are light-textured, there is potential to leach salt from the root zone through careful irrigation scheduling and mulching provided impeding layers are not present within the subsoil. However, excessive irrigation is likely to result in increasing salinity.

Ri2 - River Loamy Terrace Subsystem (235Ri_2)

Total area mapped: 343 ha (1.5%) Within focus areas: 256 ha (2.4%)

Level alluvial plain developed on the upper terraces of the Gascoyne River and carrying acacia shrubland with an understorey including buffel grass (*Cenchrus ciliaris*). Saltbush species are usually absent or a minor component of the understorey. Dominant soils are Gascoyne 'medium-textured' soils with smaller areas of the Gascoyne 'light-textured' and 'heavy-textured' soils. Soil profiles are well-drained and relatively non-saline.

Topography: Level alluvial plain, dissected by a few flow lines, on the broad upper terraces of the Gascoyne River. Level to very gently undulating microrelief of <30 cm. This unit usually lies on the middle portion of the upper terrace, further from the Gascoyne River channel than Ri1 subsystem, but closer than Ri3.

Geology: Quaternary alluvium, consisting of uniform or stratified sand to clay containing mica.

Vegetation: Acacia shrubland or open shrubland. Canopy cover: 5-20%; Height: 2-4 m.
Emergent species: Silver barked wattle (*Acacia sclerosperma*), prickly wattle (*Acacia victoriae*), curara (*Acacia tetragonophylla*) and coolibah (*Eucalyptus coolabah*) are common.
Mid-storey species: Climbing saltbush (*Rhagodia eremaea*) is common. Minga (*Heterodendrum oleaefolium*) and cotton bush (*Ptilotus obovatus*) are sometimes present.
Understorey species: Buffel grass (*Cenchrus ciliaris*) is the dominant understorey, with *Sclerolaena* spp. sometimes present. Occasional silver saltbush (*Atriplex bunburyana*) which never dominates the understorey.
Note: *Capparis lasiantha* and needle bush (*Hakea preissii*) may be found on 'medium and heavy-textured' soils.

Soils: Predominantly Gascoyne 'medium-textured', with some 'light-textured' and 'heavy-textured' soils. The profile is deep and well-drained and predominantly non-saline, with very low levels of salt in the subsoil ($EC_{1:5}$ is typically less than 15 mS/m within the top 100 cm). Occasional saline soil profiles were encountered.

Related map units: Forms an intergrade between Ri1 and Ri3, but has a higher proportion of Gascoyne 'medium-textured' soils than either (Ri1 having a greater proportion of 'light-textured' soils and Ri3 having a greater proportion of 'heavy-textured' soils.

The saline phase (Ri2s) is prone to salinity and typically identified by the presence of silver saltbush. The equivalent units mapped by Wells and Bessell-Browne (1990) are Gm, Gmc and Gm+. Small pockets of Gh and Gl may also occur.

Soil limitations and land management:
- Loamy topsoils are prone to soil structure decline
- Gascoyne 'light-textured' soils can be prone to wind erosion
- Low to moderate risk of boron toxicity in all soil types
- Risk of soil loss during major flooding events, especially if soil surface is left disturbed or unprotected
- Risk of inundation or prolonged waterlogging on heavier soils
- Reduced trafficability on heavier soils
- Some calcareous subsoils.

Land capability: High to fair (classes 2-3) for annual and perennial horticulture provided soil structure is maintained. Fair capability is associated with heavier soils.

Ri2s - River Loamy Terrace Subsystem, saline phase (235Ri_2s)

Total area mapped: 438 ha (1.9%) Within focus areas: 372 ha (3.5%)

Level alluvial plain developed on the upper terraces of the Gascoyne River and carrying acacia shrubland or very open acacia shrubland (sometimes degraded) with an understorey including silver saltbush (*Atriplex bunburyana*). Gascoyne 'medium-textured' soils are dominant with smaller areas of 'heavy-textured' soils. Soil profiles are often saline.

Topography: Level alluvial plain, dissected by a few flow lines, on the broad upper terraces of the Gascoyne River. Level to very gently undulating microrelief of <30 cm. Small scattered scalds are sometimes present.

Geology: Quaternary alluvium, of uniform or stratified sand to clay containing mica.

Vegetation: Acacia shrubland or open shrubland. Canopy cover: 1-20%; Height: 2-4 m.
Emergent species: Silver barked wattle (*Acacia sclerosperma*), prickly acacia (*Acacia victoriae*) are dominant, with curara (*Acacia tetragonophylla*) often present. Needle bush (*Hakea preissii*) and coolibah (*Eucalyptus coolabah*) are less common.
Mid-storey species: Climbing saltbush (*Rhagodia eremaea*) is common and minga (*Heterodendrum oleaefolium*), broom bush (*Exocarpus aphyllus*) and cotton bush (*Ptilotus obovatus*) are sometimes present.
Understorey species: Silver saltbush (*Atriplex bunburyana*) and buffel grass (*Cenchrus ciliaris*) are common, with occasional spiny bluebush (*Maireana aphylla*) and Gascoyne bluebush (*Maireana polypterygia*). *Sclerolaena* spp. may also be present.

Soils: Predominantly Gascoyne 'medium-textured'. Some 'heavy-textured' soils or Coburn red-brown duplexes may also be present. Moderately high to extreme levels of salt commonly occur within the subsoil ($EC_{1:5}$ at 50-100 cm is often in the 15-100 mS/m range, and at 100-200 cm is often 20-300 mS/m).

Related map units: Very similar to Ri1, but subsoil salinity is typically higher. Silver saltbush is usually present, and vegetation cover less dense. Scalds are sometimes present.

This unit differs from Ri1s (which has a higher proportion of Gascoyne 'light-textured' soils) and Ri3s (which has more Gascoyne 'heavy-textured' soils). The equivalent unit mapped by Wells and Bessell-Browne (1990) is GC2, though GC1 and GC3 partially correspond.

Soil limitations and land management:
- Subsoil salinity levels likely to reduce crop yields
- Low to moderate risk of boron toxicity in all soil types
- Risk of soil loss during major flooding events, especially if surface is disturbed or unprotected
- Susceptible to soil structure decline
- Risk of inundation or prolonged waterlogging on heavier soils
- Reduced trafficability on heavier soils
- Some calcareous subsoils.

Land capability: Fair to low (classes 3-4) capability for annual and perennial horticulture. It is more suited to shallow-rooted crops such as vegetables and bananas. Subsoil salinity may limit mango and citrus production. Careful irrigation management is critical to reduce salt in the root zone. Poor management is likely to result in increasing salinity. Gypsum applications would be required to maintain soil structure.

Ri3 - River Clayey Terrace Subsystem (235Ri_3)

Total area mapped: 49 ha (0.2%) Within focus areas: 41 ha (0.4%)

Level alluvial plain developed on the upper terraces of the Gascoyne River and carrying acacia shrubland with an understorey including buffel grass (*Cenchrus ciliaris*). Saltbush species are usually absent. Dominant soils are Gascoyne 'heavy-textured' soils with smaller areas of 'medium-textured' soils. Soil profiles are usually non-saline.

Topography: Level alluvial plain, dissected by a few flow lines, on the broad upper terraces of the Gascoyne River. Level to very gently undulating micro-relief of <30 cm. Usually lies on the middle portion of the upper terrace furthest from the Gascoyne River channel.

Geology: Quaternary alluvium, uniform or stratified loam to clay containing mica.

Vegetation: Acacia shrubland or open shrubland. Canopy cover: 5-20%; Height: 2-4 m.
Emergent species: Silver barked wattle (*Acacia sclerosperma*), prickly wattle (*Acacia victoriae*) and curara (*Acacia tetragonophylla*) with scattered coolibah (*Eucalyptus coolabah*).
Mid-storey species: Climbing saltbush (*Rhagodia eremaea*) and cotton bush (*Ptilotus obovatus*).
Understorey species: Buffel grass (*Cenchrus ciliaris*) is dominant. Also *Sclerolaena* spp. and a few silver saltbush (*Atriplex bunburyana*).

Soils: Predominantly Gascoyne 'heavy-textured' soils, with some 'medium-textured' and occasional Coburn red-brown duplexes. Profiles are predominantly non-saline, with very low levels of salt within the subsoil ($EC_{1:5}$ is typically less than 15 mS/m within the top 100 cm). Occasional saline profiles.

Related map units: Forms an intergrade between Ri2 subsystem and Delta System. Has a higher proportion of Gascoyne 'heavy-textured' soils than Ri2. Fewer Coburn and duplex profiles than adjoining Delta subsystems, and lower salinity levels. The saline phase (Ri3s) is

prone to salinity and typically identified by presence of silver saltbush. The equivalent units mapped by Wells and Bessell-Browne (1990) are: Gh, Ghc and Gh+. Small pockets of Ghd, Gm, Gmc and Gm+ may also be present.

Soil limitations and land management:

- Topsoils are prone to structural decline
- Moderate risk of boron toxicity
- Risk of soil loss during major flooding events, especially if surface is left disturbed or unprotected
- Risk of inundation or prolonged waterlogging
- Salts may accumulate in the profile under irrigation
- Reduced trafficability on heavier soils
- Some calcareous subsoils.

Land capability: Fair (class 3) for annual and perennial horticulture crops. It is more suited to shallow-rooted crops such as vegetables and bananas. Because of restricted drainage, salt may accumulate in the root zone under irrigation. Gypsum applications would be required to maintain soil structure.

Ri3s - River Clayey Terrace Subsystem, saline phase (235Ri_3s)

Total area mapped: 92 ha (0.4%) Within focus areas: 66 ha (0.6%)

Level alluvial plain developed on the upper terraces of the Gascoyne River and carrying acacia shrubland or very open acacia shrubland (sometimes degraded) with an understorey including silver saltbush (*Atriplex bunburyana*). Gascoyne 'heavy-textured' soils are dominant with smaller areas of 'medium-textured' soils. Soil profiles are often saline.

Topography: Level alluvial plain, dissected by a few flow lines, on the broad upper terraces of the Gascoyne River. Level to very gently undulating micro-relief of <30 cm. Small scattered scalds are sometimes present.

Geology: Quaternary alluvium, uniform or stratified loam to clay containing mica.

Vegetation: Acacia shrubland or open shrubland. Canopy cover: 1-20%; Height: 2-4 m.
Emergent species: Silver barked wattle (*Acacia sclerosperma*), prickly acacia (*Acacia victoriae*) with some curara (*Acacia tetragonophylla*) and coolibah (*Eucalyptus coolabah*).
Mid storey species: Climbing saltbush (*Rhagodia eremaea*), minga (*Heterodendrum oleaefolium*).
Understorey species: Common silver saltbush (*Atriplex bunburyana*), buffel grass (*Cenchrus ciliaris*), with occasional spiny bluebush (*Maireana aphylla*). *Sclerolaena* spp.

Soils: Predominantly Gascoyne 'heavy-textured' soils, with some Gascoyne 'medium-textured' and occasional Coburn red-brown duplexes. Moderately high to extreme levels of salt commonly occur in the subsoil. The $EC_{1:5}$ at 100-200 cm is typically in the 35-500 mS/m range, while within the top 100 cm values of 20-100 mS/m were often encountered.

Related map units: Very similar to Ri3, but subsoil salinity is typically higher. Silver saltbush is usually present, and vegetation cover is often less dense. Scalds sometimes present. It has a higher proportion of Gascoyne 'heavy-textured' soils than Ri2s. Duplex profiles and Coburn soils are less common than on the Delta subsystems, where the

vegetation is generally less dense and Gascoyne bluebush is more likely to be encountered. The equivalent units mapped by Wells and Bessell-Browne (1990) is probably GC3. This unit is very similar to De3 as mapped by Wells *et al.* (1990).

Soil limitations and land management:
- Salinity levels likely to reduce crop yields
- Salinity is likely to increase under irrigation
- Risk of inundation or prolonged waterlogging
- Moderate risk of boron toxicity
- Risk of soil loss during major flooding events, especially if surface is left disturbed or unprotected
- Susceptible to soil structure decline
- Reduced trafficability on heavier soils
- Some calcareous subsoils.

Land capability: Low capability (class 4) for most annual and perennial horticulture crops due to existing salinity and risk of increase under irrigation. Some of the more salt-tolerant crops could be considered, but very careful application of water would be required.

Ri4 - River Drainage Depression Subsystem (235Ri_4)

Total area mapped: 827 ha (3.6%) Within focus areas: 360 ha (3.4%)

Concave drainage depressions cutting across the upper terraces of the Gascoyne River and carrying acacia shrubland with emergent coolibah (*Eucalyptus coolabah*). Undulating microrelief with common abraided channels. Dominant soils are the Gascoyne association 'light' and 'medium-textured' soils.

Topography: Channelled and scoured drainage zones, consisting of narrow (typically 50-130 m wide) concave drainage depressions (0.5-2.0 m deep). Channels usually have defined banks and occasional deep incised oxbows. This unit is typically found cutting across RiU, Ri1, Ri2 and Ri3 (and their saline phases) on the upper terraces of the Gascoyne River, though it has also been mapped where there are defined channels on the lower terrace. These depressions usually only carry water during major flooding events.

Geology: Recent and Quaternary alluvium, consisting of uniform or stratified sand to clay loam containing mica.

Vegetation: Acacia close shrubland. Canopy cover: 10-60%; Height: 2-4 m.
Emergent species: Coolibah (*Eucalyptus coolabah*), silver barked wattle (*Acacia sclerosperma*, prickly wattle (*Acacia victoriae*), needle bush (*Hakea preissii*) and some curara (*Acacia tetragonophylla*).
Mid storey species: Climbing saltbush (*Rhagodia eremaea*).
Understorey species: Buffel grass (*Cenchrus ciliaris*) is the dominant species. Spiny bluebush (*Maireana aphylla*) and silver saltbush (*Atriplex bunburyana*) may be encountered.

Soils: Gascoyne 'light-textured' and 'medium-textured' soils are dominant. Stratified horizons are evident along stream banks and many soils contain thin layers of recent sand or loam alluvium. Most soils are deep and well-drained. Salinity levels are variable.

Related map units: Can be differentiated from the Delta Drainage Depression Subsystem (De7) by the predominance of Gascoyne 'light-textured' and 'medium-textured' soils while Coburn duplex soils are generally absent. De7 has sparser vegetation with Gascoyne bluebush largely absent. Differs from Ri6 being mostly incised into the upper terraces of the Gascoyne River (Ri6 being the surface of the lower terrace which is subject to non-channelled flooding). The channel of the drainage depression is more clearly defined here than for the flow zone phase (Ri4fz). The equivalent units mapped by Wells and Bessell-Browne (1990) are Gsc, Gg1, Gg2 and possibly Gtd.

Soil limitations and land management:

- High risk of water erosion.

Land capability: Very low capability (class 5) for horticulture due to the high risk of flooding and associated water erosion. Salinity will also be a limitation in some areas.

Ri4fz - River Drainage Depression Subsystem, flow zone phase (235Ri_4fz)

Total area mapped: 39 ha (0.2%) Within focus areas: 33 ha (0.3%)

Broad, very gently inclined, flood-scoured drainage zones on the upper terraces of the Gascoyne River.

Topography: These depressions are typically less than 1 m deep and up to 150 m wide. They lack defined banks and only carry water during major flooding events.

Geology: Recent and Quaternary alluvium, consisting of uniform or stratified sand to clay loam containing mica.

Vegetation: No sites were examined, but the vegetation appears to be an acacia shrubland with emergent coolibah (*Eucalyptus coolabah*), similar to Ri4.

Soils: No sites were examined in this unit, but the soils are likely to be Gascoyne 'light-textured' and 'medium-textured' soils similar to those in Ri4.

Related map units: The channel of the drainage depression is less clearly defined than Ri4, being shallower and lacking distinct banks. The equivalent unit mapped by Wells and Bessell-Browne (1990) is Gdz.

Soil limitations and land management:

- High risk of water erosion.

Land capability: Very low (class 5) for horticulture due to the high risk of flooding and associated water erosion. Salinity may also be a limitation in some areas.

Ri5 - River Sand Ridge Levee Subsystem (235Ri_5)

Total area mapped: 60 ha (0.3%) Within focus areas: 3 ha (<0.1%)

Sand ridges rising above the lower terrace of the Gascoyne River carrying acacia shrubland with emergent river red gum (*Eucalyptus camaldulensis*) and an understorey including buffel grass (*Cenchrus ciliaris*). Dominant soils are coarse river sands. Soil profiles are well-drained and non-saline.

Topography: Sand hummocks (dune ridges) rising up to 1-2 m above the lower terrace of the Gascoyne River and forming narrow sandy levees bordering the river channel.

Geology: Quaternary alluvium, consisting of sand.

Vegetation: Acacia shrubland or closed shrubland. Canopy cover: 10-60%; Height: 2-4 m.
Emergent species: Silver barked wattle (*Acacia sclerosperma*) with emergent river red gum (*Eucalyptus camaldulensis*).
Understorey species: Buffel grass (*Cenchrus ciliaris*) is dominant.

Soils: Dominant soils are coarse river sands, which are often paler than the Gascoyne soils. Profiles are well-drained and non-saline.

Related map units: Differs from Ri6 in rising above the lower terraces of the Gascoyne River, though still susceptible to flooding. It has coarser grained sands than Ri1 and Ri6. It sits higher than Ri7. The equivalent unit mapped by Wells and Bessell-Browne (1990) is Gr.

Soil limitations and land management:
- High risk of soil erosion during flooding
- Soils can be prone to wind erosion
- Coarse sandy soils have poor moisture and nutrient retention.

Land capability: Fair to low (classes 3-4) for horticulture due to high risk of wind erosion, water erosion and flooding. The coarser sands also reduce capability. The small areas covered by these dunes and high flood risk of surrounding units are major limitations.

Ri6 - River Lower Terrace Subsystem (235Ri_6)

Total area mapped: 359 ha (1.6%) Within focus areas: 206 ha (1.9%)

Lower, flood-scoured terraces of the Gascoyne River carrying acacia shrubland with emergent river red gum (*Eucalyptus camaldulensis*), coolibah (*Eucalyptus coolabah*) and an understorey including buffel grass (*Cenchrus ciliaris*). Gascoyne 'light-textured' soils are dominant, often with medium to coarse-grained sands. Profiles are well-drained and relatively non-saline.

Topography: Hummocky low level river terraces subject to flood scouring. This unit usually sits adjacent to the Gascoyne River channel, commonly 2 m below Ri1.

Geology: Quaternary alluvium, consisting of uniform or stratified sand and loam.

Vegetation: Acacia shrubland or closed shrubland. Canopy cover: 10-60%; Height: 2-4 m.
Emergent species: Silver barked wattle (*Acacia sclerosperma*) with emergent river red gum (*Eucalyptus camaldulensis*) and coolibah (*Eucalyptus coolabah*).
Understorey species: Buffel grass (*Cenchrus ciliaris*) is dominant.

Soils: Predominantly Gascoyne 'light-textured' soils, typically consisting of uniform profiles of sand to sandy loam, often medium to coarse-grained. Profiles are well-drained and typically non-saline, though some subsoils with low salinity (30 mS/m) were identified upstream of Rocky Pool.

Related map units: Has finer grained, browner sandy soils and more vegetation cover than Ri7. Differs from Ri1 and Ri1c in being on the lower terraces of the Gascoyne River, and more susceptible to flooding. It has more light-textured (and coarser) soil than Ri1.
This unit partially corresponds to Gtl and Gtm (and possibly some Gtd and Gg2) mapped by Wells and Bessell-Browne (1990).

Soil limitations and land management:
- High risk of soil erosion during flooding
- Gascoyne 'light-textured' soils can be prone to wind erosion.

Land capability: Very low (class 5) for horticulture due to high risk of water erosion and flooding.

Ri7 - River Low Lying Sandy Terrace Subsystem (235Ri_7)

Total area mapped: 45 ha (0.2%) Within focus areas: 10 ha (0.1%)

Lower, flood-scoured, sandy terraces of the Gascoyne River carrying sparse cover of river red gum (*Eucalyptus camaldulensis*) and little understorey. Soil profiles are well-drained and non-saline.

Topography: Hummocky low level river terraces subject to flood scouring. Usually adjacent to the Gascoyne River channel. Ri6 usually rises above this unit.

Geology: Quaternary alluvium, consisting of uniform or stratified sand to loam.

Vegetation: Very open eucalypt woodland. Canopy cover: 10-20%; Height: 2-4 m
Emergent species: River red gum (*Eucalyptus camaldulensis*)
Understorey species: Typically absent.

Soils: Coarse river sands are dominant, often paler than the Gascoyne soils. Profiles are well-drained and non-saline.

Related map units: Differs slightly from the description provided by Wells *et al.* (1992) in that it occurs on the same level, or below Ri6, not above it. It has coarser grained, paler sandy soils and less vegetation cover than Ri6. It differs from Ri1 and Ri1c in occurrring on the lower terraces of the Gascoyne River, thus being more susceptible to flooding. It has more light-textured (and coarser grained) soils than Ri1. This unit partially corresponds to Gtl and Gtm mapped by Wells and Bessell-Browne (1990).

Soil limitations and land management:
- High risk of soil erosion during flooding
- Soils can be prone to wind erosion
- Coarse sandy soils have poor moisture and nutrient retention.

Land capability: Very low (class 5) for horticulture due to high risk of water erosion and flooding.

Ri8 - River Saline Duplex Terrace Subsystem (235Ri_8)

Total area mapped: 479 ha (2.1%) Within focus areas: 297 ha (2.8%)

Level alluvial plain developed on the upper terraces of the Gascoyne River and carrying open acacia shrubland with an understorey including Gascoyne mulla mulla (*Ptilotus polakii*). Dominant soils are Coburn red-brown duplexes with smaller areas of the Gascoyne 'medium-textured' soils. Soil profiles are typically highly to extremely saline.

Topography: Level alluvial plain, dissected by a few flow lines, on the broad upper terraces of the Gascoyne River in the vicinity of Rocky Pool. Level to very gently undulating microrelief of <30 cm. Small scattered scalds are sometimes present.

Geology: Quaternary alluvium, of uniform or stratified loam to clay containing mica.

Vegetation: Open acacia shrubland. Canopy cover: 1-10%; Height: 2-4 m.
Emergent species: Prickly acacia (*Acacia victoriae*), needle bush (*Hakea preissii*), silver barked wattle (*Acacia sclerosperma*)
Mid-storey species: Climbing saltbush (*Rhagodia eremaea*), minga (*Heterodendrum oleaefolium*) and poverty bush (*Eremophila* spp.).
Understorey species: Gascoyne mulla mulla (*Ptilotus polakii*) and buffel grass (*Cenchrus ciliaris*) are dominant.

Soils: Predominantly Coburn red-brown duplexes. High to extreme levels of salt common within subsoil ($EC_{1:5}$ at 50-100 cm is often in the 50-250 mS/m range).

Related map units: Very similar to Ri3s, but subsoil salinity is typically higher and Coburn red-brown duplexes dominate rather than Gascoyne 'heavy-textured' soils. These Coburn duplexes are similar to duplex soils on the adjoining Sandal System, but are less red. The vegetation is not as sparse as on Sandal System and Gascoyne bluebush is usually absent.

Soil limitations and land management:
- Salinity levels would to severely restrict crop yields
- Salinity is likely to increase under irrigation
- Heavy-textured, sodic subsoils restrict drainage
- Moderate to high risk of boron toxicity
- Risk of soil loss during major flood events, especially if surface is disturbed or unprotected
- Susceptible to soil structure decline
- Reduced trafficability on heavier soils
- Some calcareous subsoils.

Land capability: Very low (class 5) for annual and perennial horticulture due to salinity which would be exacerbated under irrigation.

Ri9 - River Rocky Margin Subsystem (235Ri_9)

Total area mapped: 81 ha (0.4%) Within focus areas: 2 ha (<0.1%)

This is a minor unit bordering the Gascoyne River near Rocky Pool. Areas of outcropping red sandstone occur along river banks and terrace slopes. Water erosion is evident in some places. The soils are probably Gascoyne 'light' and 'medium-textured', often shallow and rocky. Vegetation is acacia shrubland or closed shrubland with few emergent coolibah (*Eucalyptus coolabah*).

Land capability: Very low (class 5) for horticulture due to shallow soils, rock outcrop and risk of water erosion.

Ri10 - River Relict Channel Subsystem

Total area mapped: 130 ha (0.6%) Within focus areas: 107 ha (1.0%)

Shallow narrow drainage depression being a prior flood channel of the Gascoyne River. Soil types include coarse-grained Gascoyne 'light-textured' and 'medium-textured' soils and Coburn red-brown duplexes. Vegetation is acacia open shrubland.

Topography: Shallow (<1 m deep), narrow (25-100 m wide) drainage depression forming the braided channel of a prior offshoot of the Gascoyne River. This relict river channel, which lacks defined stream banks, only carries water from localised run-off or via over-bank river flow during major flood events.. This unit is found cutting across Ri11.

Vegetation: Acacia open shrubland. Canopy cover: 10-20%; Height: 2-4 m.
Emergent species: Silver barked wattle (*Acacia sclerosperma*, prickly wattle (*Acacia victoriae*), curara (*Acacia tetragonophylla*).
Mid storey species: Climbing saltbush (*Rhagodia eremaea*), needle bush (*Hakea preissii*) and flat-leafed bluebush (*Maireana tomentosa*).
Understorey species: Buffel grass (*Cenchrus ciliaris*), *Sida* and *Solanum* spp.

Soils: Include Gascoyne 'light' and 'medium-textured' soils and Coburn red-brown duplexes, with the sand fraction often medium to coarse-grained. Some profiles may be saline.

Related map units: Lies slightly below the surrounding Ri11 unit. It differs from Ri4 in having coarser grained sands and more duplex profiles.

Soil limitations and land management:

- High risk of water erosion
- Poor moisture and nutrient retention in coarser grained sands
- Some saline subsoils.

Land capability: Very low (class 5) for horticulture due to the high risk of flooding and associated water erosion. Salinity will also be a limitation in some areas.

Ri11 - River Relict Terrace Subsystem (235Ri11)

Total area mapped: 285 ha (1.3%) Within focus areas: 240 ha (2.2%)

Relict terraces of a prior offshoot of the Gascoyne River. Soils include coarse-grained Gascoyne 'light-textured' and 'medium-textured' and Coburn red-brown duplexes. Vegetation is acacia open shrubland.

Topography: This offshoot is approximately 300-600 m wide and leaves the Gascoyne River upstream of Rocky Pool, flowing in a general south-westerly direction. It lies 2-3 m below the level of the surrounding plain, confined by gently sloping banks. The terraces are relatively narrow (150-500 m wide) and very gently inclined.

Vegetation: Acacia open shrubland. Canopy cover: 10-20%; Height: 2-4 m.
Emergent species: Silver barked wattle (*Acacia sclerosperma*), prickly wattle (*Acacia victoriae*), curara (*Acacia tetragonophylla*).
Mid-storey species: Climbing saltbush (*Rhagodia eremaea*), needle bush (*Hakea preissii*), minga (*Heterodendrum oleaefolium*) and poverty bush (*Eremophila* spp.).
Understorey species: Buffel grass (*Cenchrus ciliaris*) and *Solanum* spp.

Soils: Include Gascoyne 'light-textured' and 'medium-textured' soils and Coburn red-brown duplexes, with the sand fraction often medium to coarse-grained. Some profiles may be saline.

Related map units: Situated slightly above Ri10.

Soil limitations and land management:
- Risk of flooding water erosion
- Poor moisture and nutrient retention in coarser grained sands
- Poor subsoil drainage in duplex profiles
- Some saline subsoils.

Land capability: Fair to low (classes 3-4) for horticulture due to the risk of flooding and associated water erosion. Poor moisture retention and subsoil drainage should also be considered. Salinity will be a limitation in some areas.

RiU - River Undifferentiated Terraces Subsystem (235Ri_U)

Total area mapped: 1,439 ha (6.3%) Within focus areas: 28 ha (0.3%)

The River Undifferentiated Terraces Subsystem was only mapped by air photo interpretation. It mostly lies outside the focus areas identified in the Scoping Report.

The area consists of level alluvial plain, dissected by a few flow lines, on the broad upper terraces of the Gascoyne River. It is likely to consist of a combination of the Ri1, Ri2 and Ri3 subsystems, probably with some significant areas of their saline phases. Dominant soils are likely to be Gascoyne 'light-textured' and 'medium-textured' soils. Gascoyne 'heavy-textured' soils may also be present. Capability for horticulture is likely to range from high to low (classes 2-4), but it is difficult to assess in which proportions.

Sb - Sable System (235Sb)

Total area mapped: 2,070 ha (9.1%) Within focus areas: 1,162 ha (10.8%)

Nearly flat alluvial plain with occasional sandy rises supporting low shrublands of silver saltbush (*Atriplex bunburyana*) and Gascoyne bluebush (*Maireana polypterygia*) and some tall acacia shrublands. Predominantly Shallow red sandy duplex soils.

Topography: Depositional surface consisting of extensive, saline alluvial plain. Minor sandy banks and sand sheets up to 3 m above the surrounding plain are present. External drainage is not clearly defined while only minor internal drainage foci (ephemeral swamps and saline claypans) are present. Sable System lies between the Delta System and relict river channel in Focus Area 4, and to the south of the Gascoyne Junction Road in Focus Area 8.

Geology: Quaternary deposits, mostly alluvial or colluvial clay, silt sand and gravel which is semi-consolidated near river deltas. Small areas of aeolian sand.

Vegetation: Acacia open shrubland to very scattered bluebush low shrubland.
Canopy cover: 1-10%; Height: 0.8-4 m.
Emergent species: Prickly acacia (*Acacia victoriae*), silver barked wattle (*Acacia sclerosperma*), needle bush (*Hakea preissii*) and some curara (*Acacia tetragonophylla*).
Mid-storey: Climbing saltbush (*Rhagodia eremaea*) is common. *Eremophila* spp. and minga (*Heterodendrum oleaefolium*) may be present.
Understorey: Gascoyne bluebush (*Maireana polypterygia*), Gascoyne mulla mulla (*Ptilotus polakii*) and annual saltbush (*Atriplex* spp.) are common. Some spiny bluebush (*Maireana aphylla*), buffel grass (*Cenchrus ciliaris*) and occasional silver saltbush (*Atriplex bunburyana*).

Soils: Mostly a mixture of Doorawarrah and Moyamber associations. Red shallow sandy and loamy duplex soils (often alkaline) and Red loamy earths are common. Red/brown non-cracking clays are also present. Subsoils are typically heavy-textured with restricted drainage, and salinity levels are often extreme in the subsoil (200-2000 mS/m). Salinity is spatially highly variable, low to extreme salinity values can occur over short distances. Red deep sands of the Brown association are found on the sand dunes.

Soil limitations and land management:
- Clay loam subsoils contain moderately high to extreme levels of salt
- Inherently poor structure with massive and dense subsoils common
- High risk of soil structure decline
- Moderate to high risk of inundation or prolonged waterlogging
- Reduced trafficability
- Calcareous subsoils
- Moderate to high risk of boron toxicity on clay loams.

Land capability: Largely unsuited to horticultural development (low to very low capability, classes 4-5), due to poor profile drainage, moderately high to extreme salinity levels and the risk of increasing salinity under irrigation. The main exception is the well-drained Brown association profiles in the Sable Sand Dune Subsystem (Sb1) which cover just under 10% of the system (168 ha) in this survey.

The Sable System was divided into three subsystems, mainly through the interpretation of landscape features and vegetation patterns seen on the aerial photographs:

Sb1 - Sable Sand Dune Subsystem (235Sb_1)

Total area mapped: 168 ha (0.7%) Within focus areas: 93 ha (0.9%)

Small, scattered low (1-3 m high) sandy rises, banks and sand dunes occurring on the alluvial plain. Vegetation consists of scattered acacia shrubland with *Rhagodia* and *Eremophila* spp. in the second stratum. Major soils are Brown association sands; deep (typically >200 cm), fine to medium-grained, reddish sands (and occasional sandy loams). Red deep sandy duplex soils are found on the periphery of this subsystem.

The soils have a high to fair capability for horticulture (classes 2-3). They are deep and well-drained, easy to work and the fine-grained sands have reasonable moisture and nutrient retention. There is a moderate to high risk of wind erosion, especially under vegetable cropping. However, the small area of individual dunes (the largest is 44 ha, and the remainder range from 2 to 22 ha) and their narrow (75-300 m), sinuous nature severely limits potential for development.

Sb1 is very similar to De1, Sd2 and Tg1.

Sb2 - Sable Bluebush Flat Subsystem (235Sb_2)

Total area mapped: 1,588 ha (7.0%) Within focus areas: 886 ha (8.3%)

Plains carrying scattered to very scattered low (0.8-1.2 m high) shrubland dominated by Gascoyne bluebush (*Maireana polypterygia*). Taller acacia shrubs are uncommon. Dominant soils belong to the Doorawarrah and Moyamber associations, with Red shallow sandy or Loamy duplex soils (often alkaline) being most common. Duplex soils have loose to hardsetting sandy topsoils while polygonal cracking is characteristic of medium to fine textured topsoils. Most clayey subsoil horizons are poorly structured, massive and extremely dense. Soil salinity is spatially highly variable; low to extreme salinity values can occur over short distances.

This subsystem is very similar to Sd2 and De2. It tends to have a lower proportion of loamy earths than De2 and salinity levels are generally a bit higher. Sb2 can be differentiated from Sb5 in that it has considerably fewer bare or scalded areas. Sb2 is similar to the areas mapped by Wells *et al.* (1992) as Sb3.

Sb5 - Sable Scald Subsystem (235Sb_5)

Total area mapped: 313 ha (1.4%) Within focus areas: 182 ha (1.7%)

Plains and depressions with major areas of scalding. The landscape pattern consists of circular to linear bare and scalded surfaces (covering 30-50% of the subsystem) surrounded by non-scalded areas, very low hummocks and occasional sinuous sand sheets. Also included are circular drainage depressions and minor sinuous drainage depressions partially in-filled with hummocky sand deposits. Vegetation on non-scalded area is an open to very sparse acacia shrubland (2-4 m high) with an understorey dominated by Gascoyne bluebush (*Maireana polypterygia*). Gascoyne mulla mulla (*Ptilotus polakii*) may be present.

Dominant soils belong to the Doorawarrah and Moyamber associations, and include Red shallow sandy and Loamy duplex soils, Red loamy earths (clay loam texture) and Red/brown non-cracking clays. Most subsoil horizons are highly to extremely sodic and saline, while topsoil salinity varies. Salt inflorescence can be evident on the soil surface. The shallow duplex soils in bare areas are characterised by surface crusting and polygonal cracking. Topsoils are firm to hardsetting and may display sporadic A2 horizon development overlying reddish-brown sandy clay loam or clay. The upper 10-20 cm of the subsoil may display weak sub-angular blocky structure however the lower subsoil is commonly massive and dense. The vegetated areas are usually associated with loamy earths or duplex soils having relatively deeper, loose topsoil horizons.

This subsystem is similar to De5, Tg5 and Sd5. It tends to have a lower proportion of scald surfaces than De5 and Sd5. It can be differentiated from Sb2 by the predominance of scalding. Soil salinity levels are generally little higher. Sb5 is similar to areas mapped by Wells *et al.* (1992) as Sb4.

Sd - Sandal System (235Sd)

Total area mapped: 7,150 ha (31.4%) Within focus areas: 3,576 ha (33.4%)

Alluvial plain with numerous low sandy rises and banks. Open to very open low acacia shrublands with bluebush and saltbush understorey. Soils include Red shallow sandy or Loamy duplex soils and Red deep sands.

Topography: Depositional surface consisting of nearly flat alluvial plains with a mosaic of sandy banks and rises up to 5 m above the interbank plains. Drainage is internal into discrete foci (claypans) or along narrow sluggish tracts. Sandal System lies to the south of Delta System on Focus Areas 2 and 3 and south of River System in the east of Focus Area 4 and west of Focus Area 8.

Geology: Quaternary alluvium, deposits of clay, silt, sand and gravel with areas of aeolian sand.

Vegetation: Acacia open shrubland to very scattered bluebush low shrubland.
Canopy cover: 1-10%; Height: 0.8-4 m.
Emergent species: Prickly acacia (*Acacia victoriae*), needle bush (*Hakea preissii*), curara (*Acacia tetragonophylla*) and silver barked wattle (*Acacia sclerosperma*).
Mid-storey: Climbing saltbush (*Rhagodia eremaea*), minga (*Heterodendrum oleaefolium*) and *Eremophila* spp. are common, with some cotton bush (*Ptilotus obovatus*) and currant bush (*Scaevola spinescens*).
Understorey: Gascoyne bluebush (*Maireana polypterygia*) and Gascoyne mulla mulla (*Ptilotus polakii*) are common with some silver saltbush (*Atriplex bunburyana*), buffel grass (*Cenchrus ciliaris*), ruby saltbush (*Enchylaena tomentosa*), *Sclerolaena*, *Sida* and *Solanum* spp.

Soils: Mostly a mixture of Doorawarrah and Moyamber associations. These are mostly Red shallow sandy duplexes (often alkaline) with some Red shallow loamy duplexes and Red loamy earths. Red, non-cracking clays are also present. Subsoils are typically heavy-textured with restricted drainage, and salinity levels are often very high to extreme in the subsoil (100-600 mS/m). Soil salinity is spatially highly variable, and low to extreme salinity values can occur over short distances. Red deep sands and Red sandy earths of the Brown association are found on sand dunes.

Soil limitations and land management:
- Clay loam subsoils contain moderately high to extreme levels of salt
- Inherently poor soil structure with massive and dense subsoils being common
- High risk of soil structure decline
- Moderate to high risk of inundation or prolonged waterlogging
- Reduced trafficability
- Calcareous subsoils
- Moderate to high risk of boron toxicity on clay loams
- Risk of flooding and associated water erosion in some areas.

Land capability: Largely unsuited to horticulture (low to very low capability, classes 4-5), due to poor profile drainage, moderately high to extreme salinity levels and risk of increasing salinity under irrigation. The main exception is the well-drained Brown association profiles found in the Sandal Sand Dune Subsystem (Sd1) which cover about a fifth of the unit in this survey (1528 ha).

The Sandal System was divided into six subsystems, mainly through interpretation of landscape features and vegetation patterns seen on aerial photographs:

Sd1 - Sandal Sand Dune Subsystem (235Sd_1)

Total area mapped: 1,528 ha (6.7%) Within focus areas: 549 ha (5.1%)

Sandy rises, banks and sand dunes on the alluvial plain. Vegetation consists of scattered acacia shrubland with *Rhagodia* and *Eremophila* spp. in the second stratum. Major soils are Brown association sands; deep (typically >200 cm), fine to medium-grained, reddish sands (and occasional to sandy loams). Red deep sandy duplex soils are found on the periphery.

Topography: Sandy rises, banks and sand dunes rising 2-5 m above the surrounding alluvial plain. Most dunes are narrow (100-250 m) and sinuous. Some dunes form lunettes surrounding claypans. There are some large areas of sand sheets or dunefields (up to 800 m wide) which may contain swales and closed depressions.

Geology: Recent aeolian sands overlying older Quaternary alluvium. Some sandy rises represent relict alluvial banks, which have been reworked by aeolian activity.

Vegetation: Scattered acacia shrubland that may exhibit bare areas degraded by stock and accentuated by wind erosion. Canopy cover: 1-10%; Height: <1-4 m.
Emergent species: Silver barked wattle (*Acacia sclerosperma*), wanyu (*Acacia ramulosa*), prickly acacia (*Acacia victoriae*), curara (*Acacia tetragonophylla*) and needle bush (*Hakea preissii*)
Mid-storey: Currant bush (*Scaevola spinescens*), minga (*Heterodendrum oleaefolium*), climbing saltbush (*Rhagodia eremaea*), cotton bush (*Ptilotus obovatus*), quondong (*Santalum acuminatum*) and sandplain poverty bush (*Eremophila maitlandii*).
Understorey: Buck wanderrie grass (*Eriachne helmsii*), *Sida* spp. and buffel grass (*Cenchrus ciliaris*). Silver saltbush (*Atriplex bunburyana*) and Gascoyne mulla mulla (*Ptilotus polakii*) grow on the periphery.

Soils: Major soils are Brown association sands: deep (typically >200 cm), fine to medium-grained, reddish sands (and occasionally to sandy loams). Soils are structureless and loose or massive with an earthy fabric. Colour suggests they are derived predominantly from the Doorawarrah alluvial layer. Loamy earths and Red deep or shallow sandy duplex soils are found in depressions and dune swales as well as around the periphery.

Related map units: Contains the most extensive areas of sand dunes encountered in the survey. Similar units are De1, Sb1 and Tg1.

Soil limitations and land management:

- Moderate to high risk of wind erosion
- Lower moisture and nutrient retention compared with most Gascoyne soils.

Land capability: High to fair for horticulture (classes 2-3). Soils are deep and well-drained, easy to work and being elevated above the surrounding plain are not usually subject to flooding. The fine-grained sands have reasonable moisture and nutrient retention, but lower clay content than most Gascoyne soils, which indicates more intense management of irrigation scheduling would be required than in existing plantation areas. Lower rates and frequency of irrigation are likely to be necessary and soil moisture levels would need to be carefully monitored. As most profiles are deep, there is good potential for leaching salt, which accumulates in the root zone under irrigation. Moderate to high risk of wind erosion on these dunes, and windbreaks would need to be established if they were developed for horticulture. Some land reshaping may also be required on the higher dunes.

While soils are suitable for horticulture, the narrow and sinuous pattern of sand dunes limits potential development. Most of the dunes mapped cover less than 30 ha and many are less than 200 m wide. Only very small plantings could be established there. Three areas of dunes covering over 100 ha were identified. Two of these (167 and 106 ha) lie south of the Gascoyne Junction Road between Focus Areas 2 and 3 and cover relatively discrete areas. The largest is in the south of Focus Area 8. Although it covers over 700 ha, much consists of narrow offshoots about 200 m wide. These units contain some swales and depressions with unsuitable duplex soils.

Sd2 - Sandal Bluebush Flat Subsystem (235Sd_2)

Total area mapped: 943 ha (4.1%) Within focus areas: 676 ha (6.3%)

Plains carrying scattered to very scattered low (0.8-1.2 m high) shrubland dominated by Gascoyne bluebush (*Maireana polypterygia*). Taller acacia shrubs are uncommon. Dominant soils belong to the Doorawarrah and Moyamber associations, with Red shallow sandy or Loamy duplex soils (often alkaline) being most common. Duplex soils have loose to hardsetting sandy topsoils while polygonal cracking is characteristic of medium to fine-textured topsoils. Most clayey subsoil horizons are poorly structured being massive and extremely dense. Soil salinity is spatially highly variable; low to extreme salinity values can occur over short distances.

Sd2 is very similar to De2 and Sb2. It tends to have a lower proportion of loamy earths than De2 and salinity levels are generally a bit higher. Sd2 can be differentiated from Sd3 by the dominance of bluebush and reduced vegetation height. Salinity levels are generally higher. It has more bare or scalded areas than Sd3, but considerably less than Sd5.

Sd3 - Sandal Bluebush-Acacia Scrub Subsystem (235Sd_3)

Total area mapped: 2,225 ha (9.8%) Within focus areas: 978 ha (9.1.%)

Plains carrying very open acacia shrubland (2-4 m high) with an understorey dominated by Gascoyne bluebush (*Maireana polypterygia*). Dominant soils belong to the Doorawarrah and Moyamber associations, with Red shallow sandy or Loamy duplex soils (often alkaline) most common.

This subsystem is very similar to De3, but has a slightly lower proportion of loamy earths. Salinity levels are generally a bit higher.

It is an intergrade between Sd2 and Sd4. Sd3 can be differentiated from Sd4 by the more open structure of the shrubland and predominance of bluebush in the understorey. Soil salinity levels are generally a little higher and it tends to have more bare or scalded areas. Sd3 has more acacia shrubs than Sd2, and tends to be less saline and scalded.

Sd4 - Sandal Acacia Scrub Subsystem (235Sd_4)

Total area mapped: 868 ha (3.8%) Within focus areas: 486 ha (4.5%)

Plains carrying open acacia shrubland (2-4 m high) with an understorey containing Gascoyne bluebush (*Maireana polypterygia*). Dominant soils belong to the Doorawarrah and Moyamber associations, with Red shallow sandy or Loamy duplex soils (often alkaline) most common.

This subsystem is very similar to De4 and Tg4. It has a slightly lower proportion of loamy earths than De4, and salinity levels are generally a bit higher. Sd4 can be differentiated from Sd3 by the less open structure of the shrubland and fewer bluebushes in the understorey. Soil salinity is generally little lower and it tends to have fewer bare or scalded areas.

Sd5 - Sandal Scald Subsystem (235Sd_5)

Total area mapped: 1,450 ha (6.4%) Within focus areas: 794 ha (7.4%)

Plains and depressions with prominent scalding. The landscape pattern consists of circular to linear bare and scalded surfaces (covering about 50% of the subsystem) surrounded by non-scalded areas, very low hummocks and occasional sinuous sand sheets. Circular drainage depressions and minor sinuous drainage depressions partially infilled with hummocky sand deposits are included. Vegetation on non-scalded areas is an open to very sparse acacia shrubland (2-4 m high) with understorey dominated by Gascoyne bluebush (*Maireana polypterygia*). Gascoyne mulla mulla (*Ptilotus polakii*) may be present.

Dominant soils belong to the Doorawarrah and Moyamber associations, and include Red shallow sandy and Loamy duplex soils, Red loamy earths (clay loam texture) and Red/brown non-cracking clays. Most subsoil horizons are highly to extremely sodic and saline, while topsoil salinity varies. Salt inflorescence can be evident on the surface. The shallow duplex soils in bare areas are characterised by surface crusting and polygonal cracking. Topsoils are firm to hardsetting and may display sporadic A2 horizon development overlying reddish-brown sandy clay loam or clay. The upper 10-20 cm of the subsoil may display weak sub-angular blocky structure however the lower subsoil is commonly massive and dense.

Vegetated areas are usually associated with loamy earths or duplex soils with deeper, loose topsoil horizons.

This subsystem is similar to De5, Tg5 and Sb5. It tends to have a higher proportion of scald surfaces than Sb5 and Tg5, but lower than De5. It can be differentiated from Sd2 by the predominance of scalding. Soil salinity is generally a little higher. It differs from Sd6 in that vegetation is prominent and the entire area is not a bare scald surface.

Sd6 - Sandal Claypan Subsystem (235Sd_6)

Total area mapped: 110 ha (0.5%) Within focus areas: 92 ha (0.9%)

Slight depressions on the floodplain consisting of circular salt lakes and drainage foci that are predominantly bare of vegetation. Some claypans may carry a few annual grasses, annual saltbush or Gascoyne bluebush (*Maireana polypterygia*). These claypans are prone to inundation following heavy rainfall. They are often surrounded by sand dunes (lunettes mapped as Sd1).

Soils have developed from stratified silty and clayey sediments derived from the Doorawarrah alluvial layer. The claypan surface usually exhibits a polygonal or reticulated pattern that may be shiny and laminated by the precipitation of silicates and salts. Surfaces may also have a thin cover of siliceous sand or silt brought on by aeolian reworking. Subsoils are reddish-brown clay loam to clay which may exhibit black manganese-iron segregations and fine gypsum crystals. Topsoils are slightly acid to neutral while subsoils are alkaline. Claypans are generally saline, the upper 60 cm may have low to moderately high salinity while subsoils are highly to extremely saline.

Sd6 is very similar to Sb6, De6 and Tg6. It can be differentiated from Sd5 in that it occurs as discrete claypans rather than a mosaic of scalds and vegetated areas.

Sd10 - Sandal Swamp Subsystem (235Sd10)

Total area mapped: 23 ha (0.1%) Within focus areas: 0 ha

Slight depressions on the floodplain forming circular swamps. Although the centre of the swamp is often bare, the margins carry native tussock grasses, including swamp grass (*Eragrostis australasica*), reeds and thickets of coolibah (*Eucalyptus coolabah*), sometimes with silver barked wattle (*Acacia sclerosperma*) and curara (*Acacia tetragonophylla*). These swamps are usually dry but fill with water following heavy rain or flooding. Depending on internal drainage and frequency of inundation the centre of the swamp may also carry *Eucalyptus coolabah* or tussock grasses.

The soils have developed from stratified, reddish-brown, silty and clayey alluvial sediments and include Red cracking clays, Red/brown non-cracking clays and Red shallow loamy duplex soils. The soil surface usually exhibits a polygonal or reticulated pattern when dry and the upper soil horizons may have a strong sub-angular blocky structure. Topsoils are dark reddish-brown due to increased accumulation of organic matter under moist soil conditions. Salinity levels are relatively low.

This subsystem is very similar to De10. It can be differentiated from Sd6 as it is more vegetated and less saline.

Tg - Target System (235Tg)

Total area mapped: 3,310 ha (14.6%) Within focus areas: 1,483 ha (13.9%)

Gently sloping plains, carrying tall acacia shrubland, with sandy banks, narrow interbanks and numerous circular lakes. Shallow red sandy duplex soils are common, with red sands on dunes.

Topography: Depositional surfaces of low plains composed of a mosaic of sandy banks, interbank plains and numerous discrete drainage foci. Relief across the system is up to 10 m. Target System lies south of the River System in Focus Area 8 to the east of Rocky Pool.

Geology: Quaternary deposits of alluvial and aeolian clay, silt, sand and gravel.

Vegetation: Acacia open shrubland to very scattered bluebush low shrubland.
Canopy cover: 1-10%; Height: 0.8-4 m.
Emergent species: Silver barked wattle (*Acacia sclerosperma*), curara (*Acacia tetragonophylla*), prickly acacia (*Acacia victoriae*) and needle bush (*Hakea preissii*).
Mid-storey: Climbing saltbush (*Rhagodia eremaea*), *Eremophila* and *Cassia* spp. and cotton bush (*Ptilotus obovatus*).
Understorey: Gascoyne mulla mulla (*Ptilotus polakii*), Gascoyne bluebush (*Maireana polypterygia*), buffel grass (*Cenchrus ciliaris*) and *Sclerolaena* spp.

Soils: Mostly Doorawarrah and Moyamber association soils. These are mostly Red shallow sandy duplex soils (often alkaline) with some Red deep sandy duplexes. Subsoils are typically heavy-textured with restricted drainage, and subsoil salinity levels are often very high to extreme (>100 mS/m). Soil salinity is spatially highly variable; low to extreme values can occur over short distances. Red deep sands of the Brown association are found on dunes.

Soil limitations and land management:
- Clay loam subsoils contain moderately high to extreme levels of salt
- Inherently poor soil structure with massive and dense subsoils being common
- High risk of soil structure decline
- Moderate to high risk of inundation or prolonged waterlogging
- Reduced trafficability
- Calcareous subsoils
- Moderate to high risk of boron toxicity on clay loams.

Land capability: Largely unsuited to horticultural development (low to very low capability, classes 4-5), due to poor drainage, high to extreme salinity and the risk of increasing salinity under irrigation. The main exception is the well-drained Brown association profiles found in the Target Sand Dune Subsystem (Tg1) which covers just of 10% (407 ha) of the system in this survey.

The Target System was divided into four subsystems (and one subsystem phase), mainly through the interpretation of landscape features and vegetation patterns seen on the aerial photographs:

Tg1 - Target Sand Dune Subsystem (235Tg_1)

Total area mapped: 407 ha (1.8%) Within focus areas: 107 ha (1.0%)

Sandy rises, banks and sand dunes. Vegetation consists of scattered acacia shrubland with *Rhagodia* and *Eremophila* spp. in the second stratum. The major soils are Brown association sands: deep (typically >200 cm), fine to medium-grained, reddish sands (with occasional sandy loams). Red deep sandy duplex soils are found on the periphery.

Topography: Sandy rises, banks and dunes rising 2-5 m above the surrounding plain. Most dunes are narrow (50-250 m) and sinuous which indicates a long history of alluvial and aeolian reworking. Some dunes form lunettes surrounding claypans. Some large areas of sand sheets or dunefields (up to 400 m wide) may contain swales and closed depressions.

Geology: Recent aeolian sands overlying older Quaternary alluvium. Some sandy rises represent relict alluvial banks, which have been reworked by aeolian activity.

Vegetation: Scattered acacia shrubland which may exhibit bare areas degraded by stock and accentuated by wind erosion. Canopy cover: 1-10%; Height: <1.0-4 m.
Emergent species: Silver barked wattle (*Acacia sclerosperma*), wanyu (*Acacia ramulosa*), prickly acacia (*Acacia victoriae*), needle bush (*Hakea preissii*)
Mid-storey species: Currant bush (*Scaevola spinescens*), climbing saltbush (*Rhagodia eremaea*), quondong (*Santalum acuminatum*) and sandplain poverty bush (*Eremophila maitlandii*)
Understorey species: Buck wanderrie grass (*Eriachne helmsii*), *Sida* spp. and buffel grass (*Cenchrus ciliaris*). Silver saltbush (*Atriplex bunburyana*) on the periphery.

Soils: Major soils are Brown association sands: deep (typically >200 cm), fine to medium-grained, reddish sands (with occasional sandy loams). They are structureless and loose or massive with earthy fabric. Colour suggests the soils are derived predominantly from the Doorawarrah alluvial layer. Loamy earths and red deep or shallow sandy duplex soils are found in depressions and dune swales as well as around the periphery of this subsystem.

Related map units: Contains the most extensive areas of sand dunes encountered in the survey. Similar units in other systems are De1, Sd1 and Sb1.

Soil limitations and land management:
- Moderate to high risk of wind erosion
- Lower moisture and nutrient retention than most Gascoyne soils.

Land capability: High to fair capability for horticulture (classes 2-3). Soils are deep and well-drained, easy to work and being elevated above the surrounding plain, they are not usually subject to flooding. The fine-grained sands have reasonable moisture and nutrient retention, but their lower clay content than most Gascoyne soils, would require more intense management of irrigation scheduling than in the existing plantation areas. Smaller, more frequent applications are likely to be necessary and soil moisture levels would need to be carefully monitored. As most profiles are deep, there is good potential for leaching the salt which accumulates in the root zone under irrigation. There is a moderate to high risk of wind erosion on these dunes, and windbreaks would need to be established if they were developed for horticulture. Some land reshaping may also be required on the higher dunes.

While the soils are suitable for horticulture, the narrow and sinuous pattern of the sand dunes limits potential developments. Most of the dunes mapped cover less than 30 ha and many are less than 200 m wide. Only very small plantings could be established on such dunes. Two larger dunes (145 and 96 ha respectively) were identified to the south-east of Focus Area 8. Both contain some swales, depressions and claypans with unsuitable duplex soils.

Tg4 - Target Acacia Scrub Subsystem (235Tg_4)

Total area mapped: 718 ha (3.2%) Within focus areas: 353 ha (3.3%)

Plains carrying open acacia shrubland (2-4 m high) with an understorey containing Gascoyne bluebush (*Maireana polypterygia*) and silver saltbush (*Atriplex bunburyana*). Dominant soils belong to the Doorawarrah associations, with Red shallow sandy or Loamy duplex soils (often alkaline) being most common.

This subsystem is very similar to De4 and Sd4. It has a slightly lower proportion of loamy earths than De4, and salinity levels are generally a bit higher. Tg4 differs from Tg4c in that claypans that are a major feature of Tg4c are largely absent. Ri8 has similarities, but Gascoyne bluebush is generally absent from Ri8 which is characterised by the Gascoyne soils (which tend to be closer to brown), rather than the distinctly red-coloured Doorawarrah soils.

Tg4c - Target Acacia Scrub Subsystem, claypans phase (235Tg_4c)

Total area mapped: 1,675 ha (7.4%) Within focus areas: 672 ha (6.3%)

As for Tg4, but with discrete depressions containing small (up to 50 m wide) claypans comprising 10-20% of the mapping unit.

Tg5 - Target Scald Subsystem (235Tg_5)

Total area mapped: 410 ha (1.8%) Within focus areas: 324 ha (3.0%)

Plains and depressions with prominent scalding. The landscape pattern consists of circular to linear bare and scalded surfaces (covering 30-50% of the subsystem) surrounded by non-scalded areas, very low hummocks and occasional sinuous sand sheets. Also included are circular drainage depressions and minor sinuous drainage depressions partially infilled with hummocky sand deposits. Vegetation on non-scalded area is an open to very sparse acacia shrubland (2-4 m high) with an understorey dominated by Gascoyne bluebush (*Maireana polypterygia*). Gascoyne mulla mulla (*Ptilotus polakii*) may be present.

Dominant soils belong to the Doorawarrah and Moyamber associations, and include Red shallow sandy and Loamy duplex soils, Red loamy earths (clay loam texture) and Red/brown non-cracking clays. Most subsoil horizons are highly to extremely sodic and saline, while topsoil salinity varies. Salt inflorescence can be evident on the surface. Shallow duplex soils in bare areas are characterised by surface crusting and polygonal cracking. Topsoils are firm to hardsetting and may display sporadic A2 horizon development overlying reddish-brown sandy clay loam or clay. The upper 10-20 cm of the subsoil may display weak sub-angular blocky structure however the lower subsoil is commonly massive and dense. The vegetated areas are usually associated with loamy earths or duplex soils with deeper, loose topsoil horizons.

This subsystem is similar to De5, Sb5 and Sd5. It tends to have a lower proportion of scald surfaces than De5 and Sd5. It can be differentiated from Tg4c in that the scalds form an irregular uneven pattern rather than occurring as discrete rounded claypans.

Tg6 - Target Claypan Subsystem (235Tg_6)

Total area mapped: 99 ha (0.4%) Within focus areas: 27 ha (0.3%)

Slight depressions on the floodplain consisting of circular salt lakes and drainage foci that are predominantly bare of vegetation. Some claypans may carry few annual grasses, annual saltbush or Gascoyne bluebush (*Maireana polypterygia*). These claypans are prone to inundation following heavy rainfall. They are sometimes surrounded by sand dunes (Sd1).

Soils have developed from stratified silty and clayey sediments derived from the Doorawarrah alluvial layer. The claypan surface usually exhibits a polygonal or reticulated pattern which may be shiny and laminated by the precipitation of silicates and salts. Surfaces may also have a thin cover of siliceous sand or silt brought on by aeolian reworking. Subsoils are reddish-brown clay loam to clay which may exhibit black manganese-iron segregations and fine gypsum crystals. Topsoils are slightly acid to neutral while subsoils are alkaline. Claypans are generally saline, the upper 60 cm may have low to moderately high salinity, while subsoils are highly to extremely saline.

This subsystem is very similar to Sb6, De6 and Sd6. It can be differentiated from Tg5 in that it occurs as discrete claypans rather than a mosaic of scalds and vegetated areas. It is the equivalent of the unmapped claypans in Tg4c.

Appendix D – Combining this survey with existing mapping

To aid land use planning in the Carnarvon district, mapping from the 'Lower Gascoyne Survey' in this report has been combined with existing mapping of the 'Carnarvon Land Conservation District study' (Wells *et al.* 1992) and 'Soils adjacent to the plantations at Carnarvon' (Wells and Bessell-Browne 1990). Using the hierarchy of mapping units developed by the Department of Agriculture, it has been possible to produce a seamless soil-landscape map across these areas. This map is presented on the accompanying compact disc, with descriptions of the map units.

The mapping hierarchy permits correlation between surveys, allows information to be presented at different scales, and enables computer processing of data on a statewide (or national) level. The hierarchy maintains a consistent approach with different mapping scales and varying levels of complexity in both landscape and soil patterns.

The mapping hierarchy has six levels: **Region**, **Province**, **Zone**, **System**, **Subsystem** and **Phase**. The level of map unit in the hierarchy is implicit in the full map unit label. The *first* character of the full map unit label is the **Region**, the *2nd* is the **Province**, the *3rd* is the **Zone**, the *4th and 5th* are the **System**, the *6th and 7th* are the **Subsystem**, and the remainder (up to 12 characters) are the **Phase**. Tags on a published map sheet however may only display a subset of the full map unit label.

All three surveys are situated within the Carnarvon Soil-landscape Province (23). The 'Lower Gascoyne Survey' and the 'Study of soils adjacent to the plantations at Carnarvon' both lie entirely within the Alluvial Zone (235) of this province. While most of the 'Carnarvon Land Conservation District study' mapping also falls within the Alluvial Zone, the eastern margin falls within the Coastal Zone (238).

The soil-landscape systems within these zones are as described in the Lower Gascoyne and Carnarvon Land Conservation District surveys. They are based on the land systems identified by Payne *et al.* (1987):

- Brown system (235Br)
- Channel system (235Cn)
- Chargoo system (235Cg)
- Coast system (238Cs)
- Delta system (235De)
- Littoral system (238Li)
- Lyell system (238Ll)
- MacLeod system (238Mc)
- River system (235Ri)
- Sable system(235Sb)
- Sandal system (235Sd)
- Warroora system (238Wr).

The subsystems and phases are essentially as shown in these two surveys. For example the full map unit label for De1 is 238De_1, the full label for Ri3s is 235Ri_3s, and the full hierarchy label for De10 is 238De10. It should be noted that Sb1, Sb1a and Sb2 as they appear in Wells *et al.* (1992) have been changed to Sb11, Sb11a and Sb12 respectively to avoid conflict with the Lower Gascoyne Survey. The full map unit labels assigned by Wells *et al.* (1992) are shown in Table D1.

Some minor changes have been made around the edges of the map of the Carnarvon Land Conservation District, so that the unit boundaries match those of the Lower Gascoyne Survey. These changes were made with the assistance of aerial photographs and 0.5 m contour maps.

Table D1: Full map unit labels assigned to units in the Carnarvon Land Conservation district by Wells *et al*. (1992)

Wells *et al*. (1992)		Full map unit label
Brown system	Br1	235Br_1
	Br2	235Br_2
	Br2a	235Br_2a
	Br3	235Br_3
Chargoo system	Cg1	235Cg_1
	Cg2	235Cg_2
	Cg3	235Cg_3
Coast system	Cs1	238Cs_1
	Cs2	238Cs_2
	Cs3	238Cs_3
	Cs4	238Cs_4
	Cs5	238Cs_5
	Cs6	238Cs_6
	Cs7	238Cs_7
	Cs8	238Cs_8
Delta system	De1	235De_1
	De1a	235De_1a
	De2	235De_2
	De2a	235De_2a
	De3	235De_3
	De3a	235De_3a
	De4	235De_4
	De4a	235De_4a
	De5	235De_5
	De6	235De_6
	De7	235De_7
	De8	235De_8
	De9	235De_9
Littoral system	Li1	238Li_1
	Li2	238Li_2
	Li3	238Li_3
	Li4	238Li_4

Wells *et al*. (1992)		Full map unit label
Lyell system	LL1	238Ll_1
	LL2	238Ll_2
MacLeod system	Mc1	238Mc_1
	Mc2	238Mc_2
	Mc3	238Mc_3
	Mc4	238Mc_4
River system	Ri1	235Ri_1
	Ri2	235Ri_2
	Ri3	235Ri_3
	Ri4	235Ri_4
	Ri5	235Ri_5
	Ri6	235Ri_6
	Ri7	235Ri_7
Sable system	Sb1	235Sb11
	Sb1a	235Sb11a
	Sb2	235Sb12
	Sb3	235Sb_3
	Sb4	235Sb_4
Warroora system	Wr1	238Wr_1
	Wr2	238Wr_2
	Wr3	238Wr_3
	Wr4	238Wr_4
	Wr5	238Wr_5
	Wr6	238Wr_6
Other areas	Camarvon Townsite and Airport	235DeX_URBAN
		235RiX_URBAN
		238LiX_URBAN
	Gascoyne River	235Ri12
	HDA.	235DeX_
		238LiX_

Assigning a full map code to units shown in the survey of soils adjacent to the plantations at Carnarvon (Wells and Bessell-Browne 1990) was less straightforward. Although lying entirely within the area mapped by Wells *et al.* (1992), the two surveys use very different units. While Wells *et al.* (1992) based their units on the land systems of Payne *et al.* (1987), soil associations of Bettenay *et al.* (1971) were used as a basis for map units in soils adjacent to plantations at Carnarvon. This survey was also mapped at a more detailed scale.

The units of Wells and Bessell-Browne (1990) have been assigned labels at the phase level of the mapping hierarchy. The Gascoyne association map units became phases of subsystems in

the River system, the Coburn association units became phases of subsystems in the River system and the Brown association units became phases of subsystems in the Brown system. Some map units have become phases of more than one subsystem, for example the 'Gascoyne light-textured soils' occur as phases of both Ri1 and Ri2 subsystems. The 'Gascoyne-Coburn intergrade' soils occur as phase of subsystems in both the Delta and River systems. The full map unit labels assigned to the units map by Wells and Bessell-Browne (1990) are shown in Table D2.

Because the boundary between the 'Survey of the soils adjacent to the plantations at Carnarvon' and the 'Carnarvon Land Conservation District survey' was very complex, some major re-mapping was required. This mainly involved extending the units mapped by Wells and Bessell-Browne (1990) through areas of existing plantations with the aid of 0.5 m contour maps. This new mapping is shown as broken lines to differentiate it from the original mapping and to denote its lesser quality.

Table D2: Full map unit labels assigned to soils adjacent to the plantations at Carnarvon (Wells and Bessell-Browne 1990)

Wells and Bessell-Browne (1990)		Full map unit label	Wells and Bessell-Browne (1990)		Full map unit label
Brown association	Br	235Br_1Br	Gascoyne association	Gdz	235Ri_4Gdz
	Bsp	235Br_2Bsp		Gg1	235Ri_4Gg1
Coburn association	C	235De_2C		Gg2	235Ri_4Gg2
	Cdp	235De_7Cdp			235Ri_6Gg2
	Cdz	235De_3Cdz		Gh	235Ri_2Gh
		235De_4Cdz			235Ri_3Gh
	Ce1	235De_4Ce1		Gh+	235Ri_3Gh+
	Ce2	235De_5Ce2		Ghc	235Ri_3Ghc
	Cr	235De_1Cr		Ghd	235Ri_3Ghd
	Csc	235De_7Csc		Gl	235Ri_1Gl
Gascoyne-Coburn intergrade	GC1	235De_2GC1			235Ri_2Gl
		235Ri_1GC1		Gl+	235Ri_1Gl+
	GC2	235De_2GC2		Glc	235Ri_1Glc
		235Ri_2GC2		Gm	235Ri_2Gm
	GC3	235De_3GC3		Gm+	235Ri_2Gm+
		235Ri_2GC3		Gmc	235Ri_2Gmc
		235Ri_3GC3		Gr	235Ri_5Gr
				Gsc	235Ri_4Gsc
				Gtd	235Ri_4Gtd
					235Ri_6Gtd
				Gtl	235Ri_6Gtl
					235Ri_7Gtl
				Gtm	235Ri_6Gtm
					235Ri_7Gtm